universalTechnologySpecificationTextbook

from existing information.

Arguably a *more complete* theory of intelligence.

Preface.

Winners at the game of life bring the fullest diversity and quality to more players.

A transition from no wealth (ie. what animals are born with), through wealth living on us (ie. creating technological tools), to us living on and once again independent of wealth (ie. everyone born with the benefits of 'self-driving AI' and 'Virtual Reality' across an interstellar habitat throughout uninhabited space, of computers and energy generators). Completing this transition from biological to technological competence, for a populace already exhausted from video conferencing, as well as for developers who want and work for better, along with shareholders who demand their executives effort for steadier returns at minimal risk, is all in the public interest, now representing substantial 'public trust'.

Assurance that most people the universe can well support will *eventually* have - especially of *developers* eventually having - *uninterrupted, immersive, unlobotomized, challenging experiences* solving the problems of life - *cognition* having mostly more *interesting things to do* than the pocket calculator work of *automation* - as well as having unfettered wetware repair/replacement through their own neural interfaces - such assurance is a liability for 'public trust'. Such reasonable assurance of eventually reaching the point where any life can be lived settles concerns so all of the public - especially developers - can *delegate* trust to *existing organizations*.

Having a plan as reasonable assurance, a basic enumeration of possible technologies, was an essential step to reducing the strenuousness and risks of technology development, so more persons have the opportunity to find out where they might want to participate, or if the world really needs so much effort at all, and also so organizations have the cognizance to better identify promising candidates and proposals. Such transparency lends credibility to reasonable assurance so all of the public - especially developers - can *delegate* trust to *existing organizations*.

Human society not having committed to a reasonable exit strategy, having instead much apparent culture of eternal sacrifice, significantly motivated the substantial effort in creating this document. Hopefully this has created the opportunity for *delegating* more trust to *existing organizations*.

Remaining technologies are well within the means of 'community' (ie. FLOSS, makerspace/hackerspace, biohacking) developers not only to promote but to outright create. So, show us some commoditization, get us interoperable, portable, and efficient technologies, open the source code. Then our interests as open-source developers will be more aligned to *delegate* some of that to *existing organizations*.

CARDinal (VR metaverse shared space) especially is well within the resources of the FLOSS community to create. So are neuralBits, lithoDive, cognitionSplicer, sleeveDive, or even just grafting living neural tissue into embryonic tissue to integrate its memories (ie. amortality). All well within the means of a makerspace/hackerspace effort. So we can help or *delegate* to *existing organizations*.

By gamers, for gamers. A well balanced self-emergent open multiplayer world actually fulfills that promise, has many productive uses, and when such a world is not headed for vaporware, such players will happily mind their own business.

Doubtless, allow us developers our own neural interfaces, full read/write to them, and decent VR metaverse simulation software code - let us have these technologies, leave us alone and we will at least go away - maybe even volunteer helpfully.

Personally, author 'mirage335' is more interested in life as a typical 'player' than as any sort of game 'developer', solely steps up to minimize risk, and will step down from all other capacities once the self-driving AI and Virtual Reality habitat are safely deployed.

Facebook, supposedly now Meta, cannot succeed in attracting diverse talents if their intent is to de-commoditize the 'internet' into a rebranded proprietary 'Internet Explorer' as a feeble exploit of this last transition in human history. Much benefit was had from FLOSS competition as such before, and author 'mirage335' hopes, will be had again if necessary.

Disclaimer

Author 'mirage335' supports any reasonable path, valuing that many other persons have reasonable ideas, often adding new abilities and imagination.

Purpose of this document is mostly if not entirely as a loose 'almanac' . Possibilities, are enumerated.

Capital intense is expected minimal - this is not a proposal for de-commoditized or otherwise expensive projects.

Mostly, this is about what is possible, rarely if at all narrowing what should or must happen to a single possibility. Not everything, if anything, posited, should be taken literally.

Nothing herein is intended to unduly influence academic discussion, add acceptable terminology for academic publication, claim any academic credit whatsoever, show any disagreement with any public policy, or have any political effect whatsoever.

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WARNING: Extensive research notes may be less recent, less accurate, less complete, internally inconsistent, and misinterpreted.

Dedication

To whom diligently magnify the light for life, especially the engineers and electricians most recently heard from at the Titanic.

To the developers of Free-Libre / Open Source Software (FLOSS) 'web browser' software.

To those needing a tomorrow much better than a slightly worse yesterday.

To those who encourage persistence in difficult projects.

To those who would help, encouraging difficult projects to continue.

To diversity and quality of life.

To any persons or peoples I perhaps may not yet have thought to mention here.

Appreciation

PCBWay is particularly appreciated for prototype PCB manufacture and complete electronics assembly from design files, timely and affordable.

Pimax has done much for the world, continuing their long trend of leading the world with availability of professionally useful high-FOV and high-resolution Virtual Reality.

Starlink/SpaceX has started the process of replacing unmaintainably labor intensive terrestrial networks with cheaply commoditized standardized satellites.

Pondering

A quick release to FLOSS, rather than for-profit proprietary designs and textbooks, obviates issues of mass production. Far short of manufacturing runs and bringing products to market, individuals can simply give FLOSS design assembly standardized files to manufacturers, receiving small numbers of finished products at near marginal costs, with no marketing cost built-in.

"a subject of inquiry which can on no account be neglected"
"general who loses a battle makes but few calculations beforehand"
"cleverness has never been seen associated with long delays"
-Sun Tzu, Art of War, https://www.gutenberg.org/files/132/132-h/132-h.htm

"The man who asks a question is a fool for a minute, the man who does not ask is a fool for life."
-Confucius

"If all else fails, retreat."
-Thirty Six Stratagems, https://en.wikipedia.org/wiki/Thirty-Six_Stratagems

"no instance of a country having benefited from prolonged warfare"
-Sun Tzu, Art of War, https://www.gutenberg.org/files/132/132-h/132-h.htm

Before solving perceived problems, first seek every opportunity to inquire. Ask what is unknown, suggest what may be known. When solving problems, quickly find all truths. When the situation is known, bring immediate victory, or immediately retreat. Ensure there will be no dwaddling.

"Disturb the water and catch a fish."
-Thirty Six Stratagems, https://en.wikipedia.org/wiki/Thirty-Six_Stratagems

"What you do not wish for yourself, do not do to others."
-Confucius, https://en.wikipedia.org/wiki/Confucius

Widely distribute anything of one's own, surrounding what may become favorable. What is withheld, may be withheld in turn.

"Any product that needs a manual to work is broken."
"To make an embarrassing admission, I like video games."
"People should pursue what they're passionate about. That will make them happier than pretty much anything else."
"Life is too short for long-term grudges."
"There have to be reasons that you get up in the morning and you want to live. Why do you want to live? What's the point? What inspires you? What do you love about the future? If the future does not include being out there among the stars and being a multi-planet species, I find that incredibly depressing."
-Elon Musk, https://www.brainyquote.com/authors/elon-musk-quotes

Seems to recognize many aspects of a very strong case for commoditization of the experience of playing a video game across an interstellar habitat constructed by self-driving AI.

Reading the Extensively Non-Linear Documentation

Executives contemplating technology development proposals may find concepts alone sufficient, reading only a relevant part of the document.

Developers of complete hardware/software designs may require a more realistically detailed explanation. Frequent annotation and tabbing of printed copy, and searching of electronic copy, are strongly recommended for design use.

As one example, spatial filtering as explained in 'problemSolversGuide' is illustrated as a pinhole filter from multiple point sources of light. In practice, spatial filtering usually begins with focusing most of the light, as illustrated by 'lithoDive'.

Suggesting Reading for the Extensively Non-Linear Documentation

Something for everyone here, so please direct people towards what interests them, be that the hive mind and mind uploading of cognitionSplicer, the summary of modern design principles from problemSolversGuide, VR metaverse shared 3D space software from CARDinal, VR without CNS neural interfaces as described by mechDive, etc

Presented

*) problemSolversGuide - An 'executive summary' of how to develop technology in this universe.

*) Neural interface software and hardware, for 'brain upload', 'hive-mind', 'Virtual Reality', etc.
*) Mechanical interface hardware (ie. exoskeleton) for 'Virtual Reality'.

*) Metaverse shared 3D space multiplayer software (ie. CARDinal).

*) Hardware for automatic desktop prototyping <50nm linewidth (eg. resing/electroplating/casting, multiphoton deposition, multilayer PCB, CMOS).

*) Software design for self-driving AI.

As may be plausible. 'MetaEngine' from 'ubiquitous_bash', among other existing resources, may be relevant to quickly implementing designs as described and illustrated herein (ie. better than UNIX pipes).

Conclusions

*) Neural correlates of consciousness other than mere computing (eg. voltage gradients, molecules, etc, to which specific inputs account for conscious perceptions of sight/sound/touch/taste/smell/etc) may not be ruled out presently. Hardware may claim to have these conscious experiences, while in fact only emulating the behavior to make such a claim (ethically would need to be treated as sentient in either case). Consequently, interfacing wetware to hardware by neural interface and bioreactor (or similar more efficient technology) may be preferable (ie. lower risk) rather than replacing wetware with hardware.

*) Replacement of entire genome in all cells, possibly by successive replace/erase/write CRISPR, is now recognized as a possible alternative to some of the functionality of a neural interface, or at least a possible means of reducing the geometric constraints on a neural interface. Replacing or repairing neurons/synapses would still require sufficient remaining original neurons/synapses for longevity use (ie. similar spatial resolution and memory stability expectations would apply both to neuron repair/replacement as would apply to neural interface electrode sites).

*) At ~100billion stars in Milky Way galaxy, and many galaxies beyond that, and ~10^24 persons/star, there is no need to compete for control over interstellar habitats. Every person alive on Earth (~10billion) for the next several decades at least, can have their own personal star. At ~10^24 inhabitants, if as few as 1/10^12 players have interests favorable to someone else's, that someone alive today will have plenty of volunteers creating solutions relevant to their needs. There is truly nothing to gain by fighting for any kind of dominance or control over the rules of any interstellar VR habitat.

*) Self-Driving AI universally *is* 'Artificial General Intelligence'. Navigation through spacetime from a single embodiment is the fundamental problem to solve for any 'cognition', 'automation', or any kind of problem solving 'intelligence', because a universe predominated by electrons and photons dancing around predominantly finite unchangeable solid matter, is entirely reducible to one single question - where do I go or no?

*) Combining cognitionSplicer with artificial neural networks in something like a modularAI framework raises the interesting possibility of obviating the stability and training time issue of self-driving AI . Most if not all of what the more expensive artificial neural networks are needed for is solving object recognition problems, such applications can tolerate resetting of the neural network every few seconds.

*) Virtual Reality has the long term potential to provide the entertainment at the end point of human technological development, but also, to make the process of technological development much more fun and intuitive, obviating purely dry symbology in favor of more experimentation with simulation of the effects represented by that symbology, to the point of voxelGrid .

*) Dyson spheres (especially of satellite constellations), star lifting, etc, have already long been adequately hypothesized. Designs used should maximize diversity and quality of life (ie. should neither quickly expend nor substantially waste stellar energy reserves).

*) Top down (many rules, arbitrary) has the advantage of avoiding unnecessary unpleasantness - such incomprehensible nuances as the misalignment of neural and bacterial circadian rhythms. Unfortunately, top-down itself results from unpleasant Player develops Automation (PdA) effort, and to identify what is or not necessary to 'gameplay' requires taking this beyond a point of diminishing returns. Bottom up (few rules, 'big bang') has the advantage of bringing out all possible Player vs Player and Player vs Environment interactions. However, bottom up does not avert unnecessary unpleasantness - notably parasites and falling asteroids.
 *) Top down requires an abundance of caution to avoid severe stagnation.
 *) Bottom up requires a high tolerance of neutral and negative results.
 *) ACKNOWLEDGEMENT - Top down and bottom up terminology is from Sword Art Online (SAO) by Reki Kawahara , albeit possibly used in a slightly broader context.

*) Exploration
 *) Venture out to new territory. Careless navigation is sent back for a loop without reward of novelty, or results in encountering danger. Diligent navigation is rewarded by discovering new scenery (and opportunities for resources which make further discoveries possible later). Determination to remain diligent is learned. Exploration may be calibrate learning of

determination versus random carelessness, especially during 'infancy'.
*) Combat
 *) Player versus Environment
  *) Usually supports Player versus Player both as speed/precision practice and indirectly as a means of obtaining food/resources.
 *) Player versus Player
  *) Relative test of ability. Sometimes friendly for more social species, as practice for later combat between groups.
 *) Player develops Automation
  *) Symbolic manipulation motivated by absence of resources for direct experimentation. Extreme cases of this (extensive software projects) so far have been either unique to human beings, or delegated to inherent evolutionary/genetic algorithm (DNA code development). Such activities result in more automation (eg. software, DNA, hardware design).
*) Regeneration
 *) Speculative. Learning neural networks may not be 'indefinitely' stable, some partial periodic reset may be required. For complex biological neural networks today, so far, this seems to happen by complete individual death, but at least at the cost of some side effects, there definitely must be healthier workarounds.

*) Player develops Automation is symbolic gobbledygook manipulation required by insufficient resources to educate and use intuition more experimentally. Such is more suitable for pocket calculator 'automation' than 'cognition'. Spending much of a lifespan with *little opportunity for experimentation* is an *abuse of cognition*.

*) neuralBits...
 *) Commodity components many years old (ie. SerDes chips, USB3 FPGA), corrosion testing, laser cutting, surface coating, <2mil PCB fabrication, atomic-force probe or electron-beam fabrication of minimal surface area CMOS/polyamide packetizing, codec, ADC/DAC, and amplifier circuitry - are sufficient and well within the combined prototyping resources of 'makerspace', 'hackerspace', and 'biohacking' communities today. A combined community open-source effort could overcome this hurdle independently.

*) lithoDive...
 *) Convenient rapid prototyping of electronic circuitry, and small-volume manufacture of unavailable components, without user intervention, at the highest useful resolution possible (<2nm overlay), is now feasible. At the very least, such hardware should provide a more approachable, more educational, opportunity to experiment with modern photolithography optics, etching, and transistor circuitry manufacture.

*) CARDinal...
 *) All of the algorithms specified for CARDinal are straightforward without any plausible major gaps. Ability to load terrain files, import 3D objects into game engines without interruption, import real-time framebuffer video streams, and control 3D object positions, is well documented for major game engines (especially Unity). All necessary inter-process-communication and networking
is available from both MSW and Linux OS kernels. Both MSW and Linux/Cygwin OS can integrate other programs through simultaneously batch/bash interpretable anchor shell scripts from ':ubiquitous bash':. Compiled code (ie. C/C++/similar) may be relied upon entirely by standalone clients (eg. Oculus Quest, Android), or use cloud services may be used (eg. if avionics VM is desired by such users).

Roadmap and Timeline

Insofar as in terms of what is possible, rather than what could cause delays, optimistic. Insofar as in terms of reasonable development time expectations, pessimistic. Efficient parallel workflow, simultaneously solving multiple interrelated issues as usual, assumed (eg. lithoDive must be pursued before sleeveDive). Units is weeks, at approximately between ~60hour/week (10hr*6day) to ~112hour/week (16hr*7day).

All numbers are added to total (ie. these are not strictly categories, an item number does not include development time for a sub-item).

2) Legacy - MSW Host VM control under ubiquitous bash.
 d) Legacy - high speed multiplatform IPC of game object grid data (C implementation of metaEngine scene graph manager).
 +) Legacy - IPC message publication service.

*) Software Distribution
 *) MSW (VR) Host *or* Linux OpenHMD and such.
 *) Linux Software/Hardware/Wetware Design
  *) Cloud build service (ubiquitous bash).
  +) LiveCD/LiveUSB.
   +) Resettable and Nonpersistent.
   +) Hibernation Snapshotting (Save State without Virtualization).
   +) Persistent internal storage.
 *) Linux PanelVM (nominally Gentoo)
  *) Cloud build service.

2) Soldered Metal Plate (or taped/glued Carbon Fiber) Liquid Cooled PC Enclosure (ie. cryogenicComputer)

*) CARDinal
 *) Geometry Solver (voxels to polygons and vice versa, procedural modeling, import/export to reasonably common openly usable formats).
 *) Local Object storage, repositioning, and collision detection (MetaEngine).
  1) C/VRAM shared memory 2D triple framebuffer implementation.
  2) C/VRAM polygon implementation (ie. C implementation of metaEngine scene graph manager).
  5) C/VRAM voxelGrid and edge compression implementation.
  +) Bash/Filesystem infrequent update reposition import implementation.
 *) IPC protocol and implementations.
  4) C library for game engine object (including triple framebuffer) import, repositioning, and collision event reporting.
   *) Unity, FLOSS compatibility.
 x) Command Line, Screen Scraping, File Manager, etc (easily outsourced).

*) cognitionSplicer
 3) TX/RPT event lists to/from local object storage (MetaEngine).
 3) Artificial Neural Network (adequate experimental substitute for wetware).
 4) RPT correlation, iterative rewrite, overlay experiments.

*) memoryRegneration
 2) Partial reset simulation experiment, integrated with cognitionSplicer, evaluating the re-learning and continious performance of an ANN periodically gravitated mostly but not completely towards default.

5) VR Neural decoder/encoder for stimulation only ES precept calibration and conversion of sensory fields to precepts as stimulation ES patterns.
 4) Sensory nervous system ANN emulator.

*) neuralBits
 3) Circuitry.
 5) Automatic layout of repetitive circuitry and wiring into trestles, bundles, threads.
 5) USB3 FPGA, SerDes experiments.
 3) USB3 FPGA software design - 'drivers' - compatible with IPC protocol, emulated neuralBits hardware with artificial neural network.
  *) Implementation connecting and compatible with cognitionSplicier, ANN emulators, etc.

*) mechDive
 2) Prototype oversized (>>20mm instead of 2mm) tunneling (including pump) hardware design (3D printable by shapeways, commodity tungsten wire cables, etc).
 2) Artificial muscle bowden cable experiments.
 3) Prototype eddyCurrentBrake .

 3) FlexActuator - tool system at physical limits of compactness and reach into materials (ie. mechDive tunneling mounted to CNC) (ie. 'needleHours' if operated manually).

*) Position Trackers
 3) Prototype Object Emitter.
 5) Prototype Speckle Sense.

*) TazIntermediate
 4) Rehearsal Assembly in VR, demonstrating correct pre-tensioning by bolt offsets.

3) Mass production of precise optical mounts, tables, enclosures.

*) CoreFusion(s)
 3) Hardware designs upgraded with latest concepts from lithoDive.
  *) Rigid belt/pinion.
  *) Electronics always mounted close to tool, not independent of gantry.
  *) Slab.
  *) Cartridge.
 3) Klipper firmware control of hardware through IPC message publication.
 3) Prototype lithoDive capable of sub-mm resin printing and multilayer flexible PCB fab.
  3) High-vacuum, wet etch/deposition spray,
  3) Ultra-pure water, etc.
  *) Vibration isolation experiments (tennis balls or air inflated).
 9) Completely automatic from raw materials to chips.

4) sleeveDive

24) Game development, modularAI, motivation?

+) GNUelectric Transistor Design Experiment
*) OpenHMD Pimax Vision 8kX, OpenHMD Pimax 12K, etc

<130 person weeks (<2.41 person years)
Such projects as 'ubiquitous_bash', 'scriptedIllustrator', 'BOMdesigner', 'gEDAdesigner', 'arduinoUbiquitous', 'PatchRap', 'TazIntermediate', perhaps others, have benefited much more greatly from increasing commoditization through better tools for solving interrelated issues. Such ttrack record may be a more realistic estimate.

From track record for comparable scale projects, instead of total of worst case for each item, expectations may be much more realistic, albeit in fact optimistic.
16) CARDinal
12) neuralBits
04) mechDive
04) Position Trackers
02) Mass production of precise optical mounts, tables, enclosures.
24) CoreFusion(s)

<62 person weeks (<1.15 person years)

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Complexity - as a dynamic document extensively combining self-modifying interleaved shell code and markup, equation solving, Xournal sketches, modular shell scripts, etc, editing this document requires some perusal of the directory structure, and of 'ubiquitous_bash', 'scriptedIllustrator', etc.

Any third-party usability of this document at all is mostly if not entirely a byproduct of the desire to compose 'creative' (not yet routine) technical work into a loose 'almanac' because the author expects to be too exhausted for much 'creativity' during any implementation effort.

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errata

Roadmap Errata

GNU Electric -> Transistor, ADC, Multiplexing, Bus Modems, etc -> Specialized Geometry Stamps
Specialized Geometry Stamps -> lithoDive -> Analog Electronics Testing -> Corrections -> GNU Electric

Specialized Geometry Stamps -> CARDinal -> Scripting of copying component geometry to Trestles, Bundles, Threads -> Object Postions -> Complete Photomask Layers to Scan
Complete Photomask Layers to Scan -> lithoDive manufacturing -> Corrections -> CARDinal
Complete Photomask Layers to Scan -> lithoDive manufacturing -> complete neuralBits

FPGA to FPGA testing of neuralBits protocol with VR neural decoder to CARDinal IPC
	At least one FPGA is connected to a standalone program or computer emulating a 'dummy' of ES connected to an oversimplified model of expected analog read/write

CARDinal Scripting -> Artificial Neural Network -> cognitionSplicer experimental software
cognitionSplicer experimental software -> FPGA to FPGA emulated neuralBits recording and readout of connectome and synaptic weights

complete neuralBits & cognitionSplicer experimental software & neuralBits protocol with VR neural decoder to CARDinal IPC -> Personal Experimentation
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*) Recording sites for 'brain uploading' ordered by expected priority at 0.1mm/1% (neural processing cell/axon) or >100% (nerve/vertebrae transmission) - inferior temporal gyrus, corpus callosum, entire temporal lobe, somatosensory cortex, prefrontal cortex, hippocampus, entire neocortex, entire amygdala, vertebrae, glossopharyngeal nerve, vestibulocochlear nerve (inertial cues), olfactory nerve, terminal nerve (uncertain), trigeminal nerve (possibly magnetic cues), remaining cranial/peripheral nerves, all nerve endings (eg. by 'neural dust' in sensory tissue implanted under guidance towards locations causing CNS evoked potentials), all remaining neural tissue.

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Table of Contents

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problemSolversGuide

Universal charting a course (symbolic manipulation) to maneuvers through space of predominantly electrons and photons which give rise to the electromagnetic interactions of resistance, inductance, capacitance, and amplification, of which all complex systems may be modeled and then navigated. Emphasis on enabling non-technical persons in leadership positions to evaluate proposals both for adequate modeling of consequential effects, and proposals to design experiments (ie. build prototypes).

Demystifying seemingly technical problem solving.

Introduction

Possibly quite close to as 'executive summary' short as the universe gets.

*) Few common origins of all problems in the universe.
*) Reduction to other problems.
*) How far problems must be reduced to constituents.
 *) Limits to iterative problem solving (entropy, evolutionary genetic algorithm, etc).
*) Why to reduce problems as far as possible (ie. identify FUNDAMENTAL) when opportunity is available.

*) For decision making leaders (ie. executives).

*) Fundamental, if obvious, reasoning.

Presented

*) Economics - defining project success, value of experimentation as entertainment, scarcity of capital, commoditization, enjoyable problem solving as a desirable experience to maximize, etc.
*) Planning - solvable problem complexity limits (guess entropy), learning curve of symbolic manipulation, reduction of problems, problem solving algorithm by internal modeling/simulation, qualifying help and proposals by plausibility, etc.

*) Mathematics - importance of mathematics, colloquialism of mathematics, avoiding overuse of mathematics, equivalence of all mathematics to single instruction (turing completeness), etc.

*) Cognition vs Automation

*) Statistics - Noise, Signals, Statistics, Digital Communications over Analog, Cryptography

*) Modulation Equivalence - Amplitude or Frequency changes imply both amplitude and frequency shifting.

*) Circuitry - describing any machinery in a universe predominantly of electromagnetic photons.

*) Feedback - Motivation and Control of anything in the universe by operational amplifiers (and software, neural, people, organizational equivalents) from the concept of multiplying differences in quantity.

*) Optics, Physics, Quantum Physics, Signal Processing Algorithms, Control Algorithms.

*) Some common technologies (eg. collimated displays, envelope amplitude detecting).

As may be plausible, skipping some less useful details for faster comprehension of essential concepts.

Conclusions

Readers of this guide, or students, are expected to ask questions of a knowledgeable professional with industry experience. Self-learning may be possible, but this guide may not have been tested or otherwise proven for that use. Career academics with purely abstract (ie. symbolic), rather than pragmatic, experience,

A competent instructor should, within a day, be able to bring a small group (<5) motivated students, to a reasonably useful understanding, within *less than one single day*, even if completely unfamiliar with science or engineering and having at least a somewhat less than high-school 'education' understanding of relevant logic .

Due to concepts stemming from a two particle universe inevitably being *highly interrelated*, breaking into multiple sessions not recommended, and may be orders of magnitude less efficient. At best, previous instruction must be completely reviewed for

complete understanding at the beginning of each session. *Being prepared for a long day is strongly recommended*.

Complete understanding of each concept is a prerequisite for understanding others. Do NOT skip a topic if any student is having difficulty. Students having *much more difficulty demonstrating understanding* of concepts *are usually highly valuable* for both understanding and retention by other participating students of otherwise similar background. Do NOT underestimate this effect - students being from the same professional team or office is much more predictive of their ability to learn these concepts cooperatively than similar education, socioeconomic status, etc.

Circuits, Feedback, Signal Processing Algorithms, Control Algorithms, are the most universal and least commonly already deeply understood concepts to emphasize.

REFERENCE

https://web.archive.org/web/20150116020204/http://gozips.uakron.edu/~veillet/Faraday7.html
        'square root is important, because if you can achieve *negative* production, then you can have *imaginary* success'
                A clever point.

https://en.wikipedia.org/wiki/Thought_experiment

https://tvtropes.org/pmwiki/pmwiki.php/Administrivia/TropesAreTools
        'Human beings are natural pattern-seekers and storytellers. We make use of stories to convey truths, examine and exchange ideas, speculate on the future and discuss consequences. To do this, we must have a basis for our discussion, a new language to show us what we are looking at today. So our storytellers use tropes to let us know what things about reality we should put aside and what parts of fiction we should take up.'

https://tvtropes.org/pmwiki/pmwiki.php/TropesAreNotBad/TropesAreTools

https://en.wikipedia.org/wiki/Automated_planning_and_scheduling
https://en.wikipedia.org/wiki/Backward_chaining
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https://en.wikipedia.org/wiki/Future_Circular_Collider#Criticism
https://www.vox.com/future-perfect/2019/1/22/18192281/cern-large-hadron-collider-future-circular-collider-physics

https://en.wikipedia.org/wiki/Higgs_boson
        'standard model, which reduces all of reality to a dozen or so particles and four forces'

http://gnuradio.4.n7.nabble.com/IIR-filter-td40994.html
http://www.earlevel.com/main/2013/10/13/biquad-calculator-v2/

https://theory.labster.com/oxidation-state-periodic/

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        'zooplankton'

https://en.wikipedia.org/wiki/Learning_curve

https://en.wikipedia.org/wiki/2021_Suez_Canal_obstruction

https://en.wikipedia.org/wiki/SIGSALY

https://en.wikipedia.org/wiki/Phase-shift_keying
        'Although the root concepts of QPSK and 4-QAM are different, the resulting modulated radio waves are exactly the same.'

https://en.wikipedia.org/wiki/Jellium

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REFERENCE (unknown)

A documentary once cited attempts by personnel aware of an impending tsunami to warn appropriate authorities by reaching out to organizations which might have the necessary contact information. In the words of one of those persons, ' flipping through the [proverbial] phone book is dangerous ' . Example from memory is intended only to illustrate the real dangers of ' tunnel vision ' whether nearing an impending disaster or only in a competitive economy. Illustrates the need for 'agile' frequent reevaluation of whether current research directions have a possibility or statistical likelihood of bringing timely results.

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ACKNOWLEDGEMENT

Sword Art Online, at the beginning of the GGO arc, explicitly mentions that the elementary particles (ie. electrons and photons) of both the 'real' and 'virtual' worlds are the same (because the computer processors are still using these same particles). As a reader, "mirage335" greatly appreciated that moment of brilliance from the author Reki Kawahara, although "mirage335" wishes to note having long arrived at similar conclusions, having exhaustively ruled out every other possibility of using other particles (especially, any compact way such as microscopic black holes, of detecting neutrinos as a replacement for inertial position tracking).

Economics - Definition of Project Success

Economic concepts here are at leastly narrowly focused on defining non-profit project success. Many more sophisticated economic models exist beyond that narrow scope.

Equation of Project Success

```
Success == sqrt(Production/Effort)
```

As with so many equations, a simple and important, yet imprecise and inaccurate, relationship is illustrated symbolically, maybe without sufficient clarity to independently replicate the researcher's conclusions, while nevertheless implying any competent reader would fully comprehend.

Do not take such things at face value, you will see many.

'Keep calm' and such might be appropriate if not for trademarks.

Success, Production, Effort, Square Root

Project success is happiness (ie. diversity and quality of life). Production is resources multiplied by their expiration (ie. resources * time). Effort is work people do not want to do (ie. person hours).

A well managed project is genuinely successful. Where many project managers conceptualize prioritizing two of quality, cost, or speed, other stakeholders (ie. shareholders) are only well served by the uncompromising maximum possible quotient of commoditizing all three.

Entertainment

Entertainment (ie. playing a 'game' such as analyzing of a story) creates an opportunity for the experience of success, when no success is actually possible. When effort is needed, keeping entertainment as short as possible by taking away a person's own success and by effectiveness (eg. analyzing of a amazingly detailed story), may maximize effort. When partially exhausted, and effort is not useful, entertainment may as such be a productive use of such 'recovery time'. After effort is not needed, entertainment is an opportunity to experience success in another context (ie. playing a challenging game).

Thus, the small joke, an equation of success which begins this 'problemSolversGuide', defining the possibility of *imaginary success* from the *square root* of *negative production*.

Motivated readers should take this understanding of imaginary success both as illustrative information and as a tiny bit of fun entertainment, to put into their effort towards understanding the remaining information here, towards later success.

Experience of Success Maximized - Virtual Reality and Self-Driving AI

Success can be maximized unconditionally everywhere by self-driving AI, after which there is no opportunity for success. Virtual Reality can offer players choices of challenging multiplayer scenarios to enjoy the experience of success, regardless of whether the opportunity for success still exists.

Virtual Reality (aka. VR) is entertainment offering challenges to solve the social, visual, probabilistic, and maneuvering problems which may be more enjoyable to conscious beings employing *cognition* than mere 'pocket calculator' symbolic arithmetic suitable to *automation*. As such, Virtual Reality is not only efficient and effective entertainment, but also supplies patterns of contexts where some variable effort can create the experience of success, unlike pleasurable sensation alone. Virtual Reality can *offer the experience of success*.

To the problem of 'experiencing success', an AI providing 'happiness drugs', or office deskwork suitable for 'pocket calculator', may be a failure.

Any serious attempt at success today must consider Self-Driving AI and Virtual Reality, combined, as examples of technologies which may maximize any player's ability to experience their own derivation of success.

Capital is Scarce

Effort being work humans do not want to do, production will remain barely adequate to meet human needs, until success is available without effort. Capital being the accumulation of this effort, will be more scarce than any other resource. Capital implies a logistical concentration of low-entropy resources (stockpiling or heavy industrial equipment), which is very severely sensitive to disruption.

Success at the cost of making capital even more scarce - a businessperson earning a small bonus from a very large scale project - is not sustainable.

Capital is Irreplaceable

Capital in the form of machinery built by other machinery cannot be produced faster than all the underlying machinery can be built, regardless of essential. An economy or ecosystem dependent on such complex capital is unavoidably imperiled by any disruption.

Energy generation and computer production are the two essential functions of any economy.

Human concentration of capital today is already stretched at least as far as optimistic expectations allow. Today, human energy generation and computer production would plausibly decrease by orders of magnitude for several years without the continuous resources (eg. large high precision optics, internally cooled turbine blades, etc) from fewer than ten small facilities and the skills of only a few thousands of personnel, all *irreplaceable for several years*, at *many single points of failure*.

Success at the cost of making capital even more interdependent - a businessperson earning a small bonus from adding more single points of failure - is not sustainable.

Wealth and Tools

Tools, are an extension of the body. Wealth, is the accumulation of tools. When tools are produced less readily than people, or can be taken from people, wealth may concentrate (whether for better or worse is well beyond scope here). When tools are produced more readily than, or as a part of, self-replicating people, there is no longer a useful distinction - a person's wealth at that point is what they are 'born' with.

Such is the transition from biological (self-replication) to technological (self-driving AI) competence. Both these have the constraints of the behaviors of the same electrons and photons (computer processors using the same particles as any other physical objects).

Living in Virtual Reality, lifestyles may seem rather similar between biological and technological competence. People perform various activities, and enjoy the experience of success.

Activities

May be categorized.

Exploration
 Venture out to new territory. Careless navigation is sent back for a loop without reward of novelty, or results in encountering danger. Diligent navigation is rewarded by discovering new scenery (and opportunities for resources which make further discoveries possible later). Determination to remain diligent is learned. Exploration may be calibrate learning of determination versus random carelessness, especially during 'infancy'.

Combat
 Player versus Environment
  Usually supports Player versus Player both as speed/precision practice and indirectly as a means of obtaining food/resources.
 Player versus Player
  Relative test of ability. Sometimes friendly for more social species, as practice for later combat between groups.
 Player develops Automation
  Symbolic manipulation motivated by absence of resources for direct experimentation. Extreme cases of this (extensive software projects) so far have been either unique to human beings, or delegated to inherent evolutionary/genetic algorithm (DNA code development). Such activities result in more automation (eg. software, DNA, hardware design).

Regeneration
 Speculative. Learning neural networks may not be 'indefinitely' stable, some partial periodic reset may be required. For complex biological neural networks today, so far, this seems to happen by complete individual death, but at least at the cost of some side effects, there definitely must be healthier workarounds.

Generalization of these behavioral activity categories beyond human or complex biological neural networks is illustrated by 'zooplankton' using 'surplus killing' - a Player versus Environment activity.

Rationality, both Individually Selfish and Collectively Altruistic

In science, what is observed, is as true as anything can be proven true. If our memories were copied into another brain, we would observe being the same person as before that copy. Likewise, if our brains were connected to other brains in a manner similar to the separable hemispheres or other parts of human brains, we would share the conscious experience. We have no scientific observations to confirm that our own success is not the happiness of everyone on the whole.

Such a simple thought experiment suggests we cannot discount the possibility that inflicting failure to achieve success on others is not inflicting the same ourselves.

Selfishness, taking advantage of opportunities, can be rational, bringing the experience of success, when carefully justified.

Altruism, avoiding the destruction of opportunities for everyone, can be rational. Collectively, we should consider the risk that drastically reducing the happiness of most others, may inflict that on ourselves, indirectly, without our direct awareness.

Unambiguous necessary and inevitability are very high, but possibly reasonable, standards for justification.

Examples of Success (commiditization)

SpaceX, Starship, Starlink... reducing an expensive high capital intensity problem to both less expensive and lower capital intensity (commoditizing formerly capital intensive production). Starlink in particular, standardizing on more adequate software (satellite constellation position and inter-laser link management) and more adequate hardware (high-bandwidth modems), for smaller and more capable satellites, as well as using the low-cost launch services, clearly reflects great pains to reduce the capital intensity on all fronts, while terrestrial ISPs continue to navigate the complications of disparate, expensive, technologies, for harsh environments expensive to tunnel through, among other issues.

Examples of Failure (de-commiditization)

Increasing capital intensity of commodity logistics and finance - whether fuel or wholesale electrical power - by concentrating into a monopoly which creates artificial scarcity, inflating price above marginal rates (de-commoditizing - making commodity production more capital intense by requiring transfer of capital to accumulate with the monopolist). Production is entirely negative, and for the few persons who perceive some 'success', that is success is imaginary.

Marginal improvements in commodity (most notoriously fossil fuel) supply have been attempted by unjustified risk of capital for expediency. Uninspected equipment failures, insufficient precautions, insufficient modeling, etc. Sometimes this results in a bonus for some person. Sometimes very expensive capital assets become permanently unusable and irreplaceable. Since the person has taken an unnecessarily reckless path which most often results in negative production for the resources under their own control, any such success is imaginary.

Marginal marketing benefit, marginal additional cargo, causing ship hull loss or possibility of severe global traffic disruption, due to running aground (eg. in a canal). Unnecessary recklessness has mostly endangered company (and others) livelihoods (or at least insurance companies and premiums) much more than any successful incidents, so production is negative, and any such success is imaginary.

Microsoft. Set back of five years at least for the whole industry, when UNIX already existed, and continues to predominate today. Complex software projects are very difficult to develop directly for Microsoft legacy software, increasingly necessitating support of both UNIX/Linux and MSW, especially for non-commercial projects not financed by artificial scarcity also made possible by requiring compatibility with copyrighted legacy software. A tangled mess continuing to cause more negative production, a 'debt to society' never completely paid, well beyond Microsoft's own total revenue, all imaginary success.

NVIDIA. Arguable. Complete redevelopment of essentially similar processors seems to have been necessary for AMD, Google, Tesla, Amazon, EU, and others. Open-source GPU designs seem well underway, destined to overcome any legacy software compatibility barriers. More severely, NVIDIA's closed source drivers continue to obstruct distributable LiveCD compatibility, and now are exploited to dictate terms of use for purchasers paying manufacturing price for capital hardware, all causing much negative production. Mostly NVIDIA's revenue may be due to legacy game software compatibility issues, and a very slight performance advantage necessary in some very specific short-term use cases (ie. current flight sim software). Not sustainable, all imaginary success.

IPv4/IPv6 cellular tower routing. Seems probable that ISPs must route all traffic from cellular towers to central locations, to create the useful illusion of an IP address that does not change repeatedly as users switch between towers while moving. Some delays and investment in better technology to accommodate IP address changes could have shifted the burden away from complex networks to the existing datacenters/servers/routers, reducing the capital exposed to the harsh environments of terrestrial networks. Such inefficiencies combined with the expense of disparate terrestrial networks may explain the reluctance to allow reasonable bandwidth use (ie. >100GB necessary for use as home internet connection), more than supposed '5G' spectrum allocation. If such redirecting of packets to a central location does occur, that may have been much less successful than rational, so success from that shortsightedness may have been imaginary. Starlink may now mitigate these backhaul issues, many years after the deployment of '3G' when this may have become a problem, illustrating possible scenarios of imaginary success that may not be reversible for many years.

Starlink spectrum competitors and tax detractors. Years behind in deployment, for a necessary technology very long overdue. Delaying such technology for any reason can only be imaginary success.

Examples of Enjoyable Problems

Symbolic manipulation is dry, more suitable for 'pocket calculator' automation than the cognition of sentient persons. Stories and games are full of more PvE (Player versus Environment) and PvP (Player versus Player) than PdA (Player develops Automation), for the inherent social, visual, probabilistic, and maneuvering problems to solve (or at least solve by analyzing).

'TVTropes.org' deserves more credit, for cross-referencing tropes to trope naming, trope codifying, literary and 'real-life' examples, including much classic literature. TVTropes successfully identifies some common as well as rare but important behavioral patterns, many of which form enjoyable aspects of life, no doubt relevant to 'Virtual Reality' after deployment of 'self-driving AI'.

'tropes are tools'

Planning

* ATTENTION: Immediate comprehension of the algorithmic, more similar to automation rather than cognition, planning process, is not necessary. Undertaking a few necessarily capital intense capital reducing complex projects (eg. commoditization by technological development) and referring back to this section will be more productive.

Solvable Problem Complexity Limits - Entropy as a Limit, (Minimizing) Learning Curve

Cognition solves problems by iteratively guessing at how a few interactions cause complex assemblies of objects to change observations of those objects. Evolutionary genetic algorithms impart a mutation, evaluated whether more or less optimal, on the ability to sustain more offspring over many generations. Neural networks (which may be optimized by evolutionary genetic algorithms) may attempt to model the relationship between interactions and changes in observations, evaluating such guesses internally, allowing useful 'intelligent' behaviors with the low latency timeliness to catch 'Newton's proverbial falling apple'.

Sufficient resources to contemplate every guess only exist when the number of objects (including assemblies of objects) in a guess is a very small number.

Humans evolved very quickly from a situation not as demanding of intelligence, and certainly not demanding of the symbolic manipulation of Player develops Automation which is devoid of problems more detailed than 'pocket calculator' automation. Humans do not appreciate when their own happiness is clearly disregarded unnecessarily, even if otherwise comfortable.

Thus, any leader attempting success through humans performing Player develops Automation (ie. symbolic manipulation), must at every opportunity, minimize that, in favor of the entertainment of experimentation.

Learning curves result from multiplying impatience from symbolic manipulation effort with the perceived risk of uncertainty that such symbolic manipulation will be wrong and more effort will be demanded. Such risk increases exponentially with the number of guesses required, and combinations of solutions from previous symbolic manipulation without experimentation most risky of all. Few missed solutions without obvious benefit is discouraging enough, decades of learning is much to ask for, the many more years of self-invested 'higher education' quite a lot of self-proving, especially if inefficient.

Some of the longest learning curves (ie. 'higher education') are imposed artificially, often with less pragmatic learning, as a measurement of Player develops Automation initiative - willingness to voluntarily take what is already conveniently experimented with as far as possible by adding as much symbolic manipulation as possible. When wealthy students have the luxury of expending more of their entire lives on unproductive effort, or when the bottom of Maslow's hierarchy of needs is imposed as motivation, such students involuntarily complete increasingly artificially long learning curves, without any particular voluntary interest in any technical success. Distinction of voluntary initiative then requires much longer learning curves. Other issues may be related, such as the small number of people (ie. cognition) able to usefully collaborate on a single project, combined with imaginary successes of much de-commoditization preventing these problems from being broken into separate problems, reducing the number of job opportunities for essential technology development, and slowing technological progress.

Independent developers expending their discretionary time into public effort for public benefit - free/libre open-source software 'FLOSS' - are able to minimize such inflated learning curves. Voluntary initiative is visible in public repository histories, attributable on resumes due to absence of trade secrets, and corroborated by public discussion. Usefulness of such developers own voluntary inclinations can be inspected, which is not possible for those whose contributions are both involuntary and not publicly known.

Uncooperative attitudes and misinformation result when imaginary success by damaging mutual success is within the learning curve of the participants, but the understanding of solutions which result in real success requires too much Player develops Automation symbolic manipulation, not within the learning curve of the participants. Beyond that, when participants do not have sufficient margin in their daily lives - misinformation can be permanently accepted, and tolerance for diversity is eroded for no other reason.

Such are inherent 'soft limits' of cognition, which must not be underestimated, always the first obstacle to progress in a development transition, from no wealth to any, much less equally unlimited, wealth, from biological to technological. Derision of a less inflated learning curve is highly inappropriate, minimizing the learning curve, highly appropriate.

Search for Solutions

Player develops Automation problems of any complexity are combinations of machines which each implement specific consequential effects (ie, resistors, capacitors, inductors, amplifiers), or rarely (usually due to very high performance requirements) mechanisms which simultaneously implement specific consequential effects (eg. springs, quartz crystal oscillators). Due to this combinational nature, such problems are solvable by an algorithm more akin to Chess, than than other games, evaluating as many strategies as possible, and evaluating strategies from every scenario following the use of each of those strategies. Such algorithms are close to if not in fact 'automated planning', best-effort 'state space search', etc.

Such planning may contemplate all possible consequential effects of an implementation, identify all possible modules combining these implementations, and either perform experiments to model the usability of those combinations, or use existing models to internally evaluate possible guesses.

When planning is bringing better solutions, planning should continue until the point of diminishing returns. If planning is not

bringing conclusions of either better solutions or absence of solutions, reduction of problem to smaller search spaces, to allow fewer guesses, is appropriate.

Reduction of Problem to Smaller Search Spaces

When usable solutions are not obvious, more implementations of specific consequential effects (ie, arrangements of resistors, capacitors, inductors, amplifiers) must be designed. When design is not practical, experiments must improve modeling (eg. educating one&#s own intuition, or developing simulation software), or design software (eg. CAD modeling software) must be improved.

More simply put, when technological knowledge is not sufficient to identify an obvious solution, the problem may not be solvable without more technology development. Such is the extent of modern science that this is rarely if ever a problem today (usually only in very high performance air-breathing engine technology and some other energy production technology).

When the problem is reduced to problems which require a small number of guesses, after which further reduction is a point of diminishing returns, that is the time to solve the problem.

Internal Modeling by Internal Simulation from Recent Observation

One approach to self-driving AI is to observe the environment, model this as a virtual WORLD in a game engine, simulate several solutions from cognition (ie. artificial neural network), evaluate predicted scenarios for desirability after multiple rounds of possible interactions, and select the best path. Vaguely similar to solving chess.

Such may be illustrative of the problem solving process, and could in principle, however slowly and with however much complexity in the conversion from observation to virtual WORLD, solve all mining, manufacturing, maintenance, computing, energy generation, etc, problems, without actually taking unnecessary actions (eg. due to 'Sussman Anomaly'). As an oversimplification, such misses many substantial optimizations. Neural networks may be better able to identify and predicatively evaluate scenarios by object pattern recognition without resorting to completely accurate modeling of the environment. Evaluation of predicted scenarios over multiple rounds as with chess may not be a very efficient if some directions can be excluded for not having significant gain (ie. moving away from a cluster of obstacles and towards a workpiece avoids obviously unhelpful collisions with all of them).

Qualifying Help and Proposals by Plausibility of Relevant Consequential Effects

At least a partial understanding of planning techniques improves a person's own ability, especially if irrationally impatient, to quickly find enough information to seek good help.

As an example, perhaps we want to make sounds louder. Supposing information on tools to do this is not readily available, we could consider a more generic search, a more solvable problem. Looking for related events, flipping a light switch results in much more light energy is emitted. After some searches through bodies of scientific knowledge - notably internet and wikipedia search engines - we would discover the words 'amplification', 'multiplication', and 'gain' are associated with this. Cross-referencing detailed encyclopedia articles regarding 'amplification' would allow us to understand the scientific model of this phenomenon - mathematical multiplication of one signal by another. Engineering applications of the scientific model are referenced on a relevant encyclopedia page - circuits built around relays, vacuum tubes, and transistors, among others. We could conclude that gains of several hundred to one per low-cost transistor are usually available. Further investigation shows these are all electronic devices. From there, it can be inferred that someone skilled in electronics design may be prepared to pursue such a project on our behalf. We could then seek persons who have experience building amplifiers, or who are associated with such persons, to hire.

Even further investigation would quickly lead to discovery of related resistance, gain, voltage, and current characteristics of transistors, allowing us to construct a working amplifier from off-the-shelf parts ourselves.

Unfortunately, even a well meaning knowledgeable individual, can still be tempted to imaginary success in some way, especially at the expense of the exhaustive due diligence sometimes necessary. If technical personnel are theirselves not obviously satisfied that a point of diminishing returns has been reached finding more portable solutions to better minimize capital intensity, customer acceptance is unlikely.

Tool development, parts of which are sometimes referred to as 'science' and 'engineering' involve doing things completely dissimilar to what has been done before. Remaining difficulty and expected benefits is not a sunk cost argument, and must be contemplated. Some victories will be Pyrrhic.

Mathematics

Importance of Mathematics

Arithemetic, algebra, calculus, and geometry concisely summarize relationships of practical use.
Arithemetic as addition, subtraction, multiplication, and division, is the consequence of finite 'quantity' in the universe. Arithmetic is familiar for tallying suppies, however, it is addition and subtraction that make feedback possible, which allows the motivation of any machine whether cognition (often using neural networks) or automation (often using op-amps or logic gates). Arithmetic multiplication over time shifts the frequency at which things happen, meaning any shift in amplitude (any addition or subtraction of a signal) is also a multiplication of frequency, which has the essential application of frequency mixing (eg. shifting a narrow range of frequencies at >>100MHz to <<1kHz audio for radio reception or reverse for radio transmission).

Algebra allows calculation of specific elements in systems of equations to be calculated, by recognizing that operation on a variable is equal to the inverse operation on a variable which the original variable is dependent on. Modern TI-68k series (TI-89/TI-92[+]/V200/Voyage 200 [PLT]) calculators including the Derive CAS software have unmatched capability to handle especially complex systems of equations, correctly accepting and outputting boolean and/or operators. Wolfram Alpha, Qualculate, and other CAS software have similar, though less robust, capability. Convenient access to algebric (and arithmetic) functions is available through UNIX/Linux/Cygwin interactive command prompts and scripts using Qalculate, GNU Octave, backends contained by 'ubiquitous bash' .

Calculus relates functions to formulas for the rate of change with another variable. Differentation and integration are the primary operators. Again, modern TI-68k series calculators offer excellent support for these options, though other software is also available.

Geometry constructs complex shapes from simple relations of symmetry, parallelism, angles, and distances. Modern CAD software (especially FreeCAD with A2Plus) enables efficient exploration of these relationships.

Set theory and so-called relational 'algebra' or 'calculus' addresses collections of objects Operators include union, intersection, difference, and cartesion product. Such are common to 'database' automation.

Persistent storage can be defined by just four operators - Create, Read, Update, and Delete (CRUD). Also known as Modify, Add, Delete, Show (MADS), When these operations are 'atomic' - finishing before any other storage operation takes place - storage may be shared by multiple programs without risk of partial overwrites. Filesystems usually perform 'move', or equivalent 'rename' so a temporary file (eg. unsaved text editor buffer) may overwrite a permanent file (eg. text file being edited) with less risk of damage (eg. due to power loss). Lock files (causing a program to wait until another program is no longer using a resources) commonly exploit the usual 'move' filesystem feature.

Mathematic Expression is usually a Poorly Used Language

All of the observable universe can be described as a single computer instruction (ie. turing completeness), and is predominantly within the even narrower limits of the behavior of photons, electrons, and the (real or virtual) photons or phonons of photons transferring momentum between those particles.

Obviously, the vast majority of so-called 'mathematics' is merely a convenient expression of relationships, often as an interesting discussion about how something works, without nearly sufficient information for any practical use.

For example, the Navier-Stokes equations describe fluid motion as a derivative of Newton's laws of motion. Certainly it is very interesting to contemplate that a fluid may be described as a bunch of individual particles which exert pressue on neighboring particles due to inertia. Actually simulating fluid motion requires convolving the interaction of every particle with every other particle in the fluid (expotentially more computational expense per particle), as well as having very precise units and constants which may not even be known precisely enough *for such well known fluid as water*. Practically simulating requires limiting such convolution to a limited number of neighboring particles, and/or limiting such convolution to speed-of-light mechanics (as seemingly common with Conway's game-of-life but beyond the scope of an equation written for a discussion narrowly focused on purely Newtonian classical mechanics). Software infrastructure to experiment (ie. 'play') with such particle grids in Virtual Reality may not really exist. Semingly obvious and simple software to perform such experiements may not exist to this day, hundreds of years after Newton's life, discoveries, and death. To the extent such software does exist, it may not be easily interoperable (eg. with game engines), may have some complexity, may be focused on useses narrower than real-time interaction (eg. 'Blender'), and may be prohibitively expensive to license software made for any useful purpose that either professionals or amateurs would need (eg. 'Comsol').

Thus, it is entirely possible for a simple mathematical eqution to express something very interesting and useful, but with any useful implementation of it still a long way off, only due to all the useful details being left out, to the point that a single mathematical statement (ie. a One-Instruction Computer) is a more accurate description of the entire universe, than a single equation known for hundreds of years has been made useful today.

Examples - When Mathematics are NOT Worthwhile

SpaceX Starship

SpaceX has been 'launching' a number of 'Starships', and declaring these successful in their goals, despite spectacularly ending by 'crash-and-burn'. Three things account for this 'success'. First, the Starships theirselves are built for $millions, instead of the hundreds of $millions more usual of such large rockets, due to unprecedentedly inexpensive welded plate construction. Second, the apparent value of avoiding such spectacular melting of expensive rockets is offset by the cost of preparing simulations and/or licensing software to simulate, interactions between combusting fluits at complex temperature/density

gradients and thin complex welded metals. Third, there may be no way at present for welding crews to practice such assembly in Virtual Reality, much less in any way capture the complex shapes they will form with their welds.

A 'crashed' 'Starship' may slag a couple million dollars in recyclable steel, while the seemingly expensive manufacturing processes of welding, etc, are actually what is under test, and if the software even exists to model of simulate what the welded joints of a 'Starship' actually look like, it may cost more than a few million dollars to license for a suitable number of developers. Every 'Starship' launch may more cheaply evaluate some particularly important aspect of the entire manufacturing process, cheaper and better, than any mathematical model and simulation.

Of cousrse, there are a lot more issues to 'Starship' as well, such as pogo oscillation and continuing inertial navigation 'up' instead of 'down' while accelerometers are shaking, so this example is an oversimplification. Nevertheless, purely 'Newtonian' physics known for hundreds of years remain easier to experiment with to the point of spending $millions rather than licensing expensive software.

Flight Simulation

Flight simulation costs a few tens of dollars per flight hour, or less. Accuracy has improved to the point of allowing players to repeatedly practice startup, avionics, and other procedures. Commercial aviation safety has no doubt improved much due to flight simulation.

Why then do exercises continue to be flown with real aircraft?

At least one reason is the need for practicing *everything else*. Readiness is about every job, not just the pilot's job. Much of the cost is in maintenance, and maintaining older aircraft is unpredictable, since simulation software to predict exactly where and how most aircraft will degrade over their useful lifetimes may not exist. Replacement of older aircraft with newer, better aircraft, is also necessary to practice as part of readiness for future activity. Especially, such things are true of aircraft designed for competitive use - where known science is already pushed to its limits, timely modeling to predict details of future degradation is not possible. Fuel costs may be a minority of such expenses, and all jobs must be practiced, all the way back to factory production of replacement aircraft.

Thus, flying real aircraft, albeit expensive, will continue, even as practice, even when software to accurately simulate part of the job, becomes widely available.

Mathematics and Entire Universe All Always Equivalent to Just One Single Instruction (Turing Completeness)

One single instruction is sufficient to implement a computer which can emulate all operations of all functions (ie. is 'turing complete'). Some such computers use 'move', some are based on addition, some use subtraction. One single instruction is sufficient to compute anything that could possibly happen in the universe.

Quantum Computing is NOT Special

Such simple computers can also emulate quantum computers. Quantum computing also does nothing that cannot be done by another computer, only performing some very specialized operations faster, because quantum bits can be both 0 and 1 simulatenously, until all bits are collapsed to the definite state of an answer. One problem in particular is solved faster by quantum computing - halving the search space for a guess. If an algorithm produces meaningful information only from a number with 2^128 possible combinations, then a quantum computer find that number with on the order of 2^64 operations instead of 2^128.

Quantum computer hardware is comparably complex and expensive to classical computer hardware, so aside from urgently necessitating replacement of some equipment using some older ciphers, as well as possibly simulating some replacement wetware (ie. misfolding proteins), quantum computing has an thoroughly unremarkable usefulness in solving problems.

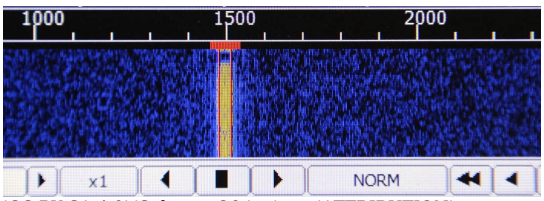
Cognition vs Automation

Humans inevitably understand the mechanics of their world in the same way as any animal with a complex learning biological neural network (ie. *cognition*) - ~300bits per second shoving things around, ~10Mbits per second observing effects, >>1Tbits iteratively computing valid models of how these outputs cause these inputs. Very few decisions (shove) cause large changes in the surrounding world (avalanche) which may be computationally expensive to adequately model (thinking about vibrations and sensitivity through of a chain of many objects between shove and avalanche).

Interactive experimentation is thus a fundamental necessity, as with cats learning depth perception in a critical period only by interaction, and symbolic manipulation on paper/computer is only important for lack of resources, always inferior to and less enjoyable than intuitive experimentation. Arithmetic as an example, tallying quantity, is simply four *automation* functions better suited to a pocket calculator and also not well enough integrated with human *cognition*.

Noise, Signals, Normality, Abnormality, Signaling Rate, Spread Spectrum, Channels, Coded Signals as Noise, Cryptography

Noise is random. Signals are not random.



'CC BY-SA 4.0' 'Splatter_Q9.jpg' see 'ATTRIBUTION'

Random noise does occur. Atmospheric turbulence (eg. from an air vent or fan) produces an essentially random acoustic noise. A clear whistle, on at some times, and off at others, at the same amplitude, is equally recognizable.

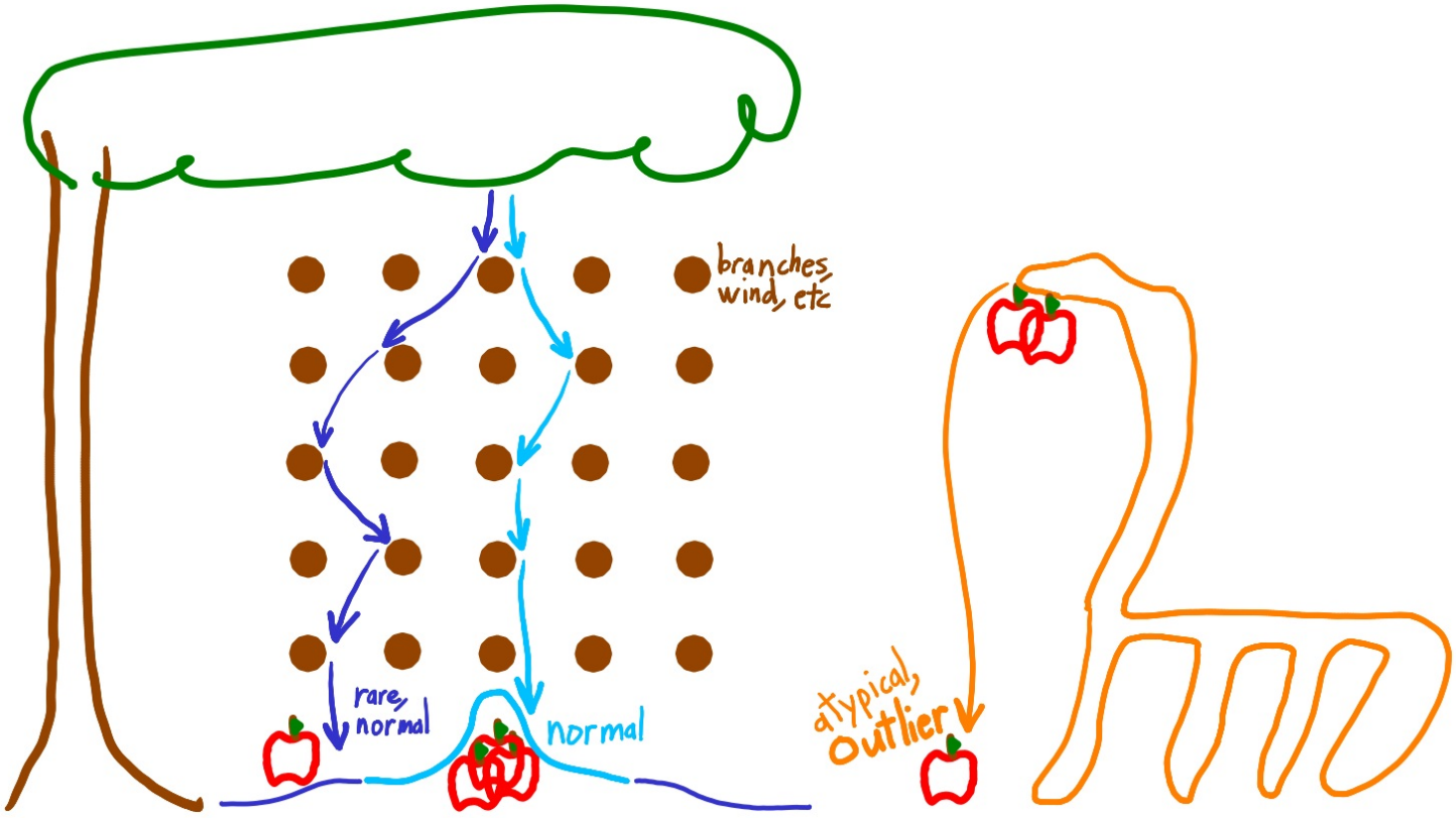
Complex signals can be correlated if in any way different from noise. Over a long time, a pattern of on/off from a whistle can be added and substracted to a 'score' for whether a code is present as amplitude shifts in a frequency bin. Searching that frequency bin for that matching code at many possible beginning times, is the cross-correlation technique that is the basis for reliably communicating, slowly, over noisy channels (eg. 'WSPR' over amateur radio), seemingly at amplitudes below the 'noise floor' (because On/Off-Keying code score is a much higher amplitude than the background noise).

Noise distributions, patterns from random events.

Random noise distributions exist - in which random events distribute things into a non-random pattern. One common such pattern is a 'normal distribution'.

Random events can distribute objects into a non-random pattern, randomly forming a random distribution. What has a number within the usual range for that distribution may be noise. What has a number very rarely occurring in that distribution (eg. only 1% likely) may be regarded as signal. Whether two random noise distributions are from events that distribute things significantly differently can also be compared on the basis of likelihood of events in one distribution occurring in another

A particularly common random noise distribution is known as a 'normal' distribution (aka. 'bell curve'). Numbers outside the usual range for a 'normal distribution' are likely non-random, possibly describable as 'atypical' or 'abnormal'. Atypical is not always abnormal or otherwise undesirable in any way, especially where there is any possibility diversity may be valuable. Usually, likely non-random is at least regarded as a possible signal.



Signaling Rate as Signal to Noise Ratio

```
bitsPerSecond == hertz * log2(1 + (signal_decibels / noise_decibels) )
```

Shannon-Hartley theorem is a simple equation specifying that communications bandwidth, in bits per second, is proportional to bandwidth used, in hertz, signal power, and noise power. Statistically, more samples are needed to distinguish barely significant signals from a noisy background, than more substantial signals from a quiet background.

For this reason, it is common for people to speak louder (ie. at greater amplitude) in a noisy, rather than quiet, room,

especially if convinced they have important information which may not have been heard.

Spread Spectrum

Spread spectrum modulates a small amount of information (ie. a single symbol) (eg. one On/Off-Keying event) is modulated with a complex code, creating a complex signal. Receivers may correlate such complex signals as different from noise. Usually, spread spectrum devices will transmit information rather quickly. As an inevitable side effect, the bandwidth of any transmission of such information - such as a radio transmission - is increased to approximately the rate of the spreading code - in radio communications the difference tends to be from a few Hz or kHz to >>1MHz .

Spread spectrum codes are often close enough to random noise to convert an obviously non-random signal (eg. morse code beeps) into something matching background noise (eg. static noise statistically similar to atmospheric and receiver thermal noise), however, any symbol codes used for communication may be chosen to resemble random noise without such 'spreading'.

As an example, modulating morse code switching the transmit key at a much faster rate, using a unique code of on/off timings, which a receiver could correlate, would be spread spectrum.

Channels

A shared communications channel may be partitioned in four ways. Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), and Space Division Multiple Access (SDMA).

Frequency Division Multiple Access (FDMA) usually takes advantage of the ability to separate frequencies with resistors/capacitors/inductors. Such frequency filters can be robust and made from common wire and foil (radio), tuning forks or wooden cavities (audio), etc. Frequency division is less favored for modern digital computer communications software modulation/demodulation obviates several issues. Notably, hardware many frequency filters must be stacked repeatedly to sharply attenuate adjacent frequencies, and adding the ability to change the bandwidth and frequency of many filters adds to that expense.

Time Division Multiple Access (TDMA) divides channel into time slots. Protocols must retransmit after collisions occur, possibly even from highly attenuated distant transmitters that could have been ignored by some code division. Very common in digital radio communications.

Code Division Multiple Access (CDMA) divides channel by different spreading codes. As a spread spectrum technique, a receiver listening for one code will receive all other codes as seemingly random noise. CMDA at low bit rates in software implementations may correlate very weak coded signals (ie. symbols) from the severe noise of many transmitters. Apparent noise from irrelevant transmitters may be reduced, and signal capacity correspondingly increased, if all CDMA transmitters cooperatively minimize transmit power upon demand by receiver. CDMA at high bit rates and/or in hardware implementations, with a synchronized clock, frequency mixer, low-pass filter, and comparator, may exceed reasonable received power limits (ie. many watts of power at receiver amplifiers causing distortion), may exceed hardware signal/noise limits (ie. low-pass filter thermal noise), etc, from noise of many (>>1000) transmitters. CDMA has been used in digital radio communications (eg. apparently 'EVDO').

Space Division Multiple Access (SDMA) deliberately points transmissions (ie. by physically moving an antenna or switching parts of the antenna) in the direction of 'less busy' receivers.

Combining FDMA, TDMA, CDMA, SDMA, has been done. Radio systems usually have some frequency filtering (FDMA) either incidentally due to antenna, or purposefully to protect their receivers from distortion due to strong out-of-band signals. CDMA may be combined with TDMA, using codes, but not all users transmitting simultaneously. SDMA is increasingly common as many low-Earth internet satellite services have many separate satellites, but each individual satellite's radio bandwidth is shared by multiple users through FDMA, TDMA, and/or CDMA.

Coded Signals as Apparent Noise

Correlating long or complex coded has the interesting property that to any receiver not aware of the code, if the code was chosen to resemble ambient random noise, it may be impossible to detect, especially if transmitted at the minimum power demanded by receiver.

For unintended receivers to be unable to guess the code, all of the code must be thoroughly unpredictable. For such communication, it is necessary that the symbols chosen cover 100% of the bit space (eg. if using 8-bit codes, all 256 symbols must be used equally), and that the symbols transmitted be *pure* ciphertext.

Receiving pure ciphertext requires attempting to decrypt incoming symbols at many possible beginning times, similar to the cross-correlation technique that is the basis for reliably communicating, slowly, over noisy channels.

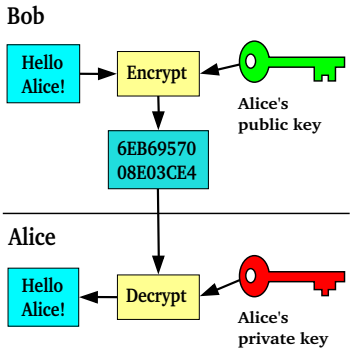
Such is very rare in digital radio communications, seemingly because software developers are more immediately concerned with quickly developing technology for communicating quickly (high-bit rate).

Satellite navigation systems seem to have some such features.

Cryptography

Cryptography combines a signal of 'plaintext' (non-random symbols) with a code of random symbols known only to intended recipients, to create 'ciphertext' indistinguishable from random noise in any way by anyone who does not possess the code. Cryptography can be *impossible* to 'break', because ciphertext can be impossible to recognize as anything other than random numbers (eg. from tossing dice).

A Perfect Cipher for Dummies and the Basis of All Ciphers - One-Time-Pad



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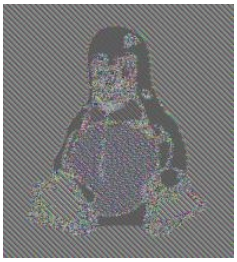

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Message on one paper. Random letters (or whatever symbols) on another paper (the 'One-Time-Pad'). Number the symbols from 1 to the maximum number (ie. 26 for A-Z). Add the random letters to the message letters, carrying any number above the maximum to a lower number (ie. modular arithmetic). Encryption complete. Without the random letters paper, the 'ciphertext' is *impossible* to distinguish from random noise.

Because the one-time-pad has as many symbols as the plaintext/ciphertext, the key is as 'large' as any encrypted message, the one-time-pad is rather inconvenient. A 'one-time-pad' cannot be memorized as a password to decrypt megabytes of files, a shared one-time-pad must be physically transported to all recipients, and any new one-time pad sent using a one-time-pad can only be as large as the original one-time-pad. Nevertheless, this has historically been used for historic communications, notably SIGSALY (which included many substantial and significant non-cryptography technical achievements), and may be used for some communications today.

Two ciphertexts from the same 'one-time-pad' can be easily decrypted by widely available statistical methods, so a one-time pad must not be used twice. Similarly, the pad itself must use strictly random numbers, any predictability can be found by widely available statistical methods, allowing the pad to be inferred, and the message made readable.

Ciphertext always uses all used symbols equally often, as to do otherwise would not exactly resemble randomness. Notably, it is not possible to create or meaningfully change encrypted messages without the 'secret', due to the exact resemblance of randomness. Authentication uses encryption in any of many schemes, due to the unforgeability of meaningful encrypted messages.

Symmetric Ciphers

Symmetric ciphers use a small key (eg. 256bits) of random numbers to create a large (usually unlimited) quantity of equally unpredictable random numbers. Such symbols recreate the effect of a one-time-pad, as any intended persons with the small key can generate the same string of random numbers for both encryption and decryption.

Stream ciphers directly combine the large quantity of random symbols with plaintext, producing ciphertext. Block ciphers can take a fixed quantity of plaintext symbols, and convert to ciphertext by several operations of addition, shifting, lookup substitution, mixing, etc. Block ciphers, when given a long string of '0' or other predictably meaningless numbers, still produces unpredictable random ciphertext, and so may be used as a stream cipher.

Symmetric ciphers are infeasible to 'break' if the stream of ciphertext cannot be statistically proven. Expert consensus is that many of the commonly used symmetric ciphers (ie. AES finalists) will not be broken by any computer or statistical analysis until long after any protected plaintext is no longer of any consequence to the originating parties (ie. long after their biological lifespans have expired), or until well after the universe itself ceases to have any non-randomness in it.

Symmetric ciphers are still sometimes chosen for convenience rather than security, resulting in some unmet expectations (eg. Wired Equivalent Protection). Block ciphers specifically can be misused in that input plaintext must always be unique, becoming a more of an alphabet substitution table than a cipher (ie. ECB mode) when this is not properly guaranteed (eg. by mixing plaintext blocks with an incrementing number for each block).

Asymmetric Ciphers

Asymmetric ciphers create a string of random numbers from an encryption key which can only be recreated for that specific message or with a separate decryption key.

Two (or more) parties can issue public encryption keys, allowing anyone to encrypt a message, which only they can decrypt with their private keys. Thus, both parties can create a private encrypted communications channel in public, and authenticate theirselves by completing the challenge of decrypting a message intended for theirselves, using the private encrypted communications channel.

In principle, pure ciphertext messages, in a noisy (eg. radio) channel, could establish a brief conversation, unlocatable and undetectable to a third party, with no 'pairing' of shared keys in advance.

Quantum computing is a risk to some asymmetric ciphers, for ciphers which use the specific mathematical operations quantum superposition can much more quickly predict (eg. elliptic curves, prime numbers). Replacing those algorithms is becoming an urgent issue, especially presenting some risk to bank accounts, bank solvency, and popular cryptocurrencies.

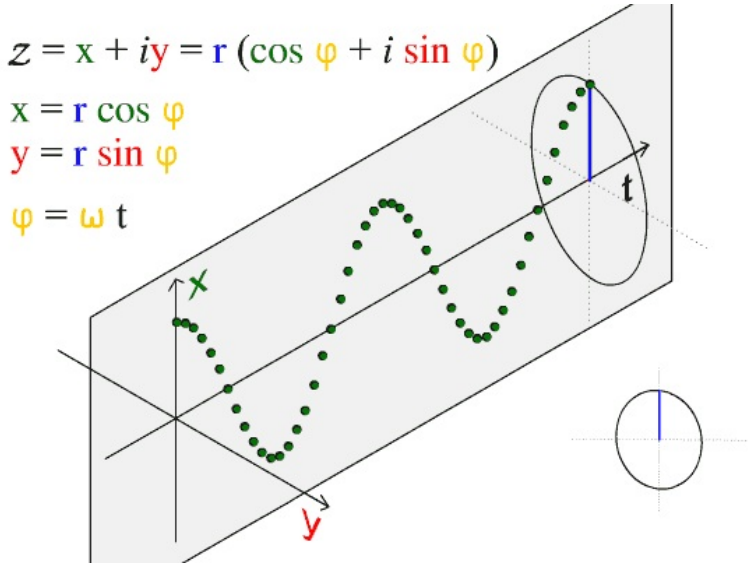
Amplitude, Time, Frequency

Amplitude is a measure of 'how much'. Amplitude could be pressure, voltage, current, or even the water level in a container. Often amplitude is measured on the vertical axis of a (eg. oscilloscope) graph.

Time is simply how long it takes one event to proceed to the next, usually measured in the SI unit, seconds.

Frequency is the inverse of time, measured in cycles per second, or hertz. An alternating current of 60Hz reverses direction 60 times per second. At this frequency, one cycle lasts 1/60th of a second.

Any change in amplitude over time gives rise to a signal with a frequency. A pure sine wave changes amplitude at a constant rate, tracing a circle. By contrast, a square wave sharply changes amplitude, giving rise to one large fundamental frequency, and many smaller amplitude harmonics. A pulse of energy is in fact a square wave, and the sudden transition from no amplitude, to amplitude, then back to no amplitude, gives rise to a wide range of frequencies.



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In practical terms, this is why switching power supplies, which deliver power one pulse at a time, generate substantial electrical noise, which results in external electrical or magnetic fields that give rise to radio wave photons, and thus, random noise on radios. Arcing electrical circuits, where energy is switched on and off repeatedly as the arc is ignited and extinguished, are also a major source of electrical/radio interference. Since a major mathematical approach to analyzing signals is by measuring frequency, this is can be very substantially undesirable in communications and diagnostic equipment.

Old analog TV and AM or single-side-band radios tend to show interference noticeably when large motors (eg. vacuum cleaners) or switching power supplies are near their sensitive receiver circuits (eg. in the same house), due to square wave 'harmonics' and frequency mixing with other rapidly switched frequencies (eg. computers with rapidly switching loads powered by rapidly switching power supplies converting power one switched packet at a time).

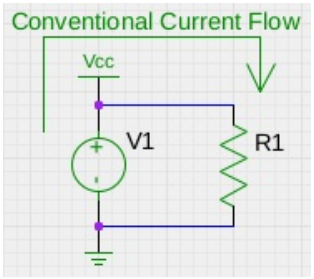
Modulating the amplitude of an oscillating sine wave with the amplitude of another sine wave of a different frequency - such a frequency mixer being as simple as a single light dependent resistor and an LED light - or a JFET transistor - tends to produce two more frequencies - the sum and difference of the multiplying frequency. Thus, one frequency (eg. 1kHz) may be shifted to two others (eg. 1GHz+1kHz, 1GHz-1kHz). Removing one of these frequencies (eg. with a pair of frequency mixing devices) is the basis for 'single-sideband' - the direct shifting of one frequency (eg. 0-20kHz audio) to another (eg. 1GHz). Thus, a computer sound card with a maximum frequency of 20kHz can directly and exactly process phase, frequency, and amplitude shifts at radio frequency of (arbitrarily) 1GHz, as a 'software radio' (though today digital communications often use sound card equivalent hardware with >>10MHz of 'baseband' bandwidth to send >>10Mbits/s).

Thus, frequency modulation, phase modulation, amplitude modulation, single-side-band modulation, are all equivalent. Such terms are more descriptive of the hardware or software specifically used, with 'On/Off Keying' being rather typical. Frequency modulation sometimes is used because such analog phase-locked loop hardware can do some 'spreading' to reduce noticeable received interference. Some multiple phase shift keying or multiple amplitude shift keying are actually equivalent in effect (eg. QPSK, QAM) and transmitted very simply by putting one of a few specified amplitudes into a frequency mixer depending on the current intended symbol. Digital communication modulation schemes are often described by terminology having much more to do with how they *are* implemented than how they *can* be implemented.

Circuits

Circuits are relevant to more than electronics. All machinery (eg. heatsinks, insulation, hydraulics, automotive shocks) can be and often is modeled as electronic circuits. Spring and material elasticity is espeically notable for having a simple, highly useful, exact electronic circuit equivalent model as a resistor, capacitor, inductor 'frequency filter' circuit. Photons (whether far field 'real' or near field 'virtual') through their electromagnetic fields are the predominant carrier for momentum between particles, and all interactions ('all forces') in the universe are transfers of momentum. Fundamentally, electronic components using electrical and magnetic fields, are a convenient, graphical way to describe paths for all such interactions.

Voltage, Current, Watts



Voltage, Current, Watts

In conductors, electrons form a liquid. They can, and do, move between atoms in a wire like fluid in a pipe.

Voltage is electrical pressure, measured in volts.

Current is the quantity of electrons moving, measured in amps.

Watts is power, pressure (volts units) multiplied by current (amps unit).

Resistance

If water is pumped through a thin pipe, higher pressure will exist on one side of the pipe than the other. A quantity of fluid will flow through the pipe proportional to this pressure drop across the pipe. The pipe itself will heat up (eg. noticeably in tractor hydraulics), as power is dissipated.

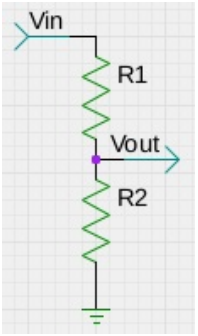
Resistors operate on exactly the same principle. Voltage is pressure. Current is flow. Power is watts.

How much current flows depends on the voltage pressure. A simple formula, Ohm's law, precisely relates this as I=V/R . One amp will flow through a one ohm resistor under one volt of pressure.

Power dissipation is the number of volts across a resistance, multiplied by the current flowing through it. One volt times one amp is one watt. Typical space heaters use ~1kW to heat small rooms.

Voltage Dividers

If holes are drilled along a long hose, most water will leak closer to the faucet, than to the drain. Along a resistance, pressure is greatest at the source. This simple principle is the most important in all circuit modeling.



Rather than a long, continious hose, consider two resistors in series across a power supply. At the positive terminal, the supply is at 10V. At the negative terminal, 0V.

Suppose both resistors are equal, perhaps 1kOhms (1000 Ohms). The terminal between these two resistors will be at 5V, exactly half the supply voltage.

Now suppose the bottom resistor is 90% of the resistance, perhaps 900Ohms, while the top resistor represents the remaining 10%, perhaps 100Ohms. Now, current flows out more readily than in. Middle terminal will now be at 1V, ten times less than input voltage.

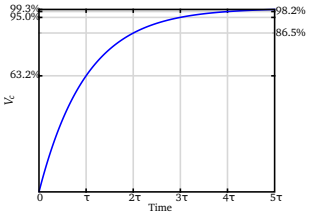
In this way, high voltages can be safely measured, up to, and far beyond, lightning strikes, by sensitive equipment which would be damaged by few volts.

Impedance

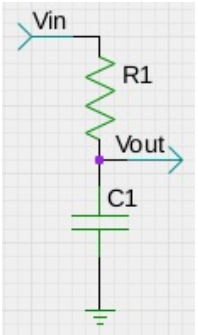
Resistors instantaneously allow current to flow in proportion to voltage. Like a hose, when pressure is applied, current flows immediately, and does not stop.

Capacitors store current, like a sealed bucket. Pour water in, and after a while, no more water can flow in. Open a tap, and water flows out, until the bucket is empty. In electronics, these buckets are pairs of plates next to each other, storing charge in an insulator.

Inductors store momentum, like flywheels connected to turbines. Force water through the turbine, and the flywheel slowly starts to spin. Release pressure, and the flywheel will continue to pull water through the turbine. In electronics, these flywheels are actually coils of wire, storing energy in magnetic fields.



'Series_RC_capacitor_voltage.svg'
see 'ATTRIBUTION'



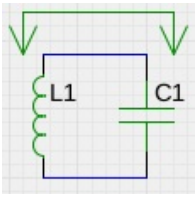
Consider what happens when a resistor and capacitor are connected together, then the circuit is connected to a power supply. At first, the capacitor will be empty - all current flowing out of the resistor immediately goes to the capacitor. Middle terminal voltage is zero. Slowly, less current will flow into the capacitor as it literally fills up. As this happens, it

will offer an imaginary 'resistance' to the flow of more current.

An inductor shows exactly the opposite behavior. At first, the full power supply voltage will be dropped across an inductor. As the magnetic field gets going, just like a flywheel, current will flow, and pressure across the inductor, like a turbine spinning freely, will fall to zero.

This simple principle allows a combination of just three components - resistors, capacitors, and inductors, to filter signals by frequency. The combination of real and imaginary resistance, as a two dimensional 'complex number' is known as 'impedance'.

Resonance



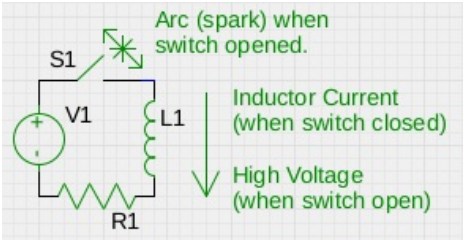
When inductors and capacitors are combined in the same circuit, current flows between them endlessly. In a hydraulic analogy, the bucket fills up, then the flywheel starts spinning. Once the flywheel is spinning, it starts emptying back into the bucket.

In practice, real inductors and capacitors made of ordinary metals have some resistance, so the oscillation stops.* This combination of inductance, capacitance, and resistance, results in selectivity to a narrow band of frequencies.

Additionally, the voltage across each component is proportional to their values, one of many ways to increase or decrease (ie. 'transform') voltage.

*Inductor/capcacitor circuits made of superconducting materials below their cryogenic critical temperature have zero internal resistance, and can sustain oscilations almost indefinitely.

Flyback

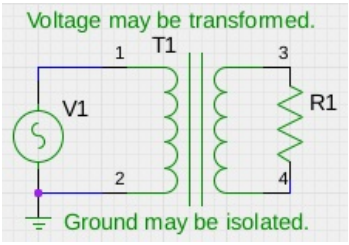


What happens when a valve to a spinning turbine is instantly sealed off? Pressure rises precipitiously. In physics, no work is done unless motion occurrs. If a spinning turbine cannot push fluid, then energy is unable to perform work. In theory, if the turbine is stopped instantly, pressure rises instantly, infinitely.

Inductors produce a similar effect, known as flyback. In theory, infinite voltage may be generated, unless a load is applied at all times. When a load is applied continiously in parallel with the inductor, the output voltage will correspond to duty cycle - percentage of time on/off. In this way, a 'buck-boost converter' may efficiently generate voltages higher or lower than the input. Most small power supplies today operate on this flyback principle.

On the other hand, flyback can be destructive. In the turbine analogy, water hammer would rapidly destroy the shut valve. Similarly, high voltage can overcome the breakdown voltage of insulators. In air, this results in a large spark. In solid devices, like transistors, the high-energy pulse may permanently destory their tiny structures.

Coupling



Capacitors store charge as an electric field on a dielectric material, while inductors store inertia in magnetic fields. Because these fields are external, these components can interact.

Two inductors close together, or wound around the same iron core, can transfer energy in a changing magentic field. Because the magnetic field produced by an inductor per volt is proportional to the number of turns in the wire coil, transformers may be used to convert voltages. Transformers can also break common ground loops (ie. isolation), which can be an important safety feature. Motors operate similarly, with the secondary inductor replaced by a spinning magnet (and vice versa for electromechanical generators).

Together, a capacitor an inductor may induce oscillating electrical or magnetic fields in the same free space, as with any inductor/capacitor circuit. However, when the transition between a strong electrical, and a strong electrical field, takes place openly, the particle associated with these fields is created - a photon. Just as a resistor emits heat, a radiation resistance arises in the circuit, emitting these photons, known as radio waves. Thus, an antenna is merely a combination of a capacitor and an inductor operating in open space, forming a circuit tuned to a specific frequency.

Coupling is not always desirable however. In particular, adjacent wires in telephone wires may generate electrical or magnetic fields, causing a signal in one wire to be picked up by another. Shielding and twisting of the wires are strategies used to short out, or randomize to an average of zero, these unwanted stray fields.

Source Impedance

Ideal power supplies, as voltage sources would have zero resistance. Real power supplies have a built-in resistance.

Recalling the principle of a voltage divider, low-resistance loads, like a high wattage light bulb, will cause power supply voltage to sag.

Signals typically have the same built-in resistance. A microphone may produce a high voltage, but little current. In effect, any load attached to a microphone, such as a loudspeaker, will cause the voltage to sag nearly to zero. Sound powered telephones do exist, but must be well designed for efficiency.

Amplification

Incoming signals often have high source impedance. Their voltages need to be matched with an increase in current, to remove the source impedance, before driving a load.

Recall that power in watts equals voltage multipled by amps. Increasing either voltage/pressure, or amps/current, increases power. To increase the current in a signal requires increasing power.

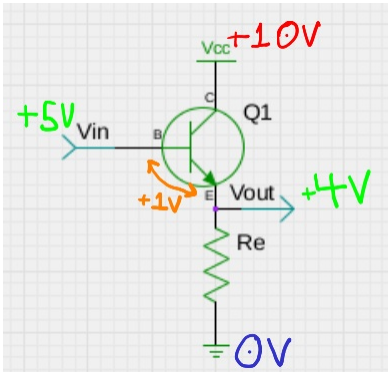
Likewise, a weak signal may have too little voltage to drive current into a load, as well as lacking current. Again, increasing the voltage of a signal requires increasing power.

Increasing power is amplification.

Amplifying devices are generally divided in two categories. Voltage amplifiers, and current amplifiers.

Voltage amplifiers are usually used for internal purposes, since the 'pressure' may carry information with little expenditure of current. Current amplifiers usually drive heavy loads, such as loudspeakers, into which large currents must flow. Before reaching a final current amplifier, a signal will usually be increased to the power supply voltage. A portable megaphone may amplify the microphone signal to match a 9V battery voltage, then use a current amplifier to drive the loudspeaker like a power supply at that voltage.

Current Amplifier



Current amplification is done with just one transistor circuit - the 'common collector' amplifier. Other amplifiers of this type (ie. vacuum tube) use almost identical circuits.

Transistors are voltage controlled switches. Collector and emitter are shorted together when turned on, disconnected when turned off. Voltage between base and emitter turns the transistor on, lack of voltage turns it off.

Consider the circuit diagram. A voltage divider should be obvious - the collector-to-emitter side of the transistor is one resistor, resistor Re is the other resistor. At the top, collector is connected to supply voltage, perhaps 10V, while Re is connected to ground, 0V. Vout will be somewhere between 10V and 0V depending on the 'resistance' of the transistor.

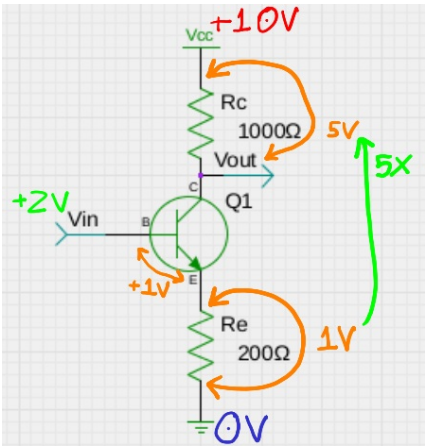
Suppose this transistor turns on when voltage between base and emitter is 1V. Further, a 5V signal is input to the base. The transistor will turn on, and voltage at Vout will rise. Since transistor emitter voltage also rises, the voltage between base and emitter drops. When the output/emitter voltage reaches 4V, base-to-emitter voltage will be just 1V. At this point, the transistor will have no further 'incentive' to continue turning on. This equilibrium is called linear amplification.

Voltage gain is unity (no amplification), current gain is (ideally) infinite. Hence, this is a current amplifier.

Many signal sources, like microphones, do not have sufficient current to drive a low resistance. In effect, these signal sources are power supplies that have passed through a high-resistance, and do not have much current flowing out.

An amplifier like this one can sample the voltage, much like a pressure gauge, and control the flow of a much larger power supply, accordingly, to drive a heavy load, like a loudspeaker.

Voltage Amplifier



Voltage amplification is also done with just one transistor circuit - the 'common emitter' amplifier. Again other amplifiers of this type (ie. vacuum tube) use almost identical circuits.

From the circuit diagram, it can be seen the common emitter amplifier is a derivative of the common collector amplifier. Once again, the emitter voltage will be driven to just a little less than the base voltage, depending on the transistor's switch on voltage.

However, another resistor Rc has been added, and typically much higher resistance than Re. Typical values are around 200ohms Re and 1000ohms Rc.

Ignoring the transistor, another voltage divider can be seen. Just passing the power supply voltage across them, which would happen with the transistor fully switched on, the voltage across Rc and Re would be proportional to their resistances.

Thus, it can be seen that the common emitter amplifier can induce a much greater voltage across Rc than it induces across Re. Since Re is approximately equal to input voltage, this shows the voltage across Rc can be much greater than the input voltage.

However, because the resistance of Rc must be high to achieve high gain, little output current is available. Common practice is to follow a voltage amplifier with a current amplifier.

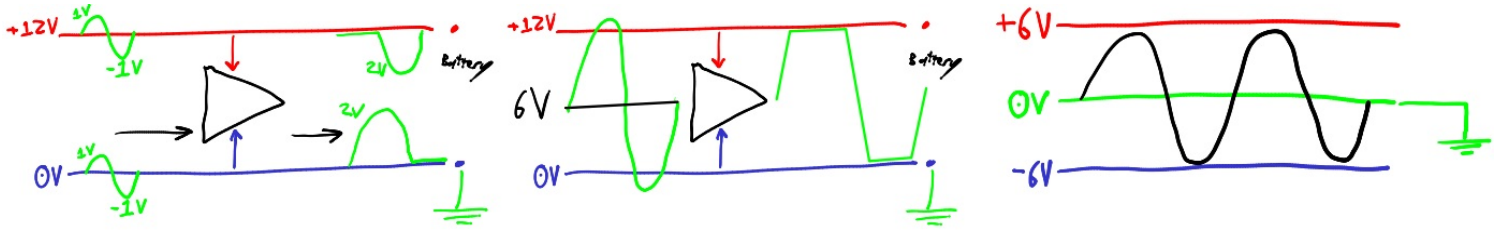
Split Power Supplies, Midpoint Ground

Amplifiers can only switch their outputs to Vcc (input voltage), 0V (ground), or something in between. To output a voltage below 0V (ground) is not possible.

An arbitrary voltage, usually exactly half the power supply voltage, can be used as 0V (ground) instead. This way, an amplifier can output an AC signal, relative to this middle voltage.

In this case, positive voltage is usually termed Vcc, negative Vee, and midpoint ground GND.

Here, an amplifier is first shown taking an input signal either +/-1V relative to Vee and Vcc. In both cases, the amplifier cannot output a voltage outside the power supply 'rails' to match the input. Then, it is shown that anytime a signal exceeds the power supply rails, the amplifier outputs the closest possible voltage, but not higher or lower voltage. Finally, an AC sine wave is shown going both above and below the chosen midpoint ground voltage, but never outside the power supply rails. This would be a good signal to work with inside an electronic device.

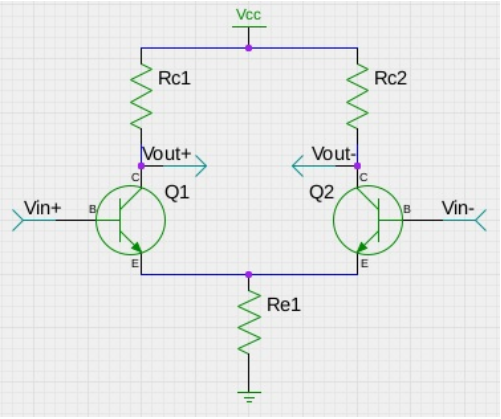


Operational Amplifier

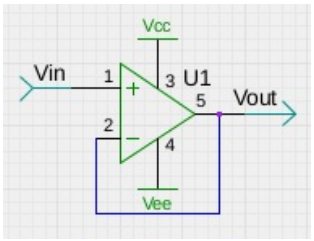
A differential amplifier is formed by combining two common emitter amplifiers. Inputting 5V to both amplifiers will result in 0V, while sending 5V to just one amplifier will result in a 5V difference between the two output terminals.

Following this with an ordinary 'single-ended' amplifier - a voltage amplifier followed by a current amplifier, results in an operational amplifier.

Operational amplifiers are the basis of modern analog electronics as well as control systems because they can be driven by *feedback*.



Feedback - How Operational Amplifier Circuits Do Everything in the Universe (and you yourself are an Operational Amplifier on feedback)



Feedback is ubiquitous. Send negative feedback, things stop happening. Send positive feedback, things start happening.

Operational amplifiers are the ultimate feedback operators. Any device, including more amplifiers, can be put in their feedback loops. This can be used to control transmitter power, drive extremely powerful broadcast amplifiers, or even steer antennas/photovoltaics toward the direction of a transmission source.

Operational amplifiers, opamps for short, have three terminals - positive, negative, and output. When the positive input is higher voltage than the negative input, output voltage increases. When negative input voltage is higher than positive input voltage, output voltage drops.

When the negative input of an opamp is tied to the output, and the output is greater than the positive input, voltage will lower. When output falls below the positive input, the cycle flips, and output voltage rises again.

Thus, an operational amplifier with a direct wire from output to negative input, will exactly copy the input voltage.

What makes this magical is the ability of the feedback loop to actively 'correct' any disturbance. If a heavy load causes the output voltage to sag, the opamp will immediately correct the error. Similarly, this basic principle can be used in control loops. Signal strength can be used as an opamp input, and antennas can be steered based on the opamp output, until the feedback loop is satisfied. Feedback can even be used to control switching circuits to convert analog signals into pulse width modulation, as done with both switching power supplies (amplifying a stable voltage reference) and very efficient, very powerful, (eg. audio) Class D amplifiers.

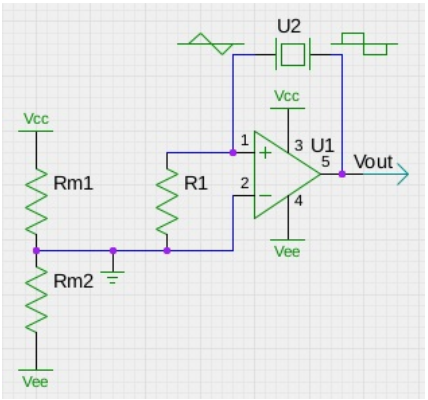
Software equivalents of opamp positive and negative inputs can be realized as simple multiplication by >>1 (eg. 1000) of the difference between inputs. Motivations of individual people, and collective groups of people, can be modeled as opamps. Entire economies have been modeled as collections of opamps.

Feedback is motivation, emerging from the fundamental universal concept of quantity - desire for more, instead of less.

Oscillation

Feeding an amplifier's output back into its *positive* input tends to result in infinite gain. When more positive feedback than negative feedback is present in a system, it tends to result in the largest signal possible.

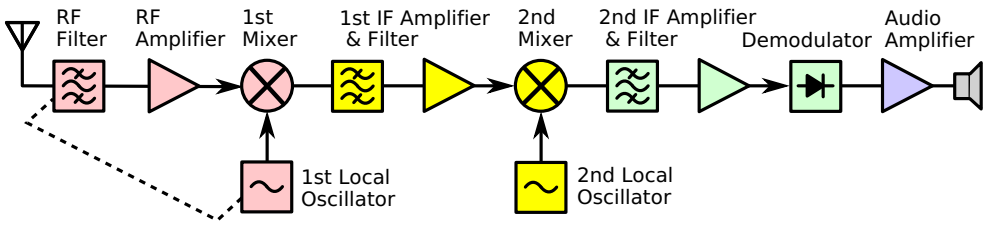
For an opamp, the largest possible signal is usually either 0V, or the power supply voltage, perhaps 10V. At this point, the amplifier is either 'on' or 'off', driven by an infinitesimal input, maybe a stray electron.



However, when positive feedback runs through a frequency filter, thermal noise is amplified, sent through the filter, and the filtered frequency is amplified - the result is oscillation. At one frequency - the frequency least attenuated by the filter -the amplifier can continuously switch on and off.

Mixing

Frequency mixing involves putting one signal through an amplifier's power supply, and the other at its input. Usually this is done by switches. Consider what happens turning a flashlight on and off once a minute, while rapidly shuttering it once a second. Both the once/minute and once/second frequencies will be transmitted, but another frequency, once per 61 seconds, will also be transmitted.



'Double-conversion_superheterodyne_receiver_block_diagram.svg' see 'ATTRIBUTION'

This shifting of frequencies is the basis for both older and modern radio transmission/reception. Amplitude modulation actually results in frequency shifting - as a high-frequency radio signal is modulated by a low-frequency audio signal, the audio frequency is actually shifted as-is all the way up to radio frequency. 'Single-sideband' is likewise just frequency shifting.

Diodes

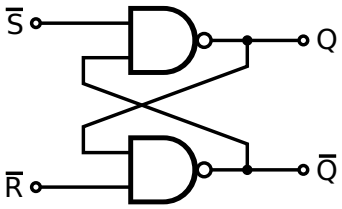
One special device is a diode. These allow electricity to flow in just one direction.

Most diodes are destroyed by excessive reverse voltages. Some, however, are designed to 'breakdown', just as air breaks down under sufficiently high voltage to jump a spark. These Zener and Avalanche diodes are used in voltage dividers, where their precise breakdown voltage is used as a reference (amplified to form a power supply). This overvoltage clamping ability is also used in surge-suppression, as are spark gaps.

'Bert Hickman' 'http://www.capturedlightning.com' 'Lichtenberg_figure_in_block_of_Plexiglas.jpg' see 'ATTRIBUTION'

Digital Logic

Amplifiers perform binary switching operations. These binary switches can be chained to produce logic gates performing five logical operations - OR, AND, XOR, NOR, NAND.



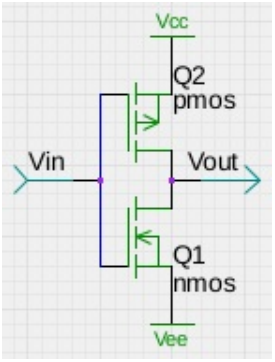
'SR_Flip-flop_Diagram.svg' see 'ATTRIBUTION'

To store and move the result of an operation, a flip flop is commonly used. These are formed by combinations of logic gates, and 'latch up' to the state input on a 'data pin', until a clock signal changes.

Reading information is done by clocking in a stream of bits into a 'register' of flip flops. Then, logic gates will settle on a decision. The output of these logic gates is connected to another register. When enough time has passed for a decision to be reached, the new data will be clocked out of the 'processor', again as a stream of new bits.

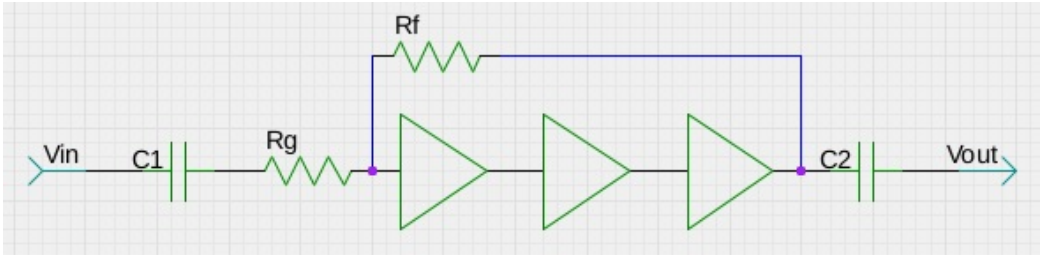
Inverter Amplifier

Interestingly, CMOS logical inverter 'gates' can be used as *linear* amplifiers. With two complimentary transistors, they are formed as pairs of 'common emitter' type amplifiers known as a push-pull configuration. Because these are inverting amplifiers, connecting their outputs back to their source forms a negative feedback loop.



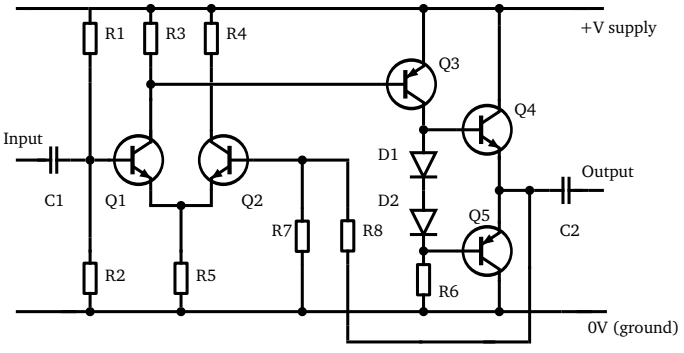
Unusually, the CMOS manufacturing process results in these transistors being so well matched, they effectively form a built-in voltage divider. Even without a positive input terminal, they will balance themselves at half the power supply voltage.

Consequently, CMOS inverter gates can be repurposed as rudimentary feedback amplifiers, following a schematic similar to an opamp configured as an inverting amplifier. A common use case is as the amplifying device in a quartz crystal oscillator.

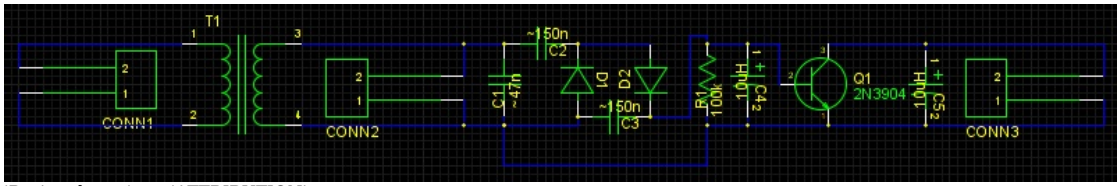


Schematic Literacy

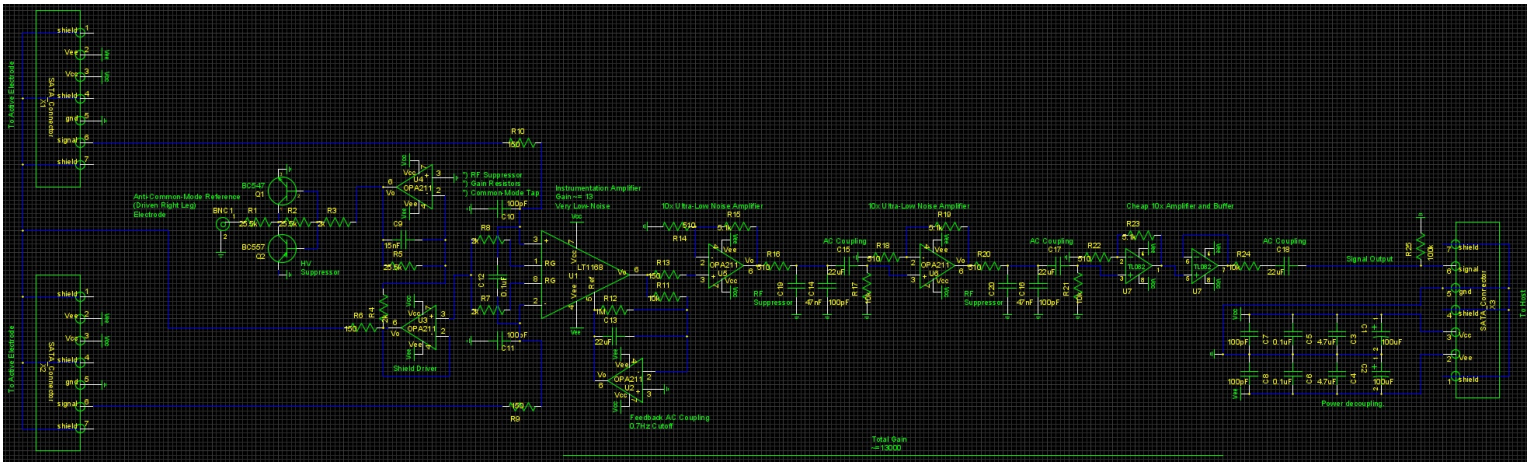
From here, it is possible to recognize key features in schematics, and research the remaining components. Rather than expecting individual components to be meaningful, they should be understood as substystems. Look for common emitter amplifiers, common collector amplifiers, opamps, feedback loops, and frequency filters, instead of transistors, resistors, and capacitors.



'Amplifier_Circuit_Small.svg' see 'ATTRIBUTION'



'Basic.sch.png' see 'ATTRIBUTION'

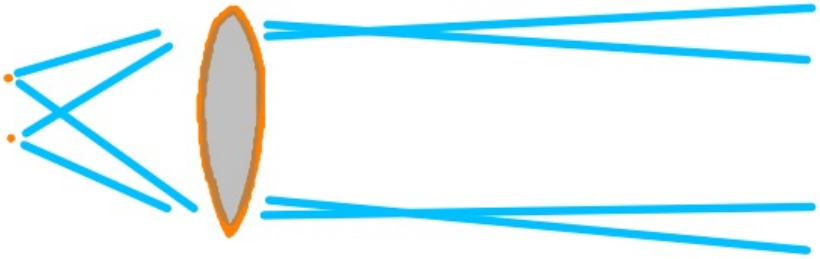


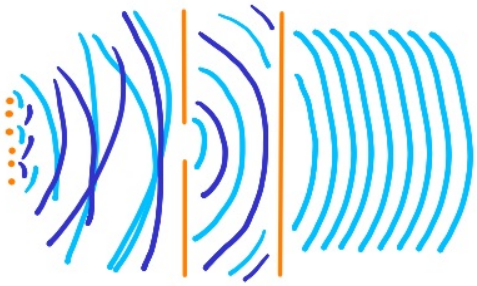
'amplifierSchematic.png' see 'ATTRIBUTION'

Optics

Collimated light from a single point source forms a perfect beam. By contrast, multiple points form multiple beams. Consequently any light from more than an infinitely small point will spread when collimated into a beam.

A pinhole filter and color filter can convert an incoherent light source, to a laser-like source. Early holograms were actually made by illumination with pinhole filtered mercury vapor lights, not lasers.





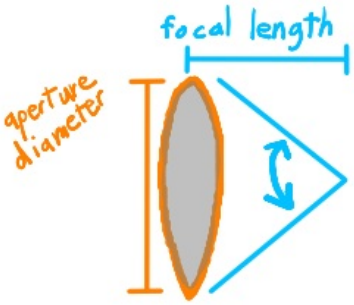
Spatial filtering an uncollimated light source has the disadvantage of discarding most of the light. Lasers are among few light sources offering both intensity and high power. Synchrotrons (big particle accelerator rings with magnetic undulators) are the other.

Even laser and synchrotron light is not perfectly collimated however. Due to the geometry of focusing a point of light into a beam with a lens,
wider beams are actually better collimated. This imposes a limit on the diameter of a projected spot at a distance.

When projecting a single spot from a large laser beam, projection resolution is actually a function of the numerical aperture. The 'faster' the lens, the more 'quickly' rays of light converge, the larger the lens relative to focal length, the smaller the spot.

Real lenses are limited to an f-number of approximately 0.5 - a convergence of 45degrees.

Thus, for laser cutters, the workpiece should be approximately as close as the lens is wide.



Collimated Displays

Heads up displays, and red dot sights, focused at infinity, project collimated light back to the user. As an example, light from a far away star
is effectively a beam of light from a particular direction. Collimated sights create beams of light aimed back at the user from the direction they are pointed, creating the illusion of a far away star, exactly where they are pointed (ie. a red dot).

Telescopes

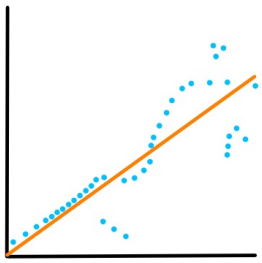
Telescopes are just beam expanders used in reverse. Objects far away are seen as beams of light from different directions. By shrinking the diameter of the beam, geometrically, the angles of incoming beams of light are exaggerated.

Telescope magnification is given as the ratio of focal lengths of the objective and eyepiece. Telescope objective and eyepiece are spaced at exactly their combined focal lengths.

Telescope (and also camera) angular resolution is equal to wavelength divided by objective diameter.

In reverse, as beam expanders, telescopes can reduce the angles of outgoing beams. Thus, starting with a larger beam of light usually results in lower divergence overall. This is one reason optical communications links involve telescopes at both ends, including proposed interstellar communication systems.

Physics



Classical Mechanics (slow and big)	Relativistic Mechanics
Quantum Mechanics	Quantum Field Theory (fast and small)

All just a collection of approximate trends. Classical Mechanics adequately predicts the vast majority of useful phenomena (ie. machinery) sufficiently for accurate simulation. Other physical models become relevant for a very few specific noticeable effects, mostly precise optical resolution and small transistor design).

Modern particle physics is an extraordinarily high confidence statistical testament, putting below insignificant probability, any possibilities of anything less ordinary than photon/electron computers and energy generators, drawing down on a finite supply of mass and energy, most of which is by definition uselessly noninteracting (ie. 'dark'). Telescopes have confirmed such physics for astronomically large and distant objects, while particle accelerators and cosmic ray detectors have confirmed such physics for the smallest and most energetic particles far beyond anything commonly available or useful. Most recently, confirming the Higgs boson has very firmly established a 'standard model' of few elementary particles, their uselessness, and the uselessness of anything those could possibly be composed of. For the most part, physics seems basically solved, to the point that carbon fiber and carbon nanotube composites are close to any possible end point of materials science. Seemingly, modern physics research effort is continuing beyond the point of diminishing returns now, albeit much effort was expended to the discovery and confirmation of such simplicity. At the very least, there is more opportunity for real success of all kinds from physics lab software for Virtual Reality, and the semiconductor industry behind that, than from finer estimation of the Higgs boson mass.

Warp drive, alternate dimensions, time travel, perpetual motion, unlimited space, unlimited time, instant computers, rapid travel to unexplored stars, more than marginally more useful superheavy stable elements, or subatomic machines, are all now very unlikely. Technology of the future will continue to work much like the biology of the past, in some cases necessarily so even within efficient Virtual Reality simulation. From doubling times to manufacturing rates, some slight improvements here and there. Suggestions otherwise are 'handwavium' (not possible by exceptionally strong scientific consensus on physical 'laws' applicable to anything in universe) and/or 'unobtainum' (requiring materials substantially beyond well established scientific consensus on limits of possible particles). Only successful communication with a neutron star or magnetar surface, or availablility of tons of antimatter from black hole sources, will substantaially change even the commonly available materials or computation rates, and then only long after humans less enjoyable labors have already been obviated by self-driving AI.

From the smallest quantum limits on computers to the most distant edges of energy from the observable universe, from beginning in chaos, to ending in chaos: you're stuck so have fun while you even get that choice. At ~10^26W/star, ~10^36W/galaxy, ~10^40-~10^60W/reachableGalaxies, and maybe ~10W/cognition, maybe ~10W/VirtualReality, *you really should be able to find some things to do and some people you can work with, without wasting so much of other people's exasperation*.

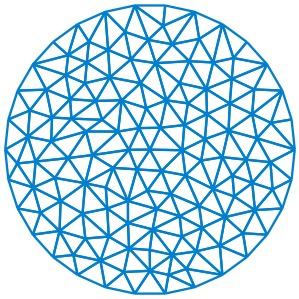
So maybe just *skim this part briefly* just to feel around the simple walls of your confinement, anchored to which your projects may build something a little more interesting within.

Subdivision

Solids, liquids, gasses, and plasmas, can be subdivided into cells, or finite elements. Failure of solids can be predicted by finding excessive stress at a given point of an object under external loads (including gravity).

Transmission of pressure and motion through fluids can be determined by arithmetic operations on volumes divided into finite elements.

Modeling failure of solids, or flow of liquids/gasses/plasmas, may require division into discrete time integrals. The combination of many finite elements and short time intervals may be computationally expensive, so accurate simulation of real-time events may be difficult (requiring much software optimization, approximation, and fast computers), but not impossible.



'Finite_element_triangulation.svg' see 'ATTRIBUTION'

'Tacoma-narrows-bridge-collapse.jpg' see 'ATTRIBUTION'

Compressibility, and the influence of past states, can complicate the behavior of materials, especially fluids. Accurately characterizing the disassembly of solids, transition between phases of matter, and flow of liquids/gasses/plasma, remains an area of intense computational study (or software improvement). Even for common materials under room temperature conditions, such as water, achieving sufficiently accurate measurements of simple physical properties, is still an area of intense scientific research.

The combined difficulty inherent to accurately modeling systems consisting of many materials, which may not be well measured, as the sum of many tiny parts, changing rapidly from one time interval to the next, is a key justification for the continued use of physical models, specifically wind tunnels and wave tanks.

Although the forces involved are always subject to simple arithmetic, complex interactions can become difficult to model. Failure of the Tacoma Narrows Bridge included interactions between at least turbulent air flow, elastic materials, and resonant mechanical circuits. Whether the ultimate cause of failure could be more accurately characterized as a match between wind gusts and a resonant filter, or areoelastic flutter, remains debatable.

Lottery machines exploit these complex interactions to generate a random stream of numbers, of cryptographically strong unpredictability.

Classical Mechanics

Newton's three laws of motion, qualified by a more modern understanding of relativity.

1) In an inertial reference frame, an object either remains at rest or continues to move at a constant velocity, unless acted upon by a force.
2) In an inertial reference frame, the vector sum of the forces 'F' on an object is equal to the mass 'm' of that object multiplied by the acceleration a of the object: 'F = m * a' .
3) When one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction on the first body.

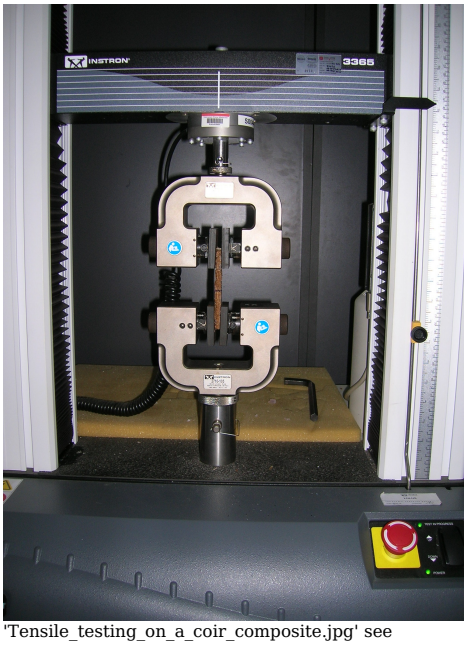
For example, Earth's gravity being a force of 10m/s^2 acceleration multiplied by interacting on the mass of an entire object, a 10kg mass on Earth, will experience a 10kgF force, and through (virtual) photon interactions, impart that 10kgF force onto the surface of the Earth it is steadily in physical contact with.

Material Strength, Deformation, Rigidity

Solid materials can be classified by their compressive, tensile, and shear strength, rated in tolerance for a given force across a given area.

Solid objects under pressure deform. Quantity of deformation per unit of pressure is determined by the material's elastic modulus.

Compressive, tensile, and shear, strength, and elasticity, are straightforward to measure with low cost equipment, and these measurements are entirely sufficient to simulate structures (tower maximum wind load, aircraft maximum load, submarine hull maximum depth, shelving maximum load, etc).



'Tensile_testing_on_a_coir_composite.jpg' see 'ATTRIBUTION'

Excessive pressure results in permanent deformation, often considered permanent damage. Pressures below the material yield strength, will result in no permanent change. This property allows precision objects, like optical flats, to safely retain their shape to subatomic tolerances during handling.

Pressures significantly beyond yield strength, measured as ultimate tensile strength, result in breakage (separation).

Geometry of solid objects may be arranged to take advantage of these properties, or multiple materials may be combined in a composite structure, but the relationships remain unchanged. A thicker steel cable may sustain greater total load, but only because the pressure to separate is spread over a wider cross-section.

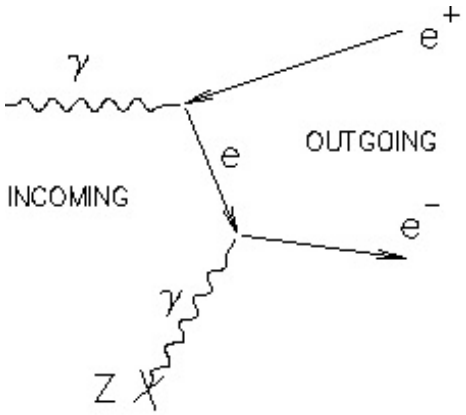
Material properties are scientific studied by destructive testing using a simple machine. Typical failure points may be used by engineers to estimate necessary materials for safe operation of structures (eg. bridges) under loads.

Relativistic Mechanics

Space and time are equivalent, as are mass and energy.

An object at rest is traveling completely through time. An object moving at the speed of light is moving completely through space. Objects, energy fields, or other entities cannot move faster than light, as they would actually be moving backwards in time.

Energy has mass. Energy, in joules, equals mass in kilograms, times meters per second squared, or E=mc^2. An object in motion or within an energy (ie. gravitational) field that would cause motion, has more mass than an object strictly at rest. Matter itself is essentially a storage medium for energy, and can be converted to forms more commonly recognized as energy. Matter/antimatter and black hole interactions in particular result in the direct conversion of matter to energetic photons. Electron/Positron (mass) interactions can produce pairs of photons (energy), and vice-versa, with some probability, when a high-energy collision seemingly causes blending of details that would give these particles distinct identities. That is to say, particles may vaguely be thought of as slightly different arrangements of the same field fluctuations.

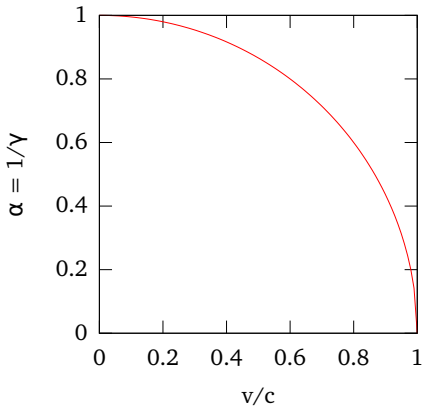


'Electron-Positron_nuclear_Pair_production_Feynman_Diagram.gif see 'ATTRIBUTION'

All of these equivalencies are relative, and usually considered only within specific frames of reference, rather than the entire universe. If a photon traveling at the speed of light were to somehow emit another photon, an external observer would see two photons traveling at the same speed, while the photon itself would 'live out its life' in the literal instant of time before the second photon could have appeared to move away, since photons travel only through space, never experiencing time. Similarly, a participant traveling at half the speed of light, launching another object at half the speed of light, would see the second object moving away at that speed, while an external observer would see the second object moving at somewhat less than twice the speed of the first. Likewise, mass and energy are measured relatively, as one spacecraft might be moving faster than the other.

Universal constants do exist, despite relativity. An electron would have 2000 times less mass than a proton in exactly the same place under exactly the same conditions, anywhere in the universe. Notably, photons of differing wavelengths, frequencies, energies, and mass, emitted by distant supernovae, have arrived on telescope imaging systems, exactly simultaneously.

While relativistic speeds or quantities of energy are not common in everyday life, practical applications do exist, as well as exceptional demonstrations of scale. Global electrical energy production at 16TWh is equivalent to 0.64 grams of mass. Significant quantities of mass actually transit over electrical power lines. Relativism also allows some particles to last longer than they otherwise would. Muon tomography, using cosmic rays to probe inaccessible locations, is a notable application (although not essential for machinery). Doppler effects, shifting the frequency/wavelength of photons, are a practical consequence of the inability to exceed the speed of light.



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Accelerating significant quantities of mass to significant fractions of the speed of light is expensive, but not impossible. Well understood laws of physics do allow large energies, high velocities, to be imparted to small particles, or with the conversion of significant mass to energy, acceleration of entire spacecraft to significant fractions of lightspeed. Resources available at stellar scale allow efficient interstellar travel, resources (ie. tons of antimatter) available at galactic scale allow travel at >0.5c, and interstellar medium allows some possibility of magnetic/fusion 'braking' for arrival.

Quantum Physics

Classical physics describe effects which predominate energy generation, and useful computer circuits.

Quantum physics explain some limitations of measurements and projections in everyday life, with the diameter of the near perfectly shaped lens of the eye accounting for angular resolution, and similar limits applying to manufacturing by photolithography. Quantum physics also has some effects constraining the design of small transistors.

Quantum Mechanics

All moving objects also vibrate. Vibration may be linear or circular, as light may be polarized. Mass and velocity determine the frequency. Frequency, across distance, determines wavelength, the geometric distance between one bounce and the next. Large masses (ie. Newton's entire falling apple) moving slowly have both low frequencies, and short wavelengths.

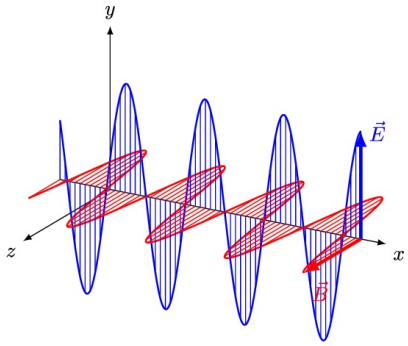
Photons exemplify quantum mechanical behavior. Small, and moving fast, their wavelengths are generally larger than their own apparent diameters. Detectable photons can be created under artificial conditions from below the range of human hearing, 10Hz, to 10^19Hz, orders of magnitude beyond trillions of times per second. Wavelengths for these photons range from planetary dimensions, to smaller than an atom. Even more energetic photons are commonly available from cosmic sources.

By contrast, a train car moving at reasonable speeds has immeasurably slow frequencies, across immeasurably short wavelengths. Classical mechanics remains an accurate model for predicting the behavior of large groups of objects that would be better described by quantum mechanics, such as atoms.

Quantum Field Theory

Particles are seen to arise from excited states of physical fields.

For example, photons arise from the swapping of electrical and magnetic fields. Capacitor plates, appropriately distanced, in free space, repeatedly charged and discharged, by an alternating current, will lose some of the energy passing through them, as photons, commonly referred to as radio waves. Antennas thus work by generating oscillating electrical or magnetic fields, which give rise to photons. After leaving the near field around the antenna, proportional to wavelength, the electrical field will swap position with a corresponding magnetic field. After another wavelength, this swap will repeat. In reverse, an antenna can convert an incoming photon to an electrical current.



'CC BY-SA 4.0' 'EM-Wave.gif' see 'ATTRIBUTION'

Rest Mass

Not all particles have rest mass, though all particles have mass when in motion (due to mass/energy equivalence).

Particles with rest mass, like atoms, do not move unless pushed by a force (an interaction transferring momentum), such as electrical charge. Particles without rest mass, may be thought of as one particular form of energy, immediately jumping away at the speed of light.

Energy mass equivalence allows massless particles, without rest mass, to cause impacts. Solar sails and metal plates developing a small positive charge when exposed to light are notable applications. Light radiation can cause pressure, pushing a spacecraft away from a light source, like the sun. Photons can knock electrons out of their orbits, generating electric current, without direct conversion by a suitably small antenna.

Massless particles, at least photons, do not collide with each other however, unless the underlying fields are saturated. Energies required to achieve this are extraordinarily far beyond current technology, including the capability to construct artificial black holes.

At least some particles, the bosons, gain rest mass by interacting with the recently discovered Higgs field. Many composite particles, such as protons, are massive, and do not jump away at the speed of light, because of their interaction with the Higgs field. Other particles, namely photons, do not, and immediately jump away at the speed of light. Discovery of the Higgs boson, an excitation of the Higgs field, has resolved fundamental questions regarding the accuracy of the modern physics Standard Model.

Uncertainty Principle, Quantum Tunneling

All interactions in the universe happen by transfer of momentum. Where these interactions happen is always somewhat probabilistic.

A photon passing through an aperture may change direction slightly, randomly with some probability, because all particles are also modelable as fluctuations in fields, which integrate interaction with neighboring particles at the speed of light. Thus quantum mechanics related to the 'uncertainty principle', limits the angular resolution of telescopes, cameras, etc, proportionally to the wavelength of light. Larger lenses or mirrors, or shorter wavelengths, linearly improve resolution, to the point that the human eye and common telescopes are limited as such.

An electron next to a thin barrier can occasionally, randomly with some probability, tunnel through that barrier, jumping to the other side. Also related to the 'uncertainty principle' - neither the electron nor the barrier have a definite location - and the transfer of momentum may occasionally not prevent an otherwise impossible crossing of a barrier.

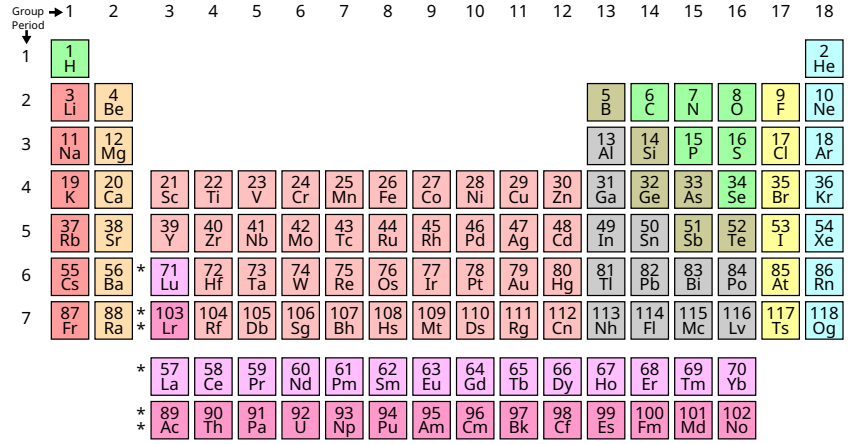
Such quantum effects do not noticeably affect machinery composed only of large objects (ie. distinct from machines dominated by classical physics). Mostly, these quantum effects impose design criteria on optics (directly interacting with small photons) and small transistors (directly interacting with small electrons).

Particles, Forces, and Interactions

Modern physics, the "standard model, which reduces all of reality to a dozen or so particles and four forces" - Lederman.

Practical applications of physics seek particles and forces with desirable interactions, then assemble solutions, using components such as bulk materials, transmitters, and receivers.

Fundamental particles (eg. photon, electron, quark, muon, neutrino, Higgs boson), fundamental force fields (eg. gravity, weak, electromagnetic, strong nuclear), the periodic table, the range of commonly available photon wavelengths, and phonons (ie. acoustic sound), may seem worth contemplating whenever it seems some new physics would be desirable if at all possible. High confidence in all research constraining these physics fundamentals does not suggest more such basic research will bring much success in any project.



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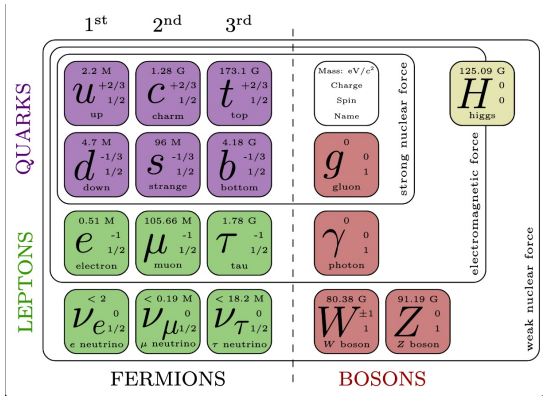

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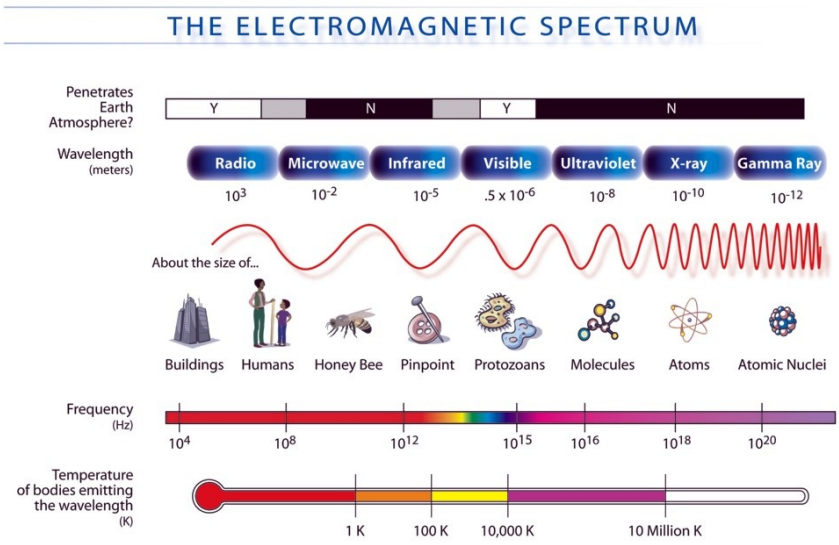

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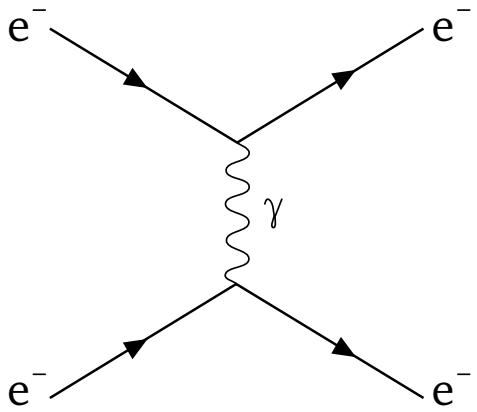


'CC BY-SA 4.0' 'Electron-scattering.svg' see 'ATTRIBUTION'

Feynman diagram of *virtual* photon, exchange of which can account for electrical and/or magnetic repulsion and/or attraction.

Electromagnetic	Gravity	Weak, Strong
Short range as attraction/repulsion (virtual photons). Long range as fluctuations of attraction/repulsion (real photons).	Long range, very weak, limited attraction.	Short range, limited configurations.
Machinery (virtual photons physical contact repulsion), communications and remote sensing (real photons), molecules (virtual photons interatomic).	Limited coalesence and orbits (ie. planets, galaxies, etc, NOT machinery).	Limited atomic nuclei only.

Photons

Photons deserve special mention because of their uniquely valuable properties for communications and probing. Photons (whether far field 'real' or near field 'virtual') through their electromagnetic fields are the predominant carrier for momentum between particles, and all interactions ('all forces') in the universe are transfers of momentum. Phonons are notable as vibrations between groups of electrons, another means of commonly available interaction, commonly transferring acoustic sound, also still predominantly made possible by photons.

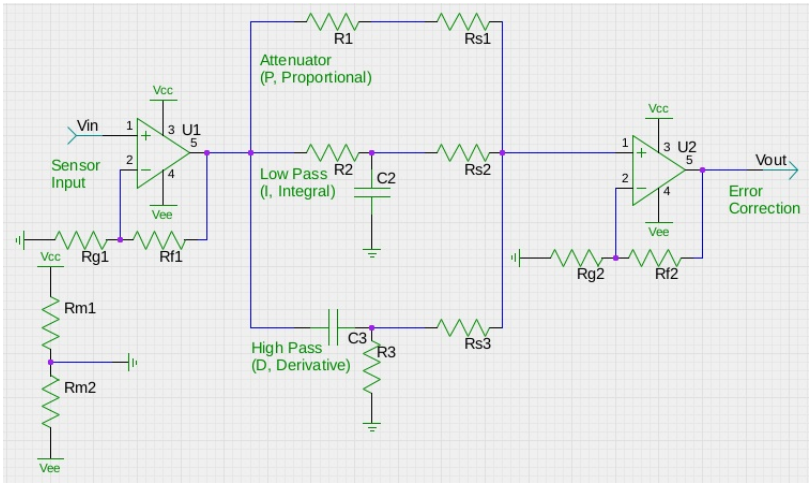
A wide range of wavelengths/frequencies/energies are easily generated by a variety of means, including black body radiation (random motion of charged electrons), amplification/duplication (masers/lasers), changing electrical/magnetic fields generated by alternating voltage/current (antennas), relativistic velocity changes of charged particles (synchrotron, bremsstrahlung), and energetic decay from other particles/fields (gamma ray emission).

As massless particles, photons jump away at maximum speed, ideal for quickly transferring information. Interactions with matter are common, allowing easy detection, as well as investigation of remote objects they encounter (ie. RADAR, LIDAR, low-coherence spatial tomography, X-Ray tomography, X-Ray crystallography). Photons emitted from other particles also have similar but unique applicaitons, as with the pairs of gamma ray photons obtained by positron-emission-tomography (PET).

By contrast, neutrinos, while typically moving at the speed of light, do not commonly interact with matter. This allows them to penetrate entire planets with a small wavelength and without inflicting damage. However, their lack of interaction limits their utility in tomography, and renders detection so challenging, even communications usage is prohibitively expensive.

Signal Processing and Control Algorithms

Proportional Integral Derivative (PID) Control



A single feedback amplifier issues proportional corrections to its outputs in response to disturbances. More disturbance, much more output to correct.

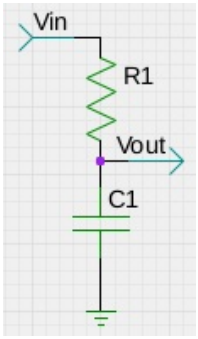
Real systems often do not respond instantly to control inputs. Power into a heater is limited, as would be any electrical input to a resistor. Temperature does not rise immediately, just as voltage applied to a resistor/capacitor voltage divider does not instantly cause the voltage across the capacitor to rise. Practical heating applications often involve multiple rapidly changing inputs to thermal circuits, as products like 3D printer filament are moved through devices like extruders at changing rates.

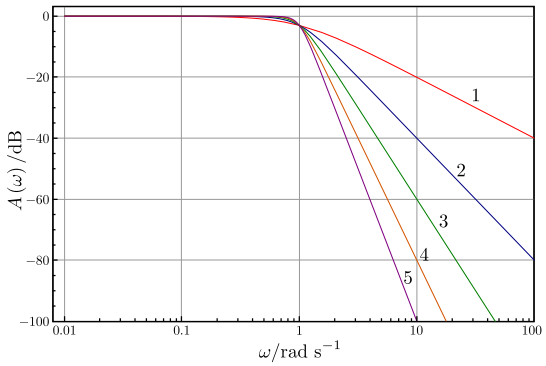
Precise control often requires consideration of how a new input, more heat or product, will impact future states.

Modern control systems implement multiple amplifiers, with low-pass and high-pass filters in the feedback loop, to compensate for past states and future trends.

Maximum control is achievable by repeated re-tuning of the P I D gain/filter parameters. Evolutionary algorthims and neural networks excel in such optimization, though more rigiorous tuning methods can be developed for specific purposes. Real-time parameter changes, with simulated disturbances, may allow better manual tuning.

Digital Equivalents of Analog Circuits





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Digital signal processing is often used to reduce bulky circuits to trivial mathematical operations. Digital systems also have the ability to make mathematically perfect copies of information - '101010' can always be copied to exactly '101010'.

However, these signal processing and control algorithms are generally most efficient when closely related to the simplest equivalent electrical circuit.

A disadvantage to digital signal processing is speed. Circuitry used to capture analog signals (analog-digital-converters) inherently includes parasitic low-pass filters. Digital processors themselves can only perform a limited number of operations per second, while analog components 'compute' using the entire degenerate gas of electrons pushed through them. For these reasons, high-speed microwave or optical communication links are often reduced in frequency before submission to computer processing.

As an example, this C preprocessor macro implements a low pass filter by adding the most recent output, to the change in amplitude, multiplied by a constant, which sets the cutoff frequency to a percentage of sample rate.

```
#define lowPass(newValue, filteredValue, inertiaFloat)                          \
filteredValue = filteredValue + (inertiaFloat * (newValue - filteredValue));
```

A more universal frequency filter can be implemented by a "biquad" topology, using multiple amplifiers and filters in the same feedback loop. Capable of implementing low/high pass as well as band pass/stop, equivalent to various RC/RL/RLC circuits, cutoff/center/bandwidth frequency characteristics can be set by adjusting component values, or constants in an equivalent digital algorithm.

```
#define IIRbiquad(newValue, filteredValue, unique_d1_name, unique_d2_name, b0, b1, b2, a1, a2)                  \
                                                                                                                \
        filteredValue = b0 * newValue + unique_d1_name;                                                         \
        unique_d1_name = (double)b1 * (double)newValue + (double)a1 * filteredValue + unique_d2_name;   \
        unique_d2_name = (double)b2 * (double)newValue + (double)a2 * filteredValue;
```

Like all low-pass filters, all of these algorithms and circuits only provide -20dB (100x) power attenuation for every ten times frequency increase beyond the cutoff. Multiple 'orders' must be connected together to achieve sharper low-pass filtering. In electronic circuits, this is done by adding more components - usually resistors, capacitors, and amplifiers. In digital circuits, this can be done with a simple for loop.

```
//High Order IIR Biquad Filter.
//Parameters b0, b1, b2, a1, a2 are filter coefficients. See http://gnuradio.4.n7.nabble.com/IIR-filter-td40994.html and
http://www.earlevel.com/main/2013/10/13/biquad-calculator-v2/ .
//Data is returned in the double named [filteredValue] .
```

```
#define highOrderIIRbiquad(newValue, filteredValue, stateOneArrayName, stateTwoArrayName, b0, b1, b2, a1, a2, filterOrder)      \
        static double stateOneArrayName[(filterOrder+1)];                                                                       \
        static double stateTwoArrayName[(filterOrder+1)];                                                                       \
                                                                                                                                \
        static int filterLoop;                                                                                                  \
                                                                                                                                \
        static double lowerOrderFilteredValue;                                                                                  \
        lowerOrderFilteredValue = newValue;                                                                                     \
                                                                                                                                \
        for (filterLoop=0; filterLoop < filterOrder; filterLoop++) {                                                            \
                IIRbiquad(lowerOrderFilteredValue, filteredValue, stateOneArrayName[filterLoop], stateTwoArrayName[filterLoop],
b0, b1, b2, a1, a2) \
                lowerOrderFilteredValue = filteredValue;                                                                        \
}
```

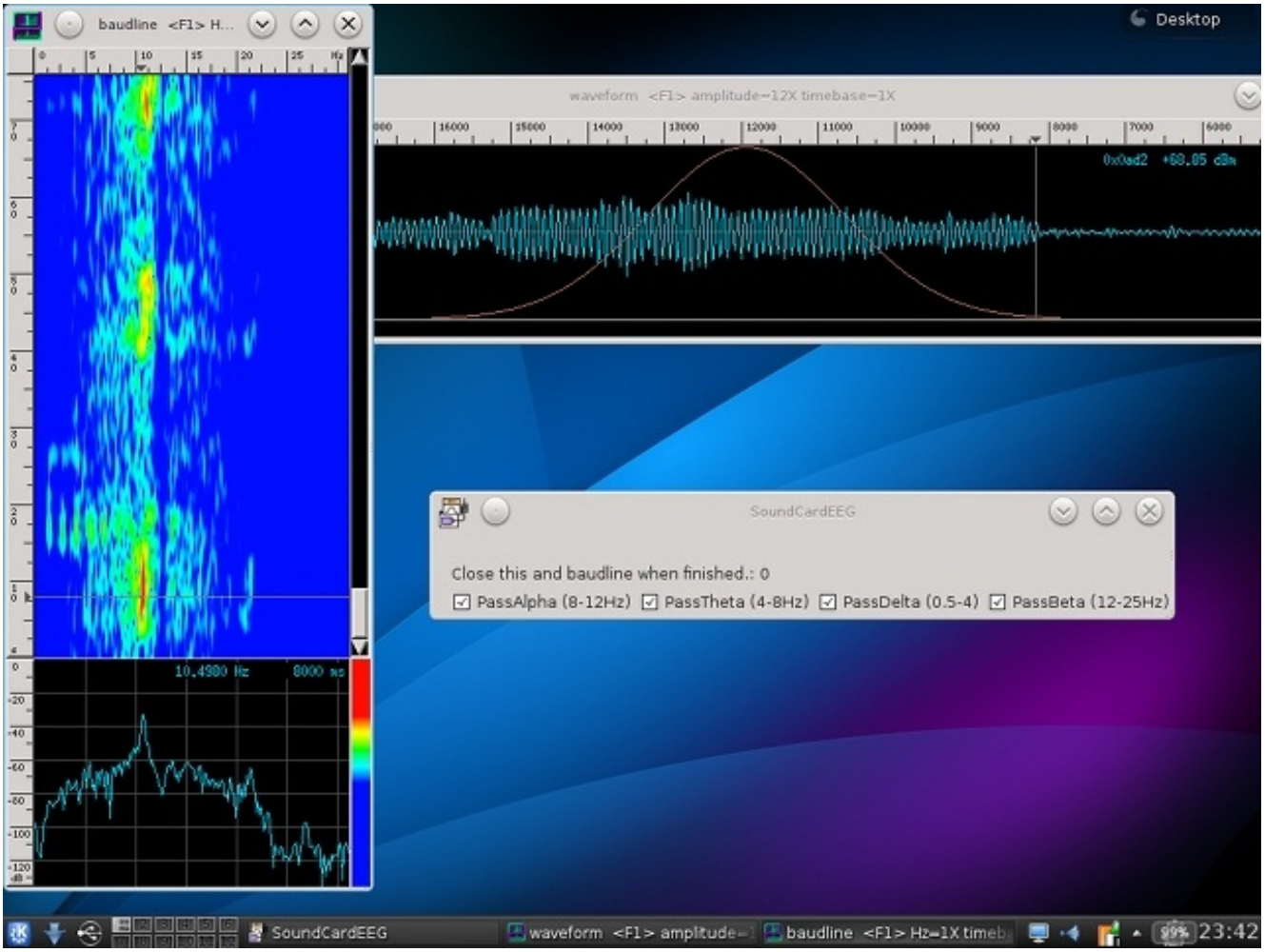
And now the advantages of digital filters are abundantly clear. At the cost of a trivial number of arithemetic operations, potentially thousands of low-noise electronic components can be substituted for a microcontroller costing few dollars. Hundreds of orders have been implemented within audio frequency range by an ATMega32U4 to clean electroencephalography data before sending along to a computer for further analysis. Filter parameters themselves can be automatically tuned by evolutionary algorithms, neural networks, or rigorous methods developed for specific purposes.

Spectrum Analysis and Fast Foruier Transform

Signal amplitude can be measured after being put through a band pass filter. Higher amplitudes indicate a closer match between filter frequency, and actual frequency. A large filter bank, or a sweeping filter, can thus be used to show the amplitudes of various frequencies in a signal.

Spectrum analysis simply implements such a filter bank, sweeping filter, or combination of these. Fast Fourier Transform (FFT) is simply a mathematical alogithm for performing this operation efficiently on digital processors. FFT is may be useful as a function more efficient than IIR filters, but knowing how to reimplement FFT is rarely called for.

Various plots are generated by this technique, including amplitude/frequency graphs and amplitude/frequency/time "waterfall" plots. The latter shows the appearance and disappearance of signals across a range of frequencies, and so can identify radio channels going on/off air, or information transmitted by shifts in frequency, as with human voice.



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DISCLAIMER: Reasonable risk of missing attributions may be taken if free web links are not obviously offered - acknowledgment may be limited to no 'originality', no 'links' - essential 'facts' from obvious sources only.

WARNING: Extensive research notes here may be less recent, less accurate, less complete, internally inconsistent, and misinterpreted.

errata

Tentative Terminology, State Space Search, Cross-Referencing, Articles with Links vs Textbook

Events are detected as phenomenon. Phenomenon are modeled. Models are developed in fields of research (electronics, optics, etc). Fields are researched through science and engineering. Science is the systematic study of phenomenon. Engineering is the assembly of known phenomenon for utility. Technology is the development of tools by engineering. Tools are an extension of the body. Tools are used to detect more phenomenon for science, or directly assemble more phenomenon for engineering.

State space search lets us determine which search terms to use, which articles to cross-reference, which books to read, or what experiments to perform. Each option is critically evaluated for the expected consumption of effort, for a given return in production, as well as opportunities for further investigation. An article rich with links for cross-referencing to related fields would be more prized than a textbook.

When State Space Search Fails, Reduce

Reduction to another problem is warranted when a state space search on the current situation does not yield reasonably efficient or adaptable solutions. Remember, success is maximum production at least effort. Any decision leading to less than that optimum can only achieve imaginary success. If a hypothesis cannot reasonably be expected to lead to production, it must be reduced upwards to a more solvable problem - new projects entirely. For example, speeding up an assembly line may encounter a physical limit - glass breaks upon high-speed impact. Recognizing the goal is increasedproduction at decreased effort, this problem may be revised upward toward simply installing another assembly line. A logical limit may then be encountered - two streams of assembled products must be handled, perhaps halving performance of a downstream operation. Going further, whether the assembled product could be revised for easier production - perhaps omitting glass - must be considered. Ultimately, whether the assembled product is valuable at all may need to be considered - perhaps a pipeline would be better than glass bottles. In the end, the original problem may not be worth solving.

Commoditizing and Existing Product

For example, if modeling a metal plate results in an expensive part, it may be more efficient to design the plate as a circuit board.

Why Complicated Mathematics for a Predominantly Simple Universe

Modeling in terms of electrons and photons does not usually happen because these are small particles moving very fast. Computing such a model would be prohibitive.

CAD Modeling - Sketch, Extrude, Assemble

Modern hardware geometry design, when practical and not dedicated to purely artistic or electronic circuit purposes, usually follows either a graphical process from a 2D sketch, or a programmatic approach.

Following the graphical approach, from a 2D sketch, is exemplified by FreeCAD with the A2Plus module. Lines, circles, and related shapes are drawn, constrained by length and angle, then this 2D profile is usually extruded to a 3D shape. Additional sketches may remove material from that 3D shape. Such 'parts' are then assembled by joining faces of 3D parts into an 'assembly'. Multiple assemblies may be combined.

As an example, to build a table, the 2inch*4inch rectangle of a 2x4 timber could be sketched, then extruded to a few feet in length, then that single timber would be assembled together at places where a table would be formed. Realistically, a real table would need some fasteners to hold those timbers together, but in CAD such details are often not modeled (and too much detailing can cause any CAD program to become slow).

Bill of Materials (aka. BOM)

Modern hardware projects may have thousands of parts. Keeping track of these by manually counting how many of each part seem present in a model is time consuming and error prone, especially if 'assemblies' in a CAD model have been assembled into more complex assemblies (nesting many assemblies). Instead, using a hierarchical program, which can assemble BOM files, is much more efficient.

Modern CAD software often includes some BOM capability built within, however, this may unnecessarily limit the project to using only that CAD program, and may miss details which are not easily modeled completely (eg. fasteners). Instead, using a separate program, with separate BOM files, is better for design software portability.

'BOM designer' exists for such, taking simple text files as input, combining totals hierarchically with 'KWrite' syntax

highlighting compatibility.

DISCLAIMER: Plausible concepts, attributed sources, oversimplifications, resonably. Rigorous mere academia NOT primary.

cognitionSplicer

Connectome and synaptic weights 'RPT correlation', overlay, from observed neural activity.

'Brain upload' and 'hive mind' made possible by observing some activity from a living neural network rather than 'scanning' 'dead' or dormant 'neural tissue'.

Introduction

Feasibility and usefulness are well founded conclusions.

Existing hardware and wetware may be entirely adequate. Minimally complex scaling of hardware designs to higher spatial resolution may be beneficial.

Presented

*) Software algorithm flow diagrams.
*) Computation times.
*) Sampling times.
*) Sampling/input bandwidths (eg. 10MHz, 500kHz, 50kHz, etc).
As may be plausible.

Conclusions

Reasonable reading, writing, and communication of human memory (objects, associations, priorities), may be feasible even from non-invasive (ie. MEG, TMS) brain interfaces, especially with minimal retraining in a VR environment. Perfect enough (ie. no retraining) memory transfers may be feasible from non-chronic invasive (ie. crude MEA) brain interfaces. Memories may have a spatial resolution parameter, much as any other object data (eg. as with visual image object pixels).

Recording small areas of brain activitiy sequentially is sufficient. Non-invasive interface in particular may benefit from sequentially 'scanning' an expensive high resolution sensor array with a small observed area across the neocortex. Optogenetic sensors may benefit similarly. Microelectrode arrays may minimize bandwidth, ADC, and amplifier circuitry by multiplexing ES when intended only for connectome and synaptic weight recording (not sensory precepts).

Small timing and voltage offsets within the membrane of a single neuron may exist. Such may account for computational performance of biological networks orders of magnitude greater than the total number of synapses at ~300Hz analog bandwidth. Visualization of differences in these offsets between events may be feasible to infer from other observed activity. Such analysis is mostly anticipated as a diagnostic tool not obviously useful or necessary for any memory or information transfer.

Side channels (ie. by 'cross-examination' under 'polygraph') have already long been sufficient to drastically reduce search space (eg. 'password' digits) for any kind of authentication - what a person knows, what a person knows they have, or what a person knows they are. Nothing about 'brain computer interface' changes the already urgent need for better secure storage, memory backups, self-wiping of mobile memory, or possibly of trusted authentication authorities.

Poor spatial resolution could plausibly obscure any connections which are within, or do not substantially activate, a large enough group of neurons. Poor temporal resolutions could obscure any connections which cause near equal changes in activity at near equal times. At least some useful results (eg. 'human connectome project') seem to have been obtained through fMRI - which relies on indirect indications having possibly the worst resolution simultaneously spatially and temporally .

More 'observedNeurons' than 10k 'logical neurons' or 10M 'physical neurons' spread across the entire neocortex are significant performance benchmarks for a brain-computer interface. Fewer might suffice within a smaller region of the neocortex for some limited use cases.

Some basis for object memory recognition from recorded neural activity exists in the form of rough but recognizable images observed from neural recordings from the visual systems of animal models (ie. cats).

REFERENCE

https://www.proteinatlas.org/humanproteome/brain/human+brain
        '16227 genes detected above cut of in the brain'
        '2587 genes have an elevated expression'
        '488 brain enriched genes'
        'Most of the enriched genes encode proteins involved in transport and signaling'
        '2587 genes defined as elevated in the brain'
        '33 genes are only detected in the brain'
        'Regional expression within the brain'
                '1059 genes classified as regionally elevated'
                'Cerebellum has the most regionally enriched genes (n=214)'
                ' interactive network plot of the regionally enriched and group enriched genes connected to their respective enriched region'

https://onlinelibrary.wiley.com/doi/abs/10.1002/cne.902400410
        CITATION - 'Photoreceptor telodendria which emanate from the basal surface of the synaptic terminal and ramify laterally for up to 40 Î¼m'

https://raw.githubusercontent.com/mirage335/Mirage335BiosignalAmp/master/amplifierSchematic.png
        CITATION - Minimalist and exemplifying best principles.

https://arxiv.org/pdf/1906.01703.pdf
        CITATION - 'A typical neuron fires 5 - 50 times every second.'

Example: Pessimistic Estimate - Recording Time - All Memories (Perfect Enough), Whole-Neocortex Interface, Physical Neurons from Million Electrode Site Micro-Electrode Array (MEA)

$dormantTime == Presume >1s .

$activeTime == Presume 0.0005s .

$observedNeurons == Presume spike sorting unusable, 10^6 electrode sites.

$desiredNeurons == 10^10

$synapsesPerNeuron == 10^4

$weakestSynapse == Negligible.

```
  'dormantTime=1'
  'activeTime=0.0005'
  'observedNeurons=10^6'
  'desiredNeurons=10^10'
  'synapsesPerNeuron=10^4'
  'weakestSynapse=1'
  '_solve' '"( \"signalsPerConversion\" == ( "$dormantTime" * ( "$dormantTime" / "$activeTime" ) ) , \"signalsPerConversion\" )"'
# 2000
  '_solve' '"( \"synapsesBetweenNeurons\" == ( "$observedNeurons" / ( "$desiredNeurons" / "$synapsesPerNeuron" ) ) ,
\"synapsesBetweenNeurons\" )"'
# 1
  '_solve' '"( \"recordingTime\" == ( ( ( "$dormantTime" * ( "$dormantTime" / "$activeTime" ) )  *  ( "$observedNeurons" / (
"$desiredNeurons" / "$synapsesPerNeuron" ) ) )  *  "$weakestSynapse" ) , \"recordingTime\" )"'
# 2000
seconds.
```

Strong inhibition and irregular synaptic weight geometric distribution may delay observations negligibly. A few hours or a few days is a resonably pessimistic expectation.

Example: Pessimistic Estimate - Computation Time - All Memories (Perfect Enough), Whole-Neocortex Interface, Physical Neurons from Million Electrode Site Micro-Electrode Array (MEA)

$listSeconds == Assume a pessimistic three hours ~10k .

$eventsPerSecond == Assume pessimistic 100 .

$findMilliseconds == Assume a pessimistic 5000ms .

$observedNeurons == Assume 4M as near plausible limits for electrode density.

$arithmeticPerSecond == Assume 10 * 200TFLOPS GPUs, typical of a commonly available GPU, at reasonable total expense.

```
  'listSeconds=10000'
  'eventsPerSecond=100'
  'findMilliseconds=5000'
  'observedNeurons=4000000'
  'arithmeticPerSecond=$(_clc "(200*10^12) * 10")'
arithmeticPerSecond= 2E15
  '_solve' '"( \"computationTime\" = ( ( "$listSeconds" * "$eventsPerSecond" * "$observedNeurons" ) * ( "$findMilliseconds" * (
"$eventsPerSecond" * 0.001 ) * "$observedNeurons" ) ) / "$arithmeticPerSecond" , \"computationTime\" )"'
# 4000000
seconds. Three months (90days) is approximately 7million seconds. One year is approximately 30million seconds.
```

Example: Pessimistic Estimate - Spatial Resolution - Visual Memories, Whole-Neocortex Interface, Logical Neurons from MagnetoEncephaloGraphy (MEG) or Transcranial Magnetic Stimulation (TMS)

$desiredNeurons == Assuming only shallow 2D cerebral neocortex surface (100cm^2) is available to MEG or TMS at relatively high resolution (between ~5mm^2 or ~0.1mm^2). A ~0.1mm resolution may be much nearer theoretical limits than existing hardware, possibly necessitating temporal patterning of TMS impedance measurement and TMS stimulation pulses.

$relevantNeuronsPerDesiredNeuron == Assume extremely pessimistically only ~0.05 of neurons in whole cerebral neocortex are in the occipital lobe or otherwise substantially store visual memories, greatly degrading possible spatial resolution.

$perceptualCompression == Seems compression of 10 from bitmap to frequency bin amplitudes and edges should be pessimistic enough.

$pixelsOrVoxels == Smaller than 100x100 texture is rather common. Maybe a person might recognize a composite object with 1000 features, or maybe a composite 'scenes' of 10000 features. Other fundamental mathematical limits to random matching, and human short-term memory limits, may impose substantially smaller object feature counts. Seems pessimistic enough at ~10k.

```
  'desiredNeurons=$(_clc "( (100 * centimeter) / (5 * millimeter) )^2" )'
desiredNeurons= 40000
  'relevantNeuronsPerDesiredNeuron=0.05'
  'perceptualCompression=10'
  'pixelsOrVoxels=10000'
  '_solve' '"( \"spatialResolution\" = "$desiredNeurons" * "$relevantNeuronsPerDesiredNeuron" * "$perceptualCompression",
\"spatialResolution\" )"'
# 20000
  '_solve' '"( \"requiredSpatialResolution\" = ( "$pixelsOrVoxels" ) , \"requiredSpatialResolution\" )"'
# 10000
```

Example: Pessimistic Estimate - Recording Time - Visual Memories, Whole-Neocortex Interface, Logical Neurons from MagnetoEncephaloGraphy (MEG) or Transcranial Magnetic Stimulation (TMS)

$dormantTime == Presume >1s .

$activeTime == Presume >0.010s (MEG bandwidth).

$observedNeurons == Assuming only shallow 2D cerebral neocortex surface (100cm^2) is available to MEG or TMS at relatively high resolution (between ~5mm^2 or ~0.1mm^2). A ~0.1mm resolution may be much nearer theoretical limits than existing hardware, possibly necessitating temporal patterning of TMS impedance measurement and TMS stimulation pulses.

$desiredNeurons == Equal to $observedNeurons. Assuming too little data will be available from the low spatial resolution.

$synapsesPerNeuron == Presume large groups of neurons may not meaningfully correlate to multiple other large groups.

$weakestSynapse == Negligible.

```
  'dormantTime=1'
  'activeTime=0.010'
  'observedNeurons=$(_clc "( (100 * centimeter) / (5 * millimeter) )^2" )'
observedNeurons= 40000
  'desiredNeurons=40000'
  'synapsesPerNeuron=1'
  'weakestSynapse=1'
  '_solve' '"( \"signalsPerConversion\" == ( "$dormantTime" * ( "$dormantTime" / "$activeTime" ) ) , \"signalsPerConversion\" )"'
# 100
  '_solve' '"( \"synapsesBetweenNeurons\" == ( "$observedNeurons" / ( "$desiredNeurons" / "$synapsesPerNeuron" ) ) ,
\"synapsesBetweenNeurons\" )"'
# 1
  '_solve' '"( \"recordingTime\" == ( ( ( "$dormantTime" * ( "$dormantTime" / "$activeTime" ) )  *  ( "$observedNeurons" / (
"$desiredNeurons" / "$synapsesPerNeuron" ) ) )  *  "$weakestSynapse" ) , \"recordingTime\" )"'
# 100
seconds.
```

Strong inhibition of such large 'logical neurons' may delay observations by a few hours.

Spatial Resolution

Capturing a person's sense of objects, associations, priorities, may require at least sufficient resolution for these objects to remain recognizable. Whether a neural interface has sufficient spatial resolution (observing sufficiently many and sufficiently small groups of neurons) may be crudely estimated by whether a hypothetical 'picture' of a 2D *texture* in 'pixels' or a 'model' in 'voxels' after proportional losses would remain recognizable.

Objects (eg. recognizable visual objects from visual memory in the visual cortex) represented within the correlated connectome and synaptic weights may have a *spatial resolution* in total perceptive fields as much as equal to 'desiredNeurons'.

```
$desiredNeurons == Total neurons (in the composite neuron sense of an artificial neural network) from connectome and synaptic weights correlated by observed neural activity.

$relevantNeuronsPerDesiredNeuron == Proportion of $desiredNeurons mostly contributing the desired memories. Presumably usually better than ~0.05 .

$perceptualCompression == From bitmap pixelsOrVoxels, to frequency bin amplitudes and edges. Presumably usually better than 10x.


"( \"spatialResolution\" = \"desiredNeurons\" * \"relevantNeuronsPerDesiredNeuron\" * \"perceptualCompression\" )"
```

Recording Time

Duration of observed neural activity before each neuron will have repeatedly reacted (or not) to every other neuron at least indirectly, which may approximately be sufficient to correlate connectome and synaptic weights. Strong inhibition, irregular synaptic weight geometric distribution, and long axons may additionally impose a minimum recordingTime of a few seconds or a few months. Applicable to fMRI, EEG, ECOG, MEG, and MEA.

```
$dormantTime == Time between TX events. Usually 20ms (50Hz) or at worst plausibly 1000ms (1Hz).

$activeTime == Temporal resolution of TX event information. Usually 0.5ms (action potential bandwdith, 1mm axon at 2m/s, etc). Some diagnostic, scientific, or simulation use cases may be short as <0.002ms (<4um dendrite at 2m/s).

$observedNeurons == Total (logical) neurons observed (eg. number of electrode sites in MEA, number of discernable areas in MEG, etc).

$desiredNeurons == Total neurons (in the composite logical neuron sense of an artificial neural network) from connectome and synaptic weights correlated by observed neural activity. Usually 10^10 cerebral neocortex neurons, or equal to $observedNeurons.

$synapsesPerNeuron == Usually 10^4 if physical neurons (eg. MEA electrode sites) or 1.0 if observedNeurons is a small number of logical neurons (eg. MEG).

$weakestSynapse == Usually 1, negligible. At worst, roughly equal to $signalsPerConversion. After all, a synapse causing activity much less often than ambient "noise" will tend to "fire out of sync" more often and "lose their link". Otherwise, presumably >0.001 RPT events per synapse TX event.

"( \"signalsPerConversion\" == ( \"dormantTime\" * ( \"dormantTime\" / \"activeTime\" ) ) )"
"( \"synapsesBetweenNeurons\" == ( \"observedNeurons\" / ( \"desiredNeurons\" / \"synapsesPerNeuron\" ) ) )"
"( \"recordingTime\" == ( ( ( \"dormantTime\" * ( \"dormantTime\" / \"activeTime\" ) )  *  ( \"observedNeurons\" / ( \"desiredNeurons\" / \"synapsesPerNeuron\" ) ) )  *  \"weakestSynapse\" ) )"
```

Computation Time

Correlation of neural activity to connectome and synaptic weights follows a summation algorithm followed by a normative statistic. TX events are converted to correlated RPT events. A similar algorithm is expected to correlate this smaller number of RPT events to other RPT events, establishing the order in which neurons are activated.

Inference of indirect neurons may require algorithmic iterative modeling of small artificial neural networks where activity is not completely accounted for by activity of other observedNeurons. Such modeling may benefit from structural assumptions (ie. a strong 90deg orthogonality between horizontal axons across 2D layers and vertical axons between 2D layers).

```
Choose RX ES (Electrode Site).
All other ES given own bins of delay windows.
 TX event from LI (LIst).
  Count some preceding TX events from LI at other ES.
   Total events and total time added to bins of all other ES.
 TX event from LI... (loop)
Bin counts significantly higher or lower than ambient normal indicate RPT correlation between chosen RX ES, corresponding other ES of that bin, with corresponding delay of that bin.
```

Each event found for a chosen RX ES will require iterating over at least recent history from LI.

```
$listSeconds == Linear multiplier. Usually approximately 3600*3hours (~10k) .

$eventsPerSecond == Usually 50Hz .

$findMilliseconds == Number of milliseconds previous to a TX event to find a TX event from a different neuron to count as an RPT correlation.

$observedNeurons == Total (logical) neurons observed (eg. number of electrode sites in MEA, number of discernible areas in MEG, etc). Maximum plausible for neocortex using MEA is likely ~4M .

$arithmeticPerSecond == Usually 200TFLOPS . Memory bandwidth may not be a problem if list is divided optimally.


"( \"computationTime\" = ( ( \"listSeconds\" * \"eventsPerSecond\" * \"observedNeurons\" ) * ( \"findMilliseconds\" * ( \"eventsPerSecond\" * 0.001 ) * \"observedNeurons\" ) ) / \"arithmeticPerSecond\" )"
```

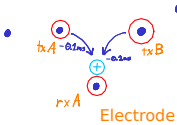
Other optimizations may be possible. An 'LI' list may be divided into smaller 'LU' lump of <<14bit numeric integers. Most RPT correlations will be short axons to only geometrically nearby neurons. Found RPT correlations can be ignored as soon as confidently identified once. Strong inhibition may be countered by using data taken at regular intervals rather than a longer continious recording.

RPT Correlation Computation - pseudocode

```
object event
 Variables:
  ES_int; //eg. "000000000000000001"
  ES_str; //eg. "ES_000_000_000_000_000_001"
  CK_int; //eg. "000000000000000001"
  CK_str; //eg. "CK_000_000_000_000_000_001"

// Observing ~10^12 events/hour from ~10^6 ES is a reasonable expectation.
// (10^6) * 50Hz * 3600 = 1.8E11
object LI[0,000100000000000000]
 Variables:
  event
 Functions:
  numberOfES() //eg. "000000000003000000"
  numberOfCK() //eg. "000000000100000000"
   numberOfCK_ms() //eg. "000000000000100000"

object ES[0,LI.numberOfES]
 Variables
  bin_delay[0,LI.numberOfCK_ms()/2]
  bin_totalTime
 Functions
  bin_eventsPerSecond(delayBinNumber)

// DISCLAIMER: May be inconsistent and incorrect, not tested in any way.
RX_ES_int="ES_000_000_000_000_000_001";
for ( currentEvent=0; currentEvent <= length(LI); currentEvent++ ) {
        // no event at chosen RX ES
        if ( LI[currentEvent].event.ES_int != RX_ES_int );

        // chosen RX ES emitted a TX event
        if ( LI[currentEvent].event.ES_int == RX_ES_int ) {
                // find preceeding events at all other ES
                // OPTIMIZATION - Instead, a small number of events from "currentEvent" , not 0. Direct synapses in neocortex may
be milliseconds apart, indirect synapses may be a multiple of that.
                for ( currentPreceedingEvent=0; currentPreceedingEvent <= currentEvent; currentPreceedingEvent++ ) {
                        // some other ES emitted a TX event, count in the corresponding bin
                        if ( LI[currentPreceedingEvent].event.ES_int != RX_ES_int ) && ( LI[currentPreceedingEvent].event.ES_int
!= "" ) {
                                //bin window, usually 2ms for action potentials, possibly longer (eg. fMRI)
                                currentBinDelay=abs(LI[currentEvent].CK_int/1000/2 - LI[currentPreceedingEvent].CK_int/1000/2)
                                ES.bin_delay[currentBinDelay]
                                ES.totalTime+=2
                        }
                }
        }
}

// if not within ambient normal, then third ES has an RPT correlation to RX_ES_int at 2ms delay
ES[3].bin_EventsPerSecond(1)
```

RPT Correlation Computation

Software Algorithm Flow



- Limited electrode sites recieving from a large number of physical neurons may be precisely analyzed as logical neurons in which a significant number of physical neurons must all emit a TX event (which may correlate as an RPT event).

Electrode Sites
(or logical aggregations thereof)

Beware, simple covariance testing may NOT distinguish between two neurons both simply responding to some degree to various other stimuli (as with classic neuroscience experiements), as contrasted with an actual specific temporal more indicative of the cause and effect between TX and RPT events.

Discarding low-confidence RPT correlations (weak synapses) may be highly beneficial.

A neuron participating in real-time processing in the recorded data should always have a strong correlation, such that negligible time would be required to be received by other real-time processing neurons. Synaptic weights (ie. memories) of non-default magnitude never used in real-time may have nonsignificant influence on modeling or motor output (aka. thoughts or behavior).

Confidence interval between RPT and ambient noise (~50Hz, individual neuron specific) TX event rates may be high if a synapse actually exists. Meaningful neural communication may require both a high S/N ratio and sufficient 'fire together wire together' not to 'fire out of sync lose their link'.

ES - Electrode Site number.
CK - Clock microseconds.

LI - List. All measurements (ME) from ADC, with increasing details annotated (eg. NR/PA/DA). Must be serializable to human-readable. Yes, these are expected to be exportable in real-time as huge text files containing every ADC data point (at least if CK is specified), though mostly not written out in practice.
LU - Lump 14bit. Integer precision and memory bandwidth optimized list fragment.

ME - Measurement (voltage/amplitude).
NR - Neuron.

PA - Phase (center/rise of Action Potential).
DA - Duration (center/fall of Action Potential), or center+(fall-rise) timings.

GR - Gradient.

HS - High Sampling
LS - Low Sampling

ES_000_000_000_000_000_001
CK_000_000_000_000_000_001
CK_000_001 ES_001 TX
CK_000_002 ES_001 TX

Underscores are human readable only, filtered out of algorithm processing.

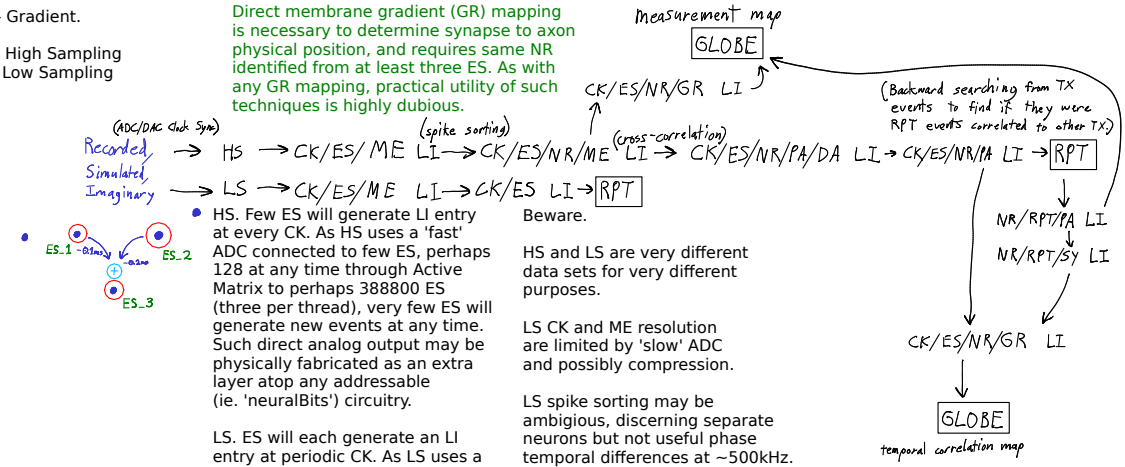
Lumps are stated as fields in serialized data, and perhaps as separate 'objects' in memory.

Expect crude neural network simulation functions - correlating the connectome and synaptic weights of simplistic Artificial Neural Network (ANN) models - will be necessary.

All metaEngine multi-pipeline characteristics, coordinate grids, IPC (especially to high-speed USB streams and simulated data stream programs) are exactly ideally suited for entirety of all these tasks.

Artificial neural network and GNU Octave covariance testing may be useful.

Direct membrane gradient (GR) mapping is necessary to determine synapse to axon physical position, and requires same NR identified from at least three ES. As with any GR mapping, practical utility of such techniques is highly dubious.



- HS. Few ES will generate LI entry at every CK. As HS uses a 'fast' ADC connected to few ES, perhaps 128 at any time through Active Matrix to perhaps 388800 ES (three per thread), very few ES will generate new events at any time. Such direct analog output may be physically fabricated as an extra layer atop any addressable (ie. 'neuralBits') circuitry.

LS. ES will each generate an LI entry at periodic CK. As LS uses a 'slow' ADC, a new LI entry will not appear at every CK 1us cycle.

PA. HS may use cross-correlation to determine center/rise of Action Potential.

DA. HS multiple cross-correlation to different waveforms may discern 1us Action Potential duration timing.

Beware.

HS and LS are very different data sets for very different purposes.

LS CK and ME resolution are limited by 'slow' ADC and possibly compression.

LS spike sorting may be ambigious, discerning separate neurons but not useful phase temporal differences at ~500kHz.

LS ES positions may drift long-term with not sufficient information to correlate back to previous RTP events.

LS temporal resolution may be less than phase difference between independent TX/RPT events.

Better LS performance specifications may be available in practice. Apparently the ADCs may operate at >20kHz (claimed 10x neuron spike duration based sampling rate) with full prorammable FIR neuron spike 'shape' cross-correlation on device within '900ns apparently claimed for Neuralink demo CNET coverage Aug28 .

SY = Synergy between two synapses. Synaptic weight of two TX events in most complex (perhaps also highest confidence) RTP event, minus weakest synaptic weight from RTP event in which just one of those two TX events did not happen (ultimately combined synaptic weight of both synapses minus synaptic weight of weakest of those two).

Synergy is essentially when two TX events happening are much more likely to cause RPT than the combined weights of either TX event alone.

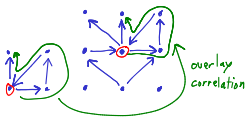
Synergy also presents a very rapid test of whether membrane voltage gradients are important in biological nerual network information processing. No synergy found, no importance. Such would be shockingly unexpected.

Ability to measure RPT patterns implies ability to present stimuli which change these RPT patterns (most efficiently by high-resolution direct neural stimulation). Erasure may exploit 'out of sync lose their link'. Writing may exploit 'fire together wire together'.

Communication directly between biological neural networks may effect a similar result in practice - transfer of memories. Filtering only TX events which activate very large groups of neurons (ie. logical neurons), especially in the motor cortex, may limit memory transfer to voluntary only.

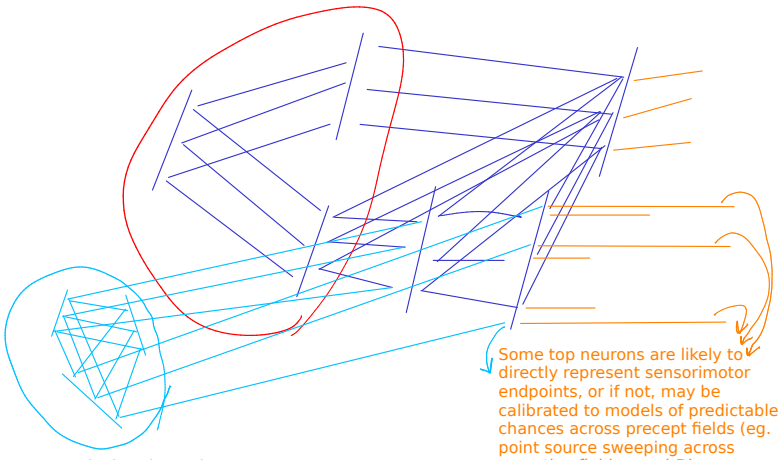
Overlay of biological neural networks - direct electrical connection - may be arranged based on spatial arrangement of RPT events as neuroanatomical 'landmarks'. Some confidence may result from uniqueness of spatial arrangement.

Memory extraction may be possible if RPT events are correlated to associated sensory precepts (eg. visual images) when a 'neural decoder' determines these occur (either as external stimuli or spontaneously internally).



Topographic Mapping from RPT Correlation

Software Algorithm Flow



Some top neurons are likely to directly represent sensorimotor endpoints, or if not, may be calibrated to models of predictable chances across precept fields (eg. point source sweeping across receptive fields, mechDive measured force/position motor outputs) (aka. 'neural decoder').

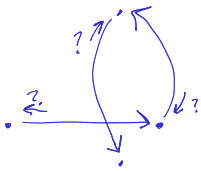
Iteratively solve red.

Find sensorimotor I/O (PNS) entry.

From orange. Action potentials may overlap with only small spike phase or duration differences.

Read only! Algorithm must NOT require arbitrary stimulation, which should only supplement recording data.

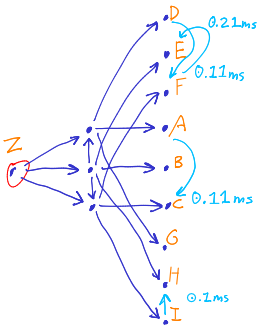
High temporal resolution and oversampled spatial resolution may be required and are feasible, constrained by SerDes bandwidth.



Low temporal resolution correlations may reveal topographic mappings, but without clearly defining the typical directionality, or possibility of bidirectional feedback, only showing both topographic maps were simultaneously activated.

Deep topographic mapping may require high temporal resolution (telodendria ~50kHz?), neuroanatomical overlay (spatial position of electrode), and/or tracing the order of RPT events by RPT correlation of RPT events themselves.

Absence of any spatial position and temporal resolution less than 10x sample rate of minimum temporal difference may increase risk of requiring more solving by more computationally expensive genetic/ANN model iteration.

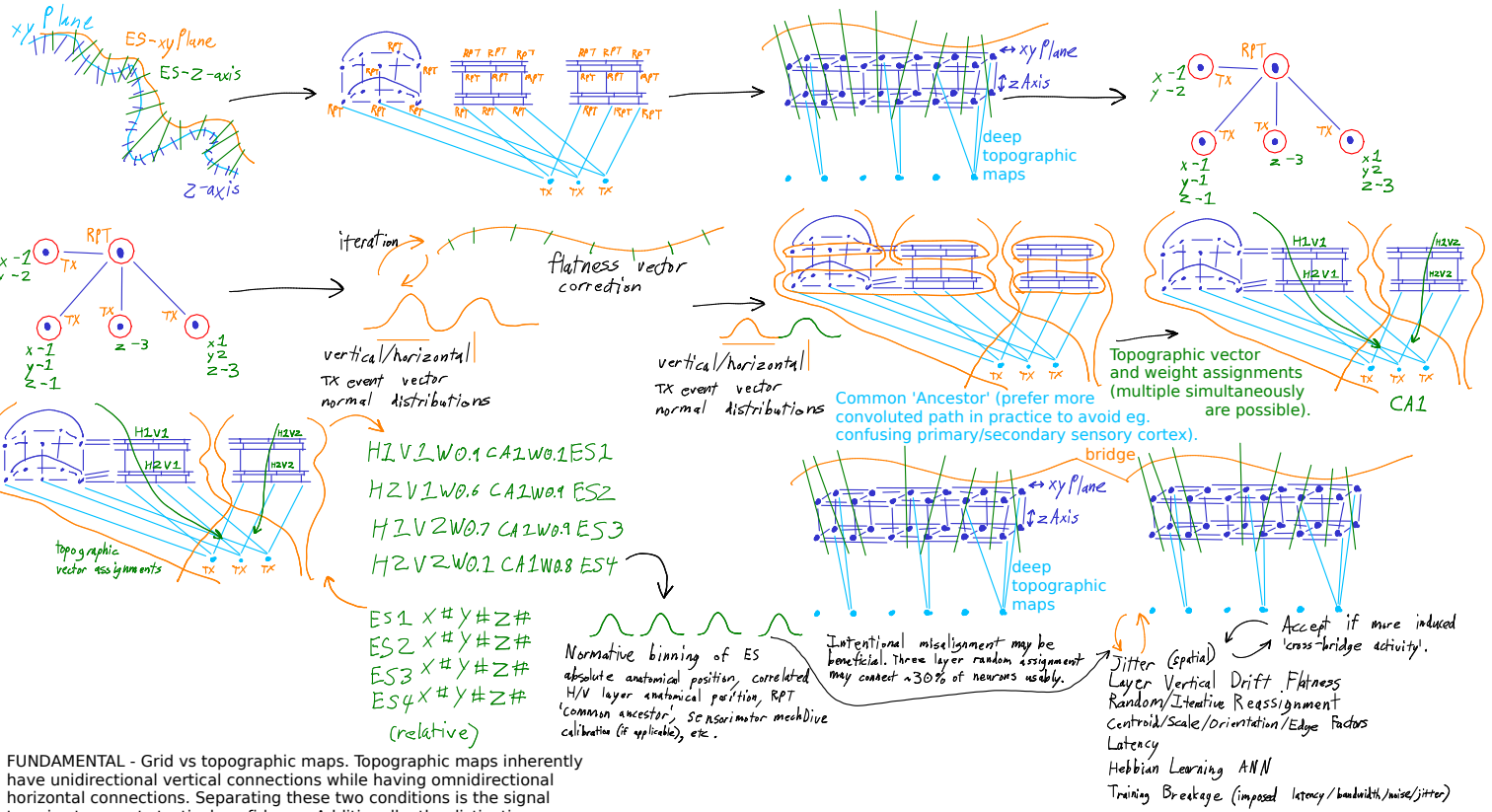


Neurons which RPT from a common vertical TX may be distinguished by their RPT of other neurons in a specific horizontal topographic map.

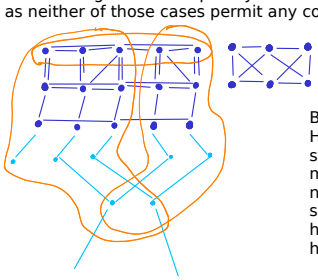
Only the RPT event F-->E, which occurs after D-->F, distinguishes E (of D,E,F horizontal) from B (of A,B,C horizontal).

Center of all topographic maps - E,B,H - will RPT simultaneously from the same vertical TX at Z.

Both B and E will RPT from the same vertical TX event. Only E will RPT of horizontal TX events from processing within that horizontal topographic map.



FUNDAMENTAL - Grid vs topographic maps. Topographic maps inherently have unidirectional vertical connections while having omnidirectional horizontal connections. Separating these two conditions is the signal to noise to assert stastical confidence. Additionally, the distinction between a grid and completely omnidirectional synapses is not relevant as neither of those cases permit any computed overlay (ie. alginment).



FUNDAMENTAL - In practice even substantial misalignment may be tolerable. Minor scaling or layer mismatch, may be adequately accommodated simply by randomizing geometric overlay (ie. alignment) slightly, allowing at least some of the neurons to send precise - if not accurate - data to some of the other neurons. With adequate precision, VR retraining or outright plasticity is expected to be sufficient to adjust sensory perceptions. Moreover, mere VR sensorimotor connection can be achieved by PNS connection which is drastically simpler to align and to supplement by a variety of calibration techniques (aka. 'neural decoder') and mechDive itself.

Biological neural network (ie. 'brain') complexity may be less than tens of thousands of topographic maps. Human Connectome and Human Proteonome projects seem to support such conclusion. Should not be surprising considering the seeming absence of complexity in other tissues derived from similar genetic mechanisms. Much complexity of biological neural networks below horizontal topographic maps (eg. large numbers of distinctly different processing structures, large numbers of distinct neuron morphologies, etc) should not be expected either.
https://www.proteinatlas.org/humanproteonome/brain/human+brain
https://humanconnectomeproject.org

Membrane Phase/Amplitude Variation Visualization

Object memories are expected to at least transfer all of their usable information to and from lower spatial resolution and lower temporal resolution patterns of RPT events from synapses. Whether visualization at better than whole neuron resolution is of practical utility is highly dubious, contemplated mostly as a diagnostic technique.

Globe mapping of phase/amplitude variation across neuron membrane.

Temporal correlation maps rank synapses by most synergistic first, and then from this *1D* plot, fold the most inter-synergistic to be closer on a 2D plot.

Alternatively, the X/Y coordinates of each synapse may be iteratively incremented/decremented with strong dithering (to break any sub-optimum locking of position) towards the lengths beween each synapse being equal to their synergistic effect on synaptic weight.

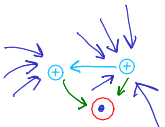
Measurement maps simply read the same neuron from multiple locations at sufficient temporal and spatial resolution to directly observe surface membrane voltage gradients. The exact phase of points along these voltage gradients may be correlated to phase of RPT events at that neuron, at least giving a sense of direction from which the gradients were received, which may be subsequently modeled by simple arithmetic latency, and displayed as a layer in the false-color visualization.

Such an arrangement would allow neuron voltage gradients to be visualized at points across the entire neural network.

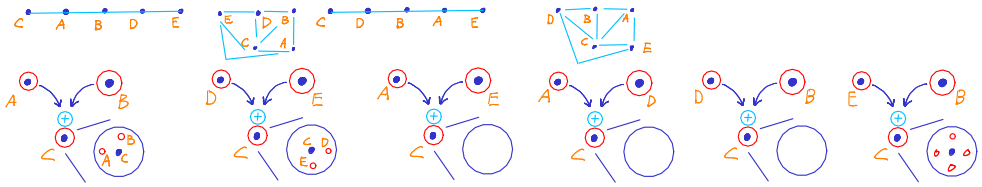
Sparse pattern mapping ranks synapses by synergy, binning synapses into separate groups that are most synergistic to each other and less so with other synapses. Visualization of this data is of the X/Y/Z coordinates of the ES (Electrode Sites) from which the relevant TX events originate.

In this way, the separate patterns recognized by neurons might be observed.

Diagonal synapses are not expected. Most synapses to a neuron are expected to be almost exclusively vertical or horizontal. Most groups are also expected mostly vertical (eg. perhaps apical synapses) or almost entirely horizontal synapses.



Small synergy between synaptic clusters may require additional analysis.

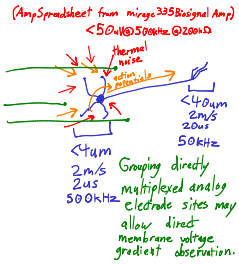


Axon (at center) may not be plotted without sufficiently high temporal and/or spatial resolution to directly observe membrane gradients.

Both phase and amplitude changes across gradients are interesting, to a very high degree of sensitivity. False color images must represent both.

As little as a 1us change in relative phase between synapses may reflect an alternate path taken to reach that synapse, carrying substantial information about the pattern of precepts processed by the receiving neuron (ie. revealing a pair of images in which certain precepts were replaced outright by other precepts).

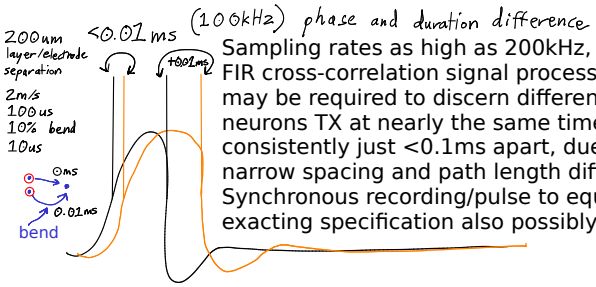
Sampling Rates



Sampling rates as high as 10MHz may be required to fully resolve smallest neural voltage gradient features, across the telodendria and dendrites. Spike sorting (single neuron recording) if not by amplitude then by temporal correlation to identified synapse, may also be required. Such precise studies may benefit greatly from Active Matrix multiplexed direct analog connection to external ADC.

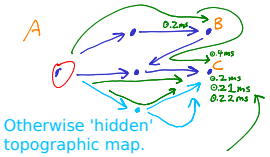
Membrane potential phase differences as high as 500kHz clearly exceed local thermal noise floor. Microelectrode signal to noise ratios are drastically worse than for membrane potential, and still remains at <50uV, below the ~100uV reported by Neuralink for relatively high amplitude spikes.

Further, this conclusion implies usability of membrane integrated biological nanowire semiconductor devices as action potential duration limiters (a possible technological addition to improve biological neuron performance without discarding possible wetware neural correlates of consciousness entirely in favor of semiconductor hardware).



Sampling rates as high as 200kHz, and FIR cross-correlation signal processing may be required to discern different neurons TX at nearly the same time, but consistently just <0.1ms apart, due to narrow spacing and path length differences. Synchronous recording/pulse to equally exacting specification also possibly required.

Very strong correlations may exist for very small timing differences, due to occasional inputs from nearly same-length paths, particularly between just two topographic layers.



Otherwise 'hidden' topographic map.

Possible phase/amplitude variation across neuron membrane?

A-->B
0.1ms, 1%weight, 99%confidence
0.2ms, 90%weight, 99%confidence
0.3ms, 1%weight, 51%confidence (spurious noise)

A-->C
0.2ms, 99%weight, 99%confidence
0.21ms, 1%weight, 99%confidence
0.22ms, 1%weight, 99%confidence

DISCLAIMER: Plausible concepts, attributed sources, oversimplifications, resonably. Rigorous mere academia NOT primary.

errata

_ Terms _
neuromorphic
iterative
microelectrode
biohybrid

electrophisiology
synaptic weight

_ Rough _

*) Electrode Sites (ES) should have long-distance/latency RPT events clustering around particular numbers of milliseconds, indicating the topographic map connected to them. These clusters must be distinguished from mere 'ambient' connections from all directions.

*) Overlay techniques.
 *) Gradual activation. As an example, visual information is likely to present a delay, at least in activating topographic maps that perform deeper processing, or are less relevant. EEG responses across the larger part of the brain after occipital lobe activation being typical of this timing difference at a low temporal resolution.
 *) Deep structure temporal inference. Really a last resort. RPT events are expected to reveal deeper topographic maps, and these are expected to have structural similarity across mammals, or at least such similarity is likely to be forced. Once good estimates for temporal map overlay have been established by other techniques, improper dissimilarities in these deeper structures may be apparent. Certainly, even the crude data of the human connectome project shows clear visual patterns among track routing - a topographic map showing strong RPT deep connections in an unexpected neuroanatomical direction should be obvious. As an example, for a topographic map aligned by other overlay techniques to have most of its RPT events in the cerebellum would be very much out of place.
  *) Topographic maps identified by RPT events will themselves need to be tagged by 'centroid' distances to other topographic maps. If deeper topographic maps are much closer to different neuroanatomy than is the case on the other side of overlay, then there is a problem.
   *) FUNDAMENTAL - A confidence interval can be established for centroid distance relative alignment. Given a scaling factor, there should be a 'normal' range for 'jitter' in these distances after a best fit sorting of deep topographic maps.
    *) SKETCH - Two topographic maps, with deep topographic maps between them. Expected temporal latencies between them shown, with one having a geometrically far smaller brain, and the other having some 'extra' topographic maps. After best match between distance lists, multiply each list by one scaling factor each an iterative equation solver minimizing the total difference between both lists of distances. What difference remains on each line will follow a normal distribution.
     *) There will be a normal amount of mismatched line-by-line distance between deep topographic map centroids. This is a case of comparing two populations for normality.
      *) This may be a case for something like a Z-Test, testing the 'populations' of deep topographic map centroid distances underlying the more accessible superficial topographic maps being overlaid.

-
REVIEW - May be duplicative from (another) part of (another) document.

*) X-Ray pinging. A CT scanner may be used to measure implant placement, at least roughly enough to overlay a cluster of microelectrodes to known anatomical markers, improving neuroanatomical overlay. A coded sequence may be emitted by the CT scanner, or contrast imaging markers may be used, to identify electrode position.

-
REVIEW - Already noted? May need to call for a little more attention?

*) FUNDAMENTAL - Electrode Sites must be addressable by X/Y/Z coordinates. RPT events are expected to be mostly correlated to vertical or horizontal TX events, with 'diagonal' events regarded as 'ambient'. Thus, there should be statistical confidence in most RPT events being correlated mostly horizontal, or mostly vertical.

*) MAJOR - RPT events not confidently correlated to either horizontal or vertical TX events are discarded as 'ambient'.

 *) Sensorimotor. Calibrate by mechDive. Presentation of visual information sweeping across receptive fields in a particular direction is likely to align to the same direction.

-
Elaboration regarding otherwise already noted concepts.

*) Topographic map alignment by alignment of small clusters of neurons cannot be assumed. Rather, RPT patterns must assign neurons to topographic maps, then polarity of the maps must be aligned by correlation to roughly similar sensorimotor I/O (ie.

both brains seeing similar not/active patterns across receptive fields on same side of the body - ie. visual left/right receptive field alignment), and centering/fine alignment must be done from there by either taking advantage of or adding a layer to the hebbian learning principles of synaptic pruning.
 *) In practice, much of this alignment may be refined manually. The number of crucially important topographic maps may be small, and the potential differences could be quite extreme in some cases (eg. as it may be plausible for visual fields to be flipped in some brains and while this may be adaptable it may be suboptimal).
 *) Timing may be relative, causing neurons to fire apart, breaking what should be useful connections.
  *) Such timing problems will be mostly macroneuroanatomical, to be corrected by layers equivalent to 'corrective lenses'.
   *) Spread compensation layer. Astigmatic increment of latency from center to edge, matching circle-to-oval and diameter differences between topographic maps. Small number of constants defining this single nonlinear latency gradient equation will be adjusted to maximize resultant RTP events, discontinuing or making large random changes if RTP event synaptic weight of any particular region drops below some acceptable limit (eg. 10%).
   *) Jitter compensation layer (or may deliberately add jitter if this ensures perhaps at least 1/3 ES TX events are able to generate RPT events on the other side as desired). Perhaps 75us (or otherwise insufficient to change to topographic map of different depth than suggested by RPT events).
   *) Resolution compensation layer. Perhaps 200us, assign one electrode site input to multiple outputs.
 *) MAJOR MAJOR - In practice, aggregates of multiple topographic maps may be read out by electrode sites (or equivalent). Due to the tendency of topographic maps to include direct links between each other, overlap is most likely tolerable in practice.

*) MAJOR MAJOR MAJOR - Merely optimizing overlay (repeatedly rearranging neurons with matching neighbor firing patterns) between neural networks may force appropriate connections, being a very simple algorithm to apply to such tissues as the corpus callosum. May already be documented.

*) Useless neurons in ANNs can simply be discarded, whereas this is NOT so much the case for biological neural networks. Consequently, interfacing ANNs to biological networks is at least more efficient if the ANN is optimized to maximize interaction with the biological network (ie. it is 'trained' simply to 'increase activity' of the biological network). A bandwidth or latency limit may be imposed to force the ANN to achieve this improvement in activity or reduced entropy with minimal influence (thus maximizing 'concise' data provided).
 *) Of course, bio/ANNs hybrids are mostly interesting only for academic purposes, this being an incredibly inefficient and not remarkable use of automation.
 *) Could be problematic - ANNs require somewhat more sophisticated learning rules to achieve the long-term stability required for achieving usefully non-chaotic results. Specifically, something like 'Oja's rule' might be needed - trending the neurons towards keyframes - at least in the medium term to limit degradation rates - and without much more sophisticated algorithms the impact of 'sensory deprivation' on the ANN could be extremely severe.

*) An ANN can be forced to mimic a biological neural network simply by adjusting each artificial neuron and synapse weights (assuming every artificial neuron starts connected to every other neuron) iteratively up and down towards each artificial neuron firing at the same times as the recorded biological data.
 *) Going a little further, the initial 'synapses' could be assigned only between neurons with known correlations in the recorded data.

*) Another way to describe ANN/bio hybrid neural networks is that a learning rule is imposed - either to mimic the original network behavior or (if connected in real-time with stimulation) to cause as much additional activity/complexity with as little input as possible.
 *) Such a learning rule is necessarily achieving a *very short term* behavioral mimic objective (absence of more complex learning rules of biological neural networks causing long term instability).

*) IIRC, an old study monitoring rat hippocampus during navigation challenges found firing patterns correlating to the relative locations of the limited navigation markers. In such a case, the environment itself provided the stimulation, which is obviously difficult to control or manipulate at sufficient bandwidth (even with VR) to achieve a meaningful readout of synapses (considering some patterns correlate to memories which the VR renderer would not have data for, in addition to other problems of simply inadequate bandwidth and spatial resolution directing stimulation to top cognition neurons).

Reference

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4206447/
        'we review a small number of studies directly comparing large-scale electrophysiological correlation with fMRI functional

connectivity-defined networks, and outline some of the theoretical and practical issues with measuring and defining functional connectivity in electrophysiology'
'Given its prominence and its practical applications for the functional connectivity mapping of brain networks, it is of increasing importance that we understand its neural origins as well as its contribution to normal brain function.'
Attempting to provide a better underpinning for fMRI.

https://www.nature.com/articles/s41598-018-36895-y
Localizes spikes between electrodes.

https://www.frontiersin.org/articles/10.3389/fnins.2014.00423/full
'Single silicon neurons have been interfaced successfully with invertebrate and vertebrate neural networks.'

https://link.springer.com/chapter/10.1007/978-3-319-54840-1_14
'compression factors from 10â€“10^5'
Consistent with expectations thus far.

https://en.wikipedia.org/wiki/Synaptic_weight
'The synaptic weight is changed by using a learning rule, the most basic of which is Hebb's rule, which is usually stated in biological terms as' ... 'Neurons that fire together, wire together.'

https://numenta.com/blog/2019/01/16/the-thousand-brains-theory-of-intelligence/
'consensus vote is what we perceive'
Basically this happens with perceptions in ANNs using complicated image processing as precepts rather than mere pixel data directly into the network. Whether such a mode of processing continues (much less predominates) in the neocortex, which may be more concerned with complex assembly models, which require somewhat more formal logic (albeit without the random access typical of automation), may be unknown.

https://www.nature.com/articles/ncomms13805
'Temporal pairwise spike correlations fully capture single-neuron information'
'We show that temporal pairwise spike correlations fully determine the information conveyed by a single spiking neuron with finite temporal memory and stationary spike statistics.'
'This distribution, P(r|s), represents the residual, noise-induced variability for a given stimulus s'
'phase'

https://videocardz.com/newz/amd-radeon-rx-6800-launch-press-deck-transcript
Int4/Int32 1024 OPS/CYCLE/CU
Int8/Int32 512
Int16/Int32 256
Int32 128
FP16 256
FP16/FP32 256
FP32 128

https://www.reddit.com/r/MachineLearning/comments/jv7nxb/n_amd_introduces_matrix_cores_as_equivalent_to/
Apparently ridiculously expensive.

https://www.sciencedirect.com/science/article/pii/S0361923015000684
'shapes'
'human or rat hippocampus, where nearby neurons fire to unrelated concepts in the first case (Rey et al., 2014) and to distant place fields in the latter (Redish et al., 2001)'
Now beyond a shadow of a doubt, while whole electrode site activity may reflect data sent long distance, single-neuron precision is required to directly analyze the most detailed neural processing.

https://upload.wikimedia.org/wikipedia/commons/1/1e/Estimations_of_Human_Brain_Emulation_Required_Performance.svg
Electrophisiology is estimated to be about 5 orders of magnitude more computationally expensive than 'neural simulation'. This continues to confirm the expected gap between neurons as single devices, and neurons as at least membranes of perhaps 10^3 relevant FEM cells .

https://en.wikipedia.org/wiki/Brain%E2%80%93brain_interface

https://en.wikipedia.org/wiki/Learning_rule

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2656500/
"Spatial and Temporal Scales of Neuronal Correlation in Primary Visual Cortex"
'Finally, we used a recently developed analysis for isolating synchronous spiking from slower covariations in firing rate.'
'Pearson correlation coefficient'
'Fisher transformation'

https://academic.oup.com/cercor/article/25/9/3182/2926133
"Local and Global Correlations between Neurons in the Middle Temporal Area of Primate Visual Cortex"
'where N1 and N2 are the spike counts of each neuron, and E and Ïƒ are, respectively, the mean and SD of the spike counts'
So, basically the already conceptualized analysis, but with a covariance analysis. Where is their confidence test?
'measured the confidence intervals using the function nlparci and ensured that these intervals did not overlap with zero'
'Pearson correlation coefficient'
'To do this, we first z-scored the spike counts so that response to each direction had mean of zero and unit variance. '
MAJOR MAJOR MAJOR - Direction response. Similar to Neuralink research. And finding synaptic correlations between neurons.

https://www.nature.com/articles/srep34886
'Correlated activity of cortical neurons survives extensive removal of feedforward sensory input'

https://www.jneurosci.org/content/jneuro/33/45/17921.full.pdf
"When and Why Noise Correlations Are Important in NeuralDecoding"
'To decode all the information, it suffices to know the probabilistic mapping between the stimulus and the population activity (Oram et al., 1998;Knill and Pouget, 2004).'
'both in the individual activity of neurons and in the correlations between their activities. U'
MAJOR - Leading to a concerning notion. A neuron may send off different spike trains in response to different stimulus being presented just once. Such would require 'memory' internal to the neuron itself, not reflected in RPT events.
May emphasize *decoding* of neural information, which is an endeavor of dubious practical utility.
'their information content. The losses can be linked to specific NIL stimulus and response features by interpreting R as a reduced representation of the population response (Eyherabide an Samengo, 2010). In such a paradigm, population responses are represented as a vector of response features, each conveying in-formation about specific stimulus features. Only some of those response features (and their information content) are preserved after the NI assumption (first stage). The analysis of the preserved and lost features allows one to determine the effect of the NI assumption on the neural code.'
Article is apparently merely restating the obvious with a very ambiguous use of the term 'noise' to refer to amplitude noise as well as statistical noise in different contexts. If a neural decoder outputs less information than all statistically significant observations of the data set, then less confidence may be available than would have been by comparing the 'noise' responses (ie. combined action potential electrical activity - 'electrical noise') of the entire 'populations' of neurons with stimuli present, versus the 'population' of perhaps the same neurons with stimuli absent.

https://en.wikipedia.org/wiki/Bayes%27_theorem

https://www.nature.com/articles/s41467-017-02009-x
'65,536 simultaneously recording and stimulating electrodes in which the per-electrode electronics consume an area of 25.5â€‰Î¼m by 25.5â€‰Î¼m'
'compressive sensing'

http://inside.mines.edu/~mwakin/talks/mbw-cwpTutorial.pdf
Essentially seems to suggest attempting to interpolate sampled analog data by adding sine waves (or equivalents), rather than 'smooth interpolation'.

http://paulbourke.net/miscellaneous/interpolation/

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5702607/
"A very large-scale microelectrode array for cellular-resolution electrophysiology"
'By removing the contribution of Pi in the per-channel data, we avoid aliasing.'
MAJOR MAJOR MAJOR - Basically sparsely samples at the ADC (varying sample rate), making evenly distributed undersampled high-frequency noise slightly concentrate at frequencies which can then be filtered out, at least in some iterative way.

Apparently scans an ADC across multiple front-end amplifiers. This is *very* dubious, as the ADC is expected to be far less demanding of chip space than the amplifiers, except in unusual situations. Then again, this device was intended for deep electrophisiology on a scale beyond what can be manipulated analog in-vitro (precisely because of the ADC bandwidth required not having sufficiently low patterning cost or compactness given the sub-membrane size 'nanowire' required), and beyond what is necessary in real time in vivo (in that case justifying multiplexed external analog connectivity), making this a very specialized science tool - FUNDAMENTAL - irrelevant.

https://www.cns.nyu.edu/csh/csh06/PDFs/nrn1888.pdf

"Neural correlations, population coding and computation"

'Both âˆ†Ishuffled and âˆ†Idiag have usually been found to be <10% for pairs of neurons. Therefore, it would seem that correlations are not important, and, in par-ticular, that correlations caused by synchronous spikes â€" the type of correlations implicated in the binding by synchrony hypothesis â€" do not carry much extra information.'

MAJOR MAJOR MAJOR - Is synchronous activity - a common phenomenon - going to be difficult to filter out, generating lots of useless RPT events by mere oscillation phase lock?

Doubtful. Such phase locking would have to be through local field potentials, or through the (useful) temporal latencies under study. Local field potentials could generate useless RPT events, however, these could be ignored by the resulting local synchronicity unless useful phase differences were observable.

MAJOR MAJOR MAJOR MAJOR - FUNDAMENTAL - Worst case, 'ambient action potential rate' must be considered to be much higher during local synchronicity events.

https://en.wikipedia.org/wiki/Neural_decoding#Spike_train_number

https://en.wikipedia.org/wiki/Neural_coding#Spike-count_rate

https://www.annualreviews.org/doi/pdf/10.1146/annurev.neuro.31.060407.125639#article-denial

'dependence on dendritic location'

MAJOR MAJOR MAJOR - Continues indications of membrane voltage gradient relevance. Also implies long-term learning may be influenced by such image gradients - suggesting image recognition may occur close to the receiving neuron cell membrane. Of course that should be expected to begin with, since telodendria are apparently short.

'nonlinear integration of synaptic modification induced by complex spike trains'

MAJOR - Does not negate the iterative algorithm appropriate to impose 'RTP events' from one network to exist similarly in another, nor does this negate the basic 'bridging' algorithm.

https://en.wikipedia.org/wiki/Neocortex#/media/File:Gray754.png

Suggests telodendria are long enough to span multiple neurons. In fact, a cube root of 10000 connections to other neurons at ~20 would allow 2um spacing between neurons at 40um telodendria length.

MAJOR MAJOR MAJOR - Most synapses to a neuron may not be dedicated to another single neuron. Actual number of neuron-to-neuron connections may be an order of magnitude lower at 1000/neuron, or more.

https://www.frontiersin.org/articles/10.3389/fncir.2016.00023/full

"Why Neurons Have Thousands of Synapses, a Theory of Sequence Memory in Neocortex"

'previously proposed that non-linear properties of dendrites enable cortical neurons to recognize multiple independent pattern'

'Experimental results show that the coincident activation of 8â€“20 synapses in close spatial proximity on a dendrite will combine in a non-linear fashion and cause an NMDA dendritic spike'

'We show the input to the cell divided into three zones. The proximal zone receives feedforward input. The basal zone receives contextual input, mostly from nearby cells in the same cortical region (Yoshimura et al., 2000; Petreanu et al., 2009; Rah et al., 2013). The apical zone receives feedback input (Spruston, 2008). (The second most common excitatory neuron in the neocortex is the spiny stellate cell; we suggest they be considered similar to pyramidal cells minus the apical dendrites.)'

https://en.wikipedia.org/wiki/Apical_dendrite

https://www.nature.com/articles/nature03366

'Although postsynaptic processing of each input is known to depend on its dendritic location1,2,3,4,5,6,7,8, it is unclear whether activity-dependent synaptic modification is also location-dependent. Here we report that both the magnitude and the temporal specificity of spike-timing-dependent synaptic modification9,10,11,12,13,14,15,16,17 vary along the apical dendrite of rat cortical layer 2/3 pyramidal neurons.'

https://en.wikipedia.org/wiki/Neural_backpropagation
	Dendrite second 'echo' due to whole neuron firing. Dubious relevance to connectome/weight mapping between neural units.

https://en.wikipedia.org/wiki/Grandmother_cell

https://www.mathworks.com/matlabcentral/answers/13687-do-you-think-that-matlab-is-expensive
	SciLab, Octave and SciPy

https://www.researchgate.net/publication/264432332_DynamicBC_A_MATLAB_toolbox_for_dynamic_brain_connectome_analysis
	'DynamicBC: A MATLAB toolbox for dynamic brain connectome analysis'
	'sliding-window analysis'
	'time-varying parameter regression'

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7443704/
	'CATMAID'
	'natverse'
	'NBLAST'
	'FAFBseg'

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4961245/
	'NBLAST'
	'We present NBLAST, a sensitive and rapid algorithm, for measuring pairwise neuronal similarity. NBLAST considers both position and local geometry, decomposing neurons into short segments; matched segments are scored using a probabilistic scoring matrix defined by statistics of matches and non-matches. We validated NBLAST on a published dataset of 16,129 single Drosophila neurons.'
		'pairwise' 'correlation' 'distribution for matching pairs'

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7242028/
	'The natverse, a versatile toolbox for combining and analysing neuroanatomical data'
	'natverse'
	'match neurons and boutons to layers'
	'Sholl analyses'
	'trees toolbox (Cuntz et al., 2010), has particularly strong support for morphological analysis of neurons but focuses on individual neurons in isolation rather than neurons within the volume of the brain as a whole'

	'align'
	'hierarchical clustering'

	'NBLAST scores can be hierarchically clustered in R, plotted as a dendrogram, and used to visualize morphological groups at a defined group number or cut height (Figure 4a). Often, this forms a good starting point for cell typing, but might not be in exact agreement with manually defined cell types (Figure 4b). This can be due to neuron reconstructions being differently severed by the field of view or size of the tissue sample collected (Helmstaedter et al., 2013), or due to registration offsets between registered neuronal skeletons (Chiang et al., 2011; Kunst et al., 2019).'

	'NBLAST scores'

	'morphologically determined similarity scores'
		Very much a dubious and not relevant technique for analyzing dead tissue slices.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3191349/
	'address-event-representation (AER)'
	'speed-up factor of 104 compared to biological real-time, which increases simulation speed and integration density of the analog neuron and synapse circuits at the same time'

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4205553/

https://en.wikipedia.org/wiki/Connectome
	'Finally, statistical graph theory is an emerging discipline which is developing sophisticated pattern recognition and inference tools to parse these brain-graphs (Goldenberg et al., 2009). '
	'Alternatively, local difference which are statistically significantly different among groups have attracted more attention as they highlight specific connections and therefore shed more light on specific brain traits or pathology. Hence, algorithms to find local difference between graph populations have also been introduced (e.g. to compare case versus control groups).[65] Those can be found by using either an adjusted t-test,[66] or a sparsity model,[65] with the aim of finding statistically significant connections which are different among those groups.'
		Comparing groups of neurons by comparing some of their prominent features to normal distribution statistics. Dubious and not relevant.
	'connectograms have been used to visualize full-brain data by placing cortical areas around a circle, organized by lobe'

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3594415
'extract cortical and non-cortical anatomical structures'
Of course. MRI/fMRI/PET/etc would rely on neuroanatomical overlay, since these techniques excel greatly in that regard, and may have neither the temporal nor spatial resolution to achieve any other means of neuroanatomically accurate mapping.
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3275792
'Statistical graph theory is an emerging discipline which is developing sophisticated pattern recognition and inference tools to parse these brain graphs (Goldenberg et al., 2009). '
'parse these brain graphs' - create them maybe not so much

https://en.wikipedia.org/wiki/Connectogram

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7443704/
'Neuron skeletons were traced in a full adult female Drosophila brain ssTEM (serial section transmission electron microscope) volume'
'Analysis and Representation of Traced Skeletons'
'nat.nblast' ... 'compare neuron skeletons by morphology and position and generate a hierarchical clustering' ... 'identifying neuron types'
Definitely not relevant.
'relay thermo- and hygrosensory information to higher brain centers, including the mushroom body and lateral horn, seats of learned and innate behavior'

https://www.sciencedirect.com/science/article/pii/S0361923015000684
'Past, present and future of spike sorting techniques'

DISCLAIMER: Plausible concepts, attributed sources, oversimplifications, resonably. Rigorous mere academia NOT primary.

neuralBits

Software frames and packets to hardware transistor logic to wetware neuron action potentials. Down to flexible PCB layout, SerDes chips, multiplexed addressable ADC/DAC, amplifiers. No Turing completeness.

Commercially economical (cost effective for all living sentient beings) 'whole-brain' brain computer interfaces are now feasible. Immediate applications include low-cost 'Virtual Reality' (ie. human) habitat, 'Virtual Reality' assisted software/hardware design, 'Virtual Reality' (re)training, 'brain upload', 'hive mind'. Accurate neural command entry, memory transfer, virtual perception input, motor output recognition, and sufficient muscle activation suppression are possible.

For plausible software design, Virtual Reality applications can use the simple calibrations of well established 'neural decoders' while 'brain upload' and 'hive mind' connectome and synaptic weights RPT correlation algorithms are available from 'cognitionSplicer'.

Introduction

Published hardware designs (eg. 'NeuraLink' already have most features. Improving number and density of Electrode Sites is straightforward cost (ie. manufacturability) and wiring (ie. surgical) optimization. Improving long-term stability after implantation, if not already adequate, has been shown entirely possibile by reducing apparent mechanical stiffness (eg. with excellent results known for mesh electrodes).

Keep in mind long-term stability is not essential - 'brain upload' once is enough to 'save a life' and transfer to more compatible wetware.

State of the art microelectrode arrays have been reviewed, and their principles combined to enumerate some parameters and techniques towards scaling up towards 3 million analog electrodes. Footprints occupied by various components - particularly amplifiers and addressing - are factored into simple equations which are hoped to illustrate some feasibility limits.

Some sources, quotes, and review of 'state of the art' microelectrode arrays (especially 'mesh' electrodes) may be included as 'errata'.

Urgent consolidation of the most useful design concepts for quick reference during intensive hardware/software/wetware design may postpone a more concise summary of existing science and technology (ie. sources mentioned in 'errata'. Perusal of 'errata' (with expert assistance if needed) is more strongly recommended than usual if attempting to design prototypes, acknowledge important research, or inform possible stakeholders. Press in particular are reasonably required to exercise extreme due diligence far beyond the apparent norms of their profession, to the point of becoming honest experts, or heavily funding research, theirselves.

Presented

*) Component connections - hardware --> backhual packetizer --> codec (optional) --> addressing counters --> ADC/DAC/amplifier --> multiplexing matrix (optional) --> wetware .
*) Transmission line quantity, bandwidth, parametric geometry, calculator table.
*) Visual spatial resolution (particularly extreme and expected unnecessary).
*) Codec, Analog ADC/DAC/Amplifier .
*) Tentative flexible PCB layout.

As may be plausible.

Any terminology introduced is NOT a proposal for external use, and may perhaps provide for internal disambiguation beyond the needs of any professional speciality. External requests to explicitly state a withdraw of any implied proposal for third party naming conventions will be given priority over any internal needs. I have no intention to get in the way of established professional academic researchers by suggesting any change in their terminology.

Conclusions

Commodity components many years old (ie. SerDes chips, USB3 FPGA), corrosion testing, laser cutting, surface coating, <2mil PCB fabrication, atomic-force probe or electron-beam fabrication of minimal surface area CMOS/polyamide packetizing, codec, ADC/DAC, and amplifier circuitry - are sufficient and well within the combined prototyping resources of 'makerspace', 'hackerspace', and 'biohacking' communities today. A combined community open-source effort could overcome this hurdle independently.

Extracting whole-brain neural tissue samples is not complicated and has long already been widely available at low-cost (eg. from 'Brain Bits LLC').

Most imperative is to get software/hardware developers read-write access to all essential parts of their own neural tissue. Expect that developers and their sponsors will be and absolutely must be first and unfettered.

Low spatial resolution of neural interface limiting the resolution of objects for 'brain uploading' purposes may be compensated by VR retraining. Developers may urgently need unfettered read-write access and exocortex software/wetware/hardware specifically to rapidly identify and correct any severe qualitative deficiencies which substantially lengthen or prevent VR retraining.

Scaling to 3million analog electrodes (across the entire neocortex) is feasible and a desirable performance benchmark.

Scaling to several million electrodes write-only across the entire visual system - including inputs along the length of the entire optic nerve and surface of the entire visual cortex - is feasible but possibly challenging enough to justify some short-term continued use of a conventional LCD/OLED/LED 'display' panels. Assuming better than 10x compression of electrodes connected to precepts, to perceived equivalent 'pixel' resolution may be a risky assumption.

Resolution beyond expected 0.1mm/1% may be beyond point of diminishing returns.

Recording sites for 'brain uploading' ordered by expected priority at 0.1mm/1% (neural processing cell/axon) or >100% (nerve/vertebrae transmission) - inferior temporal gyrus, corpus callosum, entire temporal lobe, somatosensory cortex, prefrontal cortex, hippocampus, entire neocortex, entire amygdala, vertebrae, glossopharyngeal nerve, vestibulocochlear nerve (inertial cues), olfactory nerve, terminal nerve (uncertain), trigeminal nerve (possibly magnetic cues), remaining cranial/peripheral nerves, all nerve endings (eg. by 'neural dust' in sensory tissue implanted under guidance towards locations causing CNS evoked potentials), all remaining neural tissue.

So called 'grandmother cell' research strongly implicates the inferior temporal gyrus of the temporal lobe of the cerebral neocortex. This is particularly strong evidence considering the visual nature of the stimuli considered.

REFERENCE

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6914248/
https://www.biorxiv.org/content/10.1101/703801v1.full.pdf
 An Integrated Brain-Machine Interface Platform With Thousands of Channels
        'Neuralink' 'System B'
        '192 capacitors' ... '3072'
        'Maximum differential input range, mVPP' ... '7.2mV'
        Graph apparently shows ~60uV high-frequency spikes, <180uV low-frequency local field potentials. A 6uV noise floor seems reasonable, though a 1uV ADC resolution at local field potential frequency (ie. <50Hz) may be useful.
        'Number of Channels' ... '3,072' ... '750mW' ... '(23Ã—18.5Ã—2)mm3'
                sqrt(23000Ã—18500)/sqrt(3072) == 372um * 2000um
        'Polymer threads on parylene-c substrate.'

https://github.com/mirage335/Mirage335BiosignalAmp/blob/master/AmpSpreadsheet.ods

https://www.4pcb.com/trace-width-calculator.html
        '1um' ... 'Length 1cm' ... 'Resistance 1.32e+5 ohms'

https://www.frontiersin.org/articles/10.3389/fnins.2019.00208/full
https://www.frontiersin.org/articles/10.3389/fnins.2019.00208/full#supplementary-material
 'Single-Cell Electrical Stimulation Using CMOS-Based High-Density Microelectrode Arrays'
        'we were able to stimulate the axon initial segments (AIS) with charges of less than 2 pC' ... 'Stimulation signals as low as 70 mV or 100 nA, with pulse durations as short as 18 Î¼s, yielded measurable action potential initiation and propagation.'
        'stimulation frequency was 1 Hz for both modalities'
        'electrode voltage and keeping it significantly below 0.8-1 V to obviate water electrolysis and cell and electrode damage'
        'capacitiance values of ~1.4 nF for Pt-black and ~0.07 nF for bright Pt electrodes'
        'charge needed to evoke APs in current is, indeed, by two orders of magnitude lower than in voltage mode'
        'ammounted to 0.02pC/um^2 with out HD-MEA, while, for example, retinal implants currently work with 3.5pC/um^2' ... 'A small size of electrodes and their dense packing may prove beneficial to stimulate neurons and could improve stimulation accuracy of prosthetic implants while enabling lower power consumption.'
        '26,400 bidirectional electrodes at a pitch 0f 17.5um and an electrode area of 5 x 9 um^2'

https://www.ti.com/lit/ds/symlink/iso124.pdf
        '1-pF isolating capacitors' ... 'input is duty-cycle modulated and transmitted digitally' ... 'ISO124 contains 250 transistors'
        'Noise 4uV*sqrt(Hz)' ... 'Output voltage +/-10V'

https://hackaday.io/project/177881-the-transistorpixel
        'TransistorPixel'
                Nice demonstration of an addressable pixel using only a small number of discrete transistors.

https://iopscience.iop.org/article/10.1088/1741-2552/aa8b4f/pdf
 A review on mechanical considerations for chronically-implanted neural probes
        'low Young's modulus polymers' 'hard substrates' 'variety of means' 'reduction' 'probe width and thickness' 'soft hydrogel coatings' 'release in device tethering'
        'temporary stiffness' 'buckling' 'detailed description'
        'bioresorbable'
        'next generation'

https://www.beis.de/Elektronik/DeltaSigma/DeltaSigma.html
https://en.wikipedia.org/wiki/Voltage-controlled_oscillator

https://www.youtube.com/watch?v=TXtQZQNE_iE

https://hackaday.io/project/28833-microhacks/log/157535-just-how-fast-are-74auc-gates

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DS99R105, DS99R106

https://raspberrypi.stackexchange.com/questions/87846/how-fast-can-gpio-pins-toggle

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https://ece.engin.umich.edu/stories/the-michigan-probe-changing-the-course-of-brain-research

https://hackaday.com/tag/usb-3-0/
'FX3 is a neat little chip that has a 100-MHz General Programmable Interface (GPIF) bus that basically lets it act like an easy to use FPGA' ... '200 megabytes per second' (1.6Gb/s)

https://en.wikipedia.org/wiki/Optic_radiation
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https://en.wikipedia.org/wiki/IMEC
Sketches presented predate awareness of IMEC's involvement.
'Neuropixels Technology'
'The performance of the Neuropixels probes and their potential for transformational neuroscience experiments was described in a November 9, 2017 paper published in Nature.[24] In 2019, The New York Times reported that imec's Neuropixels technology is widely recognized as the most advanced method of gathering data from brain cells.[25]'
'Brain-On-Chip Research'

Conduits (Transmission Lines, Bandwidth, Neocortex Neural Interface Component Connections, Pinout/Bus/Power/Clock)

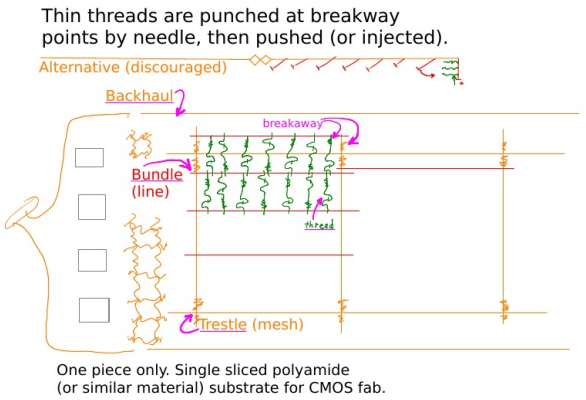
Geometric dimensions and placement of components determines manufacturability, collateral damage, bandwidth, and addressing.

Backhaul, Trestle, Bundle, Thread, ES

Backhaul --> Trestle --> Bundle --> Thread --> ES

Threads carry at least ES (Electrode Sites - microelectrodes or equivalent optical emitters/sensors, etc).

More hardware (eg. Codec, ADC, Amplifier, ActiveMatrix) may be placed as close as possible to ES, to the point of these components being on threads, or at junction between threads/bundles. Otherwise, many layers of 1um traces may connect more bulky components directly to ES. Impedance of 1um traces may be ~100kOhm (similar to ES), which may increase power consumption (especially for stimulation), degrade signal/noise, or inconveniently enlarge PCB layout designs.



Estimate - Geometry (Trestles,Bundles,Threads,totalES), Transmission Lines, Bandwidth

Bandwidth, codec, and analog circuitry requirements may be much lower for neural interfaces intended only to record activity for connectome and synaptic weights correlation - scanning relatively small 'observed areas' of neocortex by multiplexing ES with ActiveMatrix.)

Trestle, bundle, thread, and ES, quantities may be slightly smaller (eg. '45' instead of '50') due to manufacturing margin requirements at edges.

Mismatch between postulated values here or elsewhere may occur due to new publications or experiments suggesting slightly different neuron electrical characteristics, sightly different plausible electronic component capability, slightly different plausible tissue collateral damage acceptability, etc.

Chosen						
Geometry	'length_cm=10'	'width_cm=10'	'depth_mm=2.5'	'depth_es=25'	'needle_um=100'	'thread_um=25'
	'trestleGap_cm=$(_clc "0.2")'		'bundleGap_cm=$(_clc "0.2")'		'threadGap_um=325'	
Bandwidth	'eventRatePerES=50'		'rawSampRate=7000'		'compressSampRate=50'	
TransmissionLines	'transmissionLineMaxFreq=25000000'					
Analog	'ADCbitDepth=4'		'DACbitDepth=5'			

Inferred				
Geometry	totalTrestle= 50	totalBundle= 2500	totalThread= 94674	totalES= 2366850
	needleHours= 106	totalExpansion= 100 %	totalCollateral= 100 %	
	densityES_cm= 153.8457	densityES_mm= 15.38457	densityES_um= 0.01538457	
BW (raw)	rBackhaul= 66.2718 Gb/s	rTrestle= 1325.436 Mb/s	rBundle= 26508.72 Kb/s	rThread= 700 Kb/s
BW (compress)	cBackhaul= 1.5384525 Gb/s	cTrestle= 30.76905 Mb/s	cBundle= 615.381 Kb/s	cThread= 16.25 Kb/s
T Lines (raw)	rlBackhaul= 2650.872	rlTrestle= 53.01744	rlBundle= 1.0603488	rlThread= 0.028
T Lines (compress)	clBackhaul= 61.5381	clTrestle= 1.230762	clBundle= 0.02461524	clThread= 0.00065
Analog	rampFrequencyADC= 224000			
rBandwidthPerES= 28000 , cBandwidthPerES= 650 timeBitDepth= 8 , locationBitDepth= 5 secondsPerThread= 2 , needlesParallel= 1				

Both receive and transmit (ie. stimulation) bandwidth will be half-duplex near equal (worst case). Usually a neural interface will either mostly receive (ie. receive activity for correlation of connectome and synaptic weights), or mostly transmit (ie. transmit sensory precepts and receive minimal voluntary/motor output).

SerDes reduces transmission lines to <40 for external connection. Increasing transmission line frequency to remove the need for SerDes may severely increase power consumption, among other problems, especially for interfaces with many 'totalES'.

Frame, Packet, Counter, Bitmask, ActiveMatrix

Frame is a combination of packets, possibly with a 'magic number' as a 'MAC address' and a specified number of bits. Frames are transferred at very high bandwidth and may follow a defacto standard (eg. Ethernet, CSI/DSI, existing LVDS) or no standard (eg. USB3 FPGA GPIO) .

Packets are addressed to specific components (eg. Codec, ADC, DAC, ActiveMatrix) or groups of components (all components if a complete list of neural received/transmit spikes/pulses). Address space either 24bit or 48bit.

Counter takes a specified '??' number of bits, then forwards subsequent 'infinityBits', similar to many 'addressable LED pixels'.

Bitmask control of many separate ActiveMaxtrix addressed through a Counter is an example that a slowly clocked bus may at negligible component count, bandwidth, and power consumption, reprogram any Codec, DAC, ADC, ActiveMatrix (multiplexing), etc. As usual, no Turing completeness.

Hard > Frame > Packet+infinityBits > Backhaul > [Codec > ??bits+infinityBits > Counter > DAC-LF > ^Bitmask > Counter > ActiveMatrix > MeshElectrode] > Thread > [Trace > MeshElectrode] + [Codec > ??bits+infinityBits > Counter > DAC-LF > ^Bitmask > Counter > ActiveMatrix > MeshElectrode] > Wet-Needle

Hard < Frame < Packet+infinityBits < Backhaul < [Codec < ??bits+infinityBits < Counter < ADC-LF < ^Bitmask < Counter < ActiveMatrix < MeshElectrode] < Thread < [Trace < MeshElectrode] + [Codec < ??bits+infinityBits < Counter < ADC-LF < ^Bitmask < Counter < ActiveMatrix < MeshElectrode] < Wet-Needle

Example only, illustrating many plausible concepts. Other arrangements may be preferable.

Pinout

Designs for wiring (eg. PCB layout, mezzanine connector adapters, PatchRap specifications and breadboard layout, etc) should provide as much connectivity (ie. power, reference, clock, bus) to as much circuitry as reasonably possible.

+0.6V , +0.7V , +0.8V , +0.9V , +1.0V , +1.5V , +2.5V , +3.3V , +5V / +24V
-0.6V , -0.7V , -0.8V , -0.9V , -1.0V , -1.5V , -2.5V , -3.3V , -5V / -24V
pGND

Vcc/pGND
Vcc/pGND (DAC-LF only)
Avcc/sGND (ADC-LF only)

PWMdirect- , PWMalternate+
midpoint

Amplifier Reference Ground (drives output close enough to midpoint for further offset adjustment by dual-gate FET input)

40 Data LVDS Transmission Lines (SerDes)

1 Clock Low Power
1 Data Low Power (low speed frames for embedded microcontroller access to neurons)

Clock Codec

Clock ADC-LF (ie. 7kHz)
Clock DAC-LF (ie. 7kHz)

Clock Config-ActiveMatrix
Clock Config-Codec

Clock 1GHz
Clock 500MHz
Clock 250MHz
Clock 200MHz
Clock 150MHz
Clock 100MHz
Clock 50MHz
Clock 25MHz
Clock 1MHz
Clock 1kHz

Clock 48MHz
Clock 16MHz
Clock 8MHz
Clock 32.768kHz

Mezzanine connectors and foldable 'zig-zag' flexible mesh PCB areas are expected where optimum mechanical compatibility may be important.

Additional data transmission lines may be added internally (eg. Backhaul --> Codec --> DAC/ADC). A few dedicated low-frequency clock lines (eg. Clock Config-Codec) may also communicate data. Usually dedicated clock lines (or disable) should only be provided if some sort of power reduction (eg. rare reconfiguration, low-power embedded microcontroller access to neurons) may be necessary.

Visual Transmitter (Neural, Display Panel, Combined)

Visual and auditory inputs have exceptionally high spatial resolution requirements - especially for developers reading much text, pilots using traditional flight decks, anyone examining large areas of terrain, etc. Combination of both neural interface and external LCD/OLED/LED panels may be necessary to adequately mitigate fatigue.

```
  'foveatedDimension_8kPanel=0.15'
  ' desiredPixels=$(_clc "( ((7680*4320*2) * ( $foveatedDimension_8kPanel )^2 ) + ((3840*2160*2) * ( $foveatedDimension_4kPanel
)^2 ) + ((1920*1080*2) * ( $foveatedDimension_1080pPanel )^2 ) ")'
desiredPixels= 8294400
```

Retina, Optic Nerve, Optic Tracts, Neocortex (Combined Neural Interface)

Human fatigue plausibly degrades retina conversion of, and ocular focusing of, light photons. Pure neural interface for visual sensory input could at least improve on, if not bypass, such significant aberrations. Spatial resolution must be much greater than best-case human vision to avoid worsening neocortex fatigue.

Combined optic nerve and 'visual cortex' cerebral neocortex seem optimistically barely adequate. Retina electrical (non-photon) stimulation seems negligible. Dubiously, dense ES arrays deeply within other optic tracts of long axons may suffice.

Expect total bandwidth ~100Mbit, more definitely <1Gbit .

Calibration of stimulation only ES exact precept type and relative location is by neural decoder or ordered RPT correlation from a much lower resolution more 'general purpose' ES array (ie. "totalES") in neocortex. Usually, a much lower spatial resolution neural interface is expected to suffice for reading or writing connectome and synaptic weights (somewhat indirectly), while stimulating specific precepts is expected to always require a spatial resolution (directly) higher than entire sensory input.

Electrodes for stimulationES are reasonably assumed to use ~20um pitch and area of ~5um * ~10um .

Retina stimulationES are optimistically assumed to use a flat surface of electrodes at 20um pitch as a 1cm^2 flat chip similar to in-vitro MEA, with no perceptual compression benefit, providing 250000px.

Optic nerve stimulationES optimistically assumed constrained by occupied space rather than collateral tissue damage (with axons being pushed aside instead of destroyed by needle). A 50um surface spacing between threads is optimistically assumed to allow 5um diameter electrodes to expand nerve diameter ~1%, optimistically assumed close to acceptable.

Optic tracts (mostly aka. 'optic radiations') are other axons assumed anatomically similar to optic nerve.

 WARNING: More 'perceptualCompression' reliance may incur computationally prohibitive iterative calibration.

```
  'perceptualCompression=10'
  'stimulationES_diameter=0.005'
```

```
  'retina_pixels=250000'
```

```
  'opticNerve_threadSpacing=0.050'
  'opticNerve_thickness=1'
  'opticNerve_length=25'
  'opticNerve_electrodesPerThread=50'
  ' opticNerve_expansion=$(_clc "($stimulationES_diameter ^2) / ($opticNerve_threadSpacing^2)")'
opticNerve_expansion= 0.01
  ' opticNerve_stimulationES=$(_clc "( ( $opticNerve_thickness / $opticNerve_threadSpacing )^2 ) * $opticNerve_length *
$opticNerve_electrodesPerThread")'
  ' opticNerve_pixels=$(_clc "$opticNerve_stimulationES * $perceptualCompression")'
opticNerve_pixels= 5000000
```

```
  'opticTracts_threadSpacing=0.050'
  'opticTracts_thickness=3'
  'opticTracts_length=25'
  'opticTracts_electrodesPerThread=50'
  ' opticTracts_expansion=$(_clc "($stimulationES_diameter ^2) / ($opticTracts_threadSpacing^2)")'
opticTracts_expansion= 0.01
  ' opticTracts_stimulationES=$(_clc "( ( $opticTracts_thickness / $opticTracts_threadSpacing )^2 ) * $opticTracts_length *
$opticTracts_electrodesPerThread")'
  ' opticTracts_pixels=$(_clc "$opticTracts_stimulationES * $perceptualCompression")'
opticTracts_pixels= 45000000
```

```
  'totalES=3000000'
  'relevantNeuronsPerDesiredNeuron=0.05'
  ' neocortex_pixels=$(_clc "$totalES * $relevantNeuronsPerDesiredNeuron * $perceptualCompression")'
neocortex_pixels= 1500000
```

```
desiredPixels= 8294400
  ' observedPixels=$(_clc "$retina_pixels + $opticTracts_pixels + $neocortex_pixels")'
observedPixels= 46750000
```

Display Panel (Repurposing neuralBits as Improved Graphical Display Addressing)

Visual stimulation by external LCD/OLED/LED display panels, supplementing or improving neural interface spatial resolution, may use the same addressing/multiplexing/compression components usable for direct neural interfaces. Particularly useful for upgrading existing headsets with higher resolution panels, intra-ocular retina implant, or bypassing the limitations of DisplayPort/SteamVR hardware/software (ie. by compression/USB3).

Auditory stimulation is already trivial - at least if proper care is taken to flatten apparent frequency response.

Hard > Frame > Packet+infinityBits > Backhaul > Codec > ActiveMatrix > LCD/OLED/LED > Lens > Wet-Retina

Unusually, codec may use IIR filters and differences from neighboring pixels.

```
  'codecCompression=10'
  ' bandwidth=$(_clc "( $desiredPixels * 24 * 180 ) / $codecCompression ")'
bandwidth= 3583180800
```

Analog Receiver/Transmitter

Receive only neural event spike time, location, duration (dubious), sorting (prototype only). Analog receiver (amplifier, ADC, Low-Pass-Feedback) solely exists to acquire neural events. ADC resolution may be rather poor (4uV-128uV) due to insignificance of lower-noise low-frequency.

Transmitter only emits pulse stimulation time, location, amplitude (optional), duration (dubious). Amplitude may either minimize risk of degrading receivable neurons near ES, or maximize longer distance neurons reached. Crudely, transmitter may diagnose or balance ES defects (eg. electrochemical potential, impedance erosion, mechanical separation, etc), however, this must not consume significant bandwidth or circuitry (may be prototype only).

Analog waveform transmission/reception is not practically useful.

Amplifier

Amplifier must be one per ES (excepting very small stimulation only ES used for Virtual Reality), and is expected to occupy the largest 'footprint' per ES. Single-transistor amplifier or inequally sized differential long-tailed pair due to space constraints. Differential analysis (eg. spike waveforms from the same neuron across different axes between pairs of ES) is by analysis (ie. codec/software) not 'instrumentation amplifier' hardware.

ES (Electrode Sites)

LS

LS (<7kHz) should obviously use Ramp ADC or Flash ADC due to minimal circuitry, power consumption. Ramp ADC in particular has analogous precedent for comparable circuitry with very generous equivalent bit depth. Feedback AC Coupling (~0.7Hz low-pass) using a 5-bit R2R DAC (discard the irrelevant digital readout) may eliminate electrochemical potential, expanding maximum voltage by >4bits (128uV/2*64 == 4096uV) at no bandwidth and negligible circuitry.

HS

HS (>100kHz <10MHz) (prototype only) should obviously multiplex ~128 transmission lines. Both high bit depth (ie. 16bit, 24bit) and high sample rate (eg. 10MHz, 192Ks/s) may be required to sufficiently discern phase and duration.

Stimulation only ES

Stimulation only ES may be smaller, denser, and more numerous, having neither the surface area nor large amplifier needed for low-noise reception. Calibration of their exact position may be by nerual decoding of ES at topographic maps of entirely different anatomical locations (ie. calibration of peripheral neurons by ES in neocortex).

Receiver - ADC Dynamic Range

Amplifier gain and ADC resolution must combine to meet expected signal amplitudes.

4bit ADC (4uV-128uV) (aka. +/-2uV to +/-64uV)
Flash ADC - 32 Comparator
Ramp ADC - rawSampleRate*32 Ramp Frequency

Feedback AC Coupling 5-bit R2R DAC information is a useless artifact, ignored.

Prototype dynamic range may be larger, at 2uV-480uV (8bit ADC) or 2uV-2mV (10bit ADC if unexpectedly high electrochemical potential or sensitivity).

Transmitter - DAC Dynamic Range

Triangular voltage waveform only, to minimize total charge, collateral damage, and especially associated power dissipation. Must keep peak voltage <<0.8V with average current approximately +/-<420nA . Duration may be <<200us per phase, <<400us total.

Two separate 4bit R2R DAC briefly output preprogrammed waveform with dynamic range +/-25mV to +/-400mV .

Rationale

Receiver Amplifier/ADC must have a zero midpoint (to discern spikes visible between specific pairs of ES).

*) Minimum discernible input voltage step - <4uV. Relatively poor sensitivity is entirely acceptable, although narrow band noise floor may be much lower at ~1uV.
 *) Local field potentials at ~1uV@<30Hz@100kOhm (similar EEG noise floor) are vastly inferior to, and can be inferred or stimulated from, a more direct neural interface.
 *) Distant neural spikes are at higher frequency and corresponding ~6uV@<10kHz@100kOhm (Neuralink specification, thermal noise estimation).
 *) Placing ADC resolution well below the noise floor (ie. small fraction of ~6uV) is not worth much additional power consumption or circuitry which may reduce spatial resolution (ie. "totalES").

Transmitter DAC voltages must always emit +/- from a zero midpoint used by all ES. Stimulation patterns between arbitrary pairs of ES must be possible.

*) Minimum stimulation step - +/-25mV. Study (https://www.frontiersin.org/articles/10.3389/fnins.2019.00208/full) suggests useful waveforms begin with minimum voltage either ~5mV (100nA@50kOhm square wave current) or ~70mV (square wave voltage) at minimum useful duration of ~50kHz/18us (square wave current) or ~20kHz/50us (square wave voltage).
 *) Stimulation voltage waveform must be a one-time programmable or reprogrammable (prototype only) pattern. Voltage-to-current unity-gain buffer amplifier may not be useful, due to non-availability of physically large capacitors (>>50pF), resistive power consumption, no expectation of substantial or correctable ES impedance erosion, etc. Current control without strict inductive spike voltage limit may cause water electrolysis (and associate damage).
  *) Square wave current output implies triangle wave voltage output, which may minimize charge flow through nearby tissue, while maximizing charge change at distant neurons (maximizing safety).
  *) Square wave voltage implies strongly high-pass filtered current waveform, which may only maximize use of limited voltage supply.

*) Maximum stimulation voltage - +/-0.42V. Voltages closer to +/-0.8V may cause too much collateral damage. For an unreasonably pessimistic 1Mohm ES, a useful maximum of +/-420nA implies a useful maximum of +/-420mV . A 4bit DAC with a minimum of 25mV would have a maximum of 400mV. Two separate 4bit R2R DAC expand this to a dynamic range of +/-25mV to +/-400mV without risk of resistor precision limitations inducing harmful persistent DC bias currents while disabled.

*) Amplifier bias current should ideally be less than (100Ã—10^âˆ’9)/50000 == 2*10^-12 (ie. 2pA) . While reasonable, much greater bias current may be acceptable, since this is extremely conservative, some damage to nearby neurons may be acceptable, and electrochemical degradation may be more relevant.

*) Accuracy, precision (ie. voltage calibration drift), and linearity are not important. Neither analog measurement nor extensive filtering of the useful information (ie. neural spike events) is expected.

*) Ramp ADC. ISO124 amplifier (datasheet) is analogous enough as an example of Ramp ADC - at least a 10kHz usable bandwidth, extremely high signal/noise ratio (ie. bit depth), duty cycle modulation, claimed transistor count 250.
*) Flash ADC. Fast, minimal components (32 comparators at adequate 4bit resolution, 256 comparators at 8bit resolution).

*) Voltage-Frequency-Converter ADC. May have all disadvantages of Ramp ADC, with additional internal circuitry and low quality oscillator jitter. Usability may depend on feasible modulation rate (ie. sampling rate) and modulation depth (ie. bit depth) relative to noise (ie. jitter).

*) Capacitor (dis)charge ADC is severely constrained by either small capacitance (<<100pF), or by physically large capacitors and possibly high power consumption. Multiplexing, as Neuralink apparently does at a 16x ratio, increases already high frequency response requirements, and may not scale beyond a few thousand electrodes.

*) R2R DAC. More compact than an OpAmp filter with (physically large) capacitor. When the digital readout is unwanted (as with Feedback AC Coupling), the relevant memory bits may be ignored instead of sent to a bus.

Codec

Codec reduces bandwidth from analog 'audio' waveforms to mere lists of nerual spike events and pulse stimulations . Latency of 100ms acceptable. Logic circuitry must minimize footprint and power consumption - expect at least one codec per bundle.

Transmitter

List of pulse stimulation time, location, amplitude (optional), duration (dubious). Amplitude may be omitted if default, or incremental from a previous value with a 'magic number' reset to zero.

Receiver

Spike mess. Accumulates buffer of events, appends a unique identifier. Unique identifier length is ceil(solve(2^"messBitDepth" == "totalES" / "numberOfES", "messBitDepth")) .

Single events (spike time, location, duration, sorting) detected by band-pass, hysteresis, three 'tap' FIR cross-correlation, etc. Stores one value with fields indicating number of samples before a spike occurred and which electrode site.
 Time field bit depth is ceil(solve(2^"timeBitDepth" == "rawSampleRate" / "compressedSampleRate", "timeBitDepth")) .
 Location field bit depth is ceil(solve(2^"locationBitDepth" == "numberOfES", "locationBitDepth")) .
 Duration field bit depth (aka. "durationBitDepth") optionally is ("durationBitDepth" == "timeBitDepth") .
 Sorting field bit depth (aka. "sortingBitDepth") is arbitrary, prototype only, possibly an amplitude 4bit (4uV-128uV) peak value.

Multiple codecs may send a spike mess to a shared bus by waiting for the preceding codec to finish transmitting.

Prototypes may optionally interleave additional compressed (or raw) data.

*) Two band amplitude of frequency (IIR filter bank). May reduce bandwidth from 7kHz to 300Hz@<100%bitDepth (high-pass amplitude) plus 30Hz@100%bitDepth (low-pass amplitude) .

*) Spike count. Accumulates number of spikes in an output cycle. May reduce bandwidth from 7kHz to 300Hz@4bit or 300Hz@2bit (depending on maximum count per output cycle) .

If differential analysis (eg. spike waveforms from the same neuron across different axes between pairs of ES) is practically useful (ie. due to insufficient spatial resolution due to insufficient "totalES"), some experimentation (ie. with prototype) analyzing and comparing analog waveforms may be necessary to improve compressed data interpretation.

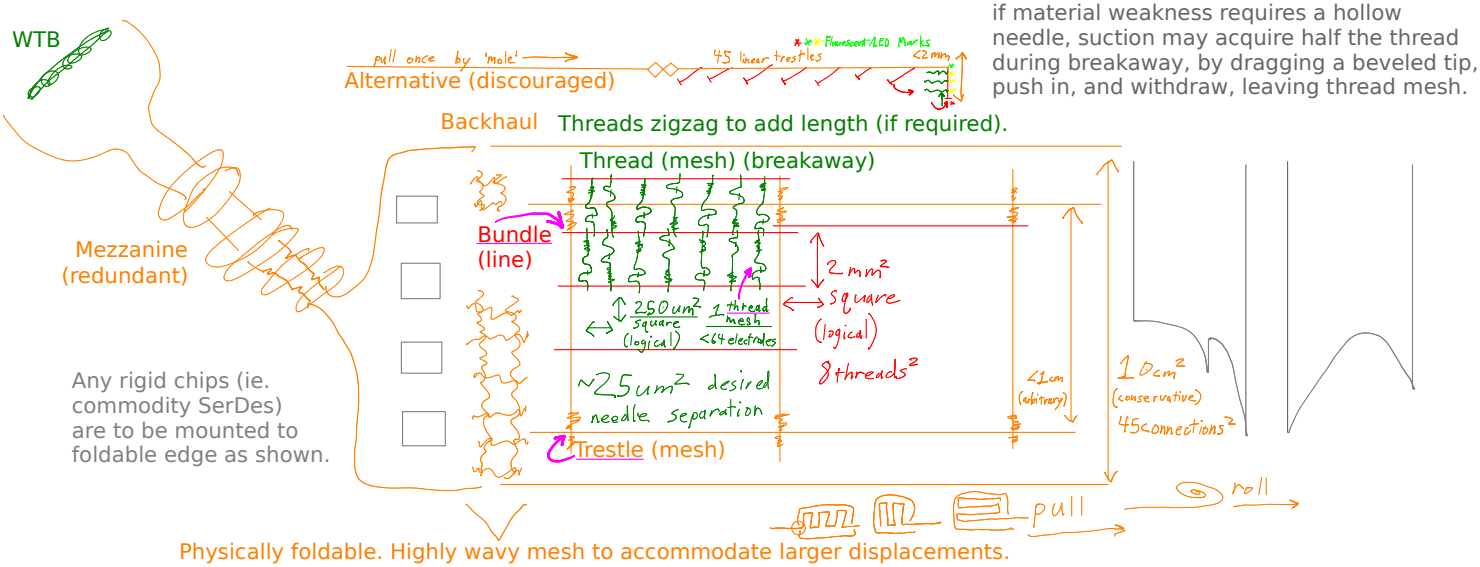
Tentative Flexible PCB Layout

Thin threads are punched at breakway points by needle, then pushed into neural tissue.
If threads are too thin and too mechanically weak to withstand this, needle may be hollow, acquiring and injecting the threads more gently.

One piece only. Single sliced polyamide (or similar material) substrate for CMOS fabrication. No rigid PCBs.

PatchRap
neuralBits

Needle may rely on insertion loop, or may use curved prongs to break, drag, twist and push thread mesh. Alternatively, if material weakness requires a hollow needle, suction may acquire half the thread during breakaway, by dragging a beveled tip, push in, and withdraw, leaving thread mesh.



Physically foldable. Highly wavy mesh to accommodate larger displacements.

Pull and roll deployment may be combined (ie. pull then unroll further), and pull deployment may be periodic, minimizing collateral.

Areas between threads, bundles, trestles, are intended as large open cutouts, as an open mesh. Mechanical flexibility to accommodate cyclic respiration/cardiac expansion, and minimal obstruction of surrounding tissue is intended.

BEWARE empty space between bundle lines must not be completely filled, due to occupying too much space needed for valuable neural tissue.

Sharp edges (ie. from drilling and cutting polyamide) strictly prohibited.

All mesh lines must be wavy to accommodate 100um respiration, cardiac, displacement.

Rearrangements or breakaway of Trestles, Bundles, Threads, is possible. Most extreme alternative is a single trestle, pulled across surface of desired tissue, with bundles and threads pulled away. Avoid doubling the thickness of Trestles or Bundles, to minimize gaps in coverage of neural tissue.

Carbon fibers, if added, must be of an appropriately calculated diameter aligned only along thread depth axis.
Encapsulation by coating of biocompatible material. Reinforcement by reinforced epoxy if necessary.
May be trimmed, breakable, bendable, foldable, and separable to accommodate non-flat surfaces.
No Turing completeness necessary.

DISCLAIMER: Plausible concepts, attributed sources, oversimplifications, resonably. Rigorous mere academia NOT primary.

errata

_ Rough _

*) Prototype should be built from discrete components. After all, 'duplicate this in VLSI' is a relatively straightforward proposal, and this allows the amplifier performance to be validated in advance.
) 0202 Components are already ~<550um~<350um ...
 *) Resolution of 6mil is 150um ...
 *) REMINDER - Re in differential tail circuit must be much higher than Rc, and ideally a pure current source, to prevent common mode voltages changing collector voltage.

*) User-selectable limits open-source firewall periodically certified software and hardware. In the most basic mode, VR only with low-resolution high-threshold motor outputs.

*) Dedicated microfluidics and fiber-optics may be added alongside, or as part of, any of these probes. Very slightly pressurizedMicrofluidic channels in particular, may improve electrode impedance, fill in collateral damage around rigid threads, or improve flexible mesh threads.

*) MAJOR - Hydrogels (ie. contact lens material) are highly plausible.

REVIEW - May be duplicative from (another) part of (another) document.

*) Regardless of whether the interface is display panel, mechanical vibration, electrotactile, or direct neural interface, video compression is applicable. VR software requires modules able to export real-time compressed greyscale video represent visual as well as tactile interactions (ie. collision virtual objects convertible to pressure, vibration, temperature, stretch).

*) Although somewhat invasive, spinning wires (eg. of tungsten carbide) with suitable tips may be used as drill bit microneedles penetrating most of skull. A large array of these (ie. ~1mm spatial resolution) could be competitive with more completely invasive interfaces for VR purposes. Especially if reaching intra-dural.
 *) Diamond abrasive tips may avoid any requirement for drill bit shaping, minimizing cost.
 *) Collateral damage to pass-through tissue (ie. scalp) would be a non-issue if diameter was a relatively small fraction of minimal spatial resolution (ie. ~0.1mm/~1mm).
 *) MAJOR - Motorization of wires is potentially a minor expense. A single motor may spin and push multiple wires simultaneously (using some kind of gearing arrangement), resulting in 'microneedle array' like behavior.
  *) Very high resolution 3D printing would may benefit this considerably.
  *) Belts may spin microneedles by friction. Pusher plates may press large groups of microneedles inwards.
 *) Similar in principle to ECoG. May also be used to push threads of a 'neuralBits' interface after minimally invasive implantation of that.

Elaboration regarding otherwise already noted concepts.
Also, references with extensive commentary, facts, interpretation, etc.

*) Published study 'Neural Dust: An Ultrasonic, Low Power Solution for Chronic Brain-Machine Interfaces' suggests scalability (of analog amplifier at least) to ~20um, largely based on required CMOS amplifier dimensions to achieve usable thermal noise and power consumption, as well as modulated load backscattered power.

*) Open Mesh Electronics, seemingly injectable as fabric, reportedly have achieved better long-term recording performance, contrasted with flexible threads.
 *) Obviously, mesh effectiveness in avoiding chronic mechanical damage, seems to require not being taunt, allowing the flexibility of the thin mesh to provide sliding elasticity.
  *) Obviously, the mesh may be relying on the intersection of four lines as anchors, while tissue may slide along the lines. This explains literal geometric translation of flexibility to elasticity in a non-taunt mesh.

*) MAJOR - 'Indeed, the brain micromotions-respiration, vascular pulsatility and head movements, induce displacements in the order of tens of microns around the silicon or metal shank, which leads to an enhanced mechanical stress around the shank [13].' - https://iopscience.iop.org/article/10.1088/1741-2552/aa8b4f/pdf
 *) MAJOR - 'single neuron activity with great tempo-ral resolution (0.2â€“7 kHz) [4]'
 *) 'In rat brains, these micromotions are on the order of tens of microns for respiration-induced pressure and 0.2 Î¼m due to cardiac-induced pressure [13] (figure 1(A)). Finite element stimulation shows that tethering forces induce elevated

strains, located principally at both tips of the probe [14] (figure 1(B)).'
 *) MAJOR - 'Therefore, the compliance is a function of structure, while flexibility (elastic modulus) is a function of material [20].'
  *) A remark predictive of the use of flexible mesh.
  *) Also, it is obvious that a 3D mesh would result in more friction, which could leave a 2D mesh as the absolute optimum.
 *) 'PDMS is widely used in microfluidic technologies, and has high viscoelasticity with a Youngâ€™s modu-lus that can be slighlty altered depending on the curing agent and temperature'
 *) 'Though PDMS exists in medical class, that meets both USP class VI and ISO 10993, it has been reported that the curing agent might be toxic [76].'
 *) MAJOR - 'The main issue with polymeric implants is the long-term reaction to a water-based environment [8], which have often been shown to fail within months as a result of polymer swelling and layer delamination [20].'
 *) MAJOR - 'to a water-based environment [8], which have often been shown to fail within months as a result of polymer swelling and layer delamination [20]'
  *) Indeed expected, albeit with more flexible underlying materials than the proposed insulation.
 *) 'Collagenase has been proposed in the literature as a structure breakdown for the collagen present in the pia mater, therefore allowing for easier implantation with mini-mum dimpling [96, 97].'
 *) 'Resorbable polyethylene glycol (PEG) as a temporary glue guarantees a more reliable adhesion [111, 112, 114] (figures 7(B) and (C)). PEG is a highly biocompatible, fast-degrading polymer, that dissolves quickly with the addition of water. The shuttle can also take the form of a cylindrical needle or a hollow tip where the device to be implanted remains shielded inside [53, 115] (figure 7(A)) and vice versa: the needle can be placed inside a tube-shaped probe [116]. Surprisingly enough, many studies have relied on wide tungsten wires or rods with rather large cross-sections [112, 114, 116, 117]. '
 *) MAJOR MAJOR - (D) 'Image of a dyed silk-coated fish-bone shaped polyimide probe with tip shown (Â© (2011) IEEE. Reprinted, with permission, from [125]).'
 *) 'Typically, the biore-sorbable coatings used are on the order of 80â€“180 Î¼m [62, 89, 151, 163], although thinner coatings have been reported [50].'
 *) '(DEX, BDNF and NGF) as well as a virally-mediated expression of Caveolin-1, and implanted in rat brains over 12 months'

*) MAJOR MAJOR MAJOR - Second sparse layer of electronics fabricated on top of the rest of the 'neuralBits', with high sample rate cross-correlation circuitry, to determine deep topographic maps by fine resolution (overlapping in time but not space) spike timing cross-correlation.
 *) A full >1MHz may be required.
  *) Direct electrode to backhaul (or even further back with active matrix to analog outputs) is entirely reasonable - one random length placed electrode site per thread would yield 129k analog electrode sites for such further analysis, more than enough to spatially oversample the expected ~5k-2.5k topographic maps. Multiplexing strictly analog outputs - reading just perhaps 128 electrodes at a time - would only require ~1k steps to 'scan' the entire connectome, is also entirely reasonable, and would allow MHz range 24bit ADCs, or even hetrodyne RF receivers, with just 8bits of high speed bandwidth being more than adequate anyway.
   *) Straight USRP connections are plausible at such scale - external connections and bit depth easily allow for this.

References missing Sources
 Somehow, the links or titles of some of the articles these apparent quotes originate from, seem to have been lost. Google or other search may be able to identify them, but the possibility of exact quotes now existing within multiple other, possibly less relevant, articles must not be discounted.

*) Action potentials are >>250Hz . Local Field Potentials are non-spike. High bandwidth (~10kHz) is in fact required, further complicating the technology.
 *) 'LFPs have a critical role in coordinating the activity of different regions of the brain, and synchronizing the activity of individual neurons with that of a neural network, through phase locking to the global rhythm10'.

*) MAJOR - Neural dust study 'Fig 8' shows very small amounts of backscattered power change (apparently *) MAJOR - This suggests much more than 20um side dimensions are actually needed, and that input transistor footprints (100um) are *much* larger than the 'thread' electrode spacing dimensions (~50um - ~75um) . This would explain the absence of addressing in-thread.

*) Neural dust study mentions that analog input FET may be calculated.

-

Neural dust study graphs should match -
Whatever Vneural is, multiply by 3, put this in as the acceptable v-n ('input-referred voltage noise') , apply correct numbers for '4 * k-B * T' , get 'minimum bias current' . Power consumption must be less than what is available on the device.

Ideally, FET size is as small as possible, before too much bias current is required.

I-DS == (pi / 4) * ((4 * k-B * T) / v-n ^ 2) * ((k-B * T) / q) * BW
and I-DS == 'minimum bias current' (power consumption)
and v-n == 'input-referred voltage noise'
and 4 * k-B * T == 'drain-source voltage of the FET must be at least ~' ... 'or 100mV'

'As a result, the FET must be large enough to be able to sustain this minimum bias current.'

'As a result, neural dust must capture enough power from the interrogator to sustain both 100 mV and the minimum current required to ensure that the thermal noise does not dominate the AP voltage. This is defined as the power limit.'

'Therefore, for a BW = 10 kHz and voltage SNR at the input of the FET of 3 (which sets vn based on Vneural), we can compute the minimum allowable size of the FET, restricted by the noise limit.'

References (Inaccessible)

*) 'Novel electrode technologies for neural recordings'
 *) 'Neuropixels' '130 nm CMOS'
 *) 'NeuroSeeker'
 *) 'polyimide' 'longevity'
 *) 'tissue-like' 'mesh electronic' 'bending stiffness'
 *) 'silicon wafers' 'standard photolithography'
 *) 'extracellular electrode' 'multiple active neurons' 'detectable distance' '~140um'
 *) 'needles' 'deliver mesh electronics' 'larger' '330-65 um'
 *) 'Neural Dust' 'yet to be evaluated'
 *) 'optetrode'
 *) 'optical fibers' 'tip size' '5-20 um'
 *) 'photonic' 'incorporated' 'Michigan array' 'photolithography' 'waveguide mixer' 'waveguide splitter'
 *) 'optically transparent' 'electrically conductive' 'zinc oxide' '125-um diameter'
 *) 'Michigan-type silicon probes' 'fabricated with integrated microfluidic channels'
 *) 'astrocytes' 'microglia' '~100 um thick glial' 'insulates' 'recording electrodes'
 *) 'taking advantage' 'dependence of bending stiffness' 'probe thickness' 'mesh electronics' is the 'only neural probe to date with effective bending stiffness comparable to that of neural tissue.'

*) 'Targeted optogenetic stimulation and recording of neurons in vivo using cell-type-specific expression of Channelrhodopsin-2' - https://experiments.springernature.com/articles/10.1038/nprot.2009.228
 *) 'optically stimulating' 'in vivo' 'electrophisiology'
 *) Illustrations and recorded waveforms seem available.

Reference

https://www.pnas.org/content/pnas/114/23/5894.full.pdf
 'Syringe-injectable mesh electronics integrate seamlessly with minimal chronic immune response in the brain'
        Extremely impressive images of tissue slices showing apparently excellent mesh electronics biocompatibility to the point of healing from the injection to at least nearly indistinguishable from healthy tissue.

https://en.wikipedia.org/wiki/Local_field_potential
        MAJOR MAJOR - 'The fact that the extracellular space is not homogeneous, and composed of a complex aggregate of highly conductive fluids and low-conductive and capacitive membranes, can exert strong low-pass filtering properties.'

errata-more

*) Voluntary filter software. Threshold number of neurons may filter involuntary brain activity from willful actions. Such a filter may apply not only to motor output (presumably such a filter is already innate) but also for any 'object' a user may 'imagine' as a means of communicating or recording mental images.

*) MAJOR MAJOR - Stimulating larger areas than recording may be highly desirable in some locations (eg. 'perhipherial' vision areas of relevant topographic maps), on account of the need to force individually strong precepts .

*) MAJOR - Thread elasticity should be considered. Spring like coiling, or regular bending, may offer both an insertion technique and better biocompatibility.

*) Electrical fields beyond the glial scarring must be sought out by transistor.
 *) Accomodating geometry. Side spines may both increase surface area and provide a location for at least some transistor parts.
 *) Persistent dispersants - break down any insulating properties of nearby non-neural tissue.
  *) Nanoparticles.
  *) Encapsulated conductive carbon nanotubes (to become more 'sticky' after some dispersion away from source).
 *) Neurons may be physically unable to tolerate mechanical motion.
  *) Retractable Coiling Space - May be used either to protect threads from external motion or to protect small projections from threads.
  *) Backward Thorn - May pull threads or subthreads outwards over time, using the mechanical energy of the otherwise problematic cardiac/respiration forces.

*) A single DAC may be multiplexed to a variety of purposes.

*) A DAC low-pass feedback filter will introduce an artifact when adjusted.
 *) Low-pass DAC increases the dynamic range by as many bits as its output minus one - due to shifting the amplifier input across half its input range with every step.

*) Successive approximation ADC should be considered due to the probable use of high-speed CMOS circuits.

*) Delta encoding should be considered due to the inherent band-pass characteristic and miminal analog low-pass requirement (lower than fast clock). Output digital bitstream must be converted to PCM (free-running) by IIR digital low pass filter. Raw bitstream allows other filtering without PCM mathematical operations.
 *) A prototype delta-sigma modulator should be built and simulated.

*) Voltage-to-Frequency converter should be considered due to the similarity to appropriate circuits for wireless/optical devices.
        *) MAJOR - FM 'capture effect' could be *extremely useful* as transmission line interference would become irrelevant.
        *) High frequency counter power dissipation at the receiving end is a probable disadvantage.
        *) Bandpass filter bank may need to be analog ... this is potentially an expensive disadvantage.

*) MAJOR - 'KHFAC block is nearly instantaneous, as shown inFigure 2. A recent study[4]used a â€˜counted cyclesâ€™ methodto measure the time to achieve complete motor block and found that it could be as rapid as 7.5â€“14 ms;' - https://www.futuremedicine.com/doi/pdf/10.2217/bem-2017-0004
 *) MAJOR MAJOR MAJOR - Perhaps only the largest sensory/motor impulses need be suppressed momentarily and partially for safe neural VR to keep the 'IRL' body reasonably relaxed.
 *) 'It is feasible to use KHFAC to block different sizes of axons, from motor[3]and sensory fibers[20], to the smallestunmyelinated axons[23].'
 *) 'The two important parameters of KHFAC nerve block are frequency and amplitude. Nerve conduction blockrequires a frequency of 1 kHz or higher[13], and typically frequencies of 5 kHz or higher have been used. Therehave been no reports of a â€˜maximum plateauâ€™ frequency to achieve KHFAC block, with the highest reportedfrequency being 50 kHz[25].'
 *) 'Both voltage-controlled KHFAC and current-controlled KHFAC waveforms have been used with no significantdifference in the reported response[27]. However, DC offsets can be a significant issue, especially in currentcontrolled waveforms, and care needs to be taken to utilize a circuit design that removes the DC offset[28].'
 *) 'Computation modeling studies indicated that KHFAC resulted in an increased inward sodium current, leading to adynamic depolarization of many nodes under the electrode[33,35].'
  *) MAJOR - At the very least, any more KHFAC nerve block than necessary, or in extreme cases of this effect, potentially dangerous permanent changes to axon may occur. At minimum, two separate electrode sites should be used, with downstream sensing of both, to allow automatic recalibration of minimum nerve block current.
 *) MAJOR - 'DC block of neural activity was first demonstrated by Pfl Ìˆuger[39]and has been reviewed previously[40].Untilrecently, however, the use of DC block was limited to physiological studies in acute animal preparations due to irreversibility of the block when utilized for more than a few minutes[41â€“43].'
  *) In other words, highly dangerous.
 *) 'Petruskaet al.[43,47]demonstrated that by ramping the amplitude of the DC over a period of approximately 100 ms, it was possible toachieve block without inducing neural activation. This is in direct contrast to KHFAC which, as described earlier,always produces onset activity, even if the amplitude is ramped. The excitation at the cessation has likewise beeneliminated using a ramp at the end of DC block[43,47,48].'
 *) 'Historically, DC block has only been utilized in acute physiological testing because the electrochemical reactionsat the

electrode will eventually result in damage to both the nerve and electrode, and is thus unsuitable for long-termacute or chronic applications[42,49â€“51].'
  *) If indeed not more than just the electrochemical reactions do not cause damage.
 *) 'Because of these issues, safeelectrical stimulation is achieved by limiting the charge delivery below established safety levels and deliveringstimulation with a charge-balancing phase so that the waveform has a zero net charge.'
  *) Which would be guaranteed by audio transformer.
 *) 'The first method has been termed the separated interface nerve electrode (SINE)and involves separating the electrodeâ€“electrolyte reactions from the nerve itself. The second method utilizes highcharge capacity materials and maintains a charge balance over a period of many seconds to a minute or more. Thislatter method is referred to as CBPC. Both of these approaches have been demonstrated to significantly extendthe duration that DC block can be reversibly applied in the acute situation (from tens of seconds for DC alone tomany hours with CBPC) but neither method has yet been used chronically.'
  *) MAJOR - DC block has not been used chronically (unsurprisingly).
 *) 'Current was delivered through the saline to the nerveto produce block. The results showed that long duration (up to 880 s) DC pulses could be delivered to the nerveat amplitudes sufficient to block conduction and still maintain complete reversibility of block once the current wasturned off[57].'
  *) 'More recently the SINE electrode has been enhanced to use carbon black in the electrolyte to extendthe run time of the device. A 50 min block was achieved with complete nerve force recovery, as shown inFigure 5'
 *) MAJOR - 'Platinum black, forexample, which is produced by electroplating platinum on platinum, has an effective surface area more than two orders of magnitude larger than bare platinum[60].'
  *) Significant implications for any neural interface electrode.
 *) MAJOR MAJOR - 'If the force generated from both the proximal and distal electrodes was the same, then nerveintegrity was maintained. The ratio of PS to DS is used as metric for nerve damage.'
  *) MAJOR MAJOR - Strictly allows an automatic safety protocol for chronic use.
 *) 'Figure 6shows the effect ofcumulative charge for bare platinum, platinum black and iridium oxide.'
  *) Iridium Oxide, again used as electrode material.
 *) 'The onset response is produced primarily by the response of the nerve to thefirst few cycles of the KHFAC wave[4].'
 *) 'demonstrated that the onset response can be reduced so that it lasts less than 1 or 2 sthrough optimization of electrode geometries and through the use of large KHFAC waveform amplitudes.'
  *) Potentially unsafe amount of time.
 *) 'Without a direct test of nerve conduction block, it isdifficult, if not impossible to discern the effect. An example of this is the use of 10 kHz waveform for spinal cordstimulation[38]. Initially it was commonly thought that this waveform produced a conduction block of fibers[25,70],but subsequent studies have shown that this is unlikely to be the mechanism of action for this particular device[71,72].'
 *) 'A better understanding of the mechanism of action should allow optimizationof the waveform parameters.'
  *) Doubtful. Modern technology allows realtime multiple digital feedback algorithms with effective IIR filters and automatic safety limits, or in the most extreme case, at least iterative optimization (prototype only).

Visual
Due to the crucial productive uses of highly accurate visual precepts, and to a lesser extent the overwhelming priority given to visual inputs (ie. inertial cues) by humans, a more conventional 'VR headset' may be appropriate in the short term.

Notably, very simple single-line Codecs (ie. DisplayPort DSC) are widely demonstrated not to have discernable artifacts, and screen 'burn in' problems do not apply either, as the images are normally never static.

Existing headsets are probably adequate for most users, while well-informed full time users have the means to modify these existing headsets with custom 16k panels, custom aspheric lenses, auto-retightening/loosening straps, cooling/heating/humidity, and microfluidic foam cleaning. Fabrication of both those technologies are within the precision of commodity stepper motors as used by 3D printers and subsequent polish staging.

Hard > Frame > Packet+infinityBits > Backhaul > Codec > ActiveMatrix > LCD/OLED/LED > Lens > Wet-Retina

In practice, the lens may be skipped if an intraocular implant is used. That, however, would likely require fast refresh rate (ie. 1kHz) as well as equally fast and single-pixel precise EOG tracking. Refresh rate requirements are far higher than for foveated rendering, due to high sensitivity to apparent motion.

neuralBits
Tentative hierarchical design redistribute amplifier, ADC/DAC, and addressing, across any geometry that may be convenient to a particular fabrication iteration, which is subject to rapid prototyping.

(Brain, OpticNerve)
Hard > Frame > Packet+infinityBits > Backhaul > [Codec > 12bits+infinityBits > Counter > DAC-LF > ^Bitmask > Counter > ActiveMatrix > MeshElectrode] > Thread > [Trace > MeshElectrode] + [Codec > 12bits+infinityBits > Counter > DAC-LF > ^Bitmask

> Counter > ActiveMatrix > MeshElectrode] > Wet-Needle
Hard < Frame < Packet+infinityBits < Backhaul < [Codec < 12bits+infinityBits < Counter < ADC-LF < ^Bitmask < Counter < ActiveMatrix < MeshElectrode] < Thread < [Trace < MeshElectrode] + [Codec < 12bits+infinityBits < Counter < ADC-LF < ^Bitmask < Counter < ActiveMatrix < MeshElectrode] < Wet-Needle

Discard ' ^Bitmask > Counter > ActiveMatrix ' for any DAC-LF/ADC-LF which is directly connected in any way to a single (or differential pair) 'MeshElectrode' instead of a set . Active matrix only serves to select electrodes connected to a single DAC/ADC, from a small set of otherwise unconnected electrodes.

(ECoG)
Hard > Backhaul > DAC-LF > Wet-Surface
Hard < Backhaul < ADC-LF < Wet-Surface

(Nerve, EOG, EMG)
Hard > Backhaul > 12bits+infinityBits > Thread > Counter > DAC-LF > [Wet-Needle , Wet-Surface]
Hard < Backhaul < 12bits+infinityBits < Thread < Counter < ADC-LF < [Wet-Needle , Wet-Surface]

-Pinout-

ATTENTION: WARNING: 'Hard' pinout, possibly with additional data lines for specific devices if necessary, is sufficient. Other pinouts dubious.

--Hard--
+0.6V , +0.7V , +0.8V , +0.9V , +1.0V , +1.5V , +2.5V , +3.3V , +5V / +24V
-0.6V , -0.7V , -0.8V , -0.9V , -1.0V , -1.5V , -2.5V , -3.3V , -5V / -24V
pGND

Vcc/pGND
Vcc/pGND (DAC-LF only)
Avcc/sGND (ADC-LF only)

PWMdirect- , PWMalternate+
midpoint

Amplifier Reference Ground (drives output close enough to midpoint for further offset adjustment by dual-gate FET input)

40 Data LVDS Transmission Lines (SerDes)

1 Clock Low Power
1 Data Low Power (low speed frames for embedded microcontroller access to neurons)

Clock Codec

Clock ADC-LF (ie. 7kHz)
Clock DAC-LF (ie. 7kHz)

Clock Config-ActiveMatrix
Clock Config-Codec

Clock 1GHz
Clock 500MHz
Clock 250MHz
Clock 200MHz
Clock 150MHz
Clock 100MHz
Clock 50MHz
Clock 25MHz
Clock 1MHz
Clock 1kHz

Clock 48MHz
Clock 16MHz
Clock 8MHz
Clock 32.768kHz

Normally, PWMdirect-/PWMalternate+ should track their midpoint around 'Amplifier Reference Ground' voltage, to prevent small DAC outputs from improperly biasing ADC inputs. However, midpoint and 'Amplifier Reference Ground' should never be a single wire due to severe noise. Consider that all DAC and ADC values may be regarded differentially in software.

PWMdirect/PWMalternate are intended for wide area stimulation/inhibition/block , in which case it is expected same signal may be directly applied to large areas, or DAC-LF output range may need to be adjusted across large areas (ie. safety limiting).

Reset lines are not externally accessible, being controlled perhaps by unique sequences in frame/packet, or at the start of frame/packet.

Some clocks may or may not be effectively identical (eg. Clock Low Power, Clock Config-ActiveMatrix, Clock Config-Codec), however, these pins must be separately available to be configured as such externally, rather than internally.

Ribbon PCB is expected as cabling, with WTB and/or mezzannine . Either should have thoroughly redundant mezzannine breakaway segment, with shear points of decreasing durability between some of those redundant connectors.

--Backhaul---

Foldable 'zig-zag' flexible mesh PCB is expected. Threads split from bundles of perhaps 50 for a maximum total of perhaps 2000 connections . Physically, multiple logical 'bundles' may be attached through a single ribbon cable, which is physically split to bundles, to threads, with the 'threads' being a finer mesh anchored by breakaways to the 'backhaul' mesh, which may have a foldable ribbon segment leading to hard chips.

Breakable strands may be used to keep mesh thread insertion points held taunt at desired places between backhaul mesh, allowing rapid, simple, dragging and pushing of the mesh fiber down at the intended location.

As an alternative to prefabricated mesh threads between backhaul mesh, bundles may be attached later by soldering. Severable 'tap' points should be included along both backhaul and thread mesh as a provision for future repair work.

If solder, metal contacts at the end of a joining thread/bundle are to be push fit into wells of already hardened low-temperature solder (>45degC or >60degC preferred), which is to be melted under this force by fiber optics. Candidates for such solder may include elemental Potassium, Field's metal, Wood's metal (Cerrobend), Bi52, Newton's metal, Rose's metal, and dental amalgam .

In any case, two large traces to the outside of the thread/bundle/backhaul connections will provide strain relief, while zig-zagging of the smaller traces leading up to the joint may ensure adequate metal elasticity. Addressable digital lines, being fewer in number and responsible for far more electrodes, must be given exceedingly high priority in this regard.

Backhaul's ActiveMatrix is of course in addition to any Thread's ActiveMatrix (which could add perhaps another 25 electrodes perhaps to reach deeper sparse neurons) .

Rigid PCBs are not to be used anywhere in the design. Reinforcement or casing to be added only as strictly necessary.

---dedicated---

Per thread, bundled. Only consider implementing these if bandwidth (ie clock speed), wire reliability, or prototype versatility, concerns, necessitate. Otherwise, each bundle should only exchange binary data across bus shared by all threads at full speed.

50bundle * 10thread
 Data Analog Electrode Lines (up to 10 analog electrode traces per thread to Backhaul's ActiveMatrix)

50bundle * 4thread
 Data Single-Ended Logic Lines (IN_data , OUT_data , IN_forward , OUT_forward)
   Format 'bits+infinityBits' , to/from Codec , which is connected to/from ADC-LF/DAC-LF, which are connected to ActiveMatrix .

50bundle * 1thread
 Config ActiveMatrix
  Format 'bits+infinityBits' . Low bandwidth. Idle when no new config.

50bundle * 1thread
 Config Codec
  Format 'bits+infinityBits' . Low bandwidth. Idle when no new config.

---shared---

Connected to all threads in each bundle, series or parallel. Thin traces may be used as fuse where appropriate.

?thread
 Vcc/pGND
 Vcc/pGND (DAC-LF only)
 Avcc/sGND (ADC-LF only)
 PWMdirect- , PWMalternate+ (DAC-LF minimum/maximum voltage)
 midpoint
 Amplifier Reference Ground (drives output close enough to midpoint for further offset adjustment by dual-gate FET input)

?thread
 Clock Data
 Data Single-Ended Logic Lines (IN_data , OUT_data , IN_forward , OUT_forward)
  Format 'bits+infinityBits' , to/from Codec , which is connected to ADC-LF/DAC-LF/ActiveMatrix .
 Clock Codec
 Clock ADC-LF

 Clock DAC-LF

4thread
 Clock Config-ActiveMatrix
 Config ActiveMatrix
  Format 'bits+infinityBits' . Low bandwidth. Idle when no new config.
 Clock Config-Codec
 Config Codec
  Format 'bits+infinityBits' . Low bandwidth. Idle when no new config.

2thread
 Reset Single-Ended Logic Lines (IN_data , OUT_data , IN_forward , OUT_forward)
  New string of bits to be sent representing ADC-LF/DAC-LF values to be passed through 'Codec' .
 Reset Config (Codec,ActiveMatrix)
  (all must be configured simultaneously, uncompressed/sparse by default)

---Bandwidth---

(12*7000)*(50*30) ~= 126Mbits/bundle

-Frame-
Multiple packets are combined into frames. A 'magic number' (eg. a specific MAC destination/source bit sequence) may flag that some range of subsequent bits contains valid packets to be routed. Frames are transferred at very high bandwidth and may follow a defacto standard (eg. Ethernet, CSI/DSI, existing LVDS) or no standard (eg. USB3 FPGA GPIO) .

Multiple slow digital inputs may be fed to a buffer to be periodically read off at higher speed (ie. serializer/deserializer). External portions of this circuitry may reasonably be built with discrete parts. Internal portions may still be implemented with small discrete parts or dedicated chips, as these are at the hardware end of backhaul, not integrated closer to electrodes.

-Packet-

Address space must not be less than 24bit . Prefer 48bit .

Address space to address threads is probably infeasible if less than 10^5 (100k neurons) divided by not more than 12 (12x transmission lines) divided by not more than 16 (minimum expected electrodes per thread). Threads may be addressed by 10bits, 12bits, or 16bits. However, this is strongly discouraged.

As an extremely minimalistic example, a 12bit address space with 12x transmission lines, would support 49152 channels, with perhaps half of these allocated to 150^2 ActiveMatrix, resulting in ~20k dedicated electrodes and 10:1 contention for 200k electrodes, which may be inadequate for any MEA CNS BMI. The contended electrodes would theoretically provide only a ~35x35 (sqrt(20000) / 4) sensorimotor 'image' - which is may be drastically below native human perceptions - and only then if precise strong precepts could be exactly correlated/stimulated by each electrode (unlikely). Additionally, a 10:1 contention ratio is already very high. However, these estimates may rely on incomplete and less than robust estimates of adequate spatial resolution.

-Codec-

Studies suggest unsorted spike detection is adequate.

Codec should be RAM programmable to some degree (deactivation at minimum), possibly reprogrammed by thread addressable wire, possibly activated by unusually low clock speed.

Must support at least -

*) Two band IIR. High pass amplitude and low pass raw. May reduce high pass samples per second to 300 instead of 7000. May reduce low pass samples per second to 30 instead of 7000. May reduce bits to less than 12, perhaps 8 .

*) Spike count. Three 'tap'/sample FIR cross-correlation match, accumulated per output cycle, in addition to low pass raw. May reduce spike count samples per second to 300. May reduce bits to 4 (2^4 == 16 ~= 7000/3/300 == 8) or 2 (2^2 == 4) .

*) Spike time. Only records first spike, counts number of samples. May interleave with other data. At 300 output samples per second, from 7000 input samples per second, 5 bits (32 times > 7000/300) would be adequate .

*) Spike list. At 300 output samples per second, from 7000 input samples per second, 5 bits (32 times > 7000/300) would be adequate . Aggregated across 30 electrode sites, assuming only two spikes across those sites in a 1/300Hz interval, bandwidth could be reduced approximately 15x, perhaps conservatively 10x , perhaps a total of ~230x compression.
 *) Much more substantial is the benefit at much higher sampling rates, assuming same rate of recorded spkiles. At a 100kHz bandwidth, a ~3000x compression ratio may be obtained, and may be crucially important for detecting miniscule and strongly low-pass filtered timing differences.
  *) Processing power is likely to be prohibitive. Many taps along an FIR cross correlation filter would likely be required to lower jitter sufficiently to allow even multiple neural events to be sufficiently correlated down to such small timing bins.
   *) A small number of such high-fidelity electrode sites may be sufficient for their deep topographic mapping purpose.

*) MAJOR MAJOR MAJOR - Such sparse high-fidelity circuitry may be allowed far looser tolerance substrate/photolithography/overlay tolerances. Consider overlaying two separate 'nerual bits' circuitry systems, all the way to dedicated electrode wires (which themselves may split across multiple 'threads' in difference to the usual approach), with the higher resolution circuitry having been covered (excepting electrode sites) with a suitable insulating crude substrate.

MAJOR MAJOR MAJOR - FUNDAMENTAL - At least some electrodes must have FULL TEMPORAL AND PROCESSING-SENSITIVE SPATIAL RESOLUTION. Otherwise, there will be no way to distinguish which topographic map received less processed (more direct) information. It is possible, though perhaps unlikely, that FULL SPATIAL RESOLUTION may be required for this specific analysis (meaning spatial oversampling and spike sorting is not necessary for conventional studies of data presented to the neocortex or stimulation/recording mapping but may be required for passive observation of the underlying topographic maps not directly sampled).

Binary adder may be faster, counter/bitstream may be simpler. Both types of digital filtering should be designed.

MAJOR MAJOR MAJOR - FUNDAMENTAL - Full FIR cross-correlation in codec may be entirely feasible, with ADC at >20kHz, given that the relevant digital electronics tend to be relatively compact and high speed. Although IIR filters and such are quite efficient, Neuralink demo video appparently published by CNET Aug 28 suggests this is actually done on chip in 900ns to the point of spike 'shape' detection.

-Bandwidth-

MAJOR MAJOR MAJOR - WARNING: - Spike time may increase these estimates significantly.

(1Ã—10^6Ã—4Ã—300)Ã—2 == 2.4Gbits (1M neurons bidirectional - spike compressed)

(1Ã—10^6Ã—8Ã—300)x2 == 4.8Gbits (1M neurons bidirectional - IIR compressed)

(1Ã—10^5Ã—8Ã—300)Ã—2 == 0.48Gbits (100k neurons bidirectional - compressed)

(1Ã—10^5Ã—12Ã—7000)Ã—2 == 16.8Gbits (100k neurons bidirectional)

(3840Ã—2160)Ã—32Ã—75Ã—2 == 39.8Gbits (2x4k VR Headset Raw Bandwidth)

-Amplifier-
Due to space constraints, it is likely imperative that only a single FET serve as the high-impedance low-noise input, even if a differential 'long tailed pair' must be used. Also, instrumentation amplifers are NOT to be used, instead relying on the inherent shielding of the 'wet' surroundings to prevent excessive sensitivity to 'outside' electrical fields (ie. 50Hz/60Hz ELF) by the small microelectrodes.

Amplifier is implied at every ADC input. Amplifier noise floor of ' (3Hz - 10KHz)5.9Î¼VRMS ' (Neuralink AnalogPixel Specification) seems fairly typical and is only slightly higher than the thermal noise floor at ' 38degC,100kOhm ' input .

Reference (ie. ground) voltage bias should ensure amplifier *output* is at midpoint. If multiple ground reference electrodes are used at different voltages, possible interference and electrochemical current balance between them must be considered. 'Common source' FET amplifiers with non-isolated power supplies may be a problem in this regard. Each thread must be able to access a reference voltage bias wire as this may be useful to generate exceptionally small gate offset voltages to accommodate CMOS tolerances between separate devices (ie. threads).

Amplifier bias voltage (ie. 'ground') must not be equal to either power supply rail (ie. not 0V) , to allow DAC stimulation to be repurposed for reversing any electrochemical charge imbalance caused by any possible bias current.

Whenever practical, amplifier shall include a low-resolution low-voltage DAC connected to a second gate (ie. a smaller gate on a dual-gate FET) or otherwise able to add low-frequency DC 'feedback' to improve ADC dynamic range (particularly if electrochemical effects are excessive). May also be usable as a software controlled gate offset voltage to accommodate CMOS tolerances between separate devices (ie. threads).

Low pass filtering of bias currents introducing significant high-frequency noise may be a design risk. This must be evaluated by simulation models, experiment, and possibly precautions. As a precautionary measure, if a single dedicated 'ground' electrode is required, this is at the top of threads, closest to the surface, where the highest resolution recordings are most likely necessary.

Amplifier bias current may present a risk of undesirable stimulation above 2pA. However, this is highly speculative, and even if numerically correct, ignores the possibility of some neural damage being tolerable.

-DAC-
Resolution must be much better than 100nA@10kOhm/50kHz equivalent pulse total charge (ie. a 12bit/300Hz ADC must have a maximum voltage of +/- 0.024576V (ie. << 1mV max)) (ie. a 1bit/300Hz ADC must have a maximum voltage of << 6uV) . However, this is highly speculative, and even if numerically correct, ignores the possible desirability of some neuron loss being tolerable to reach a wider area. Consequently, DAC-LF range should be adjustable, at least for early prototypes connected to simple microelectrode arrays for early testing.

3.3V/2^12bits/10000ohm*(50000Hz/300Hz) == 13uA@10kOhm/50kHz equivalent
(100Ã—10^â^’9)Ã—10000Ã—2^12/(50000/300) == 0.024576V
0.024576/2^12/10000Ã—(50000/300) == 0.0000001A == 100nA

Must be capable of bipolar DC output, using a split DC power supply (consider that inverters can usually split voltage), to allow reversal of electrochemical effects (ie. charge balancing). This is not taken from analog amplifier 'midpoint' reference, as that must be low-noise and may be biased to ensure midpoint amplifier output, rather than actually being at midpoint.

Must be able to briefly divert suitably attenuated output to ADC (not amplifier) input during conversion cycle, so as to be repurposed as a successive approximation ADC. Unless DAC is delta-sigma, in which case this is not feasible and the ADC is also assumed to have similar capabilities. ADC alone being of delta sigma type does not excuse lack of the divert from DAC capability, as the footprint is expected miniscule, for at least the design benefit of being able to swap another type of ADC later.

DAC output resistance must be at least 10kOhm . Any lower impedance must be limited to a small number of electrodes, especially in any single region, for SAFETY.

-Electrode-
Electrochemical dissolution is a major concern. Coating thicknesses should be at least several micrometers. Durability should be tested thoroughly by connecting to potentially damaging amounts of current in a suitably conductive fluid, device lifespan should be calculated from this and expected bias/stimulation/stray currents.

-UltraIsoPSU-
If isolated power supplies are required for some reason (perhaps one per thread), regardless of other amplifier/addressing considerations, a piezoelectric transformer should be used. As part of backhaul, a many-layer piezoelectric ultrasonic transducer should provide a power source, with isolated power supplies implemented as ~100um diameter devices near thread inputs. Footprint for such a device is expected 10mm*10mm (sqrt(10000) * 0.1mm) . As such, the secondary receiver crystal could be embedded in the thread, or in a layer stacked on top of other circuitry, or included inside chip.

Frequency must be settable, both well outside, and well inside, the useful frequency for powering neural dust.

-FakeNeuron-
A fake neuron circuit will be available.

*) Spikes (2.5ms, 10uV, 15Hz)
*) Spikes (2.5ms, 10uV, 250Hz)
*) Spikes (0.125ms, 10uV, 4kHz)
*) Common Mode Noise (millivolts).

*) Local Field Potential (1mV, 5Hz, sawtooth wave)
*) Local Field Potential (1mV, 10Hz, square wave)

*) Common Mode Rails (1mV, <1Hz)

*) Bias current pass/fail check.

-Modeling-

*) All worst-case expected parasitic effects (ie. power wire resistance/inductance/capacitance) should be modeled in simulation by discrete components.

*) A physical prototype with few channels may be built by discrete components.

NeuralDust
Published study 'Neural Dust: An Ultrasonic, Low Power Solution for Chronic Brain-Machine Interfaces' suggests scalability to ~20um, largely based on required CMOS amplifier dimensions to achieve usable thermal noise and power consumption, as well as modulated load backscattered power.

Addressing/Localizing large numbers of such devices would seem to require additional circuitry, and possibly additional bandwidth requirements.

An obvious advantage is the probable relative lack of chronic sensing issues, due to the free-floating mechanical characteristics.

Hard > Carrier-FM > Ultrasound > Resonator > Rectifier > Code > DAC-LF > Wet-Dust
        Hard > Carrier-FM > Ultrasound > Resonator > Rectifier > Power
Hard < FFT < ADC-RF < Ultrasound < Resonator < Load < ADC-LF < Wet-Dust

Hard > Carrier-FM > Ultrasound > Resonator > Load < (Resonant Frequency or Amplitude Modulating)
Hard < FFT < ADC-RF < Ultrasound < Load < (Resonant Frequency or Amplitude Modulating)

Neuralink ASIC
As described by 'An Integrated Brain-Machine Interface Platform With Thousands of Channels' .

Notalble performance characteristics include scalability to at least 3072 channels total.

Apparently a notable disadvantage of this system as described may be the rather large footprint per pixel - perhaps approximately - (sqrt(23000Ã—18500)/sqrt(3072) == 372um) * 2000um . Another notable disadvantage may be power dissipation of ~1W/4000channels , though this reported figure of 0.25uw/channel is five times the reported 5.2uW/AnalogPixel, and may be stimulation power of less thermal consequence.

Hard > Backhaul (ASIC) > DAC-LF (AnalogPixel/ASIC) > Wet-Needle
Hard < Backhaul (ASIC) < ADC-LF (AnalogPixel/ASIC) < Wet-Needle

ThreadMicroelectrode
Addressable electrodes using binary counter circuitry similar to what is expected to be found with modern 'addressable LED pixels'. In practice, amplifier circuitry is expected to occupy a larger CMOS footprint. Mesh construction should allow adequate surface area. Alternatively, amplifier footprints may force some devices to be located at electrodes, while others are sent as analog nearer or up to the backhaul point.

Hard > Backhaul > 12bits+infinityBits > Thread > Counter > DAC-LF > Wet-Needle
Hard > Backhaul > 12bits+infinityBits > Thread > Counter > infinityBits > (addresses of more Counter)
Hard < Backhaul < 12bits+infinityBits < Thread < Counter < ADC-LF < Wet-Needle
Hard < Backhaul < 12bits+infinityBits < Thread < Counter < infinityBits < (addresses of more Counter)

ActiveMatrix
Selectively applies amplifier/ADC/DAC to many more analog wires, in addition to the remaining electrodes having been converted digitally continiously (see: ThreadMicroelectrode). Intended to conserve limited total space for circuitry and minimize probe diameter. Particularly intended for research or early-adopter devices, for which the number and location of desired neurons may not be known.

Active matrix is essentially used as a simple and compact 'multiplexer'. Active matrix and associated amplifier/ADC/DAC circuitry expected to be included in backhaul. Mesh construction may negate the concern over total space for circuitry and probe diameter.

Each ActiveMatrix connects one ADC/DAC to one of a specific set of electrodes - mapping of ADC/DAC to electrode is not arbitrary, and this effectively guarantees many electrodes in a single location will not be used.

Beware the ActiveMatrix itself requires addressing by something like a binary counter .

Hard > Backhaul > 12bits+infinityBits > Counter > DAC-LF > Bitmask > Counter > ActiveMatrix > Thread > Thread > Counter > DAC-LF > Wet-Needle
Hard > Backhaul > 12bits+infinityBits > Thread > Counter > infinityBits > (addresses of more Counter)
Hard < Backhaul < 12bits+infinityBits < Counter < ADC-LF < Bitmask < Counter < ActiveMatrix < Thread < Counter < ADC-LF < Wet-Needle
Hard < Backhaul < 12bits+infinityBits < Thread < Counter < infinityBits < (addresses of more Counter)

ThreadActiveMatrix
Pushes the 'ActiveMatrix' onto the thread itself, so that only some electrodes on the thread are available simultaneously. Likely an advantage if electrodes at some depths are found not useful.

In practice, it is probably best to use a combination of 'ThreadMicroelectrode' , 'ActiveMatrix' , and 'ThreadActiveMatrix' .

Hard > Backhaul > 12bits+infinityBits > Thread > Counter > DAC-LF > Bitmask > Counter > ActiveMatrix > Wet-Needle
Hard > Backhaul > 12bits+infinityBits > Thread > Counter > infinityBits > (addresses of more Counter)
Hard < Backhaul < 12bits+infinityBits < Thread < Counter < ADC-LF < Bitmask < Counter < ActiveMatrix < Wet-Needle
Hard < Backhaul < 12bits+infinityBits < Thread < Counter < infinityBits < (addresses of more Counter)

ECoG
A far higher than usual resolution ECoG interface, or at least more convenient than EEG, in the hopes that clearer Local Field Potentials, or potential to stimulate/inhibit, will yield results which may supplement a more precise interface. Possible use cases include observing the spread of information from such a location as the occipital lobe, or improvement of sleep quality by automatic room climate control.

Hard > Backhaul > DAC-LF > Wet-Surface
Hard < Backhaul < ADC-LF < Wet-Surface

HybridOptical
Combines electrical or optical wavelength addressing of threads on backhaul with Optical Coherence Tomography scanning of points along a thread with voltage sensing dye or liquid crystal as the sensor. A single point is 'chopped' between bright/dark/amgient return signals by vibrating the Optical Coherence Tomography reference. Thread/Mesh is all-fiber-optical, with

VoltageSensitiveDye/LiquidCrystal/Photovoltaic being plated at beam-split endpoints of the fiber optics.

Speculative, of doubtful utility. Voltage Sensitive Dye or Liquid Crystal (used in place of an amplifier/ADC) may not be adequately sensitive when embedded in a device not in direct membrane contact, and may necessitate such other resources as an additional microfluidic channel. Optical fiber is expected to be difficult to weave into mechanically tolerable mesh. Nevertheless, such obstacles are likely technically possible to overcome at scale.

Extremely small optical fibers (sub-wavelength diameter) may be adequate for ~30-points. Backward pointing spines may be attached by beam splitter, so long as these are of exactly equal length. Differing lengths will prevent separation by optical coherence tomography. Output by Photovoltaic+Code requires that optical connection to electrode/amplifier/etc not be made unless a counter detects the correct pattern (or other similar signal) produced by Optical Coherence Tomography vibration.

Thinner and longer threads may be made possible by the inherent use of a single transmission line (ie. optical fiber).

Hard > [1bits+infinityBits]/[DichroicMirror] (address of thread on backhaul) > ~405nm Temperature Tuned Laser > Backhaul > Optical Coherence Tomography (address of point) > Photovoltaic+Code > Counter > DAC-LF > Wet-Needle
Hard < Spectrometer (Fluorescence/Polarization Analysis) < Backhaul < Optical Coherence Tomography (address of point) < [VoltageSensitiveDye]/[LiquidCrystal] < Wet-Needle

ReadOptical
Fully fiber optic transmission. Read-only. Relies on optical receiver being able to distinguish many transmitters by perhaps multiple high-performance techinques.

Speculative, of doubtful utility. Amplifier CMOS footprint may only be mitigated by mesh construction. 'ThreadMicroelectrode' has similar potential to stack large numbers of addressable electrodes on a single thread. Nevertheless, fully fiber optic transmission may have subtle advantages in power density, bandwidth, analog sensitivity, and transmission line diameter.

Hard < OpticalFibers < Backhaul < PassiveSplitter < Thread < WavelengthSpecificLED < RFMixer < Counter < ADC < Amplifier < Wet-Needle
	Hard > OpticalFibers > Backhaul > Photovoltaic > Power > TDM Clock/Reset
	Hard > OpticalFibers > Backhaul > Photovoltaic > Power

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Amplifier input FET dimensions? Possible at backhaul?

Addressing of wireless systems which must retransmit continiously due to inability to store power? IS FDMA/CDMA the only option?

FDMA - Intermediate Frequency (IF) Filter
	Only one component of a superheterodyne radio requires bulky passive components - the IF filter.
	Lack of ICs with precise oscillators not requiring external crystal or relatively large embedded crystal suggests this is infeasible.

FDMA - Ring Oscillator / Phased Locked Loop
	Phase Comparator (ie. Mixer) may be near equally likely to lock onto frequency multiples... this may necessitate prohibitive analog (or fast ADC/IIR/FFT) passband filtering.
		'FDMA requires high-performing filters in the radio hardware, in contrast to TDMA and CDMA.' - https://en.wikipedia.org/wiki/Frequency-division_multiple_access
	Noise will not be strongly rejected from other-channel frequencies also using frequency/phase modulation, resulting in some jitter without prohibitive analog (or fast ADC/IIR/FFT) passband filtering. This negates the otherwise perhaps high-resolution ADC from the frequency/voltage conversion.
	Inherent ADC/DAC of frequency/voltage conversion and binary digital counter conversion makes this otherwise attractive.
		Partiuclarly, the possibility of using the high-resolution DAC output as a real-time offset to the ADC would eliminate the need for local low-pass filtering.

AddressableWrite (absorbs 8bit data, outputs all subsequent data, resets to absorb another 24bits after idle)
AddressableRead (waits for idle, emits 8bit data, outputs all subsequent data, resets to absorb another 24bits after idle)
	ADC

Ramp ADC
	Comparator
		(<10x transistors)
	Binary Counter (Counts Clock Cycles, Latches on Compartor Output)
	Memory Buffer (optional, allows data read/write
	1 Clock Wire

1 Reset Wire (Unlatches Counter)
1 Ramp Wire (shared globally, possibly protected from local shorts by amplifiers/resistors)

AGCamplifier

HighPass Filter (200Hz)
Capacitor
OpAmp

BandPass (200-7000Hz)

DAC-R2R 5bit (32value, adds 4bits effective dynamic range if used as Low-Pass-Feedback to amplifier)
(>10 resistors)
Counter

Voltage-Frequency-Converter
Oscillator may be Ring/Inverter, OpAmp, or Single Transistor
Comparator
Capacitor, either to be loaded by input, or to generate internal triangle wave for ramp comparison.
(Probably not the best choice.)
Ring/Inverter
Modulate by Varactor Diode OR Transistor Supply Current Gating OR Transistor Supply Voltage Gating
(6 transistors , 3 resistors , 3 capacitors if not parasitic , 1 varactor OR 1 transistor)
Relaxaction Oscillator
Modulate by Varactor Diode
(speculative)

Flying Capacitor Filter, Flying Capacitor ADC, Flying Capacitor Instrumentation Amplifier, Low Pass OpAmp / Integrator
(Prohibitive due to large capacitance.)

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*) MAJOR - Combine neural bits analog pixels with optical inputs/outputs/fibers, including 1bit addressable LEDs, wire for LED bias current (optical gain control), etc.

*) MAJOR - Active matrix addressing of bundle digital interfaces (and associated bundle ADCs) may greatly reduce gate counts in backhaul, possibly improving both photolithography yield and throughput (especially for scanning probe or nanoimprint lithography).

*) MAJOR - Disconnectable trestles - having individual pinouts to SerDes .

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*) MAJOR MAJOR - Neuralink 'mind pong' was done April 2 2021 , as per analysis of video footage .
*) https://youtu.be/rzNOuJIzk2E?t=979
*) Neuralink is using ZeroMQ port (presumably UDP) . Reasonably compatible.

*) MAJOR MAJOR - QUESTION - NEURALINK - Has neuralink accessed spinal and PNS axons, or only neocortical CNS neuron cell bodies (ie. soma)?

*) MAJOR MAJOR - QUESTION - NEURALINK - Is sub-um thread suggested addressable simultaneously, or are full simuntaenous analog wire outputs with decent impedance deemed feasible at that scale?

*) Sensory stimulation could scan pulses across a large active matrix (ie. circuitry is negligible).

*) Optical stimulation without optogenetic techniques apparently may use thermal changes of ~5degK/10.5mW for near-fiber diameter

aperture. - https://www.nature.com/articles/s41378-020-0153-3

*) Theoretically, iccasional stimulation-only electrode sites only used to add/remove RPT correlations (ie. to write synapses) may be much smaller than otherwise acceptable. Due to very infrequent use, electrode material damage, minor collateral damage, high voltage, and active-matrix only (no other multiplexing), may be acceptable, if there is actually any plausible use for such a high density of electrode sites.

*) Carbon nanotube fusing or electromigration current density may be (10^3 MA/cm^2)/(10^5 A/cm^2)==10^4 that of copper... may be useful to reduce power dissipation, increase stimulation current, or increase amplifier power.

DISCLAIMER: Plausible concepts, attributed sources, oversimplifications, reasonably. Rigorous mere academia NOT primary.

mechDive

Mechanical actuators, versatile for all wetware harnessing purposes. Tunneling (direct neural interface), force feedback, hard exoskeleton, soft exoskeleton, tactile precepts (temperature, pressure, vibration, stretch), and compliance.

Many channels (>100) of continious controlled tension at low cost by water cooled eddy current brake (>10kgF), artificial muscle (<1mm compact).

Force multiplication if needed by a second stage of push/pull hydraulic amplifiers powered by hydrostatic transmission pumps, steam waste heat from eddy current brake, etc.

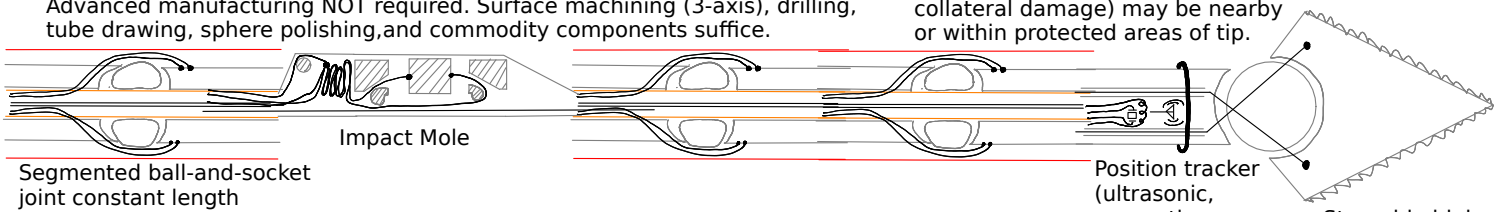
Tunneling

Nerve (peripherial, spinal, optic, cranial), NOT neocortex, interface placement.

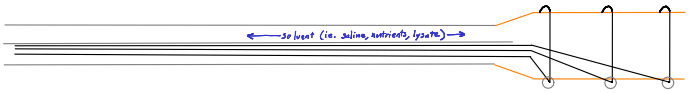
Directional Tunneling (2mm)

Advanced manufacturing NOT required. Surface machining (3-axis), drilling, tube drawing, sphere polishing,and commodity components suffice.

May be abrasive and sharp, or blunt. Optical sensors (ie. to minimize collateral damage) may be nearby or within protected areas of tip.



Triple Ring Squeeze Tube Pump (<<2mm tubing)

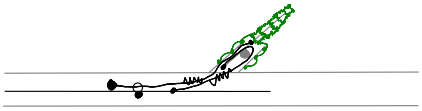


Uses three pull-strings around the perimeter of a tubing to allow entrance of material, confine material to a chamber, and squeeze the chamber after opening the other end. May pump fluid/suspension back, or open flow for solvent.

Biocompatible Lubricant

Polypropylene, fats, refined or synthetic oils, may be sufficiently biocompatible. If not, lubrication may be avoided for short distances near the ends of bowden tubes where leakage may occur.

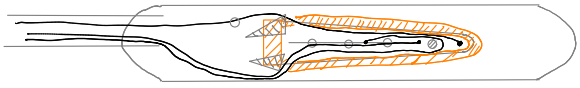
One-Pull Anchor (2mm)



Pull cables to deploy or withdraw needle. Mesh may remain after needle withdraw.

Pull with maximum force to disconnect breakaways, permanently freeing cable. Multiple anchors and other devices may share a single bowden cable. Avoid placing shared anchors in useful types of tissue, where sensors to minimize (ie. vascular) collateral damage may be necessary.

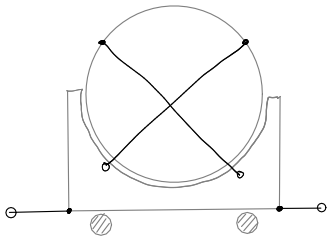
Needle Pusher (2mm)



Lifts soft-edge protective flap up to 90deg to create a working space, pulls needle down, then pulls needle back up. May be pulled along by directional impact mole. Twist bearing or wider plate may be required.

Force Feedback

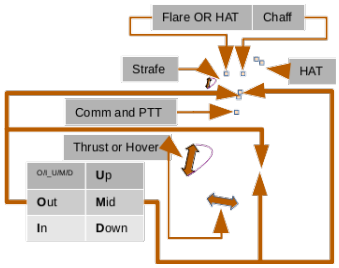
Muscle interface from iterative feedback loop converting position error to force.

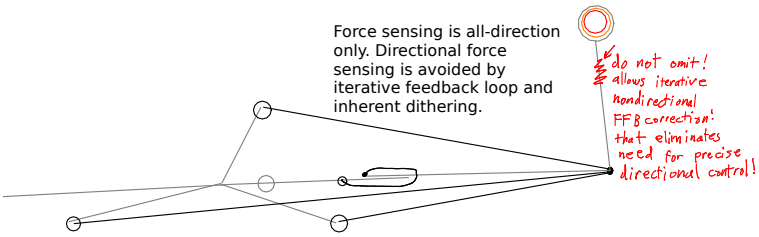


Two or more pairs of crossed cables (perhaps ideally one pair on each of four sides - eight cables total) are expected to provide adequate 3-axis iterative FFB control of a ball-and-socket joint.

Adding a single linear translation 'thrust/hover' axis under one such assembly fulfills all requirements of'extendedInterface' 'commonControlScheme' for single-stick tool and vehicle control, with force feedback notching near such dynamic conditions as cornering speed, formation keeping, optimum climb, spacecraft stabilization as well as hints of such dynamic limits as remaining time before severe turbulence causes structural failure from inelastic deformation. Stick center may be indicated by ~50Hz/60Hz vibration.

Optical center position markings (or other at least intermittently accurate position tracker) expected for stick/HOTAS control.

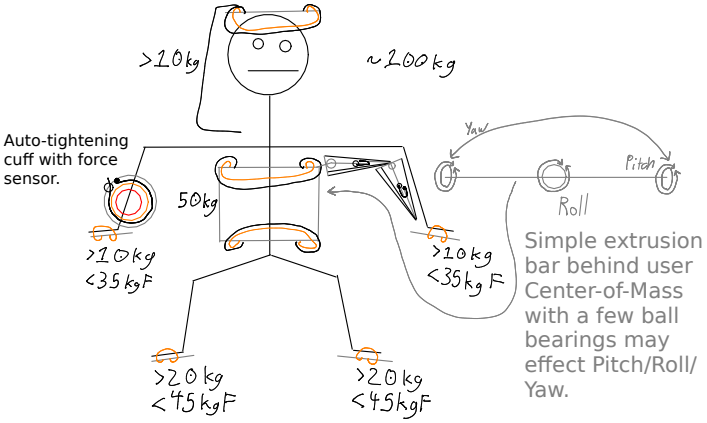




Bowden cables may extend beyond tubing spanning rigid structures as 'open construction'. Multiple layers of bowden cables, some only under small amounts of force particlularly for finer movements, may reduce vibration from backlash. Especially appropriate where large forces and ranges of motion may be necessary.

Exoskeleton

Muscle interface structure for VR from Force Feedback actuators.



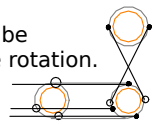
Hard exoskeletons may apply bowden cables (or similar force concentration devices capable of >10kgF) to rigid structures with suitable bearings.

Limbs are supported relative to Center-of-Mass body area. Three-axis plus extension is sufficient to apply force feedback and posture support to all limbs and head.
Force <10kgF is mostly adequate to maintain posture and inform user by force feedback.

Center-of-Mass body area is strapped to a cross bar capable of Pitch/Roll/Yaw.
Roll - large 'Lazy Susan' (aka. 'turntable') bearing.
Pitch - plain bearing between pipes or ball bearing.
Yaw - cylinder track.
All three axes of body rotation may also be provided by a single sphere driven by wheels with some friction or by a single rotatable wheel.

Soft exoskeletons are feasible, externally following internal musculature. Particularly useful as 'paw' (ie. hand/foot) joints.

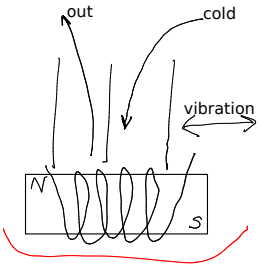
However, shoulder/hip joints may be problematic due to lack of surface rotation.



Exoskeleton users *must* have at least one safety gesture/word available out-of-band (eg. unique voice command, unique electromyographic activity pattern, glove swipe pattern, finger mounted button combination, etc). Applied tension must cease when safety stop is called, although software may continue processing positions without the force feedback if appropriate.

Tactile Precepts

Temperature, Pressure, Vibration, Stretch



Sensors
Temperature
Pressure
Electromyography
Electroconductivity
Pulse Oximetry

One solenoid, controlling a pocket of fluid, which may be liquid, gas, etc (ie. air).

Closed
Open Out (<25% in out direction) (Default)
Open Cold (<25% in cold direction)
Open Both (Optional)

Temperature
Heat - Power dissipation of resistance in coil and eddy resistance in magnet at RF. Closed.
Cold - Chilled fluid allowed to flow through. Open Both.

Pressure - Open Cold to pressurize. Open Out to depressurize. Add heat if needed.

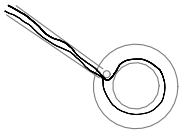
Vibration - Coil driven at three mechanoreceptor specific frequencies. Closed. Add cold if needed.

Implementations must place valve close to user for efficient vibration and resistance heating. Shared tubing from adjacent pockets must be at some distance from user to minimize cooling by 'cross talk' between separate channels.

Sensors may improve temperature and pressure accuracy as well as sense the user's temperature, pressure (eg. blood pressure), electromyography, electroconductivity, and blood flow/oxygenation, at each channel. Such distributed sensing may improve mechanical posture support, prevent pressure wounds, prevent frostbite, reduce control latency, and add additional controls.

Electromyographic sensors particularly can allow adequate intuitive control of additional limbs, such as dorsum (aka. 'back') mounted 'wings', or ear pointing of active sensors.

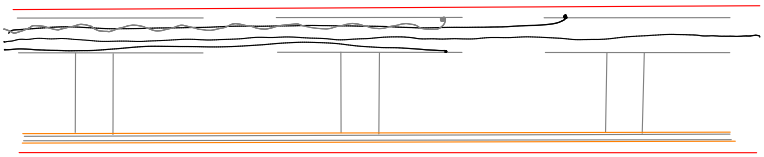
Practical designs may include short tubing and sensors in a valve module, with a cold air bus and exhaust to atmosphere on the opposite side of fluid pockets. Low cost MCUs (<$0.50) may be used as digital GPIO I/O expanders, valves being digitally controlled, analog sensors using the slowest and lowest resolution ADCs (ie. voltage-to-frequency converter, capacitor discharge, multiplexing, etc).



Stretch, although for a mechanical interface rarely if ever essential, may require a continious loop of bowden cable (or similar) to effect continious rotation pressure on a wheel. Expected slippage (especially if user moves physically) is enough to preclude relying onlimited range of motion (eg. an expanding pneumatic piston).

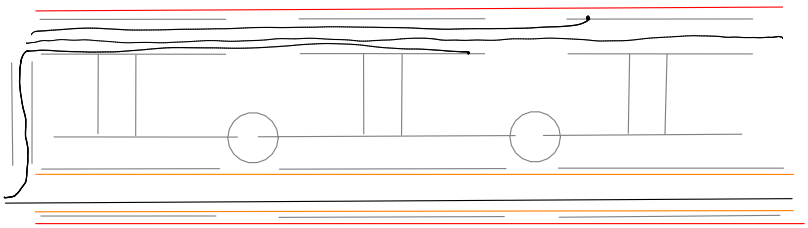
Compliance

Minimizing peak pressure with bendable surfaces and bendable cables.



Linear adjustable length cables anchored to a bendable constant length surface can reshape both surfaces. At least three segments required.

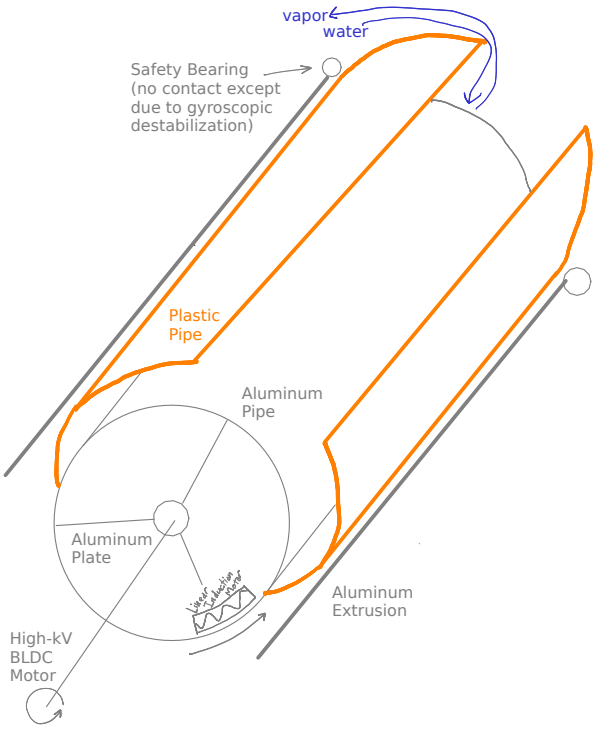
Muscular hydrostats are an extreme example.



Discrete rigid or flexural joints may improve length constancy, which may be useful if a bowden tube must be available for other devices.

Tension

Eddy Current Brake.
Many channels of strong (>10kgF) continious tension, cheap.



Rotating metal drum.
Extremely cheap and low-maintenance, mostly just a ~$200 metal pipe.

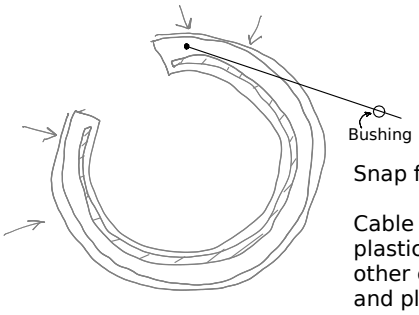
*) 1x ~6in diameter metal pipe
*) 1x >6in diameter plastic pipe
*) 2x identical aluminum plates
*) 2x identical aluminum plates
*) 3x aluminum extrusions or small pipes or small rods, etc
*) mountable bushings for bowden cables
*) either high-kV BLDC motor or Linear Induction Motor
*) cable pull plate for each channel

No brackets are required - recentering of cable pull plates along the drum is from their bowden cables. Metal pipe is aluminum or copper, but ferromagnetic materials and segmented superconductor coatings may work. Lower resistance may reduce rotation rates, increase force, and reduce power consumption due to reduced induced voltage drops from eddy currents. Copper pipe, coupling, or electroplating, may reduce power usage from aluminum by >2.5x. Plastic pipe chosen for negligible cost, material irrelevant.

Parts are all either cheap commodities (ie. plastic pipe, bushings, drum bearings) or flat plates for the most repetitive, lowest capital, lowest consumable, manufacturing (cable pull plates).

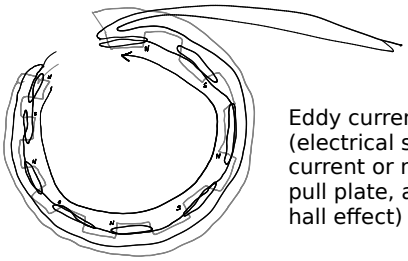
Heat dissipation is entirely at liquid or spray cooled metal drum.

A 1m length pipe with 100x 1cm cable pull plates is functionally equivalent to, but much cheaper, more compact, and much higher performance, than, 100x $20 DC motors.

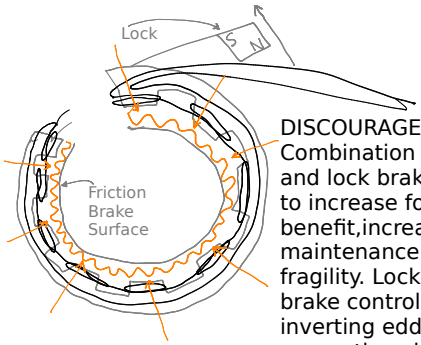


Snap fit cable pull plate.

Cable pull plate (of any kind) is a semicircle made to larger diameter than also semicircular plastic pipe. Such modules may be removed and replaced from slots without distrurbing any other cable pull plates stacked along pipe. Sheet metal may be added along cable pull plate and plastic pipe to reduce wear if necessary.



Eddy current brake - analog controlled tension - realized by adding laminated ferromagnetic (electrical steel if available) and wiring alternate magnetic polarity. When energized by DC current or not demagnetized, the eddy current brake exerts rotatry force to turn entire cable pull plate, applying tension to a bowden cable (or similar). Magnetic field strength sensor (ie. hall effect) strongly recommended to calibrate saturation and demagnetization.



DISCOURAGED
Combination eddy, friction, and lock brake integration to increase force. Doubtful benefit,increases maintenance, wear, and fragility. Lock and friction brake controlled by either inverting eddy brake magnetic polarity or AC induction force. Friction brake requires material similar to high quality vehicle brakes.

Artificial Muscle
Compact (<1mm) continious tension, cheap.

Artificial muscle bowden cable puller, inside bowden tube.

Large displacements, strong tension, fast response may be accumulated from entire length of bowden tube. Thin diameter (microns) and small number of actuators in expected applications (45 linear trestles), expensive materials (eg. multiwalled carbon nanotube assembles) may be used cheaply. Biological muscle is theoretically possible, however, other materials are much more efficient when response time is not the only performance criteria.

Resistance heating of 'fishing line' polymer/thread or shape memory alloy is suitable for large motions and strong tension. Piezoelectric elements may be uniquely suitable for nanopositioning (ie. step-stick).

Tension - Estimate - Eddy Current Brake - Peak kgF

$drum_RPM == Presume <30k to minimize requirements for drum strength and balance tolerance.

$drum_diameter == Presume <6in for convenient compactness, light weight, and low cost.

```
  'drum_RPM=30000'
  'drum_diameter_cm=15'
drum_speed_metersPerSecond=235.5

  'calibrationMagnet_mult=0.5'
  'calibrationMagnet_metersPerSecond=5'
  'calibrationMagnet_kgF=0.005'

  'magnet_mult=$(_clc "1 * $drum_distancePerRotation_cm * 0.6")'

  '_clc' '"($magnet_mult / $calibrationMagnet_mult) * ($calibrationMagnet_kgF / $calibrationMagnet_metersPerSecond) *
$drum_speed_metersPerSecond"'
# 13.31046
magnet_kgF (magnet kilograms force) .
```

Modeling, calibration, and optimization, of such an inexpensive device with such an intrinsic working principle, strongly favors experimentation instead of more extensive simulation and calculation. Estimates from experiments with permanent magnets opposing their own weight atop metal plates may be pessimistic.

errata

_ Terms _

'DC Brushed motor'
'geared'
'RC Car'
'1/10 scale'
'6000RPM'

'bowden cable housing'
'close wound'
'longer helix'

'hydrostatic transmission pump' (eBay)
'hydrostatic transmission'
'air compressor'
'diesel engine'
'hydraulic amplifier'
'pilot operated solenoid valve'

_ Rough _

*) CNC machinery may use eddy current brake, bowden cable, etc, both as extreme Y-axis drive mechanisms, or as precision multi-axis tools.

*) Pain simulation from tactile precepts - while pain may seem undesirable, when in small quantities and prompt, some necessary and essential conditioned response (de)entraining may occur. Particularly, loss of fear of heights is a common potentially dangerous side effect from VR visual input without any other sensations, while Post-Traumatic-Stress-Disorder may be treatable by VR visual input alone. Visual cliff research may be relevant.

*) Precise hand force feedback will require two sets of cables, some of which are never driven with substantial force. This is exactly equivalent to the use of both precise and strong muscle fiber types.

*) Eddy current drum motor may be right shoulder mount, being far more compact and better located for isolated use of precision hand controls.

*) Shear bolt, rupture discs, and similar 'mechanical fuses', may improve safety.

*) Power transistors driving exoskeleton must always fail to no output, with no power applied to cable puller, and appropriate flyback protection.

*) Spring and leadscrew cable pullers may substantially reduce energy consumption while holding roughly static force/position.

*) Merit figures for a successful VR exoskeleton are at least 3-day continious use, sleeping in machine every night, no interruptions, without causing substantial fatigue, pressure wounds, etc.
 *) Dexterity of finger force feedback and position must be sufficient to 'twirl a pen' simulated in VR space through the fingers (as a particularly extreme example).

*) Position feedback for VR exoskeleton should normally be exclusively from external trackers of user position in 3D space, maximizing redundancy at minimum cost. Tracking based on joints (as usual for CNC machines) for exoskeletons is fraught with severe issues - rigitidty, weight, cost, lack of redundancy, etc.

*) Eddy current brake drum uniquely shares a single mechanical power source (which may be hydraulic or turbine driven), adds a convenient flywheel, amounting to an extremely effective mechanical 'power take off' PTO . Air compressors may share the same mechanical power for cryogenic refrigerated computer cooling. Such features are particularly important to (ie. flight) simulator software constrained by single-thread CPU throughput.

*) Linear Induction Motors may use commodity ESC modules able to generate large quantities of 3-phase power.
   *) Burst current - 900A
   *) Multiple ESCs could be power balanced automatically by a simple MCU to ensure each ESC/motor/LIM contributes equally.
    *) Linear Induction Motors can be separate modules - power sharing is not necessary.

*) Liquid immersion (if used as mechanical supplement to exoskeleton) continiously, may degrade human skin. Bubblewrap padding, cloth, tubing to distribute dry gas, regular exhaust vents, may keep human skin in contact with a continious flow of dry gas.
 *) MAJOR - Tactile Precepts hardware may share the same air pockets and air flow hardware.
  *) Such an integrated arrangement may drastically improve exoskeleton power efficiency, improve exoskeleton comfort, add significant dynamic range from fluid resistance, and especially reduce cost.
  *) Layers (ie. tactile precepts bubblewrap) may be 'sewn' as patches into typical clothing (eg. shirts, denim jeans, etc) even

if liquid must be kept out, due to the continious flow of air available. Existence of such commodity components already in 'standard sizes' may significantly improve adaptability to the complex organic geometry of users, as well as improving cost effectiveness as usual.
 *) Loose ball bearing - mix of grease and steel balls used to reduce friction between PTFE liners of flexible materials used for organic interfacing.

*) CAVE Automatic Virtual Environment (aka. CAVE) using large displays, hand tracking, face/head tracking, etc, in addition to any VR headset, tactile precepts hardware, VR exoskeleton, etc, may be simultaneously connected to the same VR environment. Eating, grooming, relaxing (ie. sharing a meal), etc, can be exactly as otherwise normal while still immersed in the same shared VR multiplayer space, while temporarily not wearing obstructive (but otherwise much better resolution) VR headset or other hardware.
 *) Particularly this is helpful so long as VR headsets remain heavy or tightly strapped enough to cause any neck strain, face pressure, etc, which an exoskeleton with autotightening straps may not completely nullify. Also helpful between intervals of particularly high mental stress (ie. hardware design, VR CAD modeling, flight simulation training, etc).
 *) Fold down resources for phisiological inconveniences - keyboard/mouse/table, stowage containers for food, etc.
  *) Players might be able to order from restaurants in VR, and have delivery services bring the physical food directly to them, without leaving VR.

*) Exoskeleton users may have VR avatars illustrating the limitations of their interface. Places where force feedback and tactile precepts (eg. shirt) are available may be visualized as thick plates of semi-transparent armor (which of course do not necessarily confer in-app or game armor benefits). Analogously, avatars in some VR apps may already show users wearing 3D glasses or VR headsets when appropriate.

*) Training resistance multipliers. Exoskeleton software must include a modifier layer to increase resistance when more precision is desired or when some reflex training is desired (ie. similar to adding inertia training weights to a computer 'mouse').

*) Hybrid mechanical/neural interfaces may in some cases effect similar results with less intricate technology than more complete neural interfaces. Olfactory nerve stimulation in particular is already presumably accessible, and taste nerve stimulation has sufficiently limited requirements for extremely great success with very primitive minimally invasive microelectrode array (MEA) interfaces having few channels. Highly nutritional food could be presented as low-resolution assemblies of cubes, with apparent taste as users physically ate the food being virtually simulated by electrical input through the direct neural interface. Tactile input in this case is provided by physical shape of nutrition cubes, which range from hard to spongy, and assemble together into such shapes as sandwiches by velcro like linkages.
 *) Bypasses the usually prohibitively expensive issues of rigid precision, slow extrusion, multiple materials, and adhesion, from higher fidelity 3D printing of food.
 *) MAJOR - May be especially helpful to medical patients who, due to nauseating treatments, may find many otherwise necessary, tasty, and nutritious foods unpalatable. Significantly, public policy may also benefit from ability to present more nutritious foods as more palatable.
 *) In practice, it will be up to the players to creatively overcome the limitations of this approach, both making these things satisfying, and learning to eat them in a satisfying manner - possibly knowing to swallow promptly and quickly enough to match the (configurable) taste stimulation duration.
 *) A double tap gesture may associate the camera tracked food object with a user configurable taste and aroma (or simply activate the taste and aroma for a 4 second interval afer 2 seconds). Such reconfiguration may be especially helpful for 'energy bar' snacks - nutrition as less of a meal and more as something taken while busy doing something else.

*) Exaggerated apparent visual motion in VR may allow a much less expensive 'static' exoskeleton. Tables, chairs, etc, may be usable as-is. Such an exoskeleton would effectively work as a more intuitive, more comprehensive 'game controller', with only minimal range of motion and force feedback relative to a static posture.

*) Permanent magnets behind eddy current brakes can cheaply increase (possibly approximately double) total force when electromagnet is not opposing. Electromagnet on, same magnetic polarity as permanent magnet. Electromagnet off, opposite polarity. Suitable rare earth magnets may be quite thin to integrate with cable pull plates.

REVIEW - May be duplicative from (another) part of (another) document.

*) Although somewhat invasive, spinning wires (eg. of tungsten carbide) with suitable tips may be used as drill bit microneedles penetrating most of skull. A large array of these (ie. ~1mm spatial resolution) could be competitive with more completely invasive interfaces for VR purposes. Especially if reaching intra-dural.
 *) Diamond abrasive tips may avoid any requirement for drill bit shaping, minimizing cost.
 *) Collateral damage to pass-through tissue (ie. scalp) would be a non-issue if diameter was a relatively small fraction of minimal spatial resolution (ie. ~0.1mm/~1mm).
 *) MAJOR - Motorization of wires is potentially a minor expense. A single motor may spin and push multiple wires simultaneously (using some kind of gearing arrangement), resulting in 'microneedle array' like behavior.
  *) Very high resolution 3D printing would may benefit this considerably.
  *) Belts may spin microneedles by friction. Pusher plates may press large groups of microneedles inwards.
 *) Similar in principle to ECoG. May also be used to push threads of a 'neuralBits' interface after minimally invasive

implantation of that.

*) Wet abrasion, dry absorption.

Elaboration regarding otherwise already noted concepts.

*) Cylinder drum eddy current brake may allow useful stowage (or possibly pass-through of limbs) inside the metal drum if either supported from only one side or if bearings are at solely at drum surface instead of center. Usually not justified, but possible.

*) Flat disc flywheel, instead of cylinder drum flywheel, has been considered for eddy current brake cable puller mechanisms. Cable pull plates and restraining mechanisms would not all be exactly the same - different diameters would be needed for each cable. Complex 3D printed brackets in such case may be unavoidable. Usually, form factor is not enough to justify such more complex, slower, much more expensive manufacturing.
 *) Theoretically, flat disc eddy brakes toward mid-outside of flywheel, while cables are pulled around a narrow shaft, would have significant mechanical advantage. Practically, such is far more complex, expensive, and less compatible, than connecting bowden cables to small intermediate levers.

*) Expansion of cable pull plates into restraining plastic pipe is not the only means to prevent contact with rotating drum. Extrusions may already be sufficient without the plastic pipe, though the smaller aluminum surfaces may wear more quickly. May also use a pipe between rotating drum and cable pull plates, or possibly hydrodynamic bearing/gliding between cable pull plates and drum with oil or liquid metal lubricant.

*) Cable pull plates may of course rotate multiple times (cable spanning across the snap fit gap). Cutouts in plastic pipe may or may not be necessary (eg. for snap fit plates from both sides).

*) Due to simplicity of calibration (at least unidirectional force sensing already present), scrap motors are usable, although still usually too expensive. Torque curves must be reasonably smooth and and electronics cost must be minimal.
 *) Motor cable puller may require rotation as high as 6000RPM if 1cm/R and 100cm/s desired.

*) Pancake motors theoretically may be second to eddy current brakes in compactness, torque, and smoothness, but much more complex to manufacture.

*) Calculations suggest accelerating a 10kg object to 1m/s in 1s is 5J/s kinetic energy, or 5W continious. Approximately 500W dynamic load may be expected during intense activity.

*) Rigid aluminum cylinders over PTFE liner (in bowden cables) may offer better performance.

*) Bowden cables may be used both to extend and shorten along linear bearings. Particularly inexpensive, a hybrid roller bearing and bushing housing may be placed as a square cylinder around a 10-series extrusion as a piston. With a bowden cable run from the base of the piston to near the opening of the cylinder, and another wire from the base of the piston to the base of the cylinder, a highly rigid and inexpensive bowden push-pull mechanism may be created.

*) Barrel adjusters are apparently common with bowden cables. Any mechanism of forcing bowden tube segments apart may be used for such pre-tensioning.

*) Hydraulic amplifiers may use two valves in the same manner as a Class B linear electronic flow amplifier - a 'push-pull' between pressure supply 'rails'. The class A pressure gain stage (ie. common emitter amplifier) typical of OpAmps may exist inherently within the Class B flow amplifier as a mechanism which uses hydraulic flow to increase the valve opening pressure (ie. a pilot operated solenoid valve).

*) Exoskeleton mechanically relative to dorsum (aka. back) drastically reduces motor power and bearings complexity (rather than supporting full body weight at each limb).
 *) Limited motion of shoulders relative to hips should be adequate for all postures (including sleeping) if following existing good practices (eg. adjustable straps, pillow lumbar support). Complex mechanisms NOT necessary.
 *) Weights of individual limbs are <20kg each instead of full body weight.
 *) Force feedback is a cue, and does not necessarily need to respond with forces equivalent to full body weight. Some loss of dynamic range from maximum force is acceptable.
  *) Usually ~1kgF joystick force offers enough dynamic range for adequately precise flying. Exoskeleton force feedback of <35kgF at hand/wrist should be very much adequate.

*) Exoskeleton limbs supported by 20 series extrusions driven by 10 series pistons. Fingers and toes supported by 10 series driven directly by delta push/pull cables.

*) Exoskeleton fingers are constrained at tips only, observed by camera tracking at nuckles, and hit with mechanical ping to confirm button presses

*) Especially for flight sim, stowing some liquids and snack bars within easy reach, may substantially improve mental fatigue during long sessions.

*) Inner texture of all force feedback and tactile surfaces should be grip tape rough. This will give a sense of ''bite back' when grabbing objects harshly, as well as improve responsiveness of the system.

*) Very small resistors (eg. 0202) may be overloaded with minimal total energy, perhaps allowing a decent margin of safety (due to minimal difference between power dissipation when in contact with user or not) in simulating the feel of small burns, particularly if rapidly cooled after. Similar principles may apply using large peltier elements for most heating/cooling, while using very small peltier elements for especially hot/cold tactile precepts.
 *) Pain simulation by millimeter wave transmitter heating may have a decent margin of safety due to not requiring physical contact to ensure a predictable temperature rise with power dissipation. Mechanical relays, waveguides, and stripline, may control millimeter wave distribution from a central transmitter.

*) Silicone dipped flexible zig-zag shaped PCB may be usable for tactile precepts, possibly including electrotactile display. Similarly, adhered temporary tattoo layers, paints, adhesives, etc.

*) Dynamic maximum resistance - exoskeleton force feedback resistance may increase when maximum dynamic range is needed for best precision or decrease when desired for comfortable movement. Gravity and zero-gravity simulation by force feedback is also possible.

*) Negative resistance may be applied by exoskeleton, accelerating movement. User would then control their own limb motions more as changes in rates of acceleration rather than changes in rates of speed.
 *) Running speed may be accelerated to maximum plausible for a reasonably balanced individual plus 10percent.
  *) Humans seem able to do ~28mph, from derby records, horses and similar may have maximum muscle responses equivalent to 40mph humanoid form.
   *) 13MPH marathon, 15MPH mile, 30MPH sprint, 50inch jump
  *) Such augmentation of human motions by exoskeleton may balance the interests of such players with those of otherwise faster neural interface users.
   *) Games could impose mandatory physical stepping (even if not particularly comfortable or intuitive) to move at full speed for users *not* having exoskeleton mechanical or neural VR interface, as a way to balance the mental effort required to complete activities for all players.

*) Force Feedback from an exoskeleton may intuitively indicate limitations from injuries to a player's character.

*) Contra rotating flat disk flywheels and cylinder eddy current brakes may allow indefinite bidirectional cable pulling. These flywheels need not be exactly on-center, and may use a gearing arrangement to be driven by a single motor, or two, doubling flywheel energy capacity in all cases.
 *) MAJOR - Much more robust, less expensive, and compatible with the also much more robust and less expensive drum eddy current brake - two separate opposing cable pull plates with minimal tension kept on the side of undesired rotation.

*) Hall Effect Magnetometer within an OpAmp feedback loop may be able to sense the zero-magnetic-field condition needed to neutralize a ferroelectromagnet.

*) Inductance and resistance measured by high-frequency pulses, added noise, or reverse current spiking, may calibrate the eddy current brake force. Eddy current induction will resemble a transformer load lowering apparent impedance. Electromagnet saturation will also lower inductance to brief ~100kHz pulses. Hall Effect Magnetometer and OpAmp control of electromagnet may be much less expensive and much higher performance than the required measurement circuitry.

*) Pulleys may be used to decrease elasticity towards end effectors.

*) Paw actuators not only have independent eddy current drums/motors, but use these to augment wrist motions with control cables coming from both drums/motors. This is to shorten distance to the nearest eddy current brake to improve response time and/or apparent rigidity.

*) Portability - Collapsible wheels for frame, optional tie down straps for anchors, gyrotorquers for rapid rotational thrust.
 *) Better, collapsible wheel or cross for the bottom of the frame, with the user supported at a single point that supports pitch, roll, and yaw.
 *) Two supports going to the crossbar... allows complete pitch, and migrates yaw to the base.

*) Hard electromechanical parts in contact with user may be DLC coated. Soft underlying teflon coated fabric between those and user may be expendable.

*) Headset will have contact pads around it, which allow force transfer directly to head, with insignificant effect on headset alignment.
 *) Contact pads around the rear headset grip, around the sides of the head, and through holes in the foam at the front and top of the head. Each separately actuated, so rotation and translation cannot occur relative to head.

*) Linear cylinder motors - 'voice coil actuators' may be adequate across small travel ranges.
 *) Could use a large surrounding iron pile of ferromagnetic pipe.
  *) Saturation... 1A, 100 turns, 1inch ...

*) Tactile precepts may use simple transistor circuits to drive tristate/quadstate electomagnet from a single GPIO pin.
 *) Temperature sensing may be at very low sampling rate (once tens of seconds or more) to recalibrate thermal resistance.
 *) Timer circuit with temperature sensing limit may limit brief/safe 'burn' stimulation.
 *) Frequency filter circuits may infer a specific command (eg. translation of a 10kHz GPIO signal to power on a 100kHz RF oscillator heater).

*) Zip tie may be used in place of solder, hose clamps, etc, as versatile mounting hardware for tactile precepts.

*) Tiny steel nails may have the stiffness and ferromagnetism to create bidirectional pneumatic valves, possibly with small spring load, bias current, permanent magnet, etc, to predisposition default position.

*) High-kV BLDC motor power/speed may be improved as much as 10x by hydrogen/water/refrigerated cooling.

*) Drum may be converted by 10x gearbox to approximately 2kRPM PTO shaft - pto shaft flange.

*) Drum balance might be adjusted by adding small traces of epoxy to inside of drum.

*) All large diameter pipes may use 3d printed or wood parts as drilling and cutting jigs. Also, 3d printed shims may be used. CNC mill, lathe, etc, not necessary.

*) Thermistor multiplexing - temperature to frequency conversion. Slightly separate or random frequency FDMA, or basic CDMA chipping. Ordered addressing not required - activation of heaters will identify the associated thermistor channel. Center frequency tolerance may be loose if only thermal resistance or relative change in temperature is needed (as expected for tactile precepts).

*) Drive motor for metal drum of eddy current brake must have high torque - low mechanical impedance - if efficiency with high continuous load is important.
 *) MAJOR - Faster metal drum rotational rates per kgF from cable pull plate may reduce motor torque requirements, an impedance matching effect.

*) Bowden cables may connect to gearboxes which may pull other bowden cables, when rate of forced motion is less critical than maximum force.

Reference

https://en.wikipedia.org/wiki/Bowden_cable

https://forums.somethingawful.com/showthread.php?threadid=3900246

https://www.kjmagnetics.com/calculator.asp

https://www.calculatorsoup.com/calculators/physics/kinetic.php

https://ams.com/miniature-camera-modules
        'NanEye'

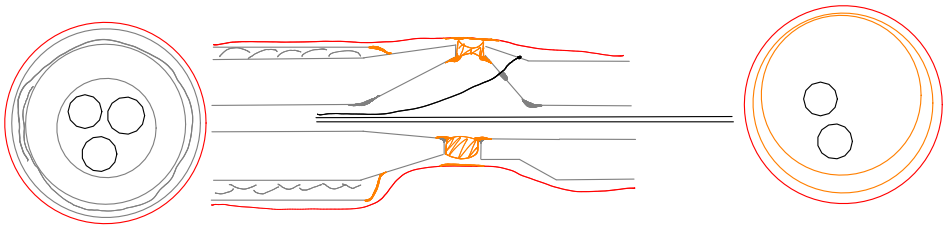
https://www.researchgate.net/publication/338575390_A_scalable_pipeline_for_designing_reconfigurable_organisms
 'A scalable pipeline for designing reconfigurable organisms'

Single direction controlled bend cable.

Polish is to be run through bowden channel until smooth then washed by <0.35um ultrapure liquid.

Biocompatible grease (not oil) is to fill channel.

Eccentric elastic spacers are sliced rubber. Wires are carbon fiber. All other parts - tubing, helical winding, pressure sensor - are counter-wound flat strips.



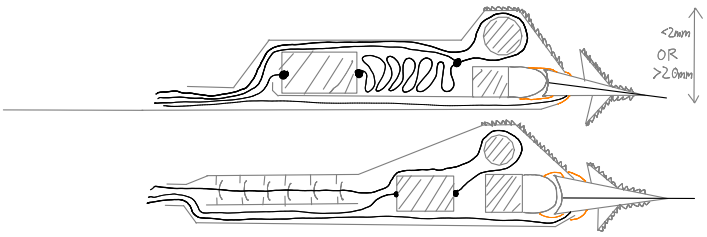
Channel diameter may be kept larger than desired wires by adding removable wires during assembly (which are pulled out later). Or if available (>>250um), heat-shrink teflon tubing may be usable.

Always consider including extra wires for addition of subsequent 'stages' later.

Simple 1D pressure sensor allows iterative software controlled mechanical compliance.

Two directional impact moles. If entire cable cannot be rotated due to insufficient compensating joints, multiple tip puller cables may be required. Needle tip may be multi-walled carbon nanotube.

Machining from a flat plate of metal is sufficient except for tip, ball/socket joint, and hammer.

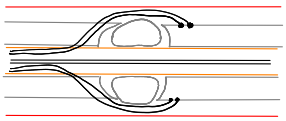


Slow motions from less than ideal bowden cables or slow actuators may be converted to rapid impact events by any means of mechanical or inertial energy storage.

A less than ideal bowden cable may be given some 'slack' that will be taken up before impact, allowing friction to pull the cable taunt before impact.

Slow actuator may use metal bending to store energy along an arbitrary length of bowden cable, generating strong impact.

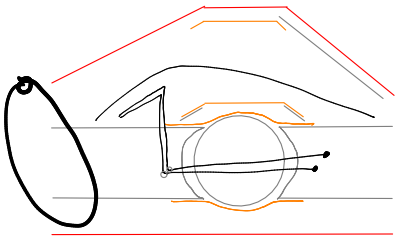
Elastic connections shown are not expected to experience any substantial adverse forces. Spherical ball/socket joint must be self-centering under forward pressure.



Ball and socket joint with internal constant-length core. Bending radius limited by crush of pass-through cables.

May be used without any external control, to allow a freely bendable joint of constant length. A cable consisting of such joints at regular intervals may zigzag parallel to or twist around another set of joints.

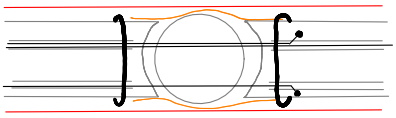
Multiaxis surface machining, or additive manufacturing, may be required for external channels (simple drilling but at an angle).



Constant length cable twisted around and tied to bendable core. Relies on sliding motion between cable and core to maintain constant length of both.

May allow tighter bending radius.

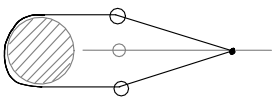
Specialized rings may be required to hold fibers inside surface machined notches.



Cables tied (or held by rings) within notches. May allow tight bending radius and low cost.

Lack of constant-length channels may necessitate additional travel and compensation for subsequent 'stages' .

Crossing between channels may limit or control twist. Two pairs of crossed wires are expected to allow full three-axis control.



Ball-and-socket joint may be controlled by a pair of motors or another ball-and-socket joint.

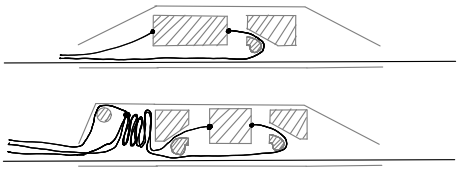
Four wires instead of three - adding an 'unnecessary' wire may in some cases allow linear trading of motion between pairs of wires, allowing bidirectional control from a single rotary axis. In turn, this may also allow inexpensive gearboxes to be added efficiently.

However, any deformation - elastic or otherwise - will at best introduce backlash. Separate force driven cable pullers are usually preferable both due to this and the possible mechanical improvement in stiffness from more optimal use of fewer wires without internal elasticity.

Crossing wires also may be possible (ie. with some ball joints), adding twist control as well (which may or may not be desirable).

Inline impact mole. May add impact force to actuated cables, or may be placed prior to a highly directional tip.

Simple surface machining will suffice. Anvil impact transfer may improve slightly if wedge is driven into cable gap (discouraged).

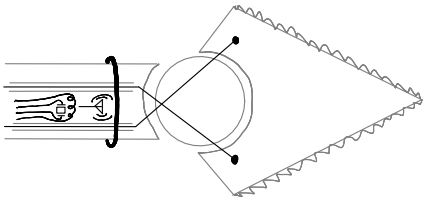


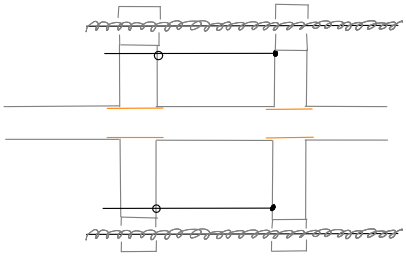
High angle tip. May be placed after inline impact mole, with or without any other joints.

May also be used as a needle tip to push threads.

Tip may be smaller, less abrasive, and may omit multiwalled-carbon-nanotube, if only soft material is expected.

Tip may be blunt if only soft tunnel is expected.

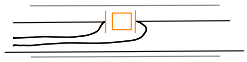




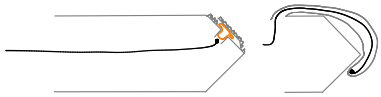
'Conventional' 'tentacle' bowden cable topology as reported by 'HackADay' article.

Small bowden actuators may be much more useful with some knowledge of the local environment. Specifically, it may be highly desirable to know whether nearby structures must be preserved (ie. capillaries) or whether a tissue boundary has been reached.

Piezoelectric crystals may translate mechanical, resistance, and pressure from bowden cable actuators, deriving tactile feedback from force and texture interactions.

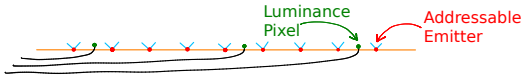


Sensors at the surfaces of impact moles can and must be protected.



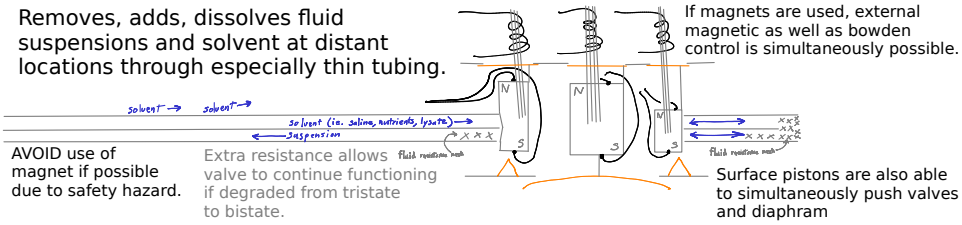
Switching emitters is expected to allow differential determination of transmittance and reflectance at each emitter, even if luminance pixels are substantially less frequent.

Bidirectional use of luminance pixels is expected, allowing the switchable emitters to be omitted. A pure fiber optic implementation with at least as many pixels as fibers is feasible. Multiplexing may be unnecessary as the total number of pixels is expected small for usual applications.



Diaphram Pump (<<2mm tubing)

Removes, adds, dissolves fluid suspensions and solvent at distant locations through especially thin tubing.



If magnets are used, external magnetic as well as bowden control is simultaneously possible.

AVOID use of magnet if possible due to safety hazard.

Extra resistance allows valve to continue functioning if degraded from tristate to bistate.

Surface pistons are also able to simultaneously push valves and diaphram

DISCLAIMER: Plausible concepts, attributed sources, oversimplifications, resonably. Rigorous mere academia NOT primary.

CARDinal

CARDinal Computer Automated Rendering Diffusion (CARD) with Cardinal Numbered WORLD Balance (Cardinal)

Specifications - protocols, algorithm flow, bandwidth estimates - for standalone netcode/inter-process-communication executable to securely share and interact geometric objects (eg. player avatars, vehicles, tools, visual effects) balanced by class (eg. fighter, interceptor, carrier) while also integrating the shared 3D spaces (WORLDs) by trade limitations, travel, and efficient instancing to reputable player run dedicated servers.

*) Encapsulation - *everything* is a 'playerItem', specified by 'CARDinal playerItem Message Byte Allocation' . Positions, rotations, always authoritatively controlled by one player. Game engines (eg. Unity, Unreal, CryEngine, F/LOSS) are all expected to interoperability import these objects (eg. 2D and 3D player avatars, tools, vehicles, voice chat clips, VM framebuffer images, etc) and positions, even for internal purposes (eg. vehicle position updates from external flight model simulation programs exclusively receiving HOTAS inputs).

*) Anti-cheat. Visibility cheating prevented by not sending any objects to other players until their avatars/vehicles/tools/etc 'playerItem' has been checked with a rough terrain model. After-the-fact claims prevented by accurate position/rotation coordinates, logging consequential coordinates, and confirmation of plausibility by other players. Faking of a type of cognition (eg. human wetware by software) may be mitigated by statistical comparison of position/rotation coordinate patterns and responses to occasional induced jitter from other players clients (similar to CAPTCHA statistical expectations). Frequent repeat offending and anti-cheat exploit searching mitigated by reputation (NOT relying on commercial price) gating (limits on activities of apparently new players).

*) Automation either prohibited from accessing other player's playerItem positions or prohibited entirely, by anti-cheat statistical comparison of position/rotation coordinate patterns. Any autopilot or autoaim is forced to preform the same cognition visual object recognition as a player would, or prevented entirely.

*) Trade out-of-WORLD limited or prohibited by statistical position/rotation pattern comparison (preventing unauthorized long-term account transfer) and transaction rate limits between players.

*) Economically valuable proof-of-cognition activities (eg. monster spawn rates) are limited and processed client side (ie. a monster is a 'playerItem' from the encountering player's client) per rules from WORLD server. Player claims are checked statistically, as well as by any other players in same instance. Earnings cheating is prevented while real-time WORLD server bandwidth and processing is avoided.

*) Balancing statistically between classes of avatars/vehicles/tools/etc. Swords/shields can be slight bullet magnets, statistically balancing skilled longsword users near equally against high rates of fire by ranged weapon users at medium range (at long range both may carry an additional sniper weapon). Vehicles of air-to-air types can be of fighter (high turn rate) or interceptor (high speed/acceleration rate) classes, statistically balanced equally in 1v1 contests (with fighters having a >50% probability of escaping the merge to turn and retaliate with the interceptor at a severe disadvantage in evasive maneuvering).

*) Crime and punishment. Players attacking other neutral or allied players unprovoked may be regarded as enemies of all. Such players if caught by other players may be limited in their activities, while catching players earn proportionate rate-limited bounties and return of undisposed valuables.

*) Anti-harassment. Rules can be established to require players to prove identity, and/or if some conditions are met (eg. defeated in PvP ambush by authorized moderator with proven identity), to report a player's known identity (eg. IPv6 address).

*) Visual Effects and Consequential Action distinction. Only a 'playerItem' capable of causing a consequential event (eg. victory, defeat) is necessarily shared with other players or visible. Visual Effects may be limited only in shared visibility conditions (eg. distance from player's avatar, during conflict) to prevent distraction. Players may always have any Visual Effects 'playerItem' visible to theirselves (eg. screen scraping from desktop applications, VM framebuffer images, interactive keyboard/mouse, avionics, etc).

*) Interoperability. Any program may send and update a 'playerItem' . Screen scraping programs send existing 2D desktops and 2D applications (eg. spreadsheets) as a 'playerItem' with attached framebuffer images. Any 3D application may directly send an interactive 'playerItem'. Also, existing 2D desktop applications (eg. web browsers) are expected to remain widely useful.

*) User interface hardware compatibility. Modularity emphasis - avatar/vehicle/tool positions sent from external programs within allowable limits - ensures not only 'VR' displays/headsets/controllers but also traditional 'flat screen'/'gamepad'/HOTAS/keyboard/mouse hardware interfaces continue to offer a comfortable experience.

*) Terrain redundancy compatible between game engines (eg. Unity, Unreal, CryEngine, F/LOSS), facilitating player choice of scenery quality, hardware. Players using high-end resources for the best visual experience (eg. CryEngine forests), can join other players who may be using lower cost or more portable hardware and software (eg. 'Linux standalone VR headsets, Linux smartphones, etc'). Instead of terrain features (eg. vegetation) specific to one proprietary game engine, multiple terrain files may be provided by WORLD server (as 'playerItem'). Vegetation and such providing partial cover must provide full cover with the lower-end 'low-poly' hardware and game engines lacking vegetation.

*) Bring own avatar, vehicle, tool, etc. Avatar/vehicle/tool/etc simulation programs are entirely separately run by players, with

WORLD servers only specifying maximum acceleration/speed/turn limits per class. WORLD server may supply flight model limits for specific classes of avatars, tools (eg. sword, mace, gun), vehicles (eg. fighter, interceptor, bomber, UAV), which players may override with more limited flight models (eg. switching to an FA18C flight model for carrier landing practice). Players are expected to bring their own avionics (ie. Linux Virtual Machines), flight decks (eg. presence or absence of canopy obstructions), flight/engine model limits, etc.

*) Experimental physics (eg. fluid, thrust, lift, etc) simulation as visual effect, converted to consequential events if WORLD server allows and appropriate. Limited set of materials allows the basic functions of additive tooling, subtractive tooling, thrust, and lift, conversion to flight model limits and such. While interesting, usually WORLD servers are expected to strictly limit or disallow such 'innovation'. Real-time problem solving is a better contest of cognition, proof-of-cognition is the basis of a robust WORLD economy, simulation resolution cannot replace experimentation for state-of-the-art manufacturing, and historically extraordinarily complicated manufacturing technology improvements over decades have only brought less than orders-of-magnitude differences between generations of vehicles (eg. P-51 turns of ~280knots/~8g).

*) Proof-of-cognition (person-hour) as WORLD economy basis and exchange rate limits between WORLD servers.

*) Travel and trade between WORLDs as rate limited, high inflation, no-history, periodic transaction confirmation list swaps between founding WORLD accredited and reputable WORLD servers. Robust, low-resource consumption, low-consequence, accounting.

*) Bandwidth efficiency, backups to players, interruption tolerance, graceful degradation. Bandwidth as low as 9600baud . Essential 'playerItem' marked by 'boneTag' (eg. right hand, head) filtered for exclusive transmission to other players when connectivity is degraded.

*) Instancing roaming, to servers/LANs owned by reputable players, swapping to higher capacity servers/WANs as needed, in real-time. Any reputable player's or their group's own server is used by default, players wandering close to the space a WORLD server has an instance reservation record for connect to that server. Without the complexities and records-per-second limits of peer-to-peer distribution (ie. 'blockchain', drastically reduces reliability and bandwidth cost issues. WORLD server centralized bandwidth is only used for consequential records (eg. victories, player corporation territories, terrain object unique identifiers, flight model limits, instance reservations, etc).

*) Astronomical objects being position translation only (no rotation), with geocentric stellar orbits, removes substantial complexities from perfectly synchronizing object motion and instance roaming to planetary surfaces, which also simplifies synchronizing player avatars to fast vehicles and their avionics displays (ie. aerospacecraft). Fast planetary rotations, lag in apparent 'speed of light' between instances, complexities of tracking workarounds, are all avoided by placing stars in ~5kls/0.05c or ~100kls/1c *geocentric* orbits, with no planetary rotation. Economics and ecosystems contend with the same constraints - day/night, interplanetary/interstellar deltaV, etc - while the *risk of software bugs* is *drastically* improved.

*) Voxel Grid fluid physics distributed at low bandwidth between computers using compressed edge grayscale perceptually lossless video compression.

*) CARDinal messages are always trivial announcements to any shared channel, usually a dedicated instancing server and/or WORLD server in a star network topology, but also shared channel inter-process-communication bus (as provided by 'ubiquitous bash', Virtual Machine emulated serial/COM/UART ports, shared serial/UART bus wires, radio 'frequency' FDMA/CDMA channels, raw WiFi/Bluetooth/Ethernet frames/packets, multicast, ring networks, etc. Especially helpful to add controllers (eg. HOTAS) by UART without mapping through legacy interfaces (eg. keyboard bindings) by sending information directly as a 'playerItem' from the device.

*) Amateur radio by HF ALE or 24hr duration HF transmission can connect players or transfer essential backups globally without any other infrastructure. Client and WORLD server software, for amateur radio use, must be able to disable encryption (including any authentication) entirely. Player impersonation can be identified and corrected from presence of a player in an instance server without matching authentic WORLD server login or agreement of other players - real-time authentication/encryption is NOT necessary. Rate limits inherently prevent severe damage due to impersonation.

Introduction

Since we rather easily can, as a matter of our own self-interest in living, we must create a habitat all plausible species would be rather happy to share.

All of the algorithms specified for CARDinal are straightforward without any plausible major gaps. Ability to load terrain files, import 3D objects into game engines without interruption, import real-time framebuffer video streams, and control 3D object positions, is well documented for major game engines (especially Unity). All necessary inter-process-communication and networking is available from both MSW and Linux OS kernels. Both MSW and Linux/Cygwin OS can integrate other programs through simultaneously batch/bash interpretable anchor shell scripts from 'ubiquitous bash'. Compiled code (ie. C/C++/similar) may be relied upon entirely by standalone clients (eg. Oculus Quest, Android), or use cloud services may be used (eg. if avionics VM is desired by such users).

Some useful code for inter-process-communication and 3D space object storage already exists as reference implementations within 'ubiquitous bash', 'MetaEngine' included with 'ubiquitous bash', and 'metaBus' demonstration of 'MetaEngine' (all of which predates and is unrelated to any other substantial 'metaverse' marketing promotion).

Presented

*) Algorithms for Instancing Roaming, Coordinates Referencing, Latency Compensation, Trade between WORLDs.
*) CARDinal playerItem Message Byte Allocation (playerItem is all-purpose).
*) Coordinates optimized for bandwidth.
*) Bandwidth and users per bandwidth calculations.

As may be plausible.

Conclusions

CARDinal is the object-sharing netcode and inter-process communication part of a larger system. Tools to create those objects (including existing CAD modeling programs), and the founding WORLDs (which may provide the most populous shared spaces and most extensive proof-of-cognition), are also essential.

CARDinal must specifically facilitate compatibility between objects. Beyond compatibility mechanics, game design is beyond the scope of CARDinal.

CARDinal's most significant feature is the opportunity to depart from the 'objects and behavior provided with game' model historic of pre-packaged games to objects and behavior provided instead by players theirselves in realtime. Developers attempting to integrate other complex software - to the point of simulated avionics using simulated displays from virtual machines with full operating systems - especially benefit, as they will be able to implement game interactive object behavior in smaller, separate, codebases.

Three founding WORLDs in particular may provide for some initial diversity and quality of life.

*) Mix of swords/bullets/towns/forests, emphasizing roughly human scale activity, single planet. Inspired as similar to all of SAO. Vehicle based tools (ie. aerospace fighter cannons) ineffective or unusable. Players may lay 'foundations' for their own buildings, so *everything* is player driven except the planetary terrain (which has dense vegetation and such). PvE may be more emphasized here, but PvP and player corporations are allowed.
*) Mix of important fighters, bombers, carriers, and logistics, ships. Inspired as a mix of Elite Dangerous, EvE Online, Descent FreeSpace . PvP is emphasized strongly. Some resources may be more available from here, making trade with these aerospace fighter pilots important.
*) More or less Earth-like. Detailed physics (ie. voxelGrid) emphasized. Realistic speed/acceleration limits in effect - players will not be doing interstellar travel for a long time here.

Trade and travel between WORLDs seamlessly part of game mechanics. Scenario here is for a player to make a 'profession' with a comfortable home somewhere on 'Swordland' planet or on a carrier bunk, fly a fighter with custom flight deck avionics and canopy from the nearest flat place, join up with a corporation's carrier group, fly fighter escort or bomber against another corporation's logistics in a major way, assist a land conflict on a nearby planet, set 'FA-18C' flight model limits to practice a carrier landing, debrief, catapult back into space, punch 'jump drive' address (IPv6 address) for Swordland planet, find a clearing outside a decent town (don't bother with strafing fire above dense 'immortal object' forests and towns), hover down, walk into town, have blacksmith polish the swords for tomorrow's duels, buy some rounds for the aerospace cannon, and happily pay a few reputable local developers for more work customizing a new drop-in avionics virtual machine.

RADAR/IR sensors might be short-range only and energy density may be limited at 'Swordland' planet to preclude finding large numbers of potential 'victims' under forests and towns from above. Calling an airstrike on known coordinates is reasonable, but expected less common than simply putting a sword or trigger on those coordinates.

Reducing Coordinate Resolution or Diameter to worse than perceptual lossless does not substantially reduce bandwidth.
Astronomical object position lists are compressed by approximately one third if galaxy diameter and resolution are appropriate.
Instancing objects to 100km^3 shared spaces reduces real-time bandwidth by approximately half.

Star coordinates and total stars must be kept to a reasonable minimum for practical WORLDs. Players can move to instances at different stars/planets without waiting for downloading if their astronomical object list (including geometry models or procedural algorithms) is complete. Regular offsite backups of corporation star/planet ownership to all players best safeguards significant investments of player proof-of-cognition from WORLD server issues

Periodic (eg. quarter-hourly) updating of astronomical object lists can reduce complexity when adding new stars and planets, at negligible bandwidth cost (8000 stars, 20bytes positions).

Either CARDinal software or SpaceX Starlink/Starship (adding much bandwidth as a worldwide lower latency IPv6 network) would substantially obviate many of the latency, bandwidth, and compatibility, issues, but not to the point of sharing voxel grids (presumably >10Mbit) between all remote players globally and simultaneously. Starlink especially has the ability to reduce latency between players on opposite sides of Earth.

Virtual 'real-estate' economic values (and appropriate cooperation/conflict) at galactic scale will be at constrained locations for resource extraction and logistics, while at planetary scale player walking distance convenience is expected to provide the constraints for land/foundation pricing.

REFERENCE

https://www.researchgate.net/publication/325816971_IPSME-_Idempotent_PublishSubscribe_Messaging_Environment/fulltext/5b272585aca272277fb70011/IPSME-Idempotent-Publish-Subscribe-Messaging-Environment.pdf
 'IPSME- Idempotent Publish/Subscribe Messaging Environment'
        Some of the netcode concepts may or may not have some similarlities.

ACKNOWLEDGEMENT

*) Sword Art Online by Reki Kawahara . Significant world building offered a hopeful approach to common game mechanics and added relevant terminology (notably CARDinal itself).

*) Elite Dangerous by Frontier Developments . As an example of everything not to do. No significant concepts or functional gameplay mechanics were learned from Elite Dangerous. Possibly Frontier Developments may never have brought a non-obvious concept or non-obvious functional gameplay mechanic. Frontier Developments's most significant achievement is a reasonable approximation of an unnecessarily realistic Milky Way galaxy approximation by rough object assignment combined with procedural terrain generation. Significant obvious unnecessarily missed potential for a more naturally harmonious multiplayer virtual habitat was more substantially demonstrated. But more than that, the hostility of PvE players who believe the galaxy cannot be shared with even the most basic legitimate PvP game mechanics (ie. 'PowerPlay' 'open-only'), resulting from too much support for only far less legitimate PvP play styles, is a testament to the very real social dangers of negligent community management built on a business model of blatant vaporware.

*) 'shaw' of '#omi-ethics' channel of 'AngellXR' 'Discord' server of 'OMI' project
 *) for protocol buffers suggestion and link to 'IPSME' papers (also 'humbletin' for 'IPSME' mention)
 *) for 'upwork' ention
 *) for 'XRPK' mention though that is definitely too complex to use directly in place of compatibility with multiple formats
 *) 'VRM' humanoid avatar ... 'gltf' ... 'normal mapping'
*) 'humbletin' - ' https://github.com/omigroup/omigroup/discussions/8 ' '
https://web.archive.org/web/20211202131827/https://github.com/omigroup/omigroup/discussions/8 '
*) 'Lyuma' - quarternions mention

*) 'SAO' may have inspired 'Original Sword Skill' mechanic. Maximum neuromuscular coordination rates were likely considered much earlier in some other contexts.

Coordinate Resolution, KeyFrame Format, Astronomical Objects

Separation of 5ly between stars is usual as with a habitable area of Milky Way galaxy. Density may be increased to ~0.05ly between stars without causing issues of reducing deltaV or possible collisions between geocentric star orbits at ~100kls .

Thickness of 0.25ly and diameter of 2ly is reasonably sufficient for all ecosystems and economics, total stars 8000 (0.25ly/0.05ly==5stars thick, 2ly/0.05ly==40stars diameter). Such guarantees nearly an entire star for any future trade, travel, cooperation, conflict, etc, per million persons from Earth, which per planet is at least one order of magnitude less than expected or historic reasonably diverse population density. Approximately 1600 paths will exist from one 'side' of galaxy to another, which may be desirable to constrain to a reasonably expected number (ie. dozens) of large player corporation alliances.

27byte 'Complete' 2.00ly Diameter 25um Resolution Address

```
  'diameter_lightYears=2.00'
  'resolution_meters=0.000025'
  'dimensions=3'
  '_clc "ceil(0.18033688 * log(((9.454255*10^15) * "$diameter_lightYears") / "$resolution_meters")) * $dimensions"'
# 27
bytes.
```

20byte 'Galactic' 2.00ly Diameter 10m Resolution Address

```
  'diameter_lightYears=2.00'
  'diameter_dimensions=2'
  'thickness_lightYears=0.25'
  'thickness_dimensions=1'
  'resolution_meters=10'
  '_clc "( ceil(0.18033688 * log(((9.454255*10^15) * "$diameter_lightYears") / "$resolution_meters")) * $diameter_dimensions ) +
( ceil(0.18033688 * log(((9.454255*10^15) * "$thickness_lightYears") / "$resolution_meters")) * $thickness_dimensions )"'
# 20
bytes.
```

12byte 'Instance' 100km Diameter 25um Resolution Address

```
  'diameter_meters=100000'
  'resolution_meters=0.000025'
  'dimensions=3'
  '_clc "( ceil(0.18033688 * log( ("$diameter_meters") / "$resolution_meters")) * $dimensions )"'
# 12
bytes.
```

Rotation Angular Resolution (6Byte), KeyFrame Format, Disagreements

Rotation angular resolution reasonably limited to ~0.25m@3500m (~0.006deg) . Interactions (or imminent interactions) between objects require rotations communicated accurately (both for visualization and confirmation before the fact by other players). Longest such interactions are ballistic and optical, which for roughly human sized machinery and optics, is limited by chaotic and quantum physics.

Rotation coordinates are absolute X/Y/Z degrees from no rotation, with this absolute directionality inherited from a 3D space in which astronomically large objects (ie. stars, planets) are arranged geocentrically with no rotation (only translation), and have absolute position coordinates.

Players are authoritative for the position and rotation of their own playerItem (eg. avatar, vehicle, tool), and any adjustments in apparent position is a deterministically applied client side only to other players apparent positions. Euler angle 'gimbal lock', as well as quarternions, are avoided by keyframes resetting to the absolute position and rotation claims made by players clients. Disagreements are accepted as is and logged occasionally for anti-cheat statistics.

```
  'rotationBytes=6'
  'dimensions=3'
  '_clc "360 / 2^($rotationBytes/$dimensions*$currentByte))"'
# 0.0054931641
degrees.
```

Bandwidth - Object Positions and Rotations

Galactic Astronomical KeyFrame bits/Second

```
  'stars=8000'
  'planetsPerStar=10'
  'bytesPerObject=20'
  'instantFramesPerDay=96'
  'galactic_baud=$(_clc "( $stars * $planetsPerStar * $instantFramesPerSecond ) / $currentByte ")'
galactic_baud= 11.111111
Average , baud , bitsPerSecond , NOT Bytes .
```

Instance KeyFrame bits/Second

Degraded - <4800bits/Second Minimal Bandwidth

```
  'instantFrameBytesPerPosition=12'
  'instantFrameBytesPerRotation=6'
  'incrementFrameBytesPerPosition=1'
  'incrementFrameBytesPerRotation=1'
```

```
  'instantFrameBytesPerBone=$(_clc "$instantFrameBytesPerPosition + $instantFrameBytesPerRotation" )'
  'incrementFrameBytesPerBone=$(_clc "$incrementFrameBytesPerPosition + $incrementFrameBytesPerRotation" )'
  'incrementFramesPerSecond=15'
  'instantFramesPerSecond=2'
  'bonesPerPlayer=4'
  'playerDegraded_baud=$(_clc "( ($instantFrameBytesPerBone * $instantFramesPerSecond) + ($incrementFrameBytesPerBone *
$incrementFramesPerSecond) ) * $bonesPerPlayer * $currentByte")'
playerDegraded_baud= 2112
Average , baud , bitsPerSecond , NOT Bytes .
```

Player Bandwidth - Nominal

```
  'instantFrameBytesPerPosition=12'
  'instantFrameBytesPerRotation=6'
  'incrementFrameBytesPerPosition=1'
  'incrementFrameBytesPerRotation=1'
```

```
  'instantFrameBytesPerBone=$(_clc "$instantFrameBytesPerPosition + $instantFrameBytesPerRotation" )'
  'incrementFrameBytesPerBone=$(_clc "$incrementFrameBytesPerPosition + $incrementFrameBytesPerRotation" )'
  'incrementFramesPerSecond=60'
  'instantFramesPerSecond=10'
  'bonesPerPlayer=80'
  'playerNominal_baud=$(_clc "( ($instantFrameBytesPerBone * $instantFramesPerSecond) + ($incrementFrameBytesPerBone *
$incrementFramesPerSecond) ) * $bonesPerPlayer * $currentByte + ceil($galactic_baud)")'
playerNominal_baud= 192012
Average , baud , bitsPerSecond , NOT Bytes .
```

Bandwidth - Internet Total, Starlink Total, Starlink Added

```
  'totalInternet_terabits=500'
```

```
  'starlinkPerSatellite_terabits=0.020'
  'starlinkTotalSatellites_immediate=2600'
  'starlinkTotalSatellites_expected=42000'
  'starlinkTotalShare_immediate=$(_clc "( $starlinkPerSatellite_terabits * $starlinkTotalSatellites_immediate ) /
$totalInternet_terabits")'
starlinkTotalShare_immediate= 0.104
```

```
  'starlinkTotalShare_expected=$(_clc "( $starlinkPerSatellite_terabits * $starlinkTotalSatellites_expected ) /
$totalInternet_terabits")'
starlinkTotalShare_expected= 1.68
```

Bandwidth - Players

per Internet

```
  '_clc "(( $totalInternet_terabits ) * 10^12) / $playerDegraded_baud"'
# 2.3674242E11
```

```
  '_clc "(( $totalInternet_terabits ) * 10^12) / $playerNominal_baud"'
# 2604003916
```

per Starlink

```
  '_clc "(( $starlinkPerSatellite_terabits * $starlinkTotalSatellites_immediate ) * 10^12) / $playerDegraded_baud"'
# 24621212121
```

```
  '_clc "(( $starlinkPerSatellite_terabits * $starlinkTotalSatellites_immediate ) * 10^12) / $playerNominal_baud"'
# 270816407
```

per Starlink (expected)

```
  '_clc "(( $starlinkPerSatellite_terabits * $starlinkTotalSatellites_expected ) * 10^12) / $playerNominal_baud"'
# 4374726580
```

per 20Gbit/Second (eg. Starlink satellite)

```
  '_clc "floor( (20 * 10^9) / $playerDegraded_baud )"'
# 9469696
```

per 100Mbit/Second (eg. dedicated amateur cubesat)

```
  '_clc "floor( (100 * 10^6) / $playerDegraded_baud )"'
# 47348
```

per 115200bit/Second (eg. USB UART for HOTAS and similar peripherial controllers)

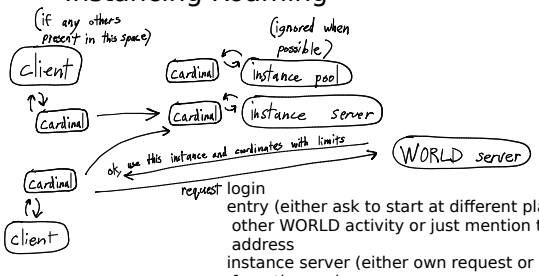
```
  '_clc "floor( (115200) / $playerDegraded_baud )"'
# 54
```

per 9600bit/Second (eg. POTS phone modem)

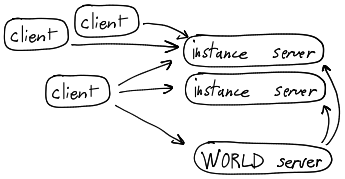
```
  '_clc "floor( (9600) / $playerDegraded_baud )"'
# 4
```

Algorithms

Instancing Roaming



entry (either ask to start at different place perhaps based on other WORLD activity or just mention the 'assign me whatever' address
instance server (either own request or 'assign me whatever' from the pool

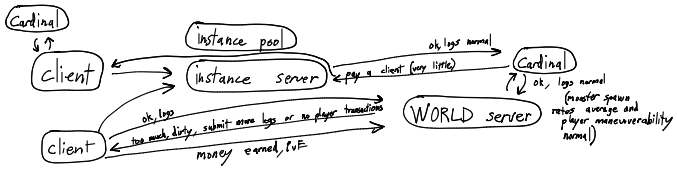


Clients connect to multiple instance servers when 'roaming' into nearby occupied spaces. In case of suspected impersonation, WORLD server connects to instance servers to request dropping of source IP addresses, signatures, names, etc, unassociated with recent authentic logins.

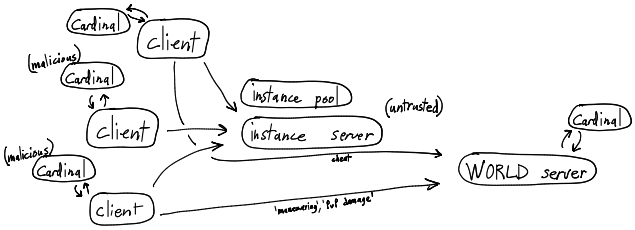
Players must have a visible indicator of connection quality from other players and which instance servers are connected.

Instance server bandwidth during popular events may be reduced by filtering traffic sent by players not causing PvP damage (ie. not participants in the contest), degrading such other players by reducing bones, F/s events, and if necessary disconnecting players for adding excessive traffic (eg. disconnecting any player adding a new 'microphone' to the already crowded space). 'Dumb' instance servers relaying a shared channel with no processing may force clients to degrade by dropping, delaying, or corrupting (by added analog noise) packets as a hint. Thus, duels and such may be observed by a large number of players in the same instance while server bandwidth is limited.

Anti-Cheat



Cheating PvE may occur with no other players present, or offline. When informed of supposed PvE progress, WORLD server may demand logs before acceptance.



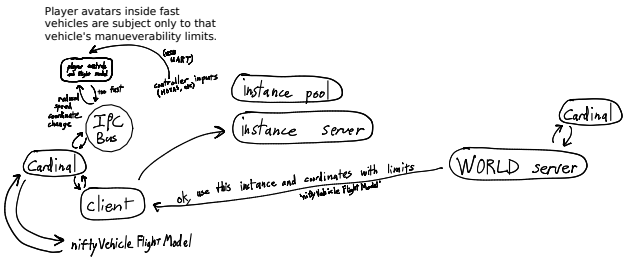
Cheating PvP between reputable players has much higher possible consequences, WORLD server may always require logs, other players are always present, and statistically detected cheating may be silently accepted for some random interval to prevent exploiting.

Statistical abnormality in logs or allegations of cheating, is cause to - after some random interval to prevent exploting - mark a a player 'dirty' for increasing durations with each offense up to 7years (5years being arguably short in place of permanent ban, 10years being arguably longer than serves any purpose, and some ability to catch 'Newton's Apple' proverbially implying some substantial multiples of that response time is enough for reasonable cognition to rationally change behavior).

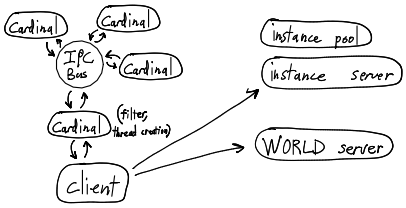
Players marked dirty may be unable to participate in many activities, may be reset, and may be reset more promptly for any suspicion of cheating. Newly created accounts may have similar limitations until sufficient proof-of-cognition has accumulated to mitigate rapid bypassing of such anti-cheat limits. Accounts marked 'dirty' for the maximum duration (7years) may be much further from participating than newly created accounts (months of limitations expected for most activities), and this is an intended effect.

Shared Channel

IPC Bus, UART Controller Peripherials, Flight Model Limits, Latency Compensation, Developer Interaction



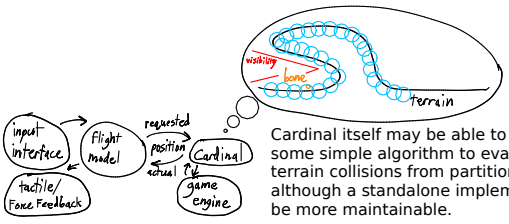
Player given program, taking input from player given controls (eg. HOTAS with USB UART having no 'DirectInput' or keyboard binding compability) may move player's vehicle 'playerItem' within manueverability limits from WORLD server. Position/rotation changes are sent to IPC Bus shared channel, forwarded by CARDinal, within Client, to instance server.



CARDinal is inherently multi-threaded, despite being a monolithic set of functions, due to the ability to call these functions over an IPC bus after calling the '_bin_IPC' function (otherwise disallowed).

Developers may interact directly with the IPC Bus.

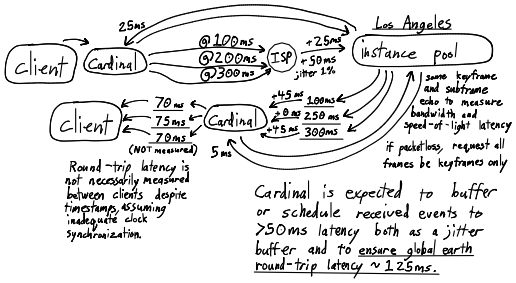
CARDinal always sends a 'playerItem' to a 'shared channel'. An instance server is expected to copy any acceptable 'playerItem' messages to all other connected players. An IPC bus is expected to copy all input to all outputs, which may change ad-hoc, exactly as a shared pair of wires hardware bus (ie. similar principle to CAN bus). Messages are NOT directed to specific recipients, as may be the case for some existing software bus implementations (eg. dbus, named pipes, etc). Suitable IPC bus reference implementations are part of 'ubiquitous bash'.



Cardinal itself may be able to include some simple algorithm to evaluate simple terrain collisions from partitioned space, although a standalone implementation may be more maintainable.

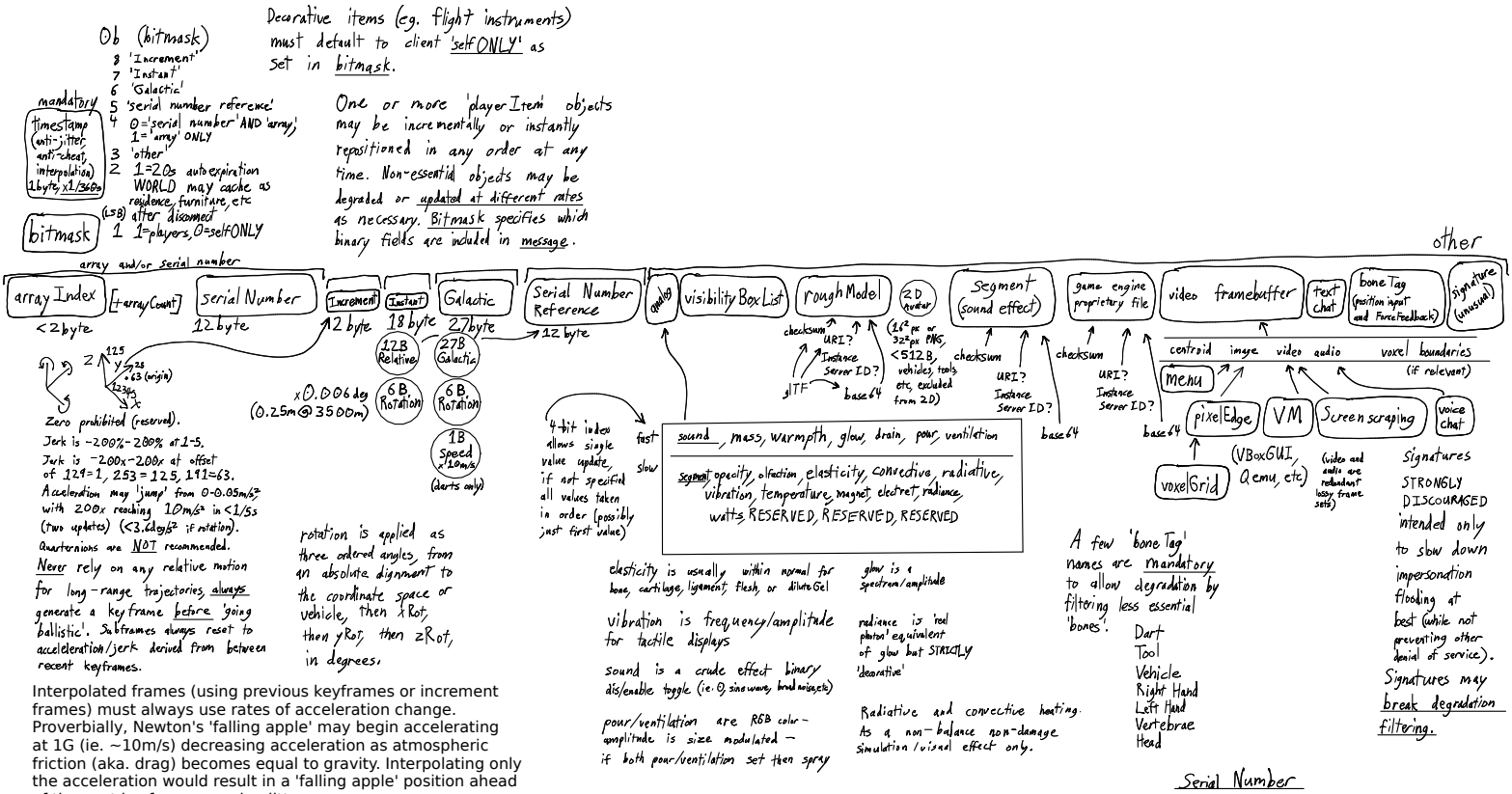
Rough terrain model may correct bone 'bounce', compensating for latency which may otherwise cause objects to appear below terrain. Especially prevents aircraft appearing to 'land undergound'.

Before PvP damage events occur, avatar/vehicle/tool/etc vehicle centroid coordinates may not be sent to prevent cheating (however, guessing with splash damage is allowed). To request other players announce their visibility, a player may declare their own presence in a semi-random announced visibility bounding box (which still prevents accurate visibility and aimbot cheating).

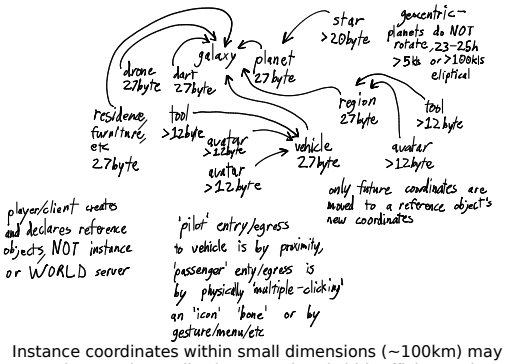


Latency compensation. A buffer must ensure latency remains approximately constant, rather than as little as possible, to mitigate jitter. Packet loss degrades acceleration rate change compression and must force keyframes only.

Cardinal playerItem Message Byte Allocation



Interpolated frames (using previous keyframes or increment frames) must always use rates of acceleration change. Proverbially, Newton's 'falling apple' may begin accelerating at 1G (ie. ~10m/s) decreasing acceleration as atmospheric friction (aka. drag) becomes equal to gravity. Interpolating only the acceleration would result in a 'falling apple' position ahead of the next keyframe, causing jitter.



Instance coordinates within small dimensions (~100km) may be referenced to 'region' markers, allowing more bandwidth efficient 12byte position keyframe coordinates. Similarly, a player avatar may use 12byte coordinates relative to a vehicle.

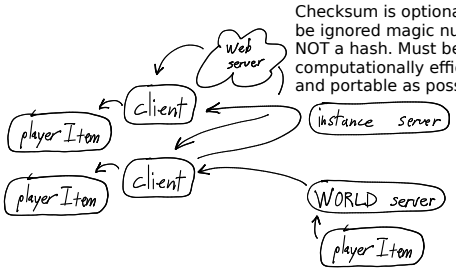
Vehicles must use 27byte position coordinates, as these may frequently move through ~100km boundaries, and players in vehicles will not gather as closely in large numbers as player avatars.

All objects near planetary surfaces must move when periodic astronomic position updates occur. If this is performed as a proximity rule, objects need not be marked or processed relative to planets.

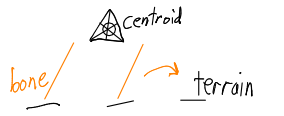
CARDinal may provide default rules to match location and prompt Task/Quest begin/intermediate/end 'playerItem', and PvE monster spawn 'playerItem'. Clients may alternatively encounter an interactive 'playerItem' which a local program is waiting for and manages. WORLD and instance servers have no part of Task/Quest/PvE events, progress of which is accepted on the basis of (if demanded) plausible logs.

Task/Quest begins as a 'playerItem' (possibly non-visible) which must be brought with a player avatar to a location, may include retrieving a 'playerItem' (possibly non-visible) from a location (eg. which may appear to the player as a conversion from a raw material to a manufactured material), and is completed when a 'playerItem' is brought to a location (eg. where the Task/Quest was given or immediately completed at the location where the 'playerItem' was retrieved).

Checksum is optional (may be ignored magic number), NOT a hash. Must be as computationally efficient and portable as possible.

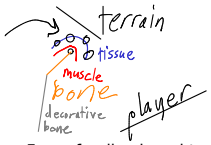


Special objects (eg. terrain, rough terrain, planetary surfaces, default vehicles, PvE items/monsters) may be available as 'playerItem' from WORLD server or mirror. Any real-time positioning, model, texture, or other changes, do NOT depend on WORLD or instance server - clients must *always* be *completely standalone* after login and instance 'relay' assignment. Large files (eg. terrain, planetary surfaces) must not be sent through instance server, instead should be downloaded by reference to an appropriate file server.



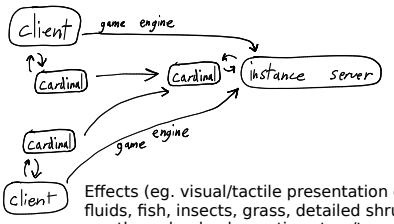
Paw bone collision event average distance and frequency are a better basis for player avatar centroid maneuverability limits. A velocity advantage is allowed for excellent footwork, whereas vehicles usually have less complicated acceleration limits from thrust/lift.

Paw placement patterns when repeated well, may be saved, replaying snaps to the original acceleration, speed, and accuracy. Such replayable patterns may be traded to other players (ie. as an 'Original Sword Skill' tradeable item mechanic). External programs may of course implement such replayable gesture snaps, modifying player avatar bone positions through IPC to CARDinal.



Force-feedback and tactile sense may be detected by collisions with non-shared objects. Game engines are apparently more able to detect such collisions than interactions between 3D model surfaces.

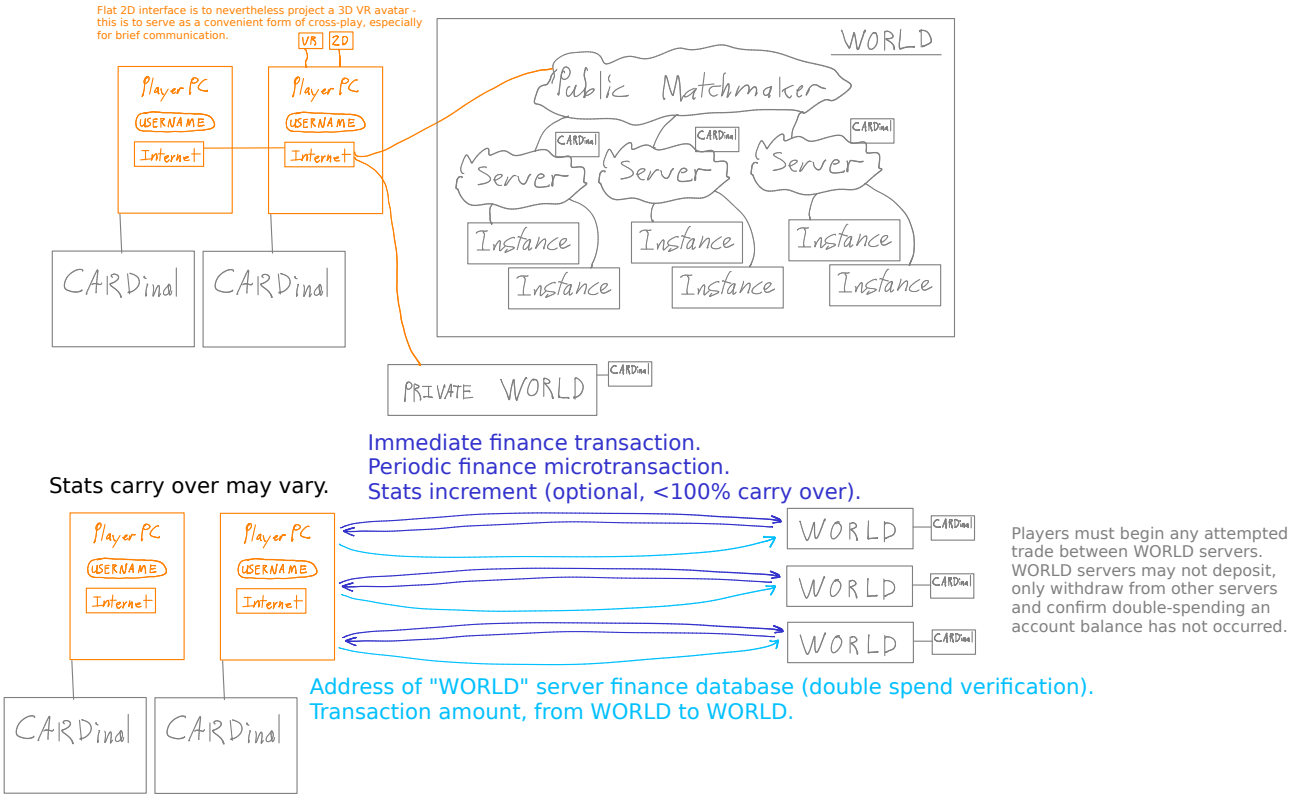
Bone position alone is enough for other players to impart force-feedback and tactile sense to other players. Composite structure from movable solid bone, through shaped elastic materials typical of muscle and any other tissue, well approximates physical contact between players, in multiplayer, without incurring the bandwidth and complexity of sharing and convolving surface deformation. Fewer than 80 bone positions are expected sufficient.



Effects (eg. visual/tactile presentation of fluids, fish, insects, grass, detailed shrubs, weather, clouds, decorative stars/terrain, etc) may be not only delegated to but also synchronized through client-specific game engine netcode. Avatars, vehicles, tools, etc, requiring balance, player maneuvering coordinates, player 3D models, coarse planet/star terrain, etc, must still rely on Cardinal exclusively and must endow multi-engine cross-play.

Trade between WORLDs

Trade between WORLD servers is expected to allow players of mostly one profession (eg. galactic space pilots) to purchase relevant services (eg. vehicle maintance) from players who mostly carry on their profession at another WORLD (eg. Swordland blacksmith). Stats matching between servers allows players 'proof-of-cognition' at one WORLD to establish their ability to participate in similar activities at other WORLDs.



Trade between CARDinal accredited and compliant WORLD servers, including both finance and stats progression, is equivalent to a 'cheque' banking system. Player issues a request to a WORLD server, to withdraw funds or match character stats from another WORLD server.

WORLD servers periodically publish a list of recent requests, confirm double spending of an entire account balance has not occurred, and publish a list of recent confirmed requests. When a WORLD server sees the transaction confirmed by the second list, the transaction is complete. All accredited WORLD servers publish all other WORLD servers recent lists to every other WORLD server. Such transactions are relatively rare, low bandwidth, and easily compressed files, swapped at most once every few tens of minutes.

Rate limits, <80% exchange rates, absence of deposit capability, and optionally any WORLD server imposed taxes, prevent economic volatility at one WORLD server from spreading to other WORLDs. Possibility of severe damage to player's account balances is also prevented. Attempting to deposit from multiple WORLD servers at a rate above limits of one WORLD server is precluded.

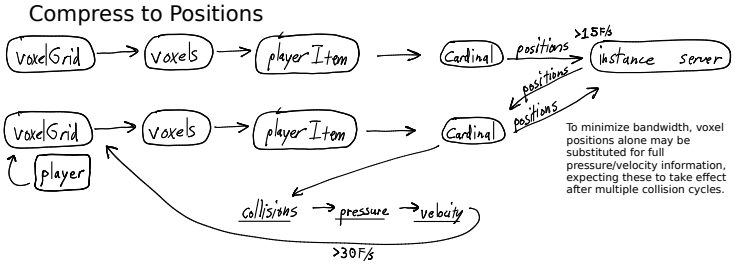
Compromised or malicious accredited WORLD server cannot deposit funds without a withdrawl request initiated by a player at other WORLD server, and only a small fraction of a player's financial balance or monthly earnings can be withdrawn from any WORLD server per month.

WORLD servers festering bigotry against player play styles (ie. severe inequality and lack of legitimate PvP activities resulting in PvE oriented players having no options for protection from unwanted random PvP hostility), otherwise inhibiting diversity and quality of life, or offering unintended brokering services to trade valuables beyond expected limits, will be noticed and lose accreditation.

Algorithms

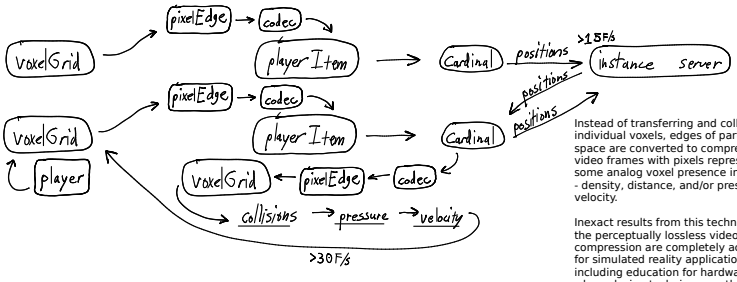
Simulated Reality (Voxels)

Compress to Positions



To minimize bandwidth, voxel positions alone may be substituted for full pressure/velocity information, expecting these to take effect after multiple collision cycles.

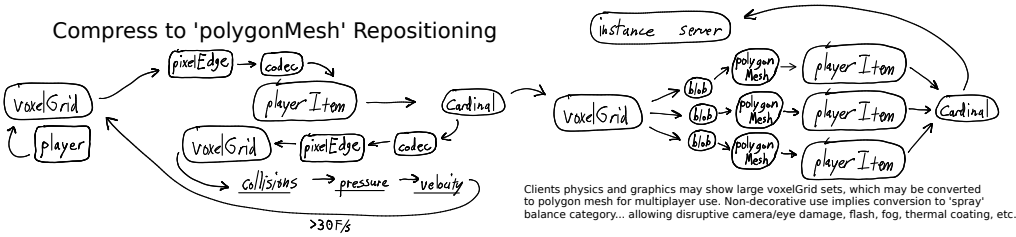
Compress to 'pixelEdge' Video Frames



Instead of transferring and colliding individual voxels, edges of partitioned space are converted to compressed 2D video frames with pixels representing some analog voxel presence indication - density, distance, and/or pressure, velocity.

Inexact results from this technique or the perceptually lossless video compression are completely acceptable for simulated reality applications, including education for hardware design, where design techniques, rather than exact designs, are most relevant.

Compress to 'polygonMesh' Repositioning

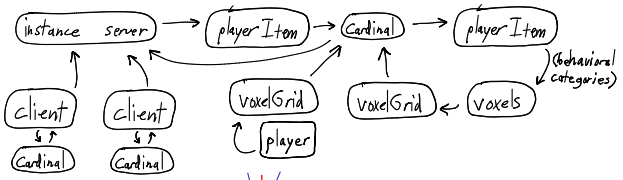


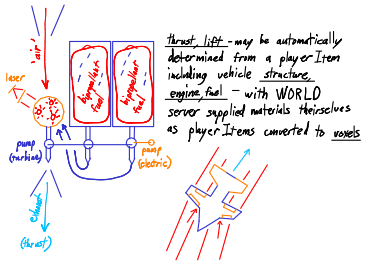
Clients physics and graphics may show large voxelGrid sets, which may be converted to polygon mesh for multiplayer use. Non-decorative use implies conversion to 'spray' balance category... allowing disruptive camera/eye damage, flash, fog, thermal coating, etc.

Sharing voxels brings 'simulated reality' capabilities, rather than 'virtual reality' at a cost in bandwidth, hardware computation, and software development, comparable to the computations performed by cognition that would use such 'simulated' or 'virtual' reality. Approximately 100Mbit/Second per player bandwidth expected from voxel grids as cubes with sides as video frames, rather than the ~100kbit/Second per player from repositioning a polygon mesh.

'Simulated Reality' using voxels is worthwhile, given the substantial benefits.
*) CAD modeling by sculpture, manufacturing methods, or iterative sense of correctness from neural interface.
*) Fluid physics simulation as deterministic large numbers of consequential events instead of decorative visual effect converted to few consequential events.
*) Vehicle thrust/lift analysis.

'Virtual Reality' also benefits from some fluid physics simulation, with at least local force feedback, and some consequential events (eg. flooding a previously habitable area with liquid).





thrust, lift - may be automatically determined from a playerItem including vehicle structure, engine, fuel - with WORLD server supplied materials themselves as playerItems converted to voxels

DISCLAIMER: Plausible concepts, attributed sources, oversimplifications, resonably. Rigorous mere academia NOT primary.

errata

_ Terms _

'WORLD'
 Perceived WORLD. As in 'virtual' WORLD, that other reality 'real' WORLD, etc. Not necessarily just one planet, may include multiple planets, stars, etc.

'instance'
 Shared channel for players in nearby space to share 3D positions/objects/etc (sometimes aka. 'shard'). Players in strategically important regions of space must be assigned and must not be able to intentionally avoid, shared same instance.

'jump drive'
 A teleport interactive device to move between WORLD servers. Usually an IP address.

'accredited server'
 A WORLD server known to FOUNDING WORLD servers from which more rapid trade may be accepted.

'reputable player'
 Having been around a while, proof-of-cognition, not automation (less diplomatically put, not an automated 'bot').

'high-stats player'
 Slight increases to maneuverability limits given to players who have been successful over a long time, and presumably prefer to work with other capable players.

'aerospacecraft'

_ Rough _

*) Penalties to player stats or other penalties (on relevant WORLD server - stats may not decrease at other servers), for death/demise, should be relatively severe, possibly person weeks of setback from useful participation with other high-stats players. Such ongoing risk should motivate players to protect team members as well as theirselves more diligently, and help improve player motivation. Stats penalties may be more relevant to 'swordland' WORLD (due to informal ambush). Monetary penalties may be more relevant to 'galactic' WORLD (due to large fleets with high losses and appropriately hazardous long distance logistics).

*) Better tools to create more diverse player-driven WORLDs discourage the simpler pre-packaged shallow gameplay that leads to addiction and festers bigotry against any players with a playstyle (eg. PvP) perceived to disrupt that addiction.

*) CARDinal's emphasis on importing object behaviors from external programs in real-time, is expected to promote development of more modular software any single developer can use to add some bits of diversity of all plausible shapes and sizes among many balanced classes of avatars/vehicles/tools/etc.

*) CARDinal player clients must sort graphical objects (ie. 3D models) by file size and rendering time, substituting with degraded models when framerates drop. Players are expected to have strong incentives to encourage other players to create avatars and vehicles reasonably low-poly for compatibility with common hardware and software.

*) Programs for 'command prompt' terminal emulators, text editors, filemanagers, VM/VPS connections, screenscraping, and text chat, are needed with CARDinal 'playerItem', instead of X11/MSW as the framebuffer output. KWrite, KDE Dolphin file manager, Xournal, VirtualBox/Qemu, VirtualDesktop/OVRDrop, Moonlight, developers, may already have relevant software, expertise, or user interface paradigms. Compatibility with '_userVBox' is especially important for connecting VM to IPC through known serial/COM/UART ports.

*) MCU/Arduino framebuffer and Klipper firmware, and similar, simulation, as an example, would allow some useful hardware and software design development more conveniently and without having to purchase such hardware, for some developers.

*) Player names should not be visible by default. Some combat, duel proposal, etc, must occur first. This prevents personal harassment.
 *) High-stats players might optionally share extra info *only* with other high stats players.
   *) This maintains the risk that any player could be high-stats, and a major risk to attack unprovoked.

*) Jump drives can move player avatars and aerospacecraft to reach other end-user WORLDs - these can accept IP addresses. FOUNDING WORLD servers may accept some very limited rate stats progression and very limited transactions from end-user WORLDs.

*) Navier-Stokes differential equations and such represent simple relationships. Reasonable approximate solutions should be much easier to explore with the voxelGrid software allowing VR users to quickly and intuitively test algorithms.

*) Better gameplay, not longer gameplay is rewarded. Rebalancing of PvE monster stats and such to allow a reasonable rate of player victories per hour, is an adaptive test by CARDinal. Playing at a higher disadvantage results in much faster stats progression than a similar number of victories with less determination. Supportiveness between cooperating players should similarly be rewarded with more success against higher difficulty, and much faster stats progression.

REVIEW - May be duplicative from (another) part of (another) document.

*) MAJOR - Non-directional muscle tensioning (eg. facial expressions, 'make a muscle' arm muscle tightening) is specific to only a few muscles - between ~30 and ~50 total muscle position 'bones' at most - and requires no mechanical skeletomuscular simulation.

*) Players might be able to order from restaurants in VR, and have delivery services bring the physical food directly to them, without leaving VR (using a CAVE possibly combined with other concurrently available VR headset/interface).

*) Safe zones may be necessary in towns solely due to possibility of low-stats players not always having overwhelming numbers to confront a small number of hostile high-stats players. Only applies to more 'organic' WORLDs (ie. 'Swordland' planet). Open space (ie. piloted vehicle combat in galactic space) is NEVER a 'safe zone', with any protection of low-stats players by escort services (usually from player corporations in corporation held territory).

*) MAJOR - Amortal lifespan. Even with continious training, player stats may peak at ~10years of life, drop gradually to 50% of max at ~20years, and remain stable from there until ~30years, dropping sharply to a reset. This forces high-stats players to periodically restart their careers and possibly consider some change of profession.

Elaboration regarding otherwise already noted concepts.

*) MAJOR- Players performing economically significant activities (eg. logistics transport, mining, facility destruction, etc) must not be able to intentionally avoid instancing with hostile players in nearby space. At the very least, CARDinal must assign players in strategically important parts of space to same instance servers, and occasionally reject positive results as an intermittent tax if separate instance servers were somehow used for such space.

*) MAJOR MAJOR - FOUNDING WORLDs must NOT use Ordinal ranking, due to risk of destabilization, risk of taking players to 'lowest-common-denominator', and risk to the credibility of VRMMOs. Most WORLDs should not use Ordinal ranking for their economics either, due to risk of destabilizing large parts of the VRMMO playerbase.

*) Cardinal numbered player stats stabilize proof-of-cognition economics/ecosystems, limiting amplification without limiting individual behavior, testing numerical superiority of competent players allied by common interests. Ordinal ranked player stats *destabilize* by amplifying fluctuations in very small (parts per thousand) differences (slightly stronger players always winning 1v1 contests) between very few (possibly not entirely competent) players. Realistically, in an open world, 2v1 is and should be unlikely to prevail, where 1v1 scenarios only occur naturally as a rare but important final contest after players have been outmaneuvered away from larger groups of players.
*) MAJOR - Sports constrain playing fields to less than open-world. While this can be useful for training sharper reflexes and the ability to complete the closest approach in a contest, sports are not a substitute for 'real-life' problem solving dynamics inherent to an open world. Competence in both long-range and short-range is an important life experience.
*) MAJOR - Ordinal ranking is notorious for motivating 'athletes' to a fault. Complaints over what qualifies as reasonably safe/effective 'performance enhancement' endanger the credibility of both technology and sports. VRMMOs depend on significantly expensive and diverse technology (eg. VR headsets with substantially different resolution or field of view), and arguments of 'performance enhancement' risk encouraging consensus among players to a 'lowest-common-denominator'.

*) CARDinal WORLD servers are *expected* to make regular publicly accessible backups of recent history (eg. corporate ownership of stars, substantial asset approximate locations). CARDinal, unlike blockchain, assumes failures *will* occur, including 'purchased' undue influence (ie. hiring players through 'upwork'). Because WORLD servers only act on matters of public record (eg. player 'foundations' equivalent to land deeds), the public is free to fork a WORLD at any time, based solely on this (possiblys somewhat limited but adequate) information. Bad incidents are simply rolled back a bit, or result in parallel WORLDs continuing much like Schrodinger's cat.

*) Deep archive and caching service. Players normally keep all their own objects (eg. vehicle 3D models) locally, sharing with other players as necessary. If other players or WORLD server do keep a cache of such objects for some reason (eg. persistent objects atop 'foundations', these could be uploaded to such a service as Amazon Glacier to retain for at least a decade. Such archiving would reduce risk of players unintentionally losing valuables due to local computer failures. Such archiving could also be applied to the small files pertaining to WORLD server public records, reducing risk of losing the proof-of-cognition invested in the WORLD itself.

*) Avatar 'quantum tunneling' out of a moving vehicle (ie. player avatars repeatedly appearing to be a few frames behind their vehicles) theoretically should be solved by 'time dilation' applied to vehicle, however, adequate framerates may be impractical. Referencing player avatar position to vehicle position is a well justified workaround.

*) Processed human interface (ie. mechDive, nerveDive, HOTAS, position trackers, software emulation of position trackers based on legacy VR controllers, eye tracking relative/absolute movements, etc) goes through CARDinal just like any other netcode messages. Only optical rendering output (ie. VR headset), camera (ie. VR/AR passthrough, telepresence), hand tracking, go directly to game engine, and only for 'specialized' use (ie. DisplayPort only accessible through legacy GUI software interfaces).

*) WORLD server standalone executables, modified CARDinal code, etc, are expected to remain inconsequential enough, or must be published, to allow public forks of a WORLD server at any time. A physical WORLD server's value (and proof-of-cognition economic reserves) is from its reputation, not irreplaceability. Any actually irreplaceable WORLD server should be avoided as undependable.
 *) MAJOR - Commercial operators are *STRONGLY* encouraged to charge at least a small (eg. $10/mo) subscription fee for sustainability. Players should be extremely wary of servers NOT charging such a fee.
  *) MAJOR - Making $10/mo in stock market capital gains is pretty trivial (ie. S&P 500), so it is entirely possible to 'set oneself for life' at a reasonable capital expense.

*) MAJOR - Wealth is taxed, as gameplay may need a greater degree of consistency. Any player account with much unspent finance or a high net worth is taxed at an exponential rate, which precludes any player holding more than a few months worth of liquid assets.
 *) MAJOR - Stats remain as earned, untaxed. Sharing of accounts is expected as occasionally unavoidable but extremely obvious, non-routine, and only used by the most blatant of tryhards, quickly caught and limited, reset, etc, to the extent appropriate.
  *) Some players may change their habits more frequently or may have an excuse (ie. recent injury) for a sudden change in their statistical positions/rotations patterns. Careful statistics will be required to properly identify remaining habits, and some WORLD server moderators may be needed to address such cases.
  *) Players changing their habits substantially enough are in effect becoming new characters, so absolutely guaranteeing unlimited access to old character stats when player habits change may be unnecessary.

*) Cryptocurrency is NOT part of CARDinal, nor used by CARDinal in any way. The conversion system functions more equivalent to a 'cheque' banking system. Should a more decentralized system be required, barter is that.
 *) Barter between players in WORLD is regarded as a transaction. A few items per day. Ridiculously high value items (more than a person-month worth) are not part of FOUNDING WORLD, and the economy of any WORLD with such items is still limited to normal trade limits with CARDinal compliant WORLDs.

*) Vehicles/Tools/etc themselves may have complex adaptive algorithms, following the tendencies and verbiage around the player. A significant benefit of everything as a separate executable program.

*) VPS providers can be used for avionics and personal computing. Cloud services are supported by 'ubiquitous bash'.

Reference

WARNING: Extensive research notes here may be less recent, less accurate, less complete, internally inconsistent, and misinterpreted.

errata-more

Cardinal
*) Delegation and interoperability through real-time netcode.
 *) Cross-play between open-source compatible coarse terrain/avatar/tool/vehicle (ie. glTF models, basic fog) mixed with 'proprietary' game engine assets (ie. Unreal/Unity/CryEngine/Lumberyard grass, fluid physics, etc).

 *) Custom player avatars/tools/vehicles.
  *) FA18C as client-side module with only flight model limits enforced by anti-cheat.
   *) Canopy 'towel rack' replaceable by 'transparent force field' for VR users.
 *) Categorical balance (alternate less-than-category flight models allowed but limited to maximum turn/acceleration rates).
  *) Combine a player's choice of 'avatar', 'body size', 'swords', 'bullets', and 'guidance' all still 'testing' the players to determine the relatively strong, with manuverability and such statistically to ensure relative fairness in a single WORLD.
   *) Balance between 'swords'/'bullets' with slightly 'bullet magentic' swords achievable but not mandatory. WORLDs may choose to allow such player flexibility ... or not.
    *) Playing it out, at long range good snipers have to rely on their cognition to anticipate moving targets with first shot, at mid range ambots would be a negligible advantage at full auto, at short range, fixed bayonets or swords may be near equally favored. Statistical balance of mid-range between swords and full auto ranged weapons may necessitate some 'parrying bullets'.
  *) 'Bombs before bombers, bombers before fighters' 'fluidic space' mechanic equivalent to Descent Freespace with fully customizeable ship appearance and flight model subtleties below maximum maneuverability limits.
  *) Mathematically perfect anti-cheat if small projectiles are allowed to 'auto-aim' up to short distance (ie. few inches) away from player 'avatar' and subsequently limited to 'pure-ballistic-trajectory' (slow moving camera drones excepted).
   *) Medium-to-long distance still evadable.
   *) Mathemtaically perfect anti-cheat is from the notion that aimbots merely adjusting the timing of a trigger pull by a small amount may be difficult to detect, while simply allowing a very small amount of auto-aim, but not sufficient to substantially reduce the need for accurate aiming, would eliminate the rare situation in which such aimbots could confer any slight advantage that could otherwise accumulate to a player having a higher score than another
 *) Distinction between limited motion (ie. anti-cheat) 'bones'/'tools'/'vehicle' polygon mesh objects and 'decorative' 'player items' allowing highly physicalized effects.
 *) Commanded 'avatar'/'tool'/'vehicle' 'motor inputs' motion as only input.
  *) Unlimited player flexibility in 'HOTAS', 'full dive', or similar interfaces.
  *) Tactile output based on 'decorative' 'player items' (not shared) collisions for 'full dive' VR interfaces.
  *) Ship computer and flight instruments as 'decorative' 'player items' allowing full-fidelity 'historical' or 'experimental' simulation, even from full Virtual Machines or other 'desktop screen scraping'.
 *) Degradation to approximately 'two byte' per object rate of acceleration changes and essential object updates only - when necessary or appropriate.
*) WORLD server interoperability, delegation and fallback.
 *) Limited inter-WORLD 'foreign' currency exchange rate.
 *) Clear delination of 'public' spaces allowing 'crowdsourced' full backup including cached public player items.
 *) Robust recent transaction lists for double-spending prevention with no long-term history (though complete records may be available), allowing complete WORLD server reset to previous information when necessary (unlike the expectations around permanent blockchains with much smaller amounts of information and processing).
*) Preferences in 'lifestyle' or 'profession' accommodated by some cross-over of currency or stats progression on one WORLD server translating to bonus 'earnings' rates on other WORLD servers, allowing players to focus mostly on a specific role without being limited to that exclusively.

Cardinal's fundamental real-time premise is that any player activity based on *rendered* information rather than game object centroids must necessarily demand the visual, probabilistic, and maneuvering problem solving which may be more enjoyable to conscious beings employing *cognition* than mere 'pocket calculator' arithemetic suitable to *automation*. Consequently, any player enhancement - including automatic 'aiming' or use of artificial neural networks - is NOT considered cheating. In fact, Cardinal may specifically allow 'player items' to maneuver on their own up to some distance from the player (or indefinitely for mere imaging and decoration). Of course, decorative items relative to a player (eg. interactive avionics screens) may be 'blind', using only the player's own centroid position self-reported to programs connected to a local IPC bus (eg. VM).

Cardinal attempts to keep public records to ensure longer-term robustness. In effect, redundant backups of an entire WORLD to recover from any abnormality are 'crowdsourced'. Anyone who wants a copy - perhaps to run a parallel WORLD or to drop on the likes of Amazon's Glacier Deep Archive service - may be able to obtain this in compact version-control friendly form. WORLD servers are encouraged to make public terrain data, cached public 'player items', player transaction balances, etc.

Cardinal rules between worlds emphasize a combination of general competence and personal preference. Transactions between servers are available on a cautiously limited basis to allow some trade between such players as shop keepers in one WORLD, and pilots of another WORLD. Stats progression on one WORLD server may carry over as a bonus to progression rate on all other WORLD servers with no 'double spending' limit. Total lifespan of a player's character over decades may be figured into stats progression with a steep decline after some decades or a full reset after defeat on any ACCREDITED WORLD server. Thus, if actually desirable, such concepts may offer a step towards preserving the meaning of long-term 'mortality' in the context of the 'amortality' consequences many players may already be briefly accustomed to.

Cardinal's most important purpose may be to provide limited long-term stability towards ensuring unlimited dimensions of interpersonal activities between players. Players are distinguished from bots by the proof-of-cognition nature of WORLD challenges (PvP, PvE). Anyone spending a sufficient fraction of an amount of time successfully earning the 'per-person-hour' statistically balanced currency over a single time interval (ie. 2days/1month) is on a binary basis assumed to be a single person (less diplomatically, not a bot). Should Cardinal's default proof-of-cognition currency or accumulation limits be suddenly overrun in some way, alienated players are expected to move to forked replacements of affected WORLD servers.

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Please consider not underestimating the value of a proper Cardinal system in reducing the significant development hassles of

proper netcode, entity management, and InterProcess-Communication bus architecture. Starting a project from Slackware may seem like a quick approach to the inexperienced, but understanding the basics of Gentoo ebuilds pays off extremely well even for short-term experimental projects. Moreover, achieving *adequate* VR immersion has many subtleties that would not have been obvious a few years prior - such as the exact extent of the lack of need for accurate skeletal muscle modeling. Cardinal reflects considerable experience in modern software architecture and VR principles.

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A 'lightweight' Cardinal implementation may apply custom flight model limits (ie. categorical balance limits), client framebuffer items, and tactile (or force feedback) collision detection items, to proprietary game assets, leveraging proprietary netcode if desirable. Particularly, this may be useful for early implementations of 'full dive' features with proprietary resources.

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*) Haxe and related.
 *) Now Protocol Buffers .
  *) Just get to an internal '_bin' function accessible from netcode through some interpreter or forward declarations or magic number catch across every input function, or something.
   *) Something like a 'case' statement or repetated 'if' statements might catch a 'magic command' into appropriate functions... that is nicely portable at least.

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*) Subscription only features (ie. $$$/month). Subscribing players may be given faster stats progression, and unsubscribed players may be shown line graphs and lists of things they would have been able to do with a subscription.
 *) MAJOR - Outright giving advantages (ie. premium tools) or cosmetics is NOT consistent with CARDinal, and must NOT be done.
 *) When WORLD server and such are adequately funded to cover all expenses and liabilities, subscription only features may be enabled for some random players.
 *) Previous subscribers should be given a one month 'grace period'.

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*) Attraction, Selection, Attrition applies to player groups and professions hosted within WORLD servers, not to WORLDs themselves. WORLDs should attract the most diverse playerbase possible.

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*) Prior art (literally). Player clients should report their own and others 'playerItem' to WORLD server public record. Server is a third-party record of player avatar/vehicle/object/etc uploads/dates/hash, especially avatars, when introduced in public places (on instance servers these are never sent upstream and only to clients). This establishes who uploaded first, mitigating questions of authorship, attribution, infringement, etc.

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*) MAJOR - 'Rough' terrain includes 'fog' to substitute for lack of flora/fauna detail. Unreal Engine and such may use vast libraries of 'visual effect' plants/animals (eg. forests, flocks) to more realistically obscure monsters.
 *) Because this is either PvE or at most 'lost tool in the grass', CARDinal only detects cheating by identifying normal distributions of productivity data, so a normal distribution associated with reported cheating may simply be 'nerfed'.
  *) Hourly income limits and wealth tax apply as always anyway, so there is little benefit to such cheating.

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*) MAJOR - Terrain collisions are detected by large numbers of objects being sampled for any collision at all. Player avatar collisions are done between entire avatars, tools, vehicles, etc, with detailed processing being done only between players in physical contact or causing effect (eg. damage). Such detailed physics may be done as a byproduct of the CARDinal physics processing (used at lower fidelity on only filtered necessary information for third-party anti-cheat), or part of game engine, etc.
 *) CARDinal netcode must be able to pass shared-memory framebuffer locations of course, for the appropriate texture surfaces...

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*) Wealth transfer. CARDinal specifically protects 'professions' and NEVER facilitates major transfers of wealth.
 *) MAJOR - Partly why CARDinal differs from blockchain. Having everyone sign the whole ledger allows a transaction to include an arbitrary amount of tokens.
  *) MAJOR - Capital ships (ie. carriers) may need to be jointly owned by multiple players. Corporations may achieve higher

spending limits, only by aggregrating *active* players limits. Thus, transfer of capital ship assets has a real transaction 'cost' to the entire playerbase involved.
   *) MAJOR - ALL transferrable assets ALWAYS have a price, to enforce limits. Non-liquid assets (ie. 'swords') might have higher values, but only to a point, to limit trading of players own accounts.

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*) MAJOR - Assets are controlled simply - complex scripting beyond physics/flight model not required. Avionics are NOT game assets, these are handled as a combination of user framebuffers, user input buttons/etc, and motor outputs to 'guide' an asset's behavior. Motor outputs MUST be in netcode format. Thus, these are ALWAYS handled by InterProcess-Communication, which allows them to scale to multi-terabyte VMs, GPGPU, etc.

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*) Stats ALLOW double-spending (progress on one server is limited progress on all). Currency must be checked to PREVENT double-spending. Non-liquid assets MAY be transferrable. Consummables ARE transferrable.

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*) MAJOR - Text Editor - CARDinal netcode protocol is to include - as an EXAMPLE - a standalone text editor program using an interactive 'playerItem' through IPC. Perhaps the individual characters will be regarded as separate object to update in the 'database' . Perhaps the 'database' will be read out periodically in full after too many 'updates' to ensure synchronization. Such may be a great way to test CARDinal protocol usability and consistency.

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*) 'Right to be forgotten'. As WORLD servers are expected to only have matters of public record, may not be relevant. Anti-cheat statistics are not expected to require individualized information. History of moderation actions on a user (eg. excused from anti-cheat account trading prevention due to injury changing habits), login credentials, etc, might be relevant.

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*) CARDinal real-time latency must always be kept >150ms, to ensure cognition inherent PID tuning is already well adapted to the approximately 200ms worst-case fiber optic latency present on such a planet as Earth .
 *) CARDinal coordinate update netcode (relative updates only not absolute confirmations) must be completely separable - marked by unique header/size/end codes - to allow priority routing over scarce bandwidth.
 *) External flight model programs may be simplified by having their own PID tuning not subject to jitter from network latency.

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*) Game masters may be appointed to create Quests/Tasks, and given some unique authority to replace terrain files (with more detailed or quest specific terrain) for parts of planetary surfaces.
 *) As always, all terrain files for all engines, including rough terrain for visibility anti-cheat, must match.

*) 'All bonus to one' mechanic avoids inflating the proof-of-cognition balance, provides a unique incentive for quests, and adds another dimension to the player trading economy (ie. hiring players into a team).

*) MAJOR - Quests are NOT expected to have a 50% first time probability of 100% survival success for five-member parties of the top percentile of high-stats PvP players. Quests are expected to provide an opportunity for challenge BEYOND the 'PvE monster hunting' and such all players may participate in. Difficulty should be high.

*) MAJOR MAJOR - Highly reputable game masters may be occasionally given the chance to create a 'ridiculously high stakes game' - to burn down much of the world if they so choose.
  *) CITATION - Admittedly, this may have been inspired by the SAO 'Caliber' arc.

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*) MAJOR - In addition to player equipment/avatars/vehicles/etc, players may put own items atop foundations marked 'public', or atop their own foundations, or within their own vehicle (or of course on their own avatars). In this way, public bulletin boards may be created, and players may permanently store objects physically.
 *) FUNDAMENTAL - However, players are always to have own copies of their objects, accessible from item storage, including those left in public places, in case of deletion or loss of WORLD server.

  *) There is to be no 'immersion timer' for pulling objects from remote places, and objects can of course be duplicated instantly as well. Decorative items may be 'teleported' instantly by something like 'jump drive' to a location near the player's avatar.
   *) 'Decorative' items (including real-time computer monitor/VM displays) only, not 'tools' or 'consumables' which have economic value. Actually having to fly a vehicle to the desired location, or at least having some economic cost for teleportation service may be appropriate.
    *) Immersion timer still NOT appropriate.

*) MAJOR - Corporations may win ownership of significant portions of land, including 'towns' where player 'foundations' (ie. houses, apartments, etc) and where quests, have already been established. Such corporations may have unlimited authority to further limit trade, income, quests, foundations, etc, as well as to appoint some of their own 'game masters', with expanded powers to reshape terrain within voxel established limits.
 *) MAJOR - In this way, WORLD leadership is intended to be highly meritocratic - leadership follows defensive capability.
 *) Limits - corporations can only limit or remove quests, not create quests/tasks. Likewise, corporations cannot change such economic constraints as sources of raw materials, locations of planets, and are not expected to meaningfully alter galactic trade routes.

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*) MAJOR - CARDinal - Eye tracking zoom. Activated by gesture, part of automatic enhanced vision system directing active sensor emissions, false color/wireframe, and zoom to where a player's focus dwells. Some low-pass filtering required.
 *) Slightly helpful for 2D desktop/VM use.

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*) MAJOR - Road wear by incremental voxel impact. Procedural terrain design technique.
 *) Or statistical measurements of travel applied as simple 2D texture imprint.
 *) Or by random mostly one directional walk, or by random sketching, as 2D image imprint.
  *) Idea is just to get something that is NOT merely a tileable image, for whatever that may be worth.

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*) Voice recognition statistical confidence combined in a phrase may be higher than statistical confidence that each word was recognized correctly. Absence of FLOSS voice command recognition software may be an issue more readily solved by command phrase recognition as such.

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*) Netcode messaging hidden object filter - other players only send hidden objects to some other 'neighboring' players for anti-cheat purposes, not to all players (to mitigate 'X-ray vision cheating').

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*) MAJOR - Netcode is human interactable.
 *) DUBIOUS - From BASIC to bytecode, objects may be created with physics and behavior scripts, roughly equivalent to FReespace EDitor (FRED). Primitive NPCs may rely on these behavior scripts (which must accept concensesus of multiplayer clients).

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*) CITATION - Contemplation of 'bytecode', coordinate spaces, bandwidth, etc, for CARDinal predates any awareness of 'Udon/VRChat' .

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*) Tournaments should be frozen at least for a reasonable time if any of the contestants have reasonable excuse.

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*) MAJOR - Gambling between substantial numbers of players may be economically destabilizing and may be limited.

-

*) Primordial terrain objects (ie. maps voxels) may have very high durability.

-

*) Module logic trace. VR environments can be very helpful to developers attempting to trace or diagram program logic flow, or connect programs together.

*) CARDinal display should offer a simple 2D interface to Swordland (ie. similar to classic 2D scrolling area RPG games for purpose of 'meeting' people through text chat).

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possible game mechanics

*) Battle opportunities will be limited somewhat (skirmishes most of the time, important fleet battles only a few times per week or so), to encourage enjoying life in VR beyond scoreboard kill counts. CARDinal should balance some short term stability between large player corporation conflicts through such mechanisms as periodic supply/demand constraints to cause some ebb and flow in logistics.

*) Winners of some events will be able to occupy habitats with favorable resources, possibly driving some real-estate value.

*) Discouraging appropriation of 'IRL' names, similar to EvE Online policy, is recommended. Public denylists usable by any server should be created collaboratively. Syllable filtering may also preclude meaningful words as names, but that may be undesired by players.

*) Voice Comms traffic must be highly compressed.

*) first step in development is cmd/vm access, with *realtime* script/code edit/reload of non-graphical systems (eg, reloading input/physics systems in place)

*) shopkeeper, merchant, and similar roles must still incentivize advancement... but these may allow a place for more casual players not interested in any form of combat

*) knife spinning on base of thumb... some things not possible should be scripted as 'fidget toys'... others like pen finger twirling should be exactly realistic (with force-feedback gloves)

*) Encourage players to train for precision, followed by speed. Precise aiming and speed run, timing completion of a practice course at 100% accuracy. Highly ranking players may be granted a special resource as acknowledgement of their efforts.

*) Bottom Feeders - Space combat at the top is warfare, piracy at the middle, and ... what are the bottom feeders? Fleet engagements will ultimately be about 'staking out watering holes in the desert', sweeping space for straggler shipments and controlling territory. Mining ships may be vulnerable if not in well protected friendly player corporation territory.
 *) There is a chance more complex operations beyond territory control may emerge... what matters is that the economics are multi-level food chains similar to real space.

*) Wretched Hive - Planetary surfaces are basically guaranteed to end up as such (swordland included), excepting any 'safe zones', with hostilities as expected.

*) Maybe require some physical stepping to move at full speed... this could be a great way to encourage adoption of force feedback hardware or other alternatives to stick/pad/button movement controls.
 *) Automatic leg extension while running fast...

*) In all cases, a reasonably equipped group of 4-9 interceptor types - not more tha 250hr capital 2.5/mo maintenance - should be able to score a kill on a single target with no chance of escape. This applies to all forms of PvP combat, including ground and space. The only exception will be hero ships, which will be one in at least one thousand.

*) all exchanges may be limited to in person only, even currency trades... corruption may be more visible this way

*) Loss of player corporation leaders, diplomats, and their logistics personnell may have such severe consequences that breakdown of alliance and infighting are probable outcomes.
 *) Like taking 30percet of the other corp's cryptocurrency and other liquid assets... including accounts receivables on the books.

*) parties are distinct from longer term corporate alliances - even corporate leades may take a leave to temporarily join a party

*) MAJOR - Five Races Trope - Unrealistically impractical specialization into characteristics that may have no particular reason for being, and definitely not appropriate for any WORLD emphasizing player customizeable avatars.

*) 13MPH marathon, 15MPH mile, 30MPH sprint, 50inch jump

*) Energy consumption is drastically raised at higher speeds. This gives VR diving players an opportunity/excuse to rest from fast motion, as keyboard/mouse players do not experience physical fatigue. Without FFB, the energy consumption rate would be shown as a bar.
 *) Walking speed or less average energy consumption is automatically regenerated. Beyond that, hunting and gathering in-game is *required*, with the bio-energy bonus being strictly nontradeable. At most 3hr of such hunting/gathering can be done per day, to a maximum of 30hr sprint reserve, usable at only 2hr per day. In practice, this will limit players to mostly walking speed, with burst beyond that being as conservative as possible. No exceptions.
 *) Keep in mind that 40mph running speed for 2hr corresponds to an 80mile distance per day... perhaps already too much... since this is somewhat a 'comfort feature', marathon distance might be better...
 *) Aside from rest, this also ensures players put maximum effort into competive situations, not running around towns ridiculously.
 *) Work time is limited per day to discourage too much PvE. Allowing a full recharge in 2hr is fine.

*) It is expected most players will reside mostly in the 'swordland' WORLD - providing them desirable habitat *is* its purpose.

*) Self-destruct to RTB definitely must not be possible. Either because there is no reason to do so or because of a severe penalty. This is an absurd mechanic of Elite Dangerous deep space 'exploration' which must be avoided.

*) Aerospace Fighters - Unobtanium (if not handwavium) Low-Waste-Heat Antimatter fuel. Atmosphere and thick nebula maneuvering enhanced. Maybe 500G acceleration. Payloads on rocket motors, emphasizing armor penetration. Pilots are amortal, and ship ordinance may be put in impact mode (though with the strong disadvantages of reduced penetration from only a single impact on a single point).
 *) Empty space battles must be rare. Finding cargo depots and the like in vast empty space may be very unlikely, and resources may be far more abundant around planets, dense nebulas, gas giants, or at least asteroids...
 *) Fighters may have to use area-effect ordinance to overwhelm point defenses, to the point any actual high density projectile on an efficient trajectory will not be detectable prior to impact. The physics of taking down carriers and cargo ships are likely very complex.
 *) Stars are not movable - such mechanics would imply such technology that ships would not be relevant in conflict.
 *) Kinetic weapons are dominant. All ships have expensive composite armor, which demands penetration.
 *) Big ships actually are still single pilot, albeit usually expensive player corporation assets, rearm/rearmor is by other ships. Big ships do not need the same kind of internal maintenance as fighters, so planetary landings are not necessary.
 *) Fighter refueling is a big deal - scouting large areas of space will usually be by flying the aerospacecraft, not dispatching swarms.
 *) Ultimately, space fighters could arguably exist because the aerofighter industry was simply scaled up in a hurry, spurred by FTL and better-than-antimatter fuel, with no opportunity to reorganize.
 *) Backstory is no backstory as usual. The humans chose to create a competitive virtual world and live in that on purpose.
  *) Along that logic, availability of handwavium shields implies cheap fusion energy tech, meaning everyone wants their own ship, and the ships are usually small, not big targets unless hauling cargo and such.

*) Desktop Switching - File manager is root window for everything. Groups of windows are based on that.

*) Only lawful kills in open-world, tournament, other stats-penalizing conditions, may be counted.

*) Supersonic leap - number of steps or mid-air hops determines distance in a purely ballistic trajectory.

*) Sword lighting - holding a sword at fixed position gestures that a predefined replayable paw placement pattern will be used if the next paw movement is in an appropriate direction (off-direction to cancel). As an 'Original Sword Skill' program, usually client side, optional, player customizeable.

*) Just because aerospace WORLD does not reset stats (which are really swordland WORLD relevant) does NOT imply ships are expendable... all ship equipment is lost on destruction.

*) Swords are gyroscopically snapped to incoming bullets.

*) Teleports (swordland) are time locked to only work at quarter-hourly intervals.

*) Fairy wings shrink, not disappear. Same for pointing ears (active sensors) and similar.

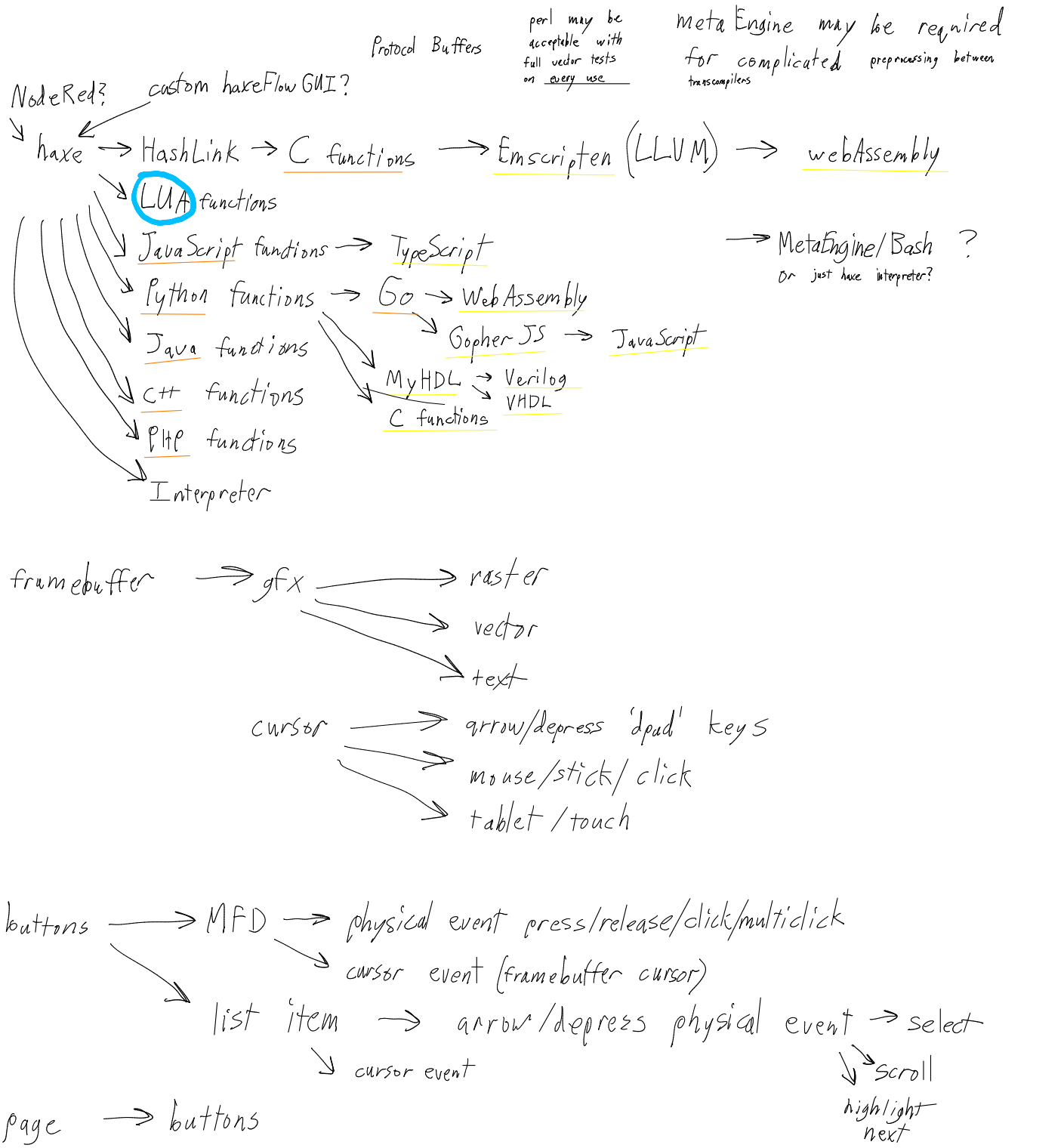
*) Footprint tracker... consider such resources (and other imaging enhancements) as sent by other clients in same instance, with usual anti-cheat detection by observing player clients, logs, etc.
 *) Ocular movements may activate related skills (EoG, eye tracking).

*) Space marines in the space based WORLD... along with galactic scale planetary landings... but all of the planets there being harsh terrain.
 *) Also mecha ... all the vehicles.

*) Carrier or other capital class ships should contain accessible sensor data logs from all landing craft as intelligence both used and captured by space marines.
 *) Necessarily, ambassador craft will be specialized to not have such logs, for meetings under truce without such risk.

*) Standalone VR with high-bandwidth but low-compute could receive 'decorative' objects obscuring lower quality graphics, rendered by more powerful computers on the same instancing server (when server bandwidth is sufficiently available).

*) Directional airflow effects (temperature, pressure, spreading out) should be discernable. Decorative collision detection objects must be sensitive to airflow direction.
 *) Particularly important for atmospheric wind.



u8glib?

CARDinal --> object benchmarks?

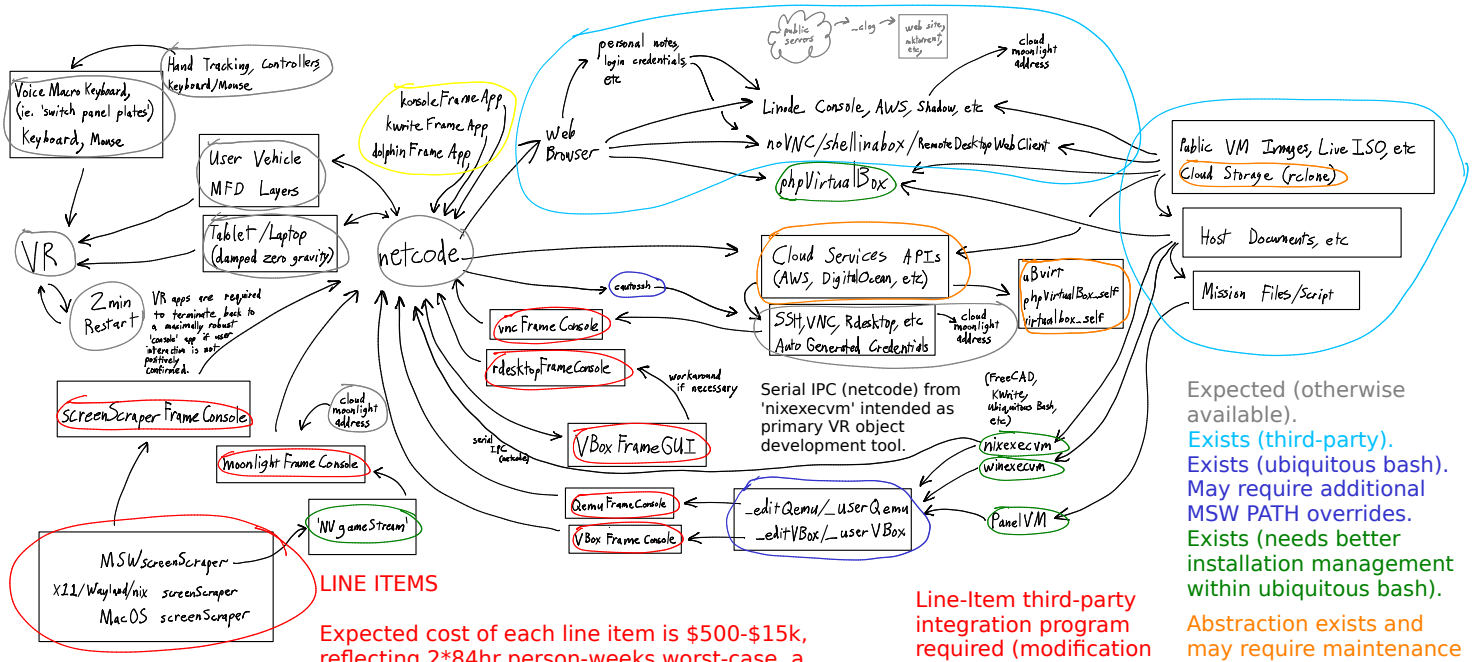
abstraction --> software/hardware UI, netcode, etc

WORLD dynamic objects, voxels, anti-cheat, physics, cross-engine terrain

TODO

- LUA interpreter function access?
- Protocol Buffers 'bin' fundion
- RPC? REST?
- Run packet through all fundions for a catch?

Protocol Buffers / Haxe Protocol Basic Example



Serial IPC (netcode) from 'nixexecvm' intended as primary VR object development tool.

Expected (otherwise available).
Exists (third-party).
Exists (ubiquitous bash).
May require additional MSW PATH overrides.
Exists (needs better installation management within ubiquitous bash).
Abstraction exists and may require maintenance (ubiquitous bash).

LINE ITEMS

Expected cost of each line item is $500-$15k, reflecting 2*84hr person-weeks worst-case, a $120k worst-case total (assuming relevant codebase familiarity per item). Not a substantial expense compared to the value of ensuring adequate 'traditional' 2D application functionality.

Line-Item third-party integration program required (modification of existing open-source).

FOSS native 'Linux' and 'MSW' implementations strictly required for all line items.

A few lightweight apps ported directly to netcode compatible framebuffer interface on both clients and servers may assist development of VR objects from clients incapable of useful 'screenScraper' or even 'InterProcess-Communication'.

Wayland protocol is NOT to be used by 'FrameConsole' and similar. Only a shared-memory triple-buffer of display frames in the exact resolution of the underlying display, and keyboard/mouse events, are to interact with 'Game Engine'. Display resolution change requests are explicit and NOT 'window resize' events.

Secondary to 'nixexecvm' functionality, some VR objects developed with that method (eg. chisel, kwriteFrameApp) are expected to modify other VR objects (eg. marble, netcode script) allowing netcode assisted voxel-to-polygon conversion VR object development.

DISCLAIMER: Plausible concepts, attributed sources, oversimplifications, resonably. Rigorous mere academia NOT primary.

lithoDive

Desktop automatic multilayer photolithography prototyping for 3D printing (ie. resin/electroplating/casting, multiphoton, deposition/etching, etc), flexible PCB manufacture, and transistor circuitry (eg. CMOS) fabrication. Techniques for maximizing overlay precision, minimizing capital cost, and manufacturing machines to make machines as may be necessary or as may workaround availability. Compatible with 405nm-10nm, <50nm@193nm multiple patterning linewidths, <5nm@193nm overlay. Maskless, or in-place mask manufacturing and swapping. Slow fabrication and inefficient consumables use may be justified by 'lights out', compact, low-capital, self-contained, small volume manufacture. Emphasis on production of open-source wetware/neural/mechanical 'full dive' interface - CAVE displays (ie. large LCD/OLED panels), flexible PCBs (including interconnect 'ribbon' cables), GPU, MCU, mechDive tunneling, and mechDive exoskeleton, hardware.

Convenient rapid prototyping of electronic circuitry, and small-volume manufacture of unavailable components, without user intervention, at the highest useful resolution possible (<2nm overlay), is now feasible. At the very least, such hardware should provide a more approachable, more educational, opportunity to experiment with modern photolithography optics, etching, and transistor circuitry manufacture.

Introduction

Where the tradeoff of reducing from very large, very expensive, factory machines, to 'desktop' prototyping, is expected to fall, is the 'field of view'. Rather than tens of millimeters and hundreds of gigabits of patterning, an area of as little as a micrometer diameter and less than one kilobit is expected to scan slowly across a workpiece.

Three issues are expected to predominate design of such a prototyping 'desktop' fabricator, when used at (ie. <100nm) high resolution. At low resolution (ie. ~300nm), none of these issues are relevant, with resolution and conveneince still useful for tasks substantially beyond commercially available services (eg. sub-mm resin 3D printing).

*) Overlay. Accuracy of alignment from previous imaging exposure to next, limits resolution, due to multiple patterning.
*) Mirror and Spatial Light Modulator surface accuracy, roughness, and reflectivity, if EUV compatible, mitigated somewhat by small dimensions and adaptive optics.
*) Dust. Mitigated somewhat by keeping all tools on one flat table which slabs can move across autonomously. At high resolutions, liquids and gasses used for polishing, coating, and etching, must be pure.

Much of the design software and relevant hardware has been deliberately proven by the successful 'TazIntermediate' project, and related projects before that.

Modern science and manufacturing technology has emerged a widely available plethora of hardware and software sufficient for individuals and small businesses to theirselves prototype all manufacturable technology, including making the prototyping technology theirselves.

*) Semiconductor lasers (ie. 405nm).
*) Pulsed YAG lasers (ie. tattoo removal lasers from eBay) for heating plasmas to EUV stimulated emission (at least if synchronized and possibly modified for semiconductor laser pumping).
*) Labs already having milliwatt desktop EUV light sources possibly already usable with suitable lithography tools.
*) Microscope objectives.
*) EUV flat/spherical mirrors (which may be sliced in half if necessary) (from Edmund Optics).
*) EUV mirror grinding and sputter coating to picometer flatness by interferometric alignment at longer wavelengths.
*) Assorted metal parts (eg. extrusions, brackets, plain bearings).
*) Linear and flexure bearings.
*) Expansion (ie. piezo) actuators and step-slip actuators.

*) PatchRap all-purpose stranded Cat6A S/FTP (shielded/foil twisted pair) cabling standards.

*) Software and VM integration (including filesystem and serial communications) by 'ubiquitous bash' .
*) Klipper firmware scheduling of mechanical and optical events corrected by low-latency computer feedback (eg. camera based computer vision of workpiece and overlay).
*) Connection of Klipper hardware serial networks to VM software serial networks by 'ubiquitous bash' .
*) VR 'hardware-in-the-loop' simulation through CARDinal IPC connected to Klipper hardware serial networks and VM emulated serial networks.
*) VR 'software-in-the-loop' simulation through CARDinal IPC connected to standalone executables with subroutines shared directly with Klipper firmware compiler.

*) Solid-state disks of high capacity for operating systems with all software installed and integrated.

*) Parametric Geometry (Sketch/Extrude/Assemble) by FreeCAD contained with 'assembly' modules by 'ubiquitous bash' .
*) Programmatic Geometry by OpenSCAD/TinkerCAD .
*) PCB layout geometry by gEDA with _gEDA_designer_geometry .
*) VLSI layout geometry by GNU Electric .
*) Bill-of-Materials (aka. 'BOM') hierarchical consolidation by BOM_designer .
*) Documentation by scriptedIllustrator, Xournal, with Qalculate and GNU Octave backends.

*) GravitySketch/MakeVR/etc for VR contemplation, rehearsal, demonstration of assembly, cabling, labor (if any), etc.

*) Building and testing of operating systems and installed software by 'ubiquitous bash' for RasPi, x64 BIOS/UEFI, LiveCD/LiveUSB, VM/VPS/Cloud, with hibernation snapshotting.
*) Software largely compatible as Linux Guest VM under MSW Host both managed by 'ubiquitous bash' (ie. 'ubiquitous bash' directly MSW compatible). Only very rare cases (ie. GravitySketch) standalone and proven cost-effective to use through MSW natively.

No manual conversions of information from fully parametric 'Geometry' (with Bill-of-Materials) to 'Stamp' (G-Code, photomasks, scale model geometry, etc, automatically exported).

No intervention from raw materials to prototype multilayer circuitry.

No need for particularly difficult to install, proprietary, or otherwise expensive software.

Convenient uninterrupted design work by people, while the rapid prototyping 'just works', is entirely feasible and appropriate.

Convenience, cost, availability, and versatility, have arguably been the limitations of existing desktop lithography, prototyping services, and existing products. Whenever possible, the narrow selection of microcontrollers, FPGAs, and similar components are used to approximate small portions of completed solutions worthy of a large manufacturing run at high capital expense and risk, which large companies may then be reasonably unwilling to carry out at all. Prototyping and small volume manufacture of some technology for niche users whose needs cannot be immediately met by existing resources, has remained elusive.

Desktop lithography (eg. e-beam, AFM) may not be convenient, slow with manual intervention between layers. CMOS prototyping services can be expensive (>>$10k) and possibly complex to work with, worth wholly outsourcing. Technically feasible fabrication (eg. of unusual LCD/OLED display dimensions/resolutions, sub-mm resolution 3D printing) may not be available as prototyping services, all capacity exclusively dedicated to high-volume manufacturing. Existing products (eg. MCUs/FPGAs/GPUs) may have dimensions too large for many uses (ie. ~2mm MCUs), insufficient performance (ie. FPGAs), may be unavailable due to supply/demand issues (ie. GPUs), or may be unusable for some purpose due to underemphasis of some single-threading performance or bandwidth (ie. CPUs, GPUs).

Presented

As may be plausible.

Sketch Illustrations

*) Tool - 'flatTool' - as a wall (ie. vertical Rigid Table) mounted to gantry. Heavy mass (>>100kg) acceleration allowed - taking advantage of inexpensive modern linear bearings, stepper/servo motors, metal frames, etc. Cube brackets as alignment stops allow tool to be dismounted from gantry within minutes for convenient assembly/maintenance. Multiple beampaths to same workpiece area (ie. combining - high-wear EUV low-NA mirror, low-wear DUV high-NA lens, electronBeam, scanningProbe, etc) may be possible .

*) Positioning hardware. Wide area (>1m), high speed (>50mm/s), high acceleration (>>0.1G), high precision (<1nm), accessible around all sides for fast assembly and maintenance.
 *) Gantry Six-Axis (Pitch/Roll/Yaw, X/Y/Z) on Rigid Table. Extreme precision (<<300nm) over a large area (>1m) by combining usual linear bearings with minimal gantry flexure, step-slip, and anchoring. Heavy tool (ie. >>100kg) compatible.
 *) Slabs with Six-Axis actuators - both expansion and step-slip - to move workpieces with extreme (<<1nm) precision.

*) Gantry may slide to ends of table, swapping multiple gantries to change tool, or may slide off end of table with or without tool on a quick change mount as well, for maintenance/assembly.

*) Cartridge associated with slab hardware. Workpieces never leave their moving slabs. Automatic loaders for FOUP (Front Opening Unified Pod, 300mm wafers), FOSB (Front Opening Shipping Box), and SMIF (Standard Mechanical Interface, 200mm wafers) industry standard cartridges may transfer to/from such slab cartridges.

*) Optical mounting and alignment hardware (low-cost).

*) Mirror, lens, workpiece (eg. silicon wafer) grinding tool.

*) Piezoelectric and thermal expansion actuators with battery protective and remote bias electronics for nanopositioning, step-slip, and adaptive optics.

*) Optical beampath - 'multiExposureTool'. Optical lens light source (spatial filtering, temporal decoherence, spatial decoherence), projection (shadow, beam shadow, beam steering), microscopy (beam splitting, beam profiling, low coherence tomography), etc. Modular arrangements optimized for compactness, low cost, and compatibility (possibility of using mirror microscope objectives for spatial filters and such up to 193nm).

Calculators

*) Fabrication time per area per layer - feed rate, field of view, power (watts, amperes, etc), dose (watt hours, joules, photons, coulombs, etc) per area.

*) Fabrication time for GPU, 'neuralBits'.

Conclusions

Overlay alignment apparently must be through the same optics/mechanics as exposure. Solid materials always seem able to expand at least several nanometers per few tens of centimeters under the best possible (<<1degC) temperature stability. Segmented mirror beamsplitters injecting long wavelength light, low power alignment illumination, scatter/morie camera observation of exposure illumination, etc, may be appropriate. Long-wavelength interferometry is comparable to subwavelength through-beam optical overlay, and has already been extended to the extraordinary resolution required to detect gravity waves. ASML's logo is a morie pattern, seemingly not for nothing.

Theoretically, pervasive displacement detection across all optical components, and better than EUV light interferometry, may allow accurate measurements of such small deformations (ie. <<2nm) between components for overlay between different instruments, sufficient to extend multiple patterning resolution. Actively feedback driven interferometers at longer wavelengths under high optical power and high resolution camera observation may be capable of <<1nm accuracy. Such would necessarily resemble gravity wave detectors in capability, distributing the high optical power across many pixels of a cryogenic sensor, correlating long exposures, statistically determining all full step boundaries, and ignoring any mechanical stepping information. Most obvious other particles for such measurements (eg. X-ray photons, electrons, neutrinos, heavy ions, etc) do not interact usefully for interferometry, scatter unhelpfully, cannot focus across long distances, are unproductively expensive, or otherwise cannot pervasively sample feasibly compact (ie. not astronomically large) beampaths.

Adaptive optics are possible, as piezoelectric unimorph mirrors coated for EUV, with low-latency correction by computer readout of overlay alignment.

Overlay alignment marks must be at regular intervals, more than one per field of view.

Practice photolithography exposures should not attempt to maximize pitch (ie. resolution) until a continuous means of testing (eg. continuous tape as workpiece, all resist spraying/etching chemical steps completely automatic, projection into another imaging microscope, scatter/morie camera) is ready.

Microphones should be attached throughout sensitive optical projection, calibrated to approximately measure nanometers of displacement by inertia, with frequency range of concern between the lowest frequency at which components vibrate independently through the highest frequency at which dampening takes effect (a passband much less than 1Hz-20kHz is expected relevant).

Nanoimprint lithography may multiply the productivity of a maskless tool. Interconnects may be patterned first by photolithography, then frequently occurring circuitry may be added between interconnects by nanoimprint lithography. Defective 'cores' and such may be disconnected from interconnects ablatively.

Resin/electroplating/casting at sub-mm resolution low-resolution photolithography is sufficient to substantially ease development of high-resolution photolithography and especially particleBeam/scanningProbe lithography. More than the small components (eg. electrostatic lenses, electromagnetic lenses) used directly, machinery to manufacture essential parts (eg. lens grinding tool, probe tip grinding tool, etc) could be revised quickly.

Full microstepping resolution does actually happen with heavy loads and has been measured by optical microscope at 3um from 8000um/(360/1.8deg)/16microstep accelerating ~10lbs by NEMA17 stepper motor (ie. TazMega) . Backlash when changing direction is typically a more substantial limitation, and highly compressed spring-loaded anti-backlash bolts may not be entirely adequate.

REFERENCE

https://www.youtube.com/watch?v=R4kh9T5L1XY
'sales revenue to service revenue'
Quite a lot of maintenance. Something to avoid for prototyping tools if possible.
'software' 'upgrades'
'45 million lines'
MAJOR - 'resolution' 'projection' 'k1' 'physical limit of 0.25'
'EUV' 'NA' '0.55' 'critical dimension' '8 nanometers'

https://wiki.hacdc.org/index.php/OpticalSubsystems
Standard axis heights!

https://en.wikipedia.org/wiki/List_of_laser_types#/media/File:Commercial_laser_lines.svg
ArF 193nm lasers seem reasonably easy to construct, flowing reasonably common elemental gas through electrical discharge.
Nitrogen 337.1nm lasers are even more easily and commonly constructed as an Earth atmospheric electrical discharge.

https://www.lasertack.com/en/200mw-375nm-laser-diode
Interesting drop-in replacement for 405nm laser diode.

https://optlasers.com/mounts/
https://www.lasertack.com/en/optomechanics
https://www.lasertack.com/en/adjustable-mirror-holder
https://www.lasertack.com/en/micro-knife-edging-/-beam-combiner-module
Many affordable optical mounts.

https://dberard.com/home-built-stm/
Affordable 'DIY' optical mounts.

https://hackaday.com/2015/12/10/esoteric-actuators/
Piezo buzzers can be repurposed as 150V/0.1mm actuators.
MAJOR - Crystal oscillators may be a higher quality source.
Piezo achieves full six-axis at least with independent power supplies. Unfortunately may change over time under DC bias.

https://hackaday.io/project/4986-scanning-tunneling-microscope
Cheap stepper motor driving a screw achieving theoretical ~6nm precision.

https://magao-x.org/publications/media/spie2018/Kautz_Manuscript.pdf
1 microradian ?
20nm/degC

https://www.youtube.com/watch?v=nMonZHMTra4
Elastomeric material and corner posts applying orthogonal rigidity. Really convenient setup.

https://rechneronline.de/sehwinkel/angular-diameter.php
Desired accuracy or precision - 0.1um , 10000um (1cm) , 10^-5radians == 10microradians

https://youtu.be/_w0Z2Y5vaAQ?t=662
https://www.youtube.com/watch?v=MdRwiI6VLmk
Step size of 100nm X/Y and 30nm Z demonstrated with autofocus capable 405nm lithography projector.

https://en.wikipedia.org/wiki/IMEC
Sketches presented predate awareness of IMEC's involvement.
'Neuropixels Technology'
'The performance of the Neuropixels probes and their potential for transformational neuroscience experiments was described in a November 9, 2017 paper published in Nature.[24] In 2019, The New York Times reported that imec's Neuropixels technology is widely recognized as the most advanced method of gathering data from brain cells.[25]'
'Brain-On-Chip Research'

Estimate - Photolithography Joules (Watt-Seconds) Constrained

```
  'photolithography_joules_cm2=$(_clc " 1000 * (1 millijoule / 1 joule) " )'
  'photolithography_watts=$(_clc " 0.01 * (1 milliwatt / 1 watt) " )'
  'photolithography_seconds_cm2=$( _clc " $photolithography_joules_cm2 / $photolithography_watts" )'
photolithography_seconds_cm2= 100000
seconds per cm^2.
```

Estimate - E-Beam Coulombs (Ampere-Seconds) Constrained

```
  'ebeam_coulombs_cm2=$(_clc " 10^-3 " )'
  'ebeam_amperes=$(_clc " 10^-9 " )'
  'ebeam_seconds_cm2=$( _clc " $ebeam_coulombs_cm2 / $ebeam_amperes" )'
ebeam_seconds_cm2= 1000000
seconds per cm^2.
```

Estimate - Scanning FOV Mechanically (mm/s) Constrained

```
  'fov_diameter_mm=$(_clc "10 * ((1 micrometer) / (1 millimeter))" )'
  'fov_speed_mmPerSecond=300'
fov_area_cm2= 0.000001

  'fov_seconds_cm2=$( _clc " 1 / ( $fov_area_cm2 * $fov_speed_cmPerSecond ) " )'
fov_seconds_cm2= 33333.333
seconds per cm^2.

  'fov_seconds_cm3=$( _clc " ( $fov_seconds_cm2 * (1 / ( $fov_diameter_mm * ((1 centimeter) / (1 millimeter)) ) ) " )'
fov_seconds_cm3= 333333.33
seconds per cm^3.
Keep in mind this is still at ~300nm expected resolution (10micrometer is the FOV not resolution) - trading resolution for FOV
(and much faster scanning) is entirely possible.
```

High-wattage (ie. >1W @ >405nm) laser (eg. for sub-mm resin 3D printing, thermal/ablative lithography, and flexible PCB photolithography) is expected to exceed stable travel acceleration for low mass optical projection tools.

Estimate - Scanning Probe Mechanically (mm/s) Constrained

```
  'probe_diameter_mm=$(_clc "300 * ((1 nanometer) / (1 millimeter))" )'
  'probe_speed_mmPerSecond=1'
  'probe_parallelism=1'
probe_area_cm2= 9E-10
  'probe_seconds_cm2=$( _clc " 1 / ( $probe_area_cm2 * $probe_speed_cmPerSecond ) " )'
probe_seconds_cm2= 11111111111
seconds per cm^2.
```

Biology and supposedly 'nanotechnology' 'self-replication' is essentially massively parallel scanning probe lithography with severe inefficiency from exceptionally frequent overlay markings (including neural axon growth markings). Fused Filament Fabrication is also a scanning probe technology, mostly appropriate for objects with mostly homogeneous bulk materials.

Manufacturing throughput in number of patterns (ie. transistors) per second is not obviously promising for scanning probe (or 'self-replication') and must be the basis for diverting substantial investment away from a proven track record.

Estimate - Wafers Per Hour (marketing specification) Constrained

Parallel E-Beam (prototyping)

```
  'marketing_prototyping_wafersPerHour=1'
  'marketing_prototyping_seconds_cm2=$( _clc " ( 1 / $marketing_prototyping_wafersPerSecond ) / $wafer_300mm_cm2 " )'
marketing_prototyping_seconds_cm2= 6
seconds per cm^2.
```

Photolithography EUVL (factory)

```
  'marketing_factory_wafersPerHour=170'
  'marketing_factory_seconds_cm2=$( _clc " ( 1 / $marketing_factory_wafersPerSecond ) / $wafer_300mm_cm2 " )'
marketing_factory_seconds_cm2= 0.035294118
seconds per cm^2.
```

Estimate - Fabrication Area

neuralBits

```
  'length_cm=10'
  'width_cm=10'
  'depth_mm=2.5'
  'totalTrestle=50'
  'totalBundle=2500'
  'totalThread=94674'
  'totalTrestle_cm2=$(_clc " $totalTrestle * $length_cm * ( 225 * (1 micrometer / 1 centimeter) ) ")'
totalTrestle_cm2= 11.25
  'totalBundle_cm2=$(_clc " $totalBundle * ( $width_cm / $totalTrestle ) * ( 75 * (1 micrometer / 1 centimeter) )")'
totalBundle_cm2= 3.75
  'totalThread_cm2=$(_clc " $totalThread * ( $depth_mm * (1 millimeter / 1 centimeter) ) * ( 35 * (1 micrometer / 1 centimeter)
)")'
totalThread_cm2= 82.83975
  'neuralBits_cm2=$(_clc "ceil( $totalTrestle_cm2 + $totalBundle_cm2 + $totalThread_cm2 )" )'
neuralBits_cm2= 98
```

Area greater than length multiplied by width of 'neuralBits' is entirely feasible - strongly recommend stacking threads as is plausible for substrate fabricated by some layer bonding, wire bonding, surface mount soldering, deposition, or resin 3D printing. Reducing thread/ES counts and such is not recommended, ~3M ES for neocortex strongly preferred, especially for sensory input.

Imaged area may be smaller than 'neuralBits' total area - expect some of flexible substrate will not be patterened with circuitry. Transmission lines, electrodes, etc, may be much thinner than trestles/bundles/threads - only analog amplifier transistors are expected to necessarily occupy a large area.

GPU

```
  'gpu_dollars=2000'
```

```
  'gpu_core_transistors=5392531'
  'gpu_core=5248'
  'gpu_transistors=$(_clc "$gpu_core_transistors * $gpu_core" )'
gpu_transistors= 28300002688
```

```
  'gpu_freq=$(_clc "2 * 10^9" )'
  'gpu_mult=$(_clc "10" )'
  'gpu_mips=$(_clc "$gpu_core * $gpu_freq" )'
gpu_mips= 1.0496E13
```

```
gpu_diameter_mm= 7.5701721
```

```
  'gpu_layers=35'
  'gpu_cm2=$(_clc "$gpu_transistors * (45 * (1 nanometer / 1 centimeter))^2 * $gpu_layers" )'
gpu_cm2= 20.057627
```

Estimate - Cost, Production (factory - imager maximum throughput only)

neuralBits

```
  'world_neuralBits_seconds=$(_clc "$neuralBits_cm2 * $world_seconds_cm2" )'
world_neuralBits_seconds= 0.034588236
  'world_neuralBits_perQuarter=$(_clc "( 3600 / $world_neuralBits_seconds ) * 24 * 90" )'
world_neuralBits_perQuarter= 224816322
  'world_neuralBits_dollars=$(_clc "$gpu_dollars *  ( $neuralBits_cm2 / $gpu_cm2 ) " )'
world_neuralBits_dollars= 9771.8439
```

GPU

```
  'world_gpu_seconds=$(_clc "$gpu_cm2 * $world_seconds_cm2" )'
world_gpu_seconds= 0.0070791625
  'world_gpu_perQuarter=$(_clc "( 3600 / $world_gpu_seconds ) * 24 * 90" )'
world_gpu_perQuarter= 1098435020
```

Estimate - Cost, Production (prototyping)

neuralBits

```
  'photolithography_neuralBits_seconds=$(_clc "$neuralBits_cm2 * $photolithography_seconds_cm2" )'
photolithography_neuralBits_seconds= 9800000
  'photolithography_neuralBits_perQuarter=$(_clc "( 3600 / $photolithography_neuralBits_seconds ) * 24 * 90" )'
photolithography_neuralBits_perQuarter= 0.79346939
```

```
  'fov_neuralBits_seconds=$(_clc "$neuralBits_cm2 * $fov_seconds_cm2" )'
fov_neuralBits_seconds= 3266666.6
  'fov_neuralBits_perQuarter=$(_clc "( 3600 / $fov_neuralBits_seconds ) * 24 * 90" )'
fov_neuralBits_perQuarter= 2.3804082
```

GPU

```
  'photolithography_gpu_seconds=$(_clc "$gpu_cm2 * $photolithography_seconds_cm2" )'
photolithography_gpu_seconds= 2005762.7
  'photolithography_gpu_perQuarter=$(_clc "( 3600 / $photolithography_gpu_seconds ) * 24 * 90" )'
photolithography_gpu_perQuarter= 3.8768295
```

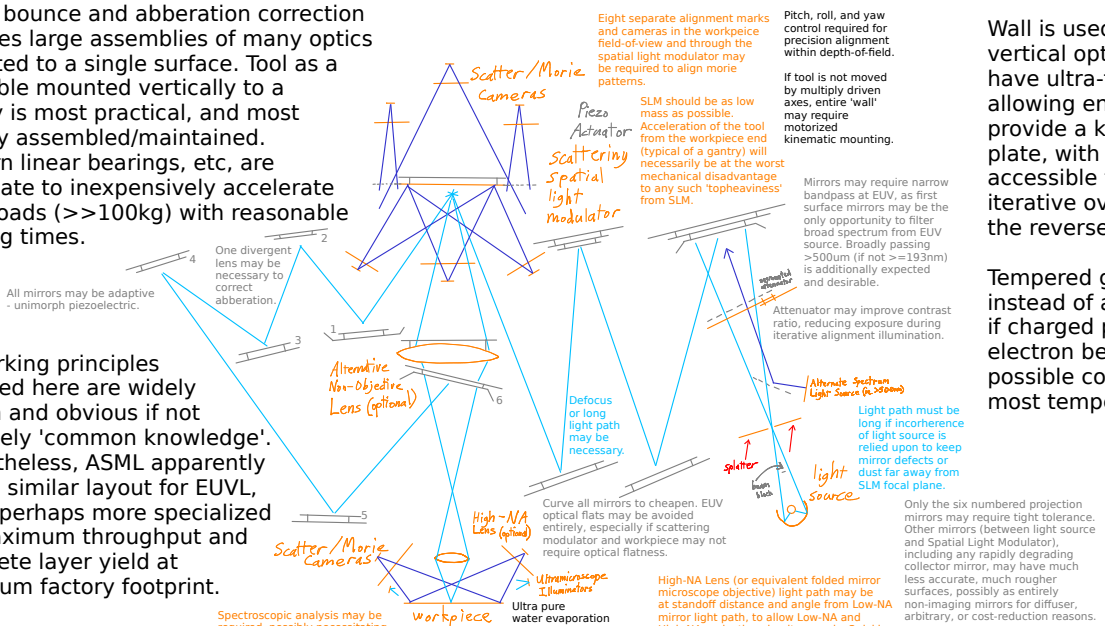
```
  'fov_gpu_seconds=$(_clc "$gpu_cm2 * $fov_seconds_cm2" )'
fov_gpu_seconds= 668587.56
  'fov_gpu_perQuarter=$(_clc "( 3600 / $fov_gpu_seconds ) * 24 * 90" )'
fov_gpu_perQuarter= 11.630489
```

flatTool

Accelerating Wall of Large Heavy Optics

Mirror bounce and abberation correction imposes large assemblies of many optics mounted to a single surface. Tool as a flat table mounted vertically to a gantry is most practical, and most quickly assembled/maintained. Modern linear bearings, etc, are adequate to inexpensively accelerate such loads (>>100kg) with reasonable settling times.

All working principles depicted here are widely known and obvious if not definitely 'common knowledge'. Nevertheless, ASML apparently uses a similar layout for EUVL, albeit perhaps more specialized for maximum throughput and complete layer yield at minimum factory footprint.



Wall is used as a dedicated vertical optical table, and may have ultra-fine-thread bushings allowing entire surface to directly provide a kinematic adjustment plate, with the adjustable screws accessible to stepper motors (for iterative overlay optimization) at the reverse side.

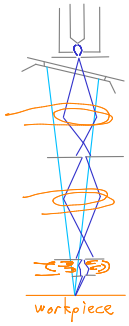
Tempered glass may be used instead of aluminum or invar alloy if charged particle deflection (ie. electron beam distortion) is a possible concern. Apparently most tempered glass is float glass.

Fabricating higher resolution components between interconnects fabricated by photolithography, is possible by adding a particleBeam and/or scanningProbe tool . Cycling of workpiece through etching will allow a tool to resolve marks for overlay produced by another tool, alligning overlay between tools.

Improving resolution of multiple patterning photolithography beyond optical overlay resolution (ie. <<2nm) by particle beam or scanning probe microscope overlay alignment is expected *infeasible* due to thermal expansion between solid components >>2nm . Productively compact, efficient, low-capital, and pervasive, to overlay entire optical beampaths, for any purpose, may not be possible.

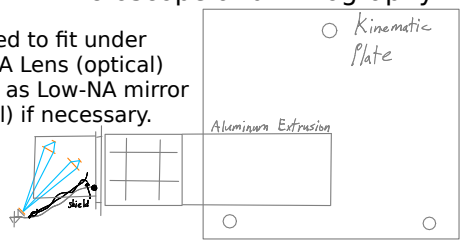
Scanning Electron Microscope and Lithography

If optional High-NA Lens (refractive light optical) is not added, electron optics may be attached to standoffs, with particularly long standoffs towards the top of the column, resulting in an electron beampath mostly offset from the light optical beampath.



Scanning Probe Microscope and Lithography

Intended to fit under High-NA Lens (optical) as well as Low-NA mirror (optical) if necessary.



Dip pen may necessitate overlay before writing to desired region. Removal of excess material from alignment marks may be necessitated subsequently.

Positioning

Gantry Six Axis (Pitch/Roll/Yaw, X/Y/Z) on Rigid Table

Multiply driven axes allow slight flexure actuation, causing causing minor X/Y/Z rotation adjustment as well as the large desired X/Y/Z translation .

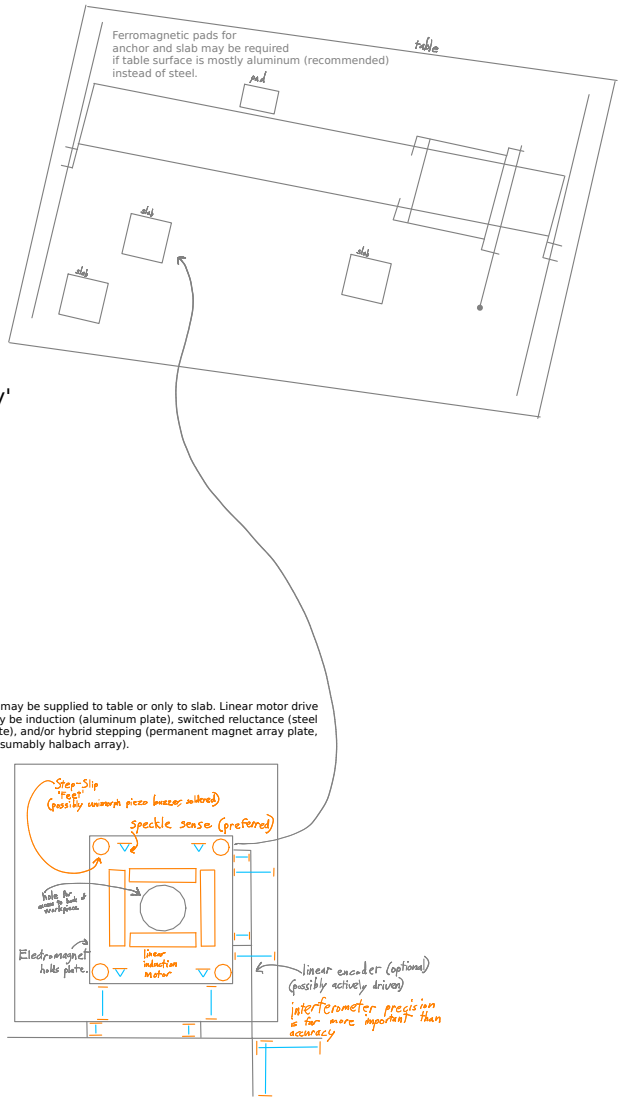
Highly geared stepper motors with extreme steps per rotation (ie. >>2000steps/rev >>16microsteps/rev) must be used to meet precision expectations (<<30nm).

Tool Z-axis (depth) linear axis straightness tolerances may be less stringent due to low-latency closed-loop feedback.

Parking anchors may be used in at least several different arrangements to improve rigidity (and mechanical/vibrational connection to slab) during actions (eg. holographic exposure) requiring an entire field of view to remain transiently stable in all dimensions to <<1nm . Slight adjustments, particularly on rotational axes, may continue after anchoring to apply finer frame tensions. Electromagnetic attachment is suggested.

Reinforcement may be made to the 'gantry', adding additional aluminum, carbon fiber, or wood, backing materials. Particularly, the sides of the 'gantry' may be stiffened by expanding to rectangular, rather than single-post, resulting in rigidity as might be more expected of a cube shaped machine, whileretaining the accessibility and modularity of a sliding gantry.

Composite reinforcement of gantry and similar by combining aluminum extrusions with such bulk materials as wood is well proven by accurate measurements showing substantial decreases in deflection per weight without significantly diminishing stability.



Slab with Six Axis Actuator

Step-Slip 'feet', possibly unimorph piezo actuators, combine both exceptionally precise motion from expansion with more sudden actuation for continuous motion at <<1nm.

Linear induction motors may allow well defined pulses of mechanical energy to overcome stiction while still keeping minimum travel distance at <<1nm.

Speckle sense, interferometers, linear encoders, etc, may have sufficient precision and stability across long travel motions of short duration to keep overlay alignment at some distance from visible overlay markers. Any position tracking other than overlay through the tool optical path can only briefly track overlay relative to that position, so interferometer precision is far more important than accuracy.

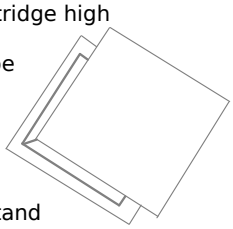
Any position tracking (ie. interferometers, speckle sense, linear encoder, etc) may not be necessary for non-experimental purposes, if overlay markings can be included at adequate intervals in workpieces.

Polishing slab and underlying table (or pad) to near typical (though not EUV) long-wavelength optical flat standards (at least across a small area) may allow an 'air cushion' to overcome stiction without degrading high vacuum (though perhaps not ultra-high-vacuum). Such polishing can be done by a small robot much like a slab itself, measuring level relative to gravity precisely by optical pendulum sensor.

Cartridge Associated with Slab

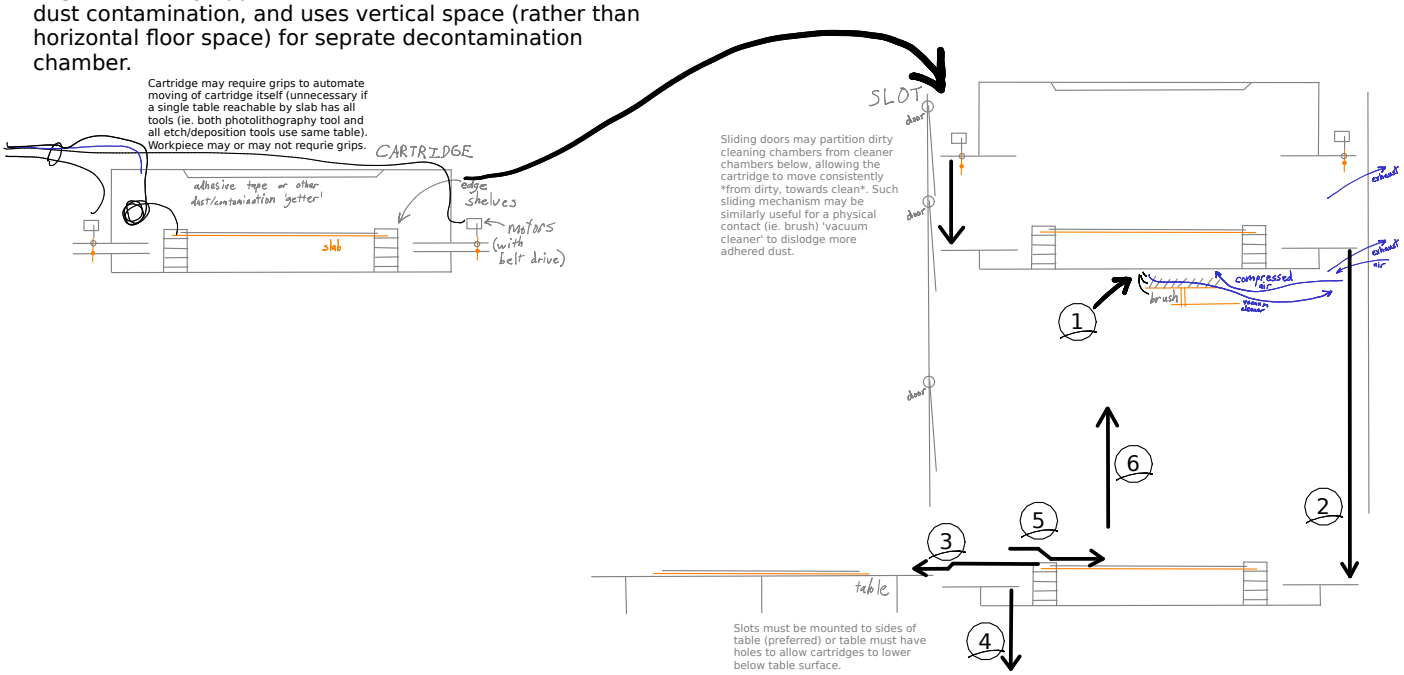
Workpieces never leave their moving slabs (from raw materials to photolithography through etching, etc).

Cartridge is usual metal plate construction, though not necessarily the usual box shape. Soldered aluminum or 308L/347 welded stainless steel 304 (high temperature) plate construction. However, there is no reason for cartridge high temperature. If workpiece must be kept in vacuum, transparent plastics are not recommended, having less strength to withstand atmospheric pressure.



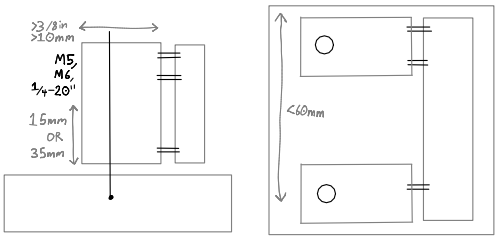
1. Clean bottom surface of cartridge.
2. Lower bottom of cartridge through inner dust protection door until desired slab is at or slightly above table height.
3. Move slab laterally onto table.
4. Lower or raise bottom of cartridge until desired shelf is at or slightly below table height.
5. Move slab laterally onto shelf.
6. Raise bottom of cartridge.

Drop down cartridge allows selection of desired slab from edge shelves by approximate Z-axis distance, minimizes dust contamination, and uses vertical space (rather than horizontal floor space) for seprate decontamination chamber.



Optical Mounting and Alignment

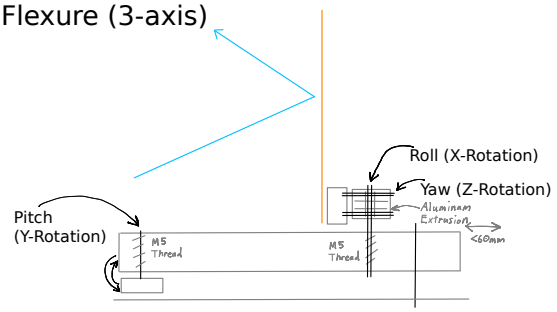
Threaded Rod Bolted Plate Tilt and Offset (4-axis each)



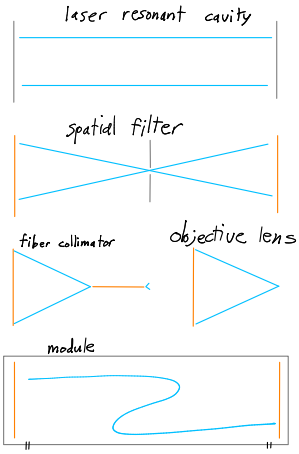
Manufacturing is by hand-held drill and 3D printed jig .

Opposing force to adjustment screws may be provided by doubling screws or by highly compressed spring.

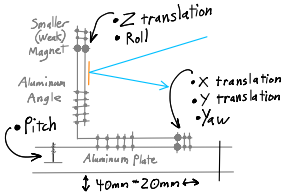
Threaded Rod Bolted Extrusion and Plate Flexure (3-axis)



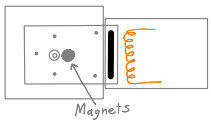
Accurate Alignment Use Cases



Threaded Rod Bolted Plate and Magnetic Sliding Plate Flexure and Translation (6-axis)

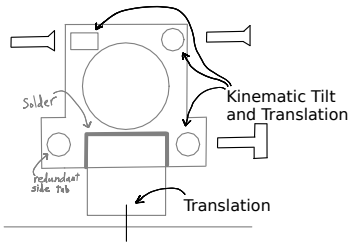


Magnetic Sliding Plate (2-axis)



Adjustable translation and rotation. Magnetic ties are laterally held by epoxy. Electromagnetic tool allows grab and release with minimal disruption. Once a correct position is set, this may be clamped under more pressure from standard aluminum extrusion brackets.

Conical Screw Double Plate Kinemitic Tilt, Kinematic Translation, Translation (4-axis)

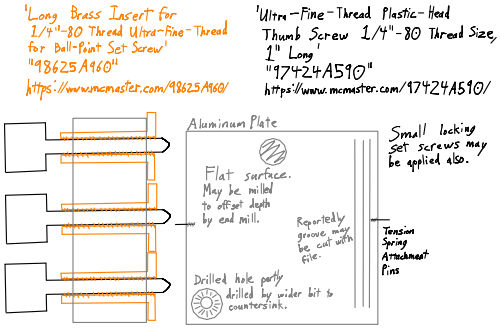


Kinematic mounting plate using only low-cost commodity components.

Cone shaped bearing surface of may metric machine screw heads is used to provide the point and rectangular contact areas for predictable Pitch, Yaw, and Y-Translation (3-axis) kinematic adjustments.

Angle corner bracket may add Z-translation (1-axis).

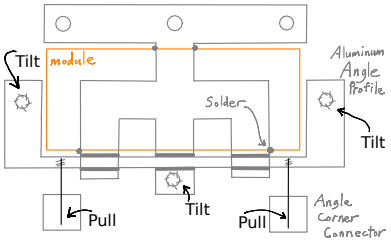
Kinematic Plate (3-axis)



Kinematic mounting plate not necessarily requiring any highly expensive materials or substantial machining job preparation. Reportedly, a drill press, usual drill bit, and file suffice, though an end mill bit may also be required if the flat surface must be offset to greater depth. May be especially suitable for stepper motor (>>2000steps/rev * 256microstep) actuation.

Credit to 'Dan Berard' , " https://dberard.com/home-built-stm/ " .

Flexure Tilt and Flexure Pull Plate (4-axis)



Pitch, Roll, Yaw, and axis height. May mount and align the beam input/output of a large module (eg. spatially filtered light source).

Manual iteration through adjustments may be necessary - some may be interdependent.

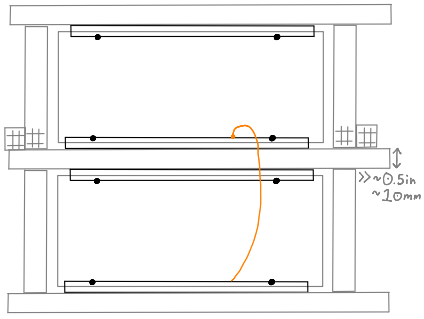
Accessible Rigid Enclosure

Substitutes soldered metal plate for compressed rubber sheets and aluminum extrusion corner posts.

May require particularly heavy plate (aluminum) or expensive composite (carbon fiber honeycomb). Aluminum extrusions may be more suitable for submodules, soldered sealed aluminum plate may be more appropriate if further adjustment will not be required.

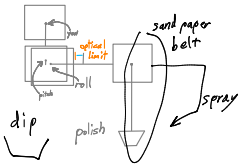
Consider orienting all readjustment screws and optical beam exits toward one 'front' access panel for user convenience.

Credit to 'Tech Ingredients' "YouTube" video 'nMonZHMTra4' .



Mirror, Lens, Workpiece (eg. silicon wafer) Grinding

Polishing



Abrasives are used.

Optically accurate surface is contoured by either equal abrasion across an area (flat), essentially random abrasion paths across a circular area (concave spherical), or similarly chosen abrasion (convex spherical).

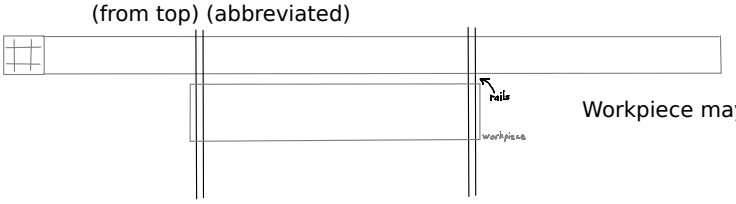
Optically flawless surface is productively corrected by abrasion at increasingly finer grit at areas identified by interferometric measurements at an optical fiber (<<1000pm accurate mirrors), a low-quality reference camera (<<100nm accurate mirrors and lenses as with telescopes), by interferometric measurements at another optical flat (<<1000pm accurate flats), or by leveling relative to gravity (<<1000nm accurate flat tables).

Locations to apply abrasion need not be at all precise. Very low cost typical CNC hardware may be used for a dedicated multi-axis abrasion tool, open-loop positioning, sharing same table as other photolithography related tools.

Abrasives may be used as spray (preferred), dip (may complicate software), or sand paper belt (may complicate maintenance). Usually spray will be highly preferable in production, sand paper or similar may be useful experimentally.

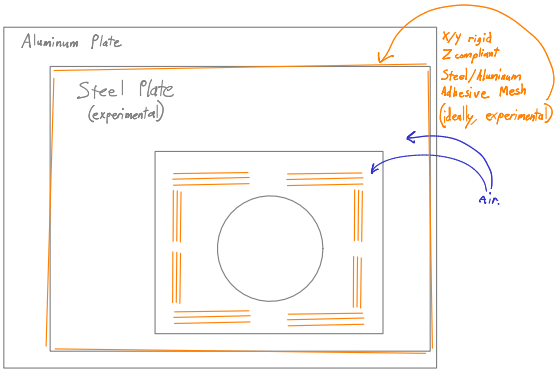
Workpiece Movement

(from top) (abbreviated)



(from side)

Workpiece may slide on rails, which may be linear bearings.

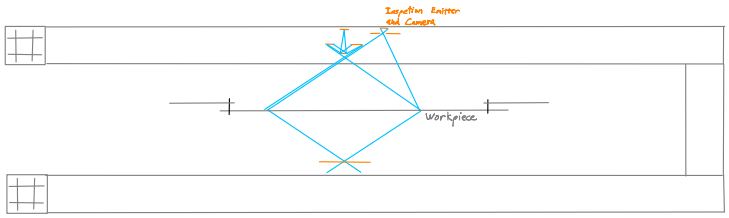


Rails may be metal plates with no linear bearings, or table may be used instead of rails. In such case, slabs may move workpieces.

Workpieces never leaving their slabs, slabs only moving onto ramps to rails when both sides must be accessed, is preferable if polishing or similar (eg. etch) may be integrated on one table surface with other tools (eg. image by photolithography).

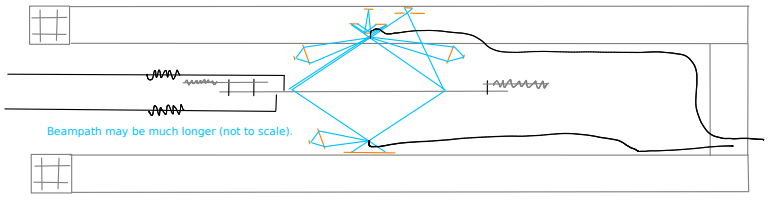
Thin edges at workpieces may remain during manufacturing in all plausible essential use cases - tapering a lens to an optically correct sharp edge is not necessary.

Inspection and Surface Correction



Workpiece may slide across rails and align between simple reference lens/mirror for interferometric measurement.

Slabs are preferred, though possibly not necessary, for their many precision axes and not requiring manual transfer of workpiece to add to other machinery.

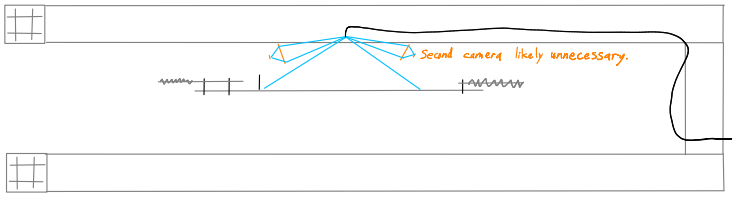


More complex reference optics may be necessary for especially small tolerances (ie. picometers for EUV mirror.)

Spot polishers may be pushed into the inspection area, especially for repeated iterative surface corrections.

Some optics (ie. mirror objectives) may require specialized smaller spot polishers, as smaller tolerances may imply smaller defect areas.

Evaporating cleaning spray may be required to remove polish particles prior to inspection measurements.



Surface correction of EUV mirrors may require deeply subwavelength interferometric analysis. Theoretically, the mirror grinding machine need only accommodate one optical fiber and one or two cameras, possibly with an array lens as a wavefront sensor.

EUV mirror roughness may be far more crucial (<50pm). Surface contour accuracy tolerance may be >>2nm.

Piezoelectric and Thermal Expansion Nanopositioning Actuators

Unimorph discs, or less available, piezoelectric cylinders, may tilt in X/Y axes or translate in Z axis, similar to, but much more precise than, kinematic plates.

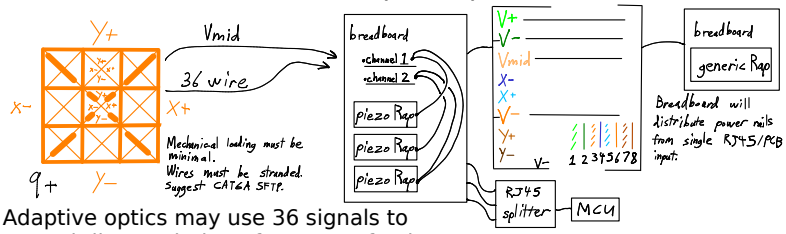
Reportedly, a typical piezo buzzer achieves 160nm/V sensitivity, with 0.01nm Z-axis (depth) precision being desirable . Reportedly, +/-15V and 62.5uV are usable. Reportedly, a +/-10V 16bit ADC would have a 305uV resolution, necessitating 'amplification with a gain of at least five or a more precise ADC' if 'feedback loop is active'.

Beyond tilt/tranlsation, piezoelectric actuators, especially unimorph discs, may deform an optical surface, allowing low-latency wavefront correction of an entire optical assembly. Such may improve overlay, or most importantly improve mirror fabrication tolerances (reducing manufacturing cost and measurement complexity).

Unimorph piezoelectric discs are divided into 36 segments, controlled by a combination of manual trimmer potentiometer adjustment, override inputs for manual control of logical groups (ie. override for all segments in addition to manual adjustment of individual segments), and DAC/ADC (ie. computer controlled adjustment or readout of manual settings).

PatchRap standards, breadboard compatibility of all PCBs, and Cat6A cabling, allows allow extremely rapid wiring of such extensive controls, minimizes noise/vibration, and minimizes cabling clutter.

Pinout Standard (PatchRap Compatible)



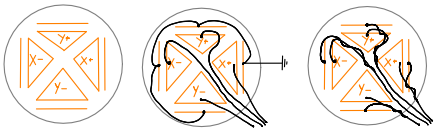
Adaptive optics may use 36 signals to control tilt/translation of 9 areas. If only tilt/translation of entire piezoelectric actuator is required, only 4 signal wires may suffice.

Differential wires (X+/X-,Y+/Y-) connect to breadboard rows, then to adjustable voltage sources (eg. piezoRap PCBs).

Overriding high-impedance voltage sources may connect to breadboard rows or through piezoRap 'NEXT' connectors, allowing manual adjustments of individual piezo segments and manual override of groups of individual piezo segments (ie. control tilt/translation for whole unimorph or one ninth of unimorph).

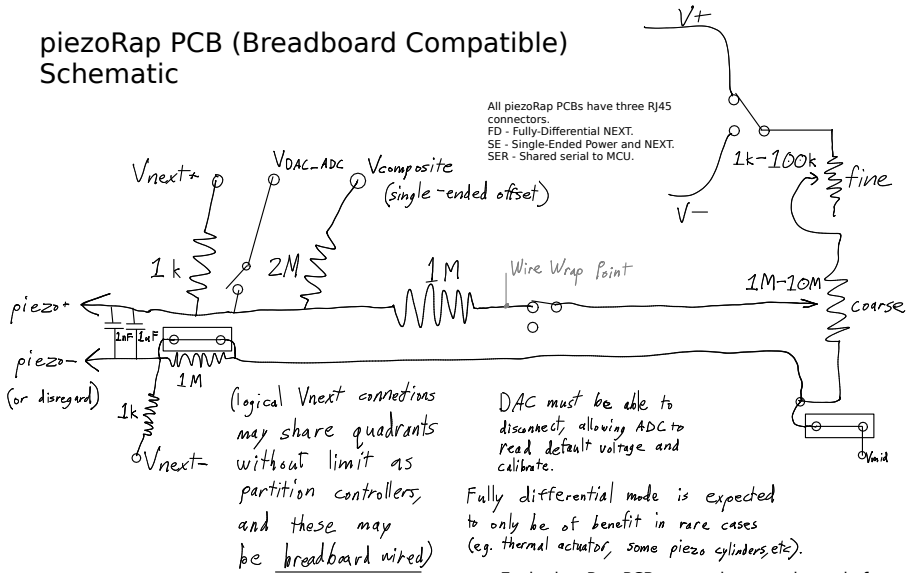
Multiple unimorph actuators, associated electronics, etc, may share high voltage (V+, V-, Vmid) through breadboard rails, and Cat6A wires may be connected directly to breadboard rows without any adapter (ie. piezoRap PCB).

Use high quality solderless breadboard in good condition, or solderable breadboard, or perfboard with wire wrap.



Fully differential control of piezoelectric actuators may be available if 'ground plane' is also segmented. May experimentally reduce interdependence (improving manual control) or reduce noise.

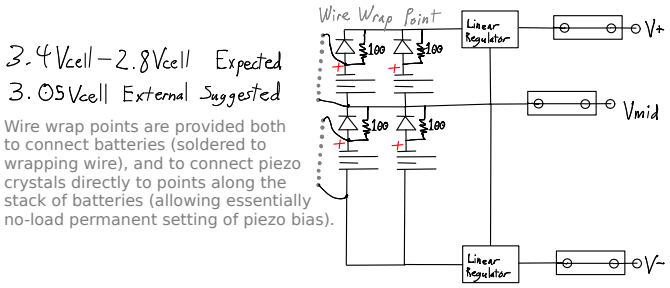
piezoRap PCB (Breadboard Compatible) Schematic



Each piezoRap PCB, managing one channel of four piezo segments, will require at least five of these adjustable voltage dividers. One each for X+, X-, Y+, Y-, and another for Vcomposite (Z+/Z-) . Six adjustable voltage dividers must be provisioned in PCB design to accommodate the possibility of some piezo cylinders with dedicated Z-axis wiring.

Battery Portable Voltage Bias for Piezoelectric Actuator

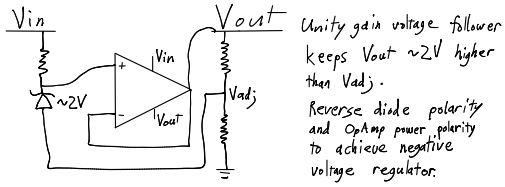
Battery high voltage supply schematic.



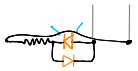
Linear voltage regulators may not be desirable considering the very low load, lithium battery stability, and loose tolerance of protectively preventing mechanical shock by keeping such circuit connected with batteries without external power long-term.
CR2032, CR2016, or 9V, lithium, suggested.

CAUTION: Beware risks of low impedance parallel connection (ie. charging).

Linear regulator.



Onboard voltage tester.



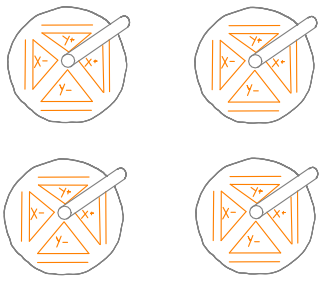
Onboard voltage tester. Wrap wire onto pins to use as probes to check voltage and polarity at battery contacts.

Actuator Mechanisms

Improved Rigidity Multi-Piezo Actuator

Unimorph piezoelectric actuators are versatile, inexpensive, precise, and widely available. Relatively heavy devices (ie. Spatial Light Modulator) may require more support than a thin unimorph piezo disc may provide, while more rigid piezoelectric cylinders may be expensive or rare.

Multiple actuators may be used as 'feet' with standoffs, similar to the individual screws of a kinematic mount. While rigidity may improve, travel range may be reduced.



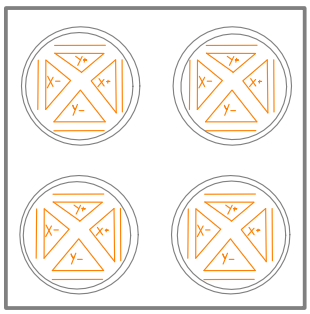
Piezoelectric cylinders are also electrically similar to piezoelectric unimorph disks, with roughly the same wiring reqirements, excepting that an additional dedicated Z-axis wire may be required, and all wires included may be fully differential.

Step-Slip Feet

Magnetically adhered (ie. not relying on gravity) plates (ie. slab) theoretically may be nanopositioned by driving unimorph piezo actuators with 'sawtooth' waveforms.

Piezo actuators used as such may not require the usual center standoff posts, and are expected to remain flat when not biased (ie. unpowered).

Irregular solder points and plate recesses may be required to accommodate expected flexing.



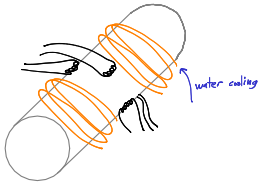
Thermal Expansion Nanopositioning Actuator

Pipe or aluminum extrusion may be used. Water cooling may run through center channel, from optics end to mounting end, causing the outside of pipe or the outside t-slots to cause expansion when heated, and contract back to original shape when heating is discontinued.

Drive circuitry is essentially similar to piezoelectric, excepting that actuation is necessarily dynamic, adjusted by low-latency feedback, and high power.

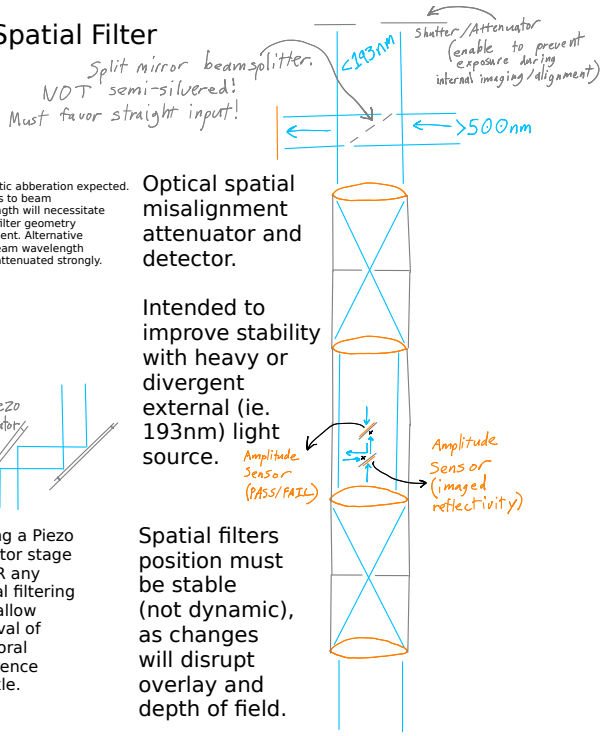
Artificial muscle bowden cables may or may not have better stability due to their heat dissipation, much greater length, and much lower thermal mass.

Bowden cables driving adjustment screws may have much better stability and precision.



Optical Beampath

Spatial Filter



Chromatic abberation expected. Changes to beam wavelength will necessitate spatial filter geometry adjustment. Alternative input beam wavelength will be attenuated strongly.

Optical spatial misalignment attenuator and detector.

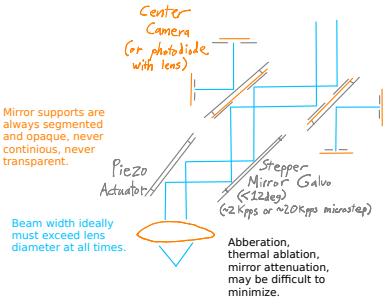
Intended to improve stability with heavy or divergent external (ie. 193nm) light source.

Placing a Piezo actuator stage AFTER any spatial filtering may allow removal of temporal coherence speckle.

Spatial filters position must be stable (not dynamic), as changes will disrupt overlay and depth of field.

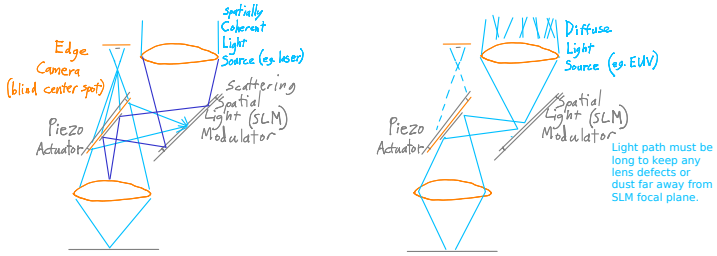
Especially ensures light source modules focus to diffraction limited point.

Beam Steering Scanner



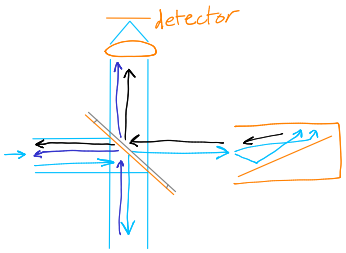
May be especially useful for rapidly moving a diffraction limited point, as with low coherence tomography, confocal tomography, and thermal lithography (ie. ablative).

Maskless Optical Projection Lithography (MOPL)

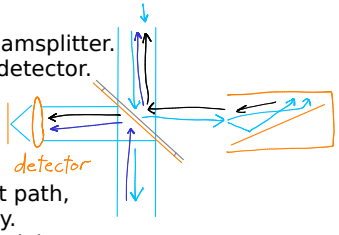


Scattering must occur either at the Spatial Light Modulator, or before with the diffuse light source itself being inherently scattered.

Beamsplitter

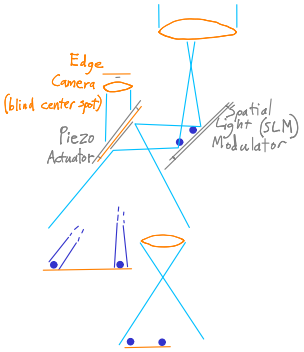


Highly reflective beamsplitter.
Source side-input.
Source-To-Detector
2x Beamsplitter
1x Wall



Weakly reflective beamsplitter.
Beam is off-axis from detector.
Source straight-input.
Source-To-Detector
2x Beamsplitter
1x Wall
Preserves original light path, may improve efficiency.
Weakly reflective materials may be *more commonly available*.

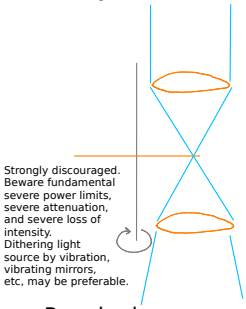
Laser Shadow Projection Lithography



Requires exceptionally spatially coherent light source and cannot directly focus to convergent diffraction limited points.

May be useful where wide field-of-view is more essential than resolution (eg. PCB fabrication).

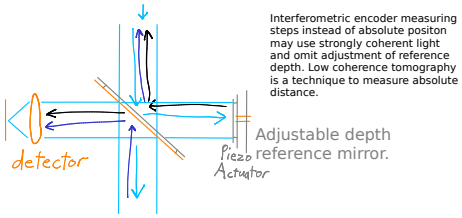
Rotary Diffuser



Strongly discouraged. Beware fundamental severe power limits, severe attenuation, and severe loss of intensity. Dithering light source by vibration, vibrating mirrors, etc, may be preferable.

Rough glass or rough mirror rotary diffuser to remove spatial coherence, reducing speckle and widening illumination angles.

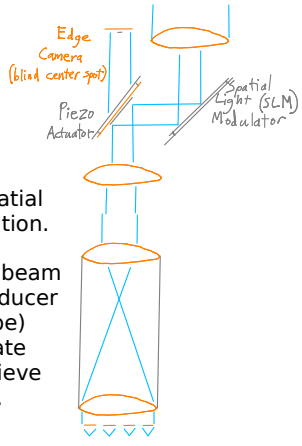
Optical low Coherence Tomography (OCT)



Interferometric encoder measuring steps instead of absolute positon may use strongly coherent light and omit adjustment of reference depth. Low coherence tomography is a technique to measure absolute distance.

Optical low Coherence Tomography (OCT) will only show interferometric rings (aka. depth correlated oscillation) when reference is near equal distant from object. Input light must be extremely low coherence (ie. broad spectrum LED if not white light, not laser). Beamsplitter may be necessarily ~50% reflective.

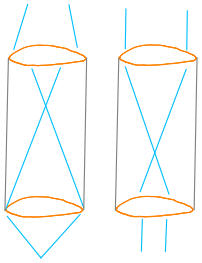
Zone Plate Array Lithography (ZPAL)



Coherent spatial light modulation.

May require beam expander/reducer (ie. 'telescope') and zone plate array to achieve useful focus.

Microscope, Telescope



DISCLAIMER: Plausible concepts, attributed sources, oversimplifications, resonably. Rigorous mere academia NOT primary.

errata

_ Terms _

_ Rough _

REVIEW - May be duplicative from (another) part of (another) document.

Elaboration regarding otherwise already noted concepts.

*) FUNDAMENTAL - MAJOR MAJOR - Clearly shows optical overlay is used with a 193nm light source. Albeit the machine may be rather old (1993), the 193nm light source continued to represent state-of-the-art until EUV. Consequently, it is not plausible that the interferometers also shown were used have ever been expected to remain accurate beyond a single wafer exposure.
 *) MAJOR - ASML's logo is obviously the optical overlay technique.
 *) MAJOR - Interferometric 'positioning resolution down to 5nm' .
  *) Although two marks are shown, theoretically at least four should be required to calibrate mass and thermal expansion changes over time expected of the interferometrically monitored walls of the slab. Some interpolation and assumptions may be implied.
   *) Animation shows only one of the alignment marks is measured twice, implying one mark is indeed sufficient for magnification and second mark is for thermal expansion calibration.
 *) High angle image sensors are indeed used to make detailed confirmations of 'focus, alignment, leveling' .
 *) Interferometer seems to claim '3-axis', presumably X translation, Y translation, and Z rotation (twist).
 *) Leveling is implied to take place by a system similar to an AFM laser side-bounce technique, implying that while X/Y overlay must be done to alignment marks, Z-axis tolerances are tighter than can be maintained across the travel distance. Whether this compensation remains adequate at EUV or even multiple patterning seems dubious.
  *) Perhaps more likely the additional leveling is done merely to reduce out-of-focus exposure time.
 *) Air turbulence control is implied to be laminar airflow across wafer. Obviously, this does not apply at vacuum, and at ambient, necessitates only a constant stream of airflow through the tool.
 *) https://www.youtube.com/watch?v=a5CxGbs4ROw

*) MAJOR - Slab and tool cabling may require encapsulation (ie. tubing) or coating to prevent dust particles, due to frequent fast motions.

References (Inaccessible)

'Deposition of Mo/Si multilayers onto MEMS micromirrors and its utilization for extreme ultraviolet maskless lithography'

'Precision X-Y positioning systems using linear induction motors'

'EUV Lithography Insertion in High-Volume Manufacturing'

'Precision X-Y positioning systems using linear induction motors'

'Performance validation of Mapper's FLX-1200 (Conference Presentation)
	'65,000 parallel electron beams'
	'1 wph throughput at 300 mm wafers'
	'28nm node patterns'
	'electron optics' 'no central crossovers'
	'60nm dense lines and spaces'

'Overlay improvement in nanoimprint lithography for 1Ã—-nm patterning'
	'morie fringe detection' 'accuracy below 1nm' 'overlay accuracy below 5nm'

'Moire interferometric alignment and overlay techniques'
	'0.47 micrometers pitch gratings' '1-nm alignment resolution'

'latent image structures immediately after exposure'

'Scatterometry-based overlay metrology'
'overlay' 'fitting the optical properties' 'with spectra calculated using a model' 'coupled wave analysis'
Seems like an iterative computer optical holography model solver, reducing detected wavefront to iteratively interpolated 'Airy disk' point sources.

'Projection Systems for Extreme Ultraviolet Lithography'

'100-picometer interferometry for EUVL'
'in all likelihood' 'six-mirror'
'aspheric mirror' 'absolute figure accuracy' '100pm rms'
'phase shifting diffraction interferometry (PSDI)'
'250pm'
'lensless imaging' 'computational diffractive back-propagation'

'Phase shifting diffraction interferometry for measuring extreme ultraviolet optics'
'0.25nm rms' 'intrinsically achieve'
'two independent spherical wavefronts are generated' ... 'measurement wavefront' ... 'reference wavefront' .,.. 'relative amplitude and phase can be controlled' ... 'phase shifting capability'
'diffraction from a single mode optical fiber'
'measure individual mirrors or entire imaging systems' ... 'of an EUV projection system'

'Determination of wavefront structure for a Hartmann wavefront sensor using a phase-retrieval method '
'error' ... 'one order of magnitude smaller'

'DIMENSIONAL METROLOGY OF A PLASMONIC NANO-LITHOGRAPHY MACHINE'
'maskless lithography'
'half pitch width' '22 nm' '35 mm' '2000 revolutions per minute'
'evaluate the machine's positioning performance'

'Maskless EUV lithography, an alternative to e-beam'
'outline a maskless EUV scanner design'
'numerical aperture' '0.55'
'microlens array' 'âˆ¼2 million individual beams' 'separate, diffraction-limited focal points'
'raster-scanned' 'individually modulated by MEMS microshutters integrated within the microlens array'
'compared' 'mask-projection EUV lithography' ... '1000 x' 'lower throughput' 'power' '1000 x' 'lower' 'advantage of maskless operation'
'comparison' 'e-beam mask writers' 'higher resolution' 'at least double the throughput' '10 x' 'higher dose'

References (Unknown)

*) 'spatial-phase-locked electron-beam lithography (SPLEBL)'

*) Lithography throughput ... Blu-ray pickup ... (1000^2) âˆ• (100 Ã— 1000 Ã— 0.15) ... 66seconds/cm^2 (ridiculously optimistic... 1000x slower more reported for resin printer study) .
*) Which is only ~10x faster than ebeam ...

Reference
https://en.wikipedia.org/wiki/Point_diffraction_interferometer#Two-beam_phase-shifting_PDI

https://en.wikipedia.org/wiki/Shack%E2%80%93Hartmann_wavefront_sensor

https://link.springer.com/content/pdf/10.1007/s00340-016-6595-5.pdf
'A desktop extreme ultraviolet microscope based on a compact laserâ€‘plasma light source'
Beam block suggested for EUV source. Mirror spectrum also suggested.

https://en.wikipedia.org/wiki/Extreme_ultraviolet_lithography#Single_patterning_extension:_anamorphic_high-NA
Depth of field, numeric aperture for ASML similar systems - ~1nm at 0.33NA EUVL, ~0.40nm at 0.55NA EUVL, ~1nm at 1.35NA 193nm (DUV).

https://ams.com/miniature-camera-modules
1mm^2 camera
Conveinent for sampling optical beam paths or scattering at many confined places.

https://youtu.be/-BeTq99LqUo?t=798
Transparent cubes, due to corner retroreflection, geometrically form optical resonant cavities (ie. laser cavity).

https://youtu.be/-BeTq99LqUo?t=895
Commodity inexpensive pulsed laser. May have sufficient power or at least most components for usual high-temperature EUV

light source.
	YAG Laser (1064nm) may be Q-Switched by absorptive device rather than reflective, allowing the crystal to become completely 'excited' before optical amplification causes discharge.

https://eksmaoptics.com/nonlinear-and-laser-crystals/passive-q-switches/
	CR:YAG Crystals , CO:SPINEL Crystals

https://4lasers.com/components/crystals/passive-q-switch-crystals
	Cr:YAG crystals , V:YAG crystals , Co:Spinel crystals

https://en.wikipedia.org/wiki/Nd:YAG_laser
	'also used as pump sources for vibronically broadened solid-state lasers such as Cr4+:YAG or via the second harmonic for pumping Ti:sapphire lasers'

https://www.sciencedirect.com/science/article/pii/S1369702105006991
 'Maskless lithography'
	'This is a much more daunting task and in fact it cannot be solved in closed form; empirical information must supplement the computation.'

https://en.wikipedia.org/wiki/Electron-beam_lithography
	'For example, assuming an exposure area of 1 cm2, a dose of 10âˆ’3 coulombs/cm2, and a beam current of 10âˆ’9 amperes, the resulting minimum write time would be 10^6 seconds (about 12 days).'
		AFM lithography, among other sources, would presumably be much slower than that.

https://github.com/ricktu288/ray-optics
https://ricktu288.github.io/ray-optics/
https://ricktu288.github.io/ray-optics/simulator/

WARNING: Extensive research notes here may be less recent, less accurate, less complete, internally inconsistent, and misinterpreted.

errata-more

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flatTool, Positioning, Cartridge Associated with Slab

*) MAJOR - EUV requires extremely low surface roughness (<0.5nm locally, perhaps ~5nm across 1um^2) to achieve reflectivity - a Spatial Light Modulator (SLM) will NOT be scattering in this case. Moreover, the low intensity of the EUV source will likely be within the focus of the workpiece as a consequence, requiring some beamstop or similar anti-vignetting technique. Ultimately, both the Spatial Light Modulator (SLM) and EUV light source are likely necessarily in focus at the workpiece.
 *) FUNDAMENTAL - EUV *cannot* be imaged to a single point on the workpiece, due to low intensity.
 *) High-intensity sources (ie. lasers) will most likely resolve to a single point both at the Spatial Light Modulator and at the workpiece unless condensing optics are deliberately moved out of focus or the laser is passed through a diffuser.
  *) Rotary diffuser approach reduces the intensity of the laser and may directly emulate the EUV light source behavior.
  *) Simply moving the laser source slightly outside the focal point of the condenser optics may be adequate.
   *) This may not create an adequately diverse 'wavefront' of rays from different directions across the entire non-scattering Spatial Light Modulator.

*) As many as 5 separate air cushion tubing inputs to slab may be required (center+corners). Not only does this allow independent control of Z-axis and tilt, this ensures a single channel cannot, by vibration, take up all the airflow, and then latchup with that leak, which would cause severe vibration or misalignment.
 *) FUNDAMENTAL - MAJOR - This suggests an air cushion may actually be used to achieve nanometer tilt control, similar to, but more dynamic and probably more precise, than the mechanical bearings of a kinematic mount. Only piezo actuators could plausibly be more precise.

*) MAJOR MAJOR MAJOR - FOUP (Front Opening Unified Pod, 300mm wafers) and SMIF (Standard Mechanical Interface, 200mm wafers)

industry standard cartridges are apparently available at reasonable cost. At somewhat less reasonable cost, automatic openers and automatic loaders too. Opens the possibility of more reasonable integration between such an entry-level EUVL stepper tool and a larger fab, perhaps exchanging just a single wafer would allow splicing smaller prototyping operations into larger fabs.
 *) FOSB (Front Opening Shipping Box) are apparently rather cheap (0). If mechanically compatible, these would be useful.
  *) Definitely automatically transferable between these two boxes.

*) MAJOR MAJOR - Narrowing spatial filter 'pupil' required, *especially* if 'incandescent' (or vaguely incandescent stimulated emission) source (ie. EUV plasma) may be used.

*) MAJOR - Name 'flatTool' and 'tool' terminology predates any awareness of 'alpha demo tool' or similar names by ASML, origin of this naming scheme being the premise that a 'tool' is an extension of the body.

*) MAJOR - Slight possibility magnification control may be required, necessitating vertical movement of the Spatial Light Modulator (SLM) and/or movement of a divergent/convergent pair of mirrors somewhere, possibly a separate pair for X magnification and Y magnification. Thermal expansion affecting overlay dimensions is the problem here.
 *) In this case, with a very small area being exposted and stitched by frequent alignment marks, using maskless overlay and exposure, such problems may be irrelevant. At worst, oversampling the pixels might allow software correction.

*) An 'optical leverage' tool similar to an AFM read laser - which still requires high NA focus - may use side-bounce independent of the projection lens and with a non-exposing wavelength - to adjust Z-axis translation (depth of focus) alignment in a manner similar to the X/Y translation interferometers.
 *) Unlike simply aiming interferometers at the workpiece surface, this may measure Z-axis translation directly at projection focal lens/mirror , while well beyond the ~90deg focus of a high-NA projection focal lens/mirror .
 *) Though in practice 'polka dot' beamsplitters allow introduction of off-wavelength directly into the beampath, and mirrors are used, any chromatic abberation may be ignored by this method.

Mirror, Lens, Workpiece (eg. silicon wafer) Grinding

*) Separate rigidTable Y-axis gantry rails may be used for some tools as appropriate (ie. separate gantry at separate area of a large table).

*) Roughly shaped blanks with standardized mounting fixtures may be placed in dedicated spot polish/inspection machines for specific purposes (ie. EUVL mirror grinders).

*) MAJOR MAJOR MAJOR - Wafer polishing metrology is important for *recycling*. After completely scrubbing off a bad pattern, reuse of a wafer may be extremely important where low-resolution wavelength and low purity consumables (ie. cheap) are used for 'practice', experimental designs, or calibration.

*) Single point (ie. optical fiber) interferometric mirror measurement techniques are detailed further in academic literature - this somewhat computational technique not only being simpler in implementation but also much more accurate. Very tall measurement devices may be needed to allow concave mirror to be brought to a focus. Divergent mirrors may require concave mirrors for reference, though the divergent nature of incandescent light assumed by 'flatTool' might not require any divergent mirrors.

Piezoelectric and Thermal Expansion Nanopositioning Actuators, Optical Mounting and Alignment

*) Thermal manipulation of optical alignment, exploiting thermal expansion, by electrical resistance heating, may inefficiently achieve same result as piezoelectric actuator. However, this is unlikely to stabilize quickly, perhaps even if thermally insulative materials are used.

*) MAJOR MAJOR - Narrowing spatial filter 'pupil' required, *especially* if incandescent source (ie. EUV plasma) may be used.
 *) May require 4x piezoelectric actuators, possibly a single plate mounted to standoffs and split by photolithography etching to allow the edges to be brought closer together though normally near-sealed. Should be fairly simple - metal plate, soldered standoffs, glued to piezoelectric actuators, and then split into quadrants by etching.

*) OPTLasers, Lasertack, eBay, etc

Optical Beampath

*) Diffuser in place of scattering Spatial Light Modulator (or unmodulated considering the existing scattering function) may be used as a laser speckle imaging system with the Maskless Optical Projection Lithography (MOPL) module. Then again, structured light from the Spatial Light Modulator may be algorithmically simpler to implement, at least early in development.

*) Zone Plate Array Lithography (reportedly used at least experimentally for 193nm projection) may only be efficient with high-harmonic-generation continuous (or at least nearly continuous) <193nm light or possibly laser source.

*) MAJOR - Raster scan in same direction must *always* be used (to avoid severe mechanical backlash). May reduce throughput if FOV is exceptionally narrow (ie. laser focused to diffraction limited spot).

*) Simple lenses may be used in place of mirror objectives for relatively inexpensive and/or compact 405nm tools. Attenuator may be necessary if overlay must be done above a significant lasing threshold.

*) MAJOR - Maskless Optical Projection Lithography (MOPL) may require diffuser, not merely out-of-focus laser, if Spatial Light Modulator (SLM) is non-scattering.

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wallMask (errata only)

*) MAJOR MAJOR MAJOR - Magnetic light valve may be more precisely selected by laser heating in the same manner as magneto optical. Mechanical restraint of magnetic light valves may be established by a nonmagnetic mesh. Distilled water spray may be frozen as the thermally sensitive laser meltable adhesive.

*) MAJOR MAJOR MAJOR - Magneto Optical itself is something of a phase modulating photomask, and EUV phase modulating photomasks should be usable. If right-angle polarization modulation can be achieved by Magneto Optical writing, amplitude modulation outright may be achieved when using a polarized EUV light source. If any EUV transparent material can exhibit a strong magneto optical polarization changing effect, and/or if strong EUV polarization filtering/interaction is possible.

*) MAJOR MAJOR MAJOR - Detachable/movable edge/center reticles may be used for certain otherwise maskless alignments, so long as the total overlay error remains below 1nm (ie. by smaller stitching regions).

*) Magnetically actuated light valves may be changed by magnetic probe (ie. an AFM tip or HDD pickup). Of course, this may introduce patterning speed limitations comparable to AFM.

*) MAJOR MAJOR MAJOR - Piezo dithering may solve problems with purely reflective (rather than partly scattering) SLM alignment as may be necessary with EUVL .

*) MAJOR MAJOR MAJOR - Classic 'Etch-A-Sketch' and 'Magic Slate' techniques may be usable with freezeable solvent (ie. water) and magneto-optical techniques. Etch-A-Sketch in particular technique may be feasible with as an *absorptive* layer to be placed atop a proper dichroic filter reflector for EUVL.
 *) Considering metals may absorb EUV, sputter coating may be used to mask off the dichroic filter, reticle may be brought near melting temperature, laser may selectively melt independently thermally insulated grid squares (these made by photolithography), and mechanical wiping may 'clean' the thawed areas. Repeating this process should be workable so long as alloys are not formed (ie. underlying metal does not dissolve appreciably) or erosion/contamination otherwise does not occur.

*) MAJOR MAJOR MAJOR - Perhaps the most aggressive 'maskless' lithography technique is to build a miniature 405nm photolithography multiple patterning reticle fabricator based on a microscope objective, directly at the EUVL SLM location, with the X/Y/Z movable slabs and cartridges being able to reuse, polish off, and fully recycle, thousands of reticle squares in total.
 *) Such slabs might need to work *against* gravity (not merely without gravity), or have unsupported centers.
 *) Reticle fabricator might have to work against gravity for all steps, from the direction of the EUV light source.
 *) MAJOR - Of course, all these tricks are questionable given the high probability of being able to simply modify (remove protective window, add EUV reflective coating, etc), create, and dither (to workaround possible reflection angle accuracy requirements), a proper DLP/MEMS chip.

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*) MAJOR - Klipper firmware support for 24bit ADC/DAC !

*) Piezo/projection optics in theory might be able to offer enough structured light to image alginment marks holographically. However, this is theoretical at best, and still leaves a requirement for 3-4 alignment marks in the FOV of the current exposure.
*) https://hackaday.io/project/11621-holoscope-superresolution-holographic-microscope

*) MAJOR MAJOR - Flexure mounts probably do not have adequate performance, much less stability. Incentive to permanently bias piezo mounts.
 *) Stated 100microradians of variation precision limit. Presumably lower much lower stability.
 *) https://youtu.be/nMonZHMTra4?t=596

*) MAJOR MAJOR - Overlay is the most significant problem. FUNDAMENTAL - Overlay is apparently done by imaging light in photolithography, not by accuracy of any other systems.
 *) https://youtu.be/JHTh_S29yWo?t=1004
  *) Accuracy and Precision are both mentioned correctly.
  *) SEM can examine device features to recalibrate overlay based on detected exposure errors (ie. tweaking the machine based on its output over time). Damage to device during this is possible, however, the concern seems plausibly for devices already fabricated, leaving open the possibility SEM is never used in real-time for actual overlay, only ever for calibration.
   *) Made explicit by 'Post-Etch' in red cell.
    *) https://youtu.be/JHTh_S29yWo?t=1134
  *) Scatterometry is apparently based on mask itself (no need for dedicated patterns as with imaging), however, statterometry seems more vulnerable to 'process variations'.
   *) Nonetheless, scatterometry under maskless lithography may be plausible.
 *) Search for term 'overlay' on the 'Multiple Patterning' wikipedia article confirms all expectations. So-called 'self-assembly' is used to eliminate overlay as a problem.

*) EUV source, 50kHz - https://www.youtube.com/watch?v=NHSR6AHNiDs

*) EUV Lithography - If done by high vacuum, turbomolecular pumps may necessarily be located near EUVL source. - https://www.youtube.com/watch?v=skUCP2f4HIM

*) FUNDAMENTAL - Mirrors reflect only EUV. - https://www.youtube.com/watch?v=6LfFjmWCWPw
 *) Linewidth of 5nm is implied, linewidths of ~15nm known IIRC, acceptable dust particle on mask explicitly stated at ~30nm. Implies demagnification from mask to wafer of <6x, or maybe more plausibly ~2x.

*) FUNDAMENTAL - MAJOR MAJOR - Confirms use of behind-mask camera-read alignment marks by morie/scatterometry technique. - http://cnt.canon.com/technology/alignment-overlay/

*) FUNDAMENTAL - Illustrates how point illumination of a scattering surface results in polarization (ie. glare) and other changes being projected which may reflect subwavelength features.
 *) Explicitly mentions simulations and measurement comparison to achieve 'the grating shape is retrieved' .
 *) https://www.youtube.com/watch?v=bu8v-SfLH20
 *) https://www.youtube.com/watch?v=e_c2NpZR7jA
  *) Further exemplifies need for more measurement control software, an interactive equivalent of what has been used to manually align 3D printer extruders by microscope. - https://youtu.be/e_c2NpZR7jA?t=1724

*) FUNDAMENTAL - MAJOR MAJOR - Subwavelength features apparently have amplitude, polarization, and spectral shifts, which are scattered off the surface. Apparently may be correlated to the exact mechanical position, allowing some readout of slightly subwavelength features, with a single-point capability similar to the long lines correlated by lengthy morie patterns.

*) FUNDAMENTAL - MAJOR MAJOR - Multilayer 3D monolithic ICs may be produced at more reasonable combined yields if layer interconnects are destructable, or failed layers are otherwise semi-removable (ie. to remove 'short-circuits').

*) FUNDAMENTAL - MAJOR MAJOR - Resin printer must be able to operate in completely resin flooded location (ie. submerged window).
 *) Build platform 'tilting' is necessary to detach the printed part from the transparent window. Implies vastly stronger chemical adhesion to build platform than to window.
  *) Window thermal cycling may improve this, at some loss of optical alignment.
  *) Thin knife may also enable better part removal from transparent window during layer transition.
 *) https://en.wikipedia.org/wiki/Stereolithography
  *) ' Then the vat is 'rocked', '
  *) ' approach is typical of desktop SLA printers, while the right-side-up approach is more common in industrial systems '

*) ASML reticle stage apparently accelerates on the order of or faster than 10G (~100m/s^2) .
 *) 'The reticle stage' 'accelerates faster than a fighter jet.' 'with nanometer accuracy' - https://www.youtube.com/watch?v=B9uDMNmajgw

*) Five axis... piezo... wafer
 *) https://www.youtube.com/watch?v=uZmS36pvQFU
  *) 'Speed up to 2m/s' 'acceleration to 2G'
  *) 'coarse wafer leveling and alignment' '+/- 6 mrad' 'resolution' '0,02 urad'
  *) '+/- 500 um' 'resolution 1 nm'
  *) '+/- 20um' 'resolution' '0,5 nm'
  *) '2.5kg'
  *) 'resonant' '300 Hz'
  *) 'XY Air Bearing' '5 Axis Piezo Stage'

*) ASML PAS 5500 seems to exist at Standford, and seems to have achieved '300nm isolated lines' . This may be much less than what is physically possible, although 'alignment accuracy' of '60nm' is more encouraging.
 *) https://snfexfab.stanford.edu/docs/operating-instructions/asml
 *) https://snfexfab.stanford.edu/snf/operating-instructions/asml

*) PAS 5500
*) Interferometric X/Y position tracker is reportedly 80nm/'pulse' . From the video, it can be seen multiple lasers on each side can differentially observe the mirror changing angle with movements on the opposite axis, as well as distance on the measured axis. This may be controlled further by moving only one axis at a time, also reducing backlash.
 *) http://diyhpl.us/~nmz787/mems/unorganized/ALIGN-ASML.pdf
*) Red laser illuminates alignment mark, only one at a time.
*) 'Field by Field Alignment - This method uses marks that are part of the CAD data for each mask layer; they are typically not exposed individually. These marks may be placed in the scribe lanes. Field by field alighment takes longer than global alignment because each die is aligned, but provides more accurate overlay between layers.'
 *) https://www.yumpu.com/en/document/read/31780620/asml-pas-5500-job-creation-revc-smfl

*) PAS 5500 - Cornell University Video
 *) https://vod.video.cornell.edu/media/ASML+PAS+5500+300C+DUV+Wafer+Stepper+Training+Video/1_2hljhwjl/180053182
 *) 'Energy mJ/cm2'.
 *) 'Aligning the reticle through the lens against the stage'. Seems to illustrate the need to image a wafer without markings at all on first pass, which would challenge a machine without automatic depth of focus through the lens.
  *) Plausibly, a calibration pattern could be projected through the lens to determine depth of focus relative to some scanning probe or such. Plausibly would be less desirable than relying on contrast focusing schemes much like a typical 'blu ray deck' tool.
 *) Seems like calibration could consume many expensive wafers, and these can be imaged very quickly. Appropriate for very high volume factory production. Prototyping should perform overlay before every image, minimizing any use of motion tracking relative to a previous location, however brief.
 *) Machine can vary focus and energy per die, repeating the same reticle with different parameters for each die - implying every mask design is so tested - such would be truly excruciating in prototyping.

*) EUVL mask manufacturing is apparently accounted for by few companies with a total revenue ~billion . Reportedly 'maskless lithography'.
 *) https://en.wikipedia.org/wiki/Extreme_ultraviolet_lithography#cite_note-21
 *) https://heidelberg-instruments.com/
  *) 'first hybrid system to write anything from 15nm to 100um'
  *) 'hybrid direct laser sublimation and grayscale patterning capability'
   *) 'first commercial thermal scanning probe lithography tool'
   *) 'markerless overlay'
   *) 'comparison of the written and target patterns during writing'
   *) 'sub-2 nm vertical precision for 2.5D (grayscale) shapes of any complexity'
   *) Minimum lines and spaces [half pitch, nm] - 25nm (thermal probe writing) - 1000nm (direct laser sublimation)

Reference

https://www.youtube.com/watch?v=CFsn1CUyXWs

https://www.youtube.com/watch?v=V__HbVlnICc
        EUV Starlith 3000

'30 conference presentations' 'academic theses' 'industry papers'
'studies of the alpha demo tool'
'ASML NXE:3400B' 'field size' '33 millimeters by 26 millimeters'
'some types of reticle defects are' *'invisible'* 'to an electron microscope' 'Zeiss took that machine and added to it an atomic force microscope'
Combination of E-Beam and Scanning Probe microscope in one tool already apparently in production use.
'MeRiT LE column'
Nice illustration. Complete machine seems rather large, presumably all etch/deposition happening internally.
Interesting defect examples.
'lens flare'
Apparently scattering by so much as 250pm mirror surface roughness (comparable to the 13nm light wavelength) at mirrors after to Spatial Light Modulator, would cause 25% lens flare, presumably an unacceptable contrast ratio.
'Direct Current Magnetron'
'reflect just around 70%'

https://www.euvlitho.com/2019/P24.pdf
'Ion Beam Figuring'
'50pm'
'overlay' '<2 nm'

https://en.wikipedia.org/wiki/Figuring
'large mirrors, ion figuring' 'neutral atoms'

https://snfexfab.stanford.edu/guide/equipment/asml-pas-550060-i-line-stepper-asml

https://www.youtube.com/watch?v=aR-4AH6n_w8
https://www.youtube.com/watch?v=yNbKkpcmjxk
https://www.youtube.com/watch?v=GBdMRUG69uc

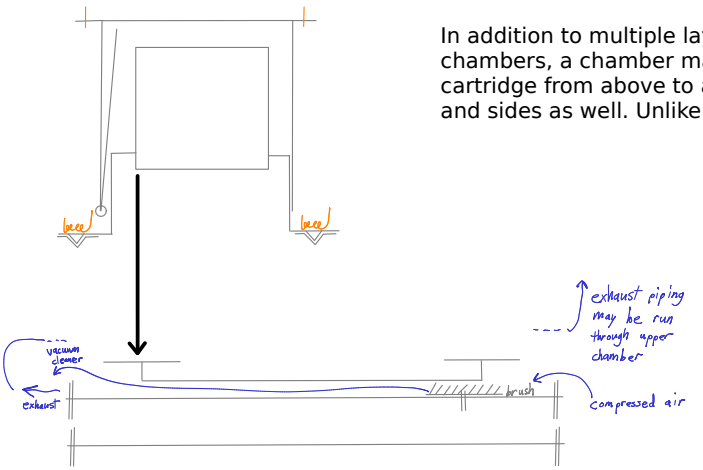
https://www.youtube.com/watch?v=YU6TK2uoYX4
'first EUV scanner' 'EUV Alpha Demo Tool.' 'At that time it took 23 hours to expose a single wafer.' 'IMEC'
'whole system into vacuum' 'we could toss our material catalog for Deep UV'

https://www.youtube.com/watch?v=jH6Urfqt_d4
Shows 'twinscan' slabs moved diagonally. May or may not reflect different linear encoder.

https://youtu.be/jH6Urfqt_d4?t=148
Frame briefly apparently showing twinscan wafer movement with actual hardware instead of CAD model illustration.

https://en.wikipedia.org/wiki/Wafer_(electronics)
'Silicon wafers' 'initial impurity doping' 'either bulk n-type or p-type'

https://caly-technologies.com/die-yield-calculator/

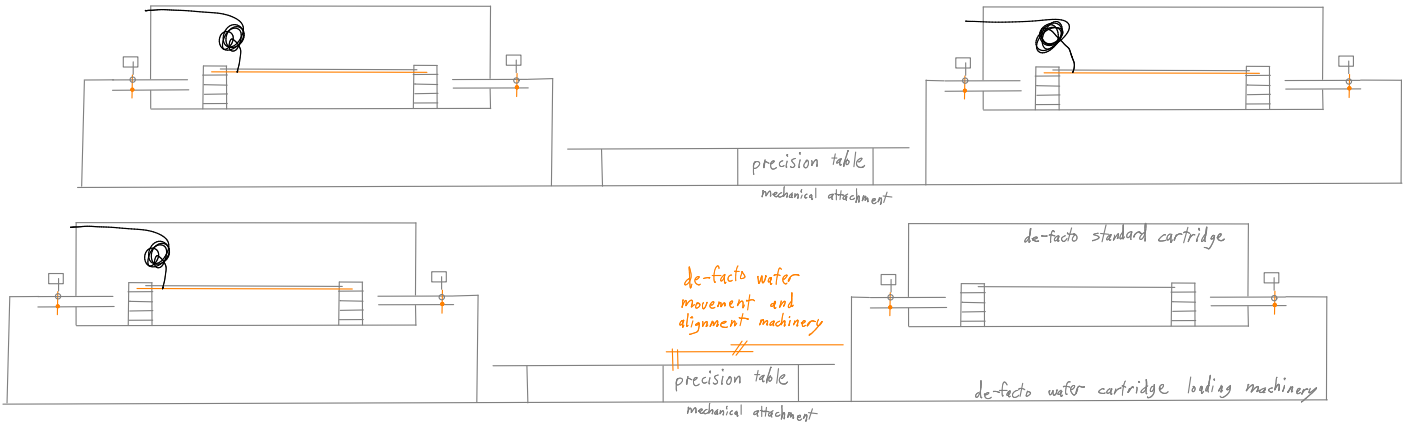


In addition to multiple layers of cartridge floor cleaning chambers, a chamber may be lowered on top of the cartridge from above to allow automatic cleaning of top and sides as well. Unlikely to be appropriate.

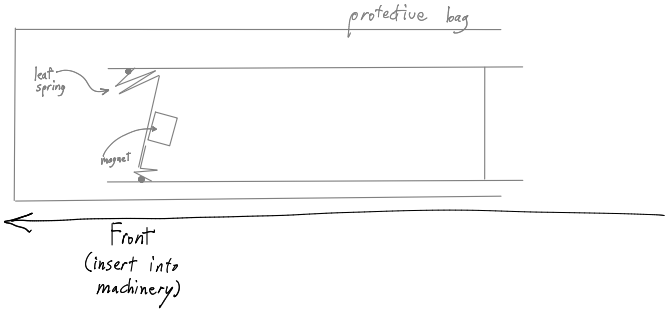
Loading workpieces from table sides - perhaps with entire movable slabs preattached - allows the workpiece to be selected simply by lowering the cartridge until the desired workpiece is at the table depth.

Under sufficiently clean conditions, de-facto standard cartridges may be converted to a more desirable cartridge in this way.

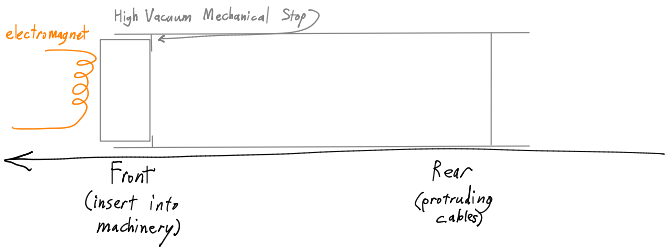
However, except possibly for 'etch' processes tolerance for dust may be very low around 'image' processes.



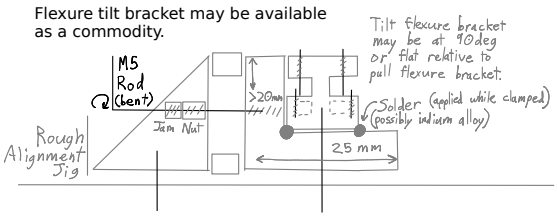
Front load cartridges are not promising, due to workpiece/slab sliding across a cartridge door area that may not be clean, much more lateral 'floor space' occupied for cleaning chambers, and possibly much more mechanical complexity.



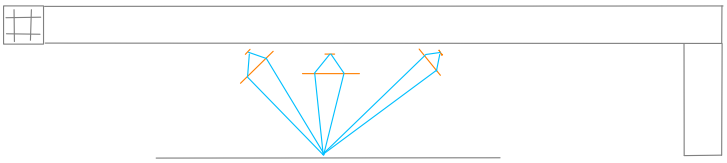
Cartridge must not allow dust to enter. Cartridge may need to have a door which can be opened by electromagnet to access the workpiece.



Threaded Rod Bolted Plate and Flexure Tilt Bracket
Flexure and Translation (3-axis)



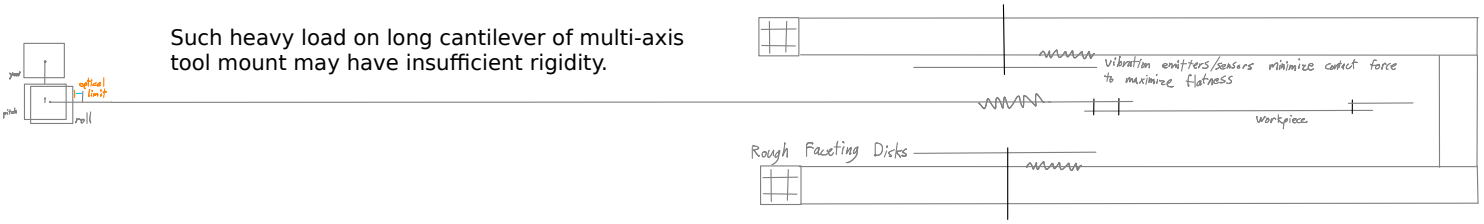
Wafer polishing may require specialized metrology, and may rely on nanopositioned slabs with piezo/linear actuators. Such wafers may then be spot polished by other hardware described herein.

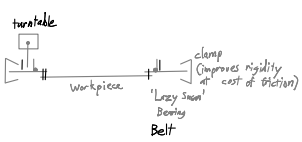


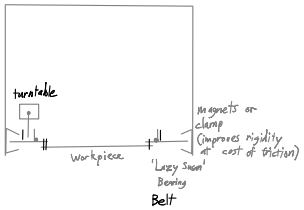
Linear axes (or mere strings) can translate/tilt, dropping a workpiece onto a faceting disk, spot polishing tool, inspection area, etc. Slabs should be far more useful.

Workpiece is mounted as a tool, to be faceted. May be useful to create spinning mirrors and such from such surfaces as the endpoints of motor spindles.

Such heavy load on long cantilever of multi-axis tool mount may have insufficient rigidity.







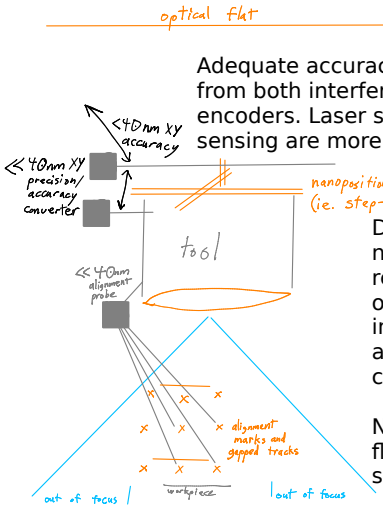
Other mechanisms to bring workpiece in contact with faceting disk and similar tools may be possible.

Optical Disc Pickup

Briefly, relative to nearby locations, some interferometric encoders may allow tool to keep overlay from one position to another.

At least five alignment marks should be within tool field of view for overlay.

Probe may add an additional, crude, overlay mechanism to a tool.



Adequate accuracy is theoretically available from both interferometric and scale linear encoders. Laser speckle and displacement sensing are more speculative.

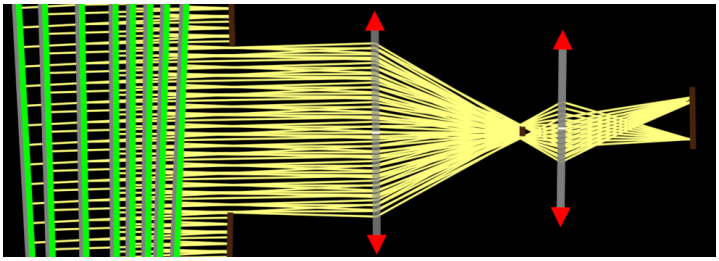
Depth accuracy (Z) not necessary due to reasonable expectation of adequate incoherent interferometry or automatic depth of field correction.

Nonetheless, an optical flat may be used across small (<5cm) distances.

Diffuse Light Source, Spatial Light Modulator, Optical Projection Lithography

Demonstrates that spatial diversity from diffuse light source allows obstructions in focal planes,
but not obstructions out of focus, to modulate projected image.

Similar experiments may be performed with software at - ' https://ricktu288.github.io/ray-optics/simulator ' .



Polar machinery may be mounted atop an already moving slab and well integrated with other nanopositioning machinery. Thus, the benefits may be explored conveniently.

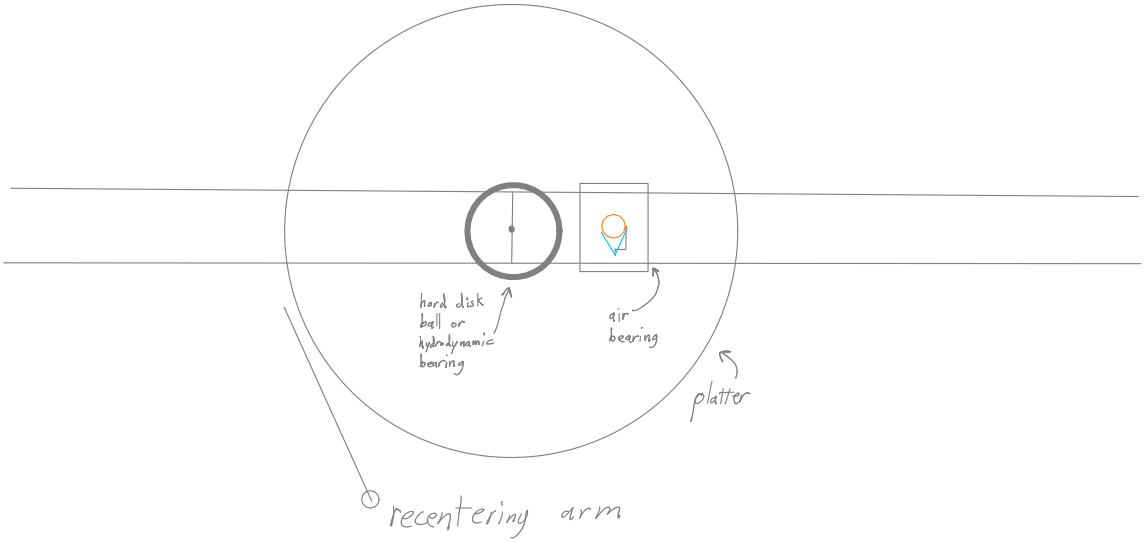
Polar motion allows movements to remain unidirectional and single-axis, allowing some drastically simplified approaches to achieving accuracy (not merely precision). Accuracy as high as 5nm has been reported, unfortunately with a ~1um/1degC thermal expansion error, prohibitive for overlay.

If entire polar motion machinery can tolerate deposit/drill/polish/coat/develop/strip/dissolve (or if the polar machinery is entirely consumable - entire machine may be consumable actually), this technique offers the possibility of non-optical photolithography overlay. Unfortunately, these steps would likely introduce drastic temperature changes.

Overlay may be achieved optically by as little as two or three marks. One line (rotary 0 coordinate), one inner ring (inner centering), one outer ring (outer centering and thermal expansion calibration). Such marks may be inscribed by photolithography or scanning probe. Unfortunately, reading these marks at full rotation speed is likely to prove challenging.

Lens simplicity (possibly merely focusing on a single spot) may allow scanning probe to be placed directly in the optical path with exceptionally rigid mounting geometry directly attached to lens. Unfortunately, this may not be workable at high RPM needed to minimize runout (ie. wobble).

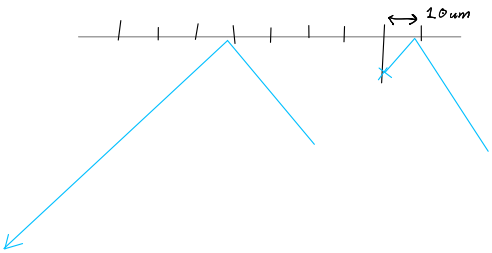
Ultimately, such geometry thoroughly refutes the possibility of alternatives to EUVL (photolithography) optical overlay. Plausible limits are poor for any machinery reliant on mechanical rigidity, unidirectional rigidity, and/or non-optical overlay. Nanoimprint lithography with e-beam overlay and possibly thermal expansion calibration remains the only plausible candidate alternative, with substantial limitations expected, especially in yield.

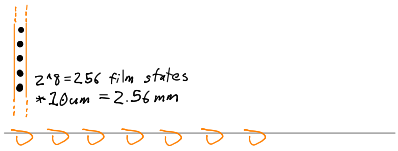


Workpiece chuck may be magnetic, pressure/vacuum/adhesive, however, is required to allow 'shove' by recentering arm.

Wall absorbers are proprosed as a new scatering spatial light modulator technique, emphasizing EUV lithography compatibility. Instead of changing the angle or position of mirrors, a single mirror is perforated, and small walls are pushed through to selectively cast a shadow.

This has the advantage of repurposing existing simple EUVL reflective flats, without substantially changing their optical properties.



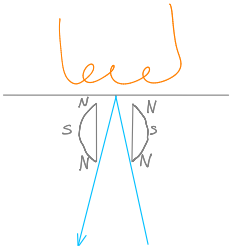


An 8-bit film strip may include all possible 256 states, switchable by simple stepper motor with optical encoder. An 8*8=64 pixel mechanically actuated array may be formed this way, running over top the EUV mirror flat, with no perforation. Of course, the 'film strip' must have physically open/closed shutters, to prevent EUV absorption.

Mechanically actuated microshutter arrays may scale to 30 shutter linear arrays if pulled by mechanical cables connected to solenoids.

Alternatively, mechanically scanned electromagnet array should be able to set these efficiently.

Microstepping is expected to be particularly fast, and may actuate 'light valves'.



Availability of even 405nm photolithography enables the gradual removal of DLP protective covering, or the direct fabrication of a new MEMS micromirror/microshutter device. Slip-step and electrostatic actuators with active matrix or linear binary on/off addressable register arrays may be preferable. Coating existing DLP MEMS micromirrors for EUV reflectivity is expected feasible.

positionTrackers

Combined camera, 'lighthouse', ultrasonic, interferometric, speckle (highly precise structured light), magnetic, and/or ultrasonic, position tracking, for best possible accuracy and precision, at lowest cost.

Low-cost surface-mount commodities (ie. microcontroller, LEDs, laser diodes, MEMS inertial chips, inductors, frequency mixers, envelope detector schottky/germanium diodes) are sufficient to track objects with best possible accuracy and precision beyond-line-of-sight for all plausible uses (eg. 'VR roomscale', 'VR HOTAS emulated controllers', mechDive exoskeleton, mechDive tunneling, CNC low-latency position feedback correction).

Introduction

Single (possibly flexible) PCB can integrate all the negligible cost widely available hardware for each plausible use case. Microcontrollers of the lowest cost and highest availability have sufficient analog and digital hardware.

Object emitter. Sub-mm for 'VR roomscale', mechDive exoskeleton, tool/workpiece
*) LED CDMA emitters. Frequently (>>10Hz) calibrate accurate position to camera line-of-sight. Communicate button presses beyond-line-of-sight.
*) Magnetic inductor differential *emitter* (magnetic field RF antennas), analog frequency filters, diode detectors, frequency (or phase comparing) mixers, amplifiers. Frequently (>>10Hz) calibrate accurate position beyond-line-of-sight after occasional (<3600second) LED/camera calibration line-of-sight.
*) MEMS accelerometers. High frequency (>>100Hz) precise position/rotation increments from low-frequency tracking.

Overlay and VirtualStick tracker. High-precision (<250um) short distance (<0.5m) for hand/finger tracking (ie. precision paw tracking, 'VR HOTAS emulated controllers'), tool/workpiece. Less common than object emitter alone due to strict line-of-sight requirement.
*) Camera, low-resolution high-framerate (ie. HID mouse optical tracking camera). Precisely observes movement of structured light from laser speckle.
*) Object emitter. Less precise, occasional (<180second) accuracy recalibration, communication of button presses and such.

Short distance limitation of speckle sense is due to eye damage risk of >>30mW point sources of light. Where this is not a concern (ie. sealed CNC machinery), tracking distance may be much longer (~5m, or >>5m with focusing optics).

Ultrasonic tracking is only useful for mechDive tunneling, using inexpensive piezoelectric materials and inexpensive hydrophones (which may be fiber optic). Such rare usage would nevertheless justify any plausible expense or inconvenience.

Interferometric tracking of linear distance - by resonant optical cavity or (more speculatively) synthetic aperture observations of a point source - feasible at low cost - is expected either unnecessary (due to through-lens overlay) or limited to the very specialized mechanism to track the edges of workpiece slabs .

Presented

*) Sketches of plausible use cases and component layouts.
*) Angular resolution calculations.
As may be plausible.

Conclusions

Magnetic tracking is usually superior to ultrasonic tracking, though less compact. Magnetic tracking is most useful for beyond-line-of-sight tracking after occasional (a few times per hour) calibration. Ultrasonic tracking may lose accuracy immediately after any calibration due to refractions and reflections, so is most useful where compactness, precision, and beyond-line-of-sight are imperative (ie. mechDive tunneling).

Oculus constellation has rare low-cost ~1000FPS cameras. Alternative is USB3 FPGA3 adapters to adequate camera sensor chips.

Due to dependency on high-frequency capture of small amplitude changes at any reasonable rate of motion, amplitude modulated identification of individual speckle sense transmitters is probably not feasible.

REFERENCE

https://specklesense.media.mit.edu/text/zizka_specklesense_uist_2011.pdf
 'SpeckleSense: Fast, Precise, Low-cost and Compact Motion Sensing using Laser Speckle'

https://en.wikipedia.org/wiki/Angular_diameter
https://en.wikipedia.org/wiki/Angular_resolution
        Equation - radians == wavelength / diameter .

https://www.google.com/search?q=arc+seconds+per+radian
        '206265' arc seconds per radian by 'google' conversion

Estimate - Angular Diameter and Resolution - VR HOTAS positioning.

Notably, if the ratios of observation diameter/distance and aperture wavelength/diameter are equal, then the observation angular diameter and aperture angular resolution will also be equal.

Observation diameters larger than ~50um (much larger than wavelength) may use non-coherent LED ultraviolet light sources (ie. 365nm).

```
  'radian_arcSeconds=206265'
```

Observation

```
  'observation_distance_m=5'
  'observation_diameter_mm=0.5'
  '_clc "($observation_diameter_mm * millimeter) / ($observation_distance_m * meter) * $radian_arcSeconds"'
# 20.6265
arc seconds.
```

Aperture

```
  'aperture_diameter_mm=10'
  'aperture_wavelength_nm=1000'
  '_clc "(( $aperture_wavelength_nm nanometer) / ( $aperture_diameter_mm millimeter)) * $radian_arcSeconds"'
# 20.6265
arc seconds.
```

Estimate - Angular Diameter and Resolution - Overlay ~10um .

```
  'radian_arcSeconds=206265'
```

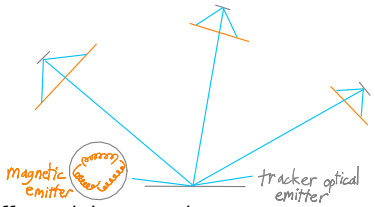
Observation

```
  'observation_distance_m=2.5'
  'observation_diameter_mm=0.009125'
  '_clc "($observation_diameter_mm * millimeter) / ($observation_distance_m * meter) * $radian_arcSeconds"'
# 0.75286725
arc seconds.
```

Aperture

```
  'aperture_diameter_mm=100'
  'aperture_wavelength_nm=365'
  '_clc "(( $aperture_wavelength_nm nanometer) / ( $aperture_diameter_mm millimeter)) * $radian_arcSeconds"'
# 0.75286725
arc seconds.
```

External Camera



Differential magnetic emitters may continue precise position/rotation tracking beyond-line-of-sight, with similar location specific communication and identification advantages.

Unmatchable advantages.

*) Complete coverage.
*) High resolution (up to ~10cm lens diameter).
*) High framerate (up to ~1000fps) .
*) Wide compatibility - several protocols allowing mix of different camera framerates and capabilities.
*) Simultaneous integration with other position trackers.
*) Standalone with onboard pixel tracking and non-networked wireless out-of-band protocols.
*) Dedicated spatial channel allocated to each tracker.
*) Communication, location specific and directional.

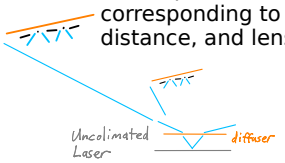
Inertial tracking may interpolate between positions/rotations from other resources.

Ultrasonic

Ultrasonic emitters may improve distinctiveness of small points in liquid or gel beyond-line-of-sight.

Speckle Sense

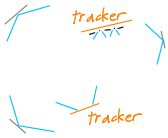
SpeckleSense can be understood as an especially detailed laser shadow projection structured light technique, with the size of 'speckles' corresponding to wavelength, distance, and lens.



As with any structured light or interferometric position tracking, whole steps must be counted specifically to overrule any accumulated errors from 'microstep' interpolation.

Wavelenght division is necessary for multiple speckle sense emitters, to prevent overlapping projected patterns.

Due to limited number of wavelengths separable by inexpensive, compact, robust filters (as few as two), if multiple trackers are used, the trackers must be cameras (eg. image sensors from HID mouse), since only few emitters can be used simultaneously.



Lighthouse

Precision more acceptable than unmarked camera inferring position from relative shift of nearby scenery. Substantial, severe, disadvantages.

Emitter Location-Specific Communication Protocol

Modulation illustrated is of single magnetic or optical emitter (ie. LED), not RF, not wavelength divided.
Usually short UV 365nm wavelength is strongly preferred for precision.

Any non-default emitter amplitude modulation must be demanded of that specific emitter by RF packet.

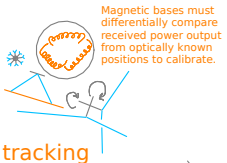
Non-directional communication (ie. from magnetic emitter instead of LED to camera) may use CDMA codes with 2^6 addresses or TDMA with random timeslots unless non-random TDMA timeslots have been demanded.

Demand RF packet begins with a high-energy RF pulse to cause MCU interrupt from analog bandpass and diode envelope detector, follows with emitter identifier, and ends with a magic number corresponding to the demand.
Fragile network protocols, complicated or expensive network hardware (ie. Bluetooth), are unnecessary and *strongly discouraged*.

Default mode, identifier 8bit or 10bit, followed by 2byte rate of acceleration change.
Identifier immediately repeats if accelerometer output is unnecessary or unavailable.
Continious emission, minimum power.
Ensures fast tracking with low framerate cameras and minimal software complexity.
Arbitrary data. Button press, accelerometer output, acknowledgement of demand, etc.
RF packet of similar format to demand packet may be used instead (discouraged).
Blink.
Usually an acknowledgement of demand, to locate a specific emitter quicky.

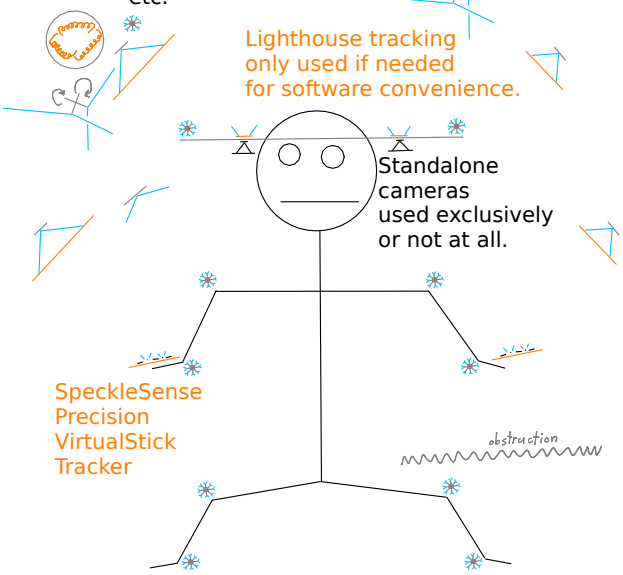
VR Exoskeleton Tracking

Exoskeleton relies on Force-FeedBack, does NOT need controllers with buttons, sticks, etc.

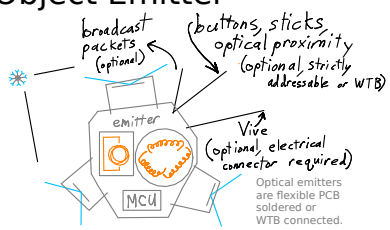


Lighthouse tracking only used if needed for software convenience.

Standalone cameras used exclusively or not at all.



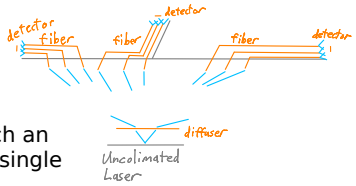
Object Emitter



Standard single PCB with all components for any sub-mm line-of-sight accuracy calibration, beyond-line-of-sight precision, and inputs from buttons or sensors.

errata

Synthetic aperture. Theoretically, combining multiple points interferometrically should cause the received speckle to oscillate amplitude more frequently (per travel distance), due to receiving waves in different phases simultaneously. Thus, speckle pattern feature size may shrink as may be expected of an image taken by a larger diameter lens. Some tinkering with the optics (eg. removing diffuser, interferometric lens combining) may be appropriate.

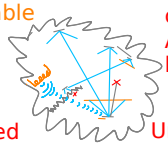


Lithography 'overlay' is the only known production use for such an elaborate tracking system emphasizing accurate locaton of a single point source of light.

Absolute position correlation to relative 'single-pixel' fiber optic readouts may be indirectly calibrated to single-microstep stepper motor travel along any single axis, as these motions typically achieve extreme precision. Especially after significant travel in a single direction has overtaken any backlash. Otherwise, fiber optic single pixel readouts may not directly indicate absolute position (which would result in a precise rather than accurate measurement), and may not have any absolute units.

Magnetic tracking can be calibrated by even brief visibility to camera, and remains observable behind obstructions.

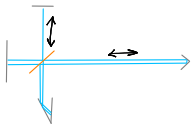
External cameras require substantial processing or bandwidth. Moreover, API forward compatibility becomes a major concern.



Obstructed view from central location.

Unwieldy high rotational inertia from distant camera mount.

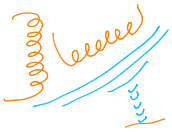
Placing cameras on device improves convenience. However, tracking accuracy may be much less, cost may be higher, and obstructed objects can only be tracked magnetically. Rather than adding more hardware in these cases, software VR ergonomics (ie. very large HOTAS controls, headlook menu systems, and controller gesture/button vehicle/standing mode switching) in software is likely to be far more practical.



Linear Interferometric - coherent or white-light - encoders may offer extreme accuracy (particularly when counting whole 'steps'). However, realizing this accuracy may require linear tracking of flat mirrors, precisely manufactured retroreflectors, precise reference beambath changes, and/or fast signal processing. All of these requirements are expensive, limiting, or both. As such extreme accuracy is not required for VR tracking, but may be for manufacturing tools (ie. photolithography overlay), this is a technique to consider for as appropriate for specific use cases.

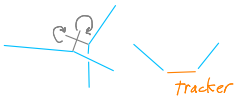
Radio phase comparison and time of flight. Accuracy may be limited by frequency response of components. Accuracy may degrade due to multipath. Frame rate may be limited by correlation time. Computer processing may be necessitated by correlation, especially under multipath.

Sometimes convenient. Accuracy, and framerate may be fundamentally limited.



Magnetic phase tracking may not have adequate precision. Differential amplitude signal may be more precise.

Lighthouse tracking has proven workable, with some limitations and reported reliability issues. Only worthwhile to support legacy (ie. 'SteamVR') software.



Lens diameter is limited due to spinning mass limitations.

Photosensor response times, and diode laser modulation rates, for commodity devices, have been barely adequate. Any degradation is likely to cause failure.

Any 'bumps' in mechanical spin cause loss of precision.

Power consumption and cost per tracker has remained high for commercially available devices, making accessories expensive and require frequent recharging.

Accuracy is not achieved unless reference trackers are placed. Due to high cost, and lack of integration with existing lighthouses, 'floor' position tends to 'shift' several centimeters with every power cycle.

Safety problems with ~200mW lasers may necessitate overly cautious fail-safe disablement of otherwise usable devices.

Only obvious advatage of Lighthouse tracking is the lack of computer processing required. Modern technology has been displacing scarce laser barcode scanners with computer processing of camera images for more than ten years now. Moreover, the disadvantages of laser scanning absolutely limit range, absolutely preclude communication over the same channel, and raise unnecessary safety issues.

DISCLAIMER: Plausible concepts, attributed sources, oversimplifications, resonably. Rigorous mere academia NOT primary.

sleeveDive

Thoroughly interfacing, rearranging, and rewiring, the organic components. Wetware equivalent of FPGA for harnessing any last neural correlate of consciousness.

Wetware/hardware design to sustain (ie. 'mindUploading') and/or supplement (ie. 'exocortex') any possible neural correlates of consciousness (ie. replacement wetware instead of hardware) and computational capability recorded by 'neuralBits' and correlated to connectome and synaptic weights from 'cognitionSplicer'. Emphasis on minimizing risk of losing neural correlates of consciousness (ie. NOT using brain simulation software on silicon hardware for now), and 'full-dive' Virtual Reality (VR) or preferably Simulated Reality (SR) , while keeping both capital and ongoing costs (ie. Total Cost of Ownership) close to high-end GPUs (~$2k capital, ~$10/hr).

Feasible, as a combination of 'neuralBits' (or similar) electrical interfaces bridging fragments of brain tissue, kept alive by artificial or natural sources of suitable fluids, all after some electrical stimulation to impose connectome and synaptic weights similar to that of previously recorded brain activity. A recreation of (eg. human) brain across a combination of hardware and separable wetware components.

For early venturing early users of 'neuralBits', having 'sleeveDive' already available as emergency replacement wetware could be a life saving fallback if anything goes awry within the first few hours. Thus, 'sleeveDive' also mitigates the most substantial risks of invasive neural interfaces.

Introduction

*) Extracting and keeping alive for several hours, brain tissue, to the point of entire rat or guinea pig brains, by perfusion of elemental mineral solutions (ie. aCSF), under anaesthetic, is already routine.

*) Electrical neural interfaces beyond thousands of neurons are already available for in-vitro, and are becoming more available for in-vivo.

*) Extending existing brain tissue survival time and yield is feasible, if not by better control of the extraction and aCSF (artificial Cerebral Spinal Fluid) then at least by leaving the brain tissue in-vivo with natural dCSF (derived Cerebral Spinal Fluid) as normal.

*) Extending electrode quantities to suffice for brain-to-brain interfaces between brain tissue 'wetware components' with 'neuralBits' hardware is feasible - specialized hardware for immovable or in-vitro brain tissue is substantially cheaper.

Presented

As may be plausible.

Sketch Illustrations

*) Automated, fast extraction, slicing, and dicing, of brain tissue (if necessary - survival time and yield presumed to improve with less time and trauma).
*) Accessible grid of <<1mm containers to anchor, nourish, and interface neural cells, with small openings for axons between neurons. Manufacturing these is expected to require sub-mm resin 3D printing, or photolithography prototyping by etching.

*) Bulk tissue framing, nourishment, and interfacing.
*) Whole organism natural dCSF, homeostasis management and sensation, harnessing (life support).

*) 'Bioprinting' needle designs to pick and place small quantities of biological tissue with minimal time, trauma, collateral damage, or other degradation.

Calculations

*) Neurons per cubic volume of brain tissue to total neurons within cubical container of specified edge dimension.

Conclusions

Photolithography resolution compatibility of hardware designs must be >>300nm to minimize unnecessary cost or prototyping difficulty. Arbitrary rearrangement of wetware obviates concern over collateral damage or electrode density, with only the total quantity of electrodes significant.

MAJOR - FUNDAMENTAL - Electroplating at 25um/h suggests a growth rate highly similar to axons. While acceptable, improvement would be desired if possible by physics.

Container grid can be fabricated by etching based photolithography (not electroplating). Plastic substrates from sub-mm resin printing will most likely be more durable under the chemical erosion of nearby wetware than any metal or protective coating on metal.

Isolated brain tissue may be regarded similarly to an electronic component, suitably connected to an appropriately manufactured socket.

Apparent time acceleration, usefully, must accelerate single-threaded cognition abilities to the point of catching a faster falling Newton's proverbial apple. A small acceleration factor (ie. >3x) may sufficiently separate WORLD (ie. both VR WORLDs and that other 'IRL' WORLD) economies to eliminate any perceived need for interference from inhabitants of one WORLD with any other (ie. insisting players in virtual WORLDs leave too often for an immersive experience).

Such time acceleration by single-threaded performance improvement may not be possible by adding more neurons or by increasing power density (ie. metabolism). Rather, reducing resistance/capacitance time constant of neuron membranes, or increasing decision making efficiency for groups of neurons, may be necessary. Reducing resistance/capacitance time constant may require active components on the membrane (ie. nanowire semiconductors from added genetic material, voltage gated ion channel improvements, more voltage gated ions channels). Increasing decision making efficiency may require using only one fraction of neural tissue at a time, another fraction taking update connectome and synaptic weight changes, and all remaining neural tissue kept comatose to recover.

Silicon hardware exocortex may not have correlates of consciousness, while any memories created by such may seem equally genuine in retrospect. While a silicon hardware exocortex may have better single-threaded performance for more time acceleration, risks of not having neural correlates of consciousness to actually experience anything, *must not be disregarded*. Any use of a silicon hardware exocortex should be only supplementary until proven to at least have very appropriate analogues of any remaining candidates for any last neural correlates of consciousness. Such may include neural membrane shape, ion channels, transient voltage gradient shapes, as well as the merely hopeful possibility that any similar software algorithm could have some 'consciousness' - extreme skepticism is appropriate absent absolute logical proof. Regardless, any entity capable of ethically claiming self-awareness and a desire to exist must be treated accordingly.

Parallel neural cognition performance improvement, if cost effective, may include - up metabolism, up ATP/ADP concentration, up mitochondria, up sodium/potassium pump, up blood/dCSF/aCSF flow, down inflammatory enzymes, down blood immune system.

Cubical containers are ideal for any experiments to increase neuron performance or latency, due to high flow and containment of occasional failures (eg. excessive multipliction, abrupt circulatory changes, etc) to a small area.

Open circulatory systems are well precedented in nature. Significant survival of brain tissue for multiple hours strongly implies open circulatory system is at least adequate, if not beneficial, obviating recreation of parts original circulatory of brain tissue.

Multiple extracoporeal circulatory systems seem feasible, and have the substantial benefits of redundancy and reduced replacement difficulty .

CSF may ultimately be the only fluid all CNS neurons are directly in contact with - if true only oxygen, carbon dioxide, and glucose would need to be added to a typical 'aCSF' 'buffer solution'. Due to the peripheral nerves mostly carrying neural axons (at least at some distance), CSF would likely be adequate for the PNS as well. CNS and PNS both may naturally rely entirely on outward flow of CSF fluid.

Cubes are suggested mostly to minimize collateral damage from occasional inappropriately multiplying cells (ie. cancer, bacteria).

Rather than cubes, simply pressing an entire slice of tissue into suitably perforated and textured machined plate may be more useful, technically more efficient, and simpler.

Continuously flowing water with gates may allow slices to be collected by automatic means, to be dispensed towards an appropriate plate.

REFERENCE

https://www.sciencedirect.com/science/article/pii/S2451929418301724
 ' Recent Advances in Nanowire-Biosystem Interfaces: From Chemical Conversion, Energy Production to Electrophysiology '

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4924811/
 ' Cortical Specializations Underlying Fast Computations '

https://www.nature.com/articles/s41467-020-15759-y.pdf
 ' Bioinspired bio-voltage memristors '

https://www.brainbitsllc.com/e18-rat-whole-brain
https://www.brainbitsllc.com/e18-rat-cortex
        'Guaranteed to Yield 2.0 Million Viable Cells'
                Perhaps a rather high yield, actually.

https://brainxell.com/mixed-cortical-neurons
https://www.allencell.org/
https://catalog.coriell.org/

https://www.brainbitsllc.com/faq/
        'Brains will be dissected after anesthesia with halothane or pentobarbital.'
        'The cortical BrainBits probably has about 10% astrocytes. If you culture in serum, you will get many more. We recommend culture in B27/Neurobasal (Invitrogen/GIBCO). This inhibits glial growth without AraC.'
                'astrocytes' 'you will get many more'
                        Presumably avoidable and possibly undesirable.
        'Usually, our experience is that yours is the only sample contaminated out of all our shipments for the week, so please understand that we require the above tests.'

https://en.wikipedia.org/wiki/Isolated_brain

https://en.wikipedia.org/wiki/Artificial_cerebrospinal_fluid
        Seems cerebrospinal fluid has far fewer constituents than blood, presumably due to the brain-blood barrier. Should be much more straightforward to sustain neural tissue from mineral solutions costing a few hours per hour in raw materials outright, if not somewhat less to recycle.

https://en.wikipedia.org/wiki/Dialysis
        'dialysis solution has levels of minerals like potassium and calcium that are similar to their natural concentration in healthy blood'

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4157386/
 'Cerebrospinal fluid outflow along lumbar nerves and possible relevance for pain research: case report and review'
        'It has been traditionally accepted that cerebrospinal fluid (CSF) flows from the subarachnoid spaces (SAS) through the cribriform plate into the cervical lymphatics, and similarly, along all brain nerves and all peripheral nerves into the respective tissues. This CSF outflow can transport antigens from CSF spaces to the extracellular fluid of peripheral tissues'
                Strongly implies (1) CSF nourishes peripherial nerves and (2) antigens are present in CSF, further strongly implicating (3) only adaptive immune response is present outflowing from CNS or PNS, and no immune response in CNS.

https://en.wikipedia.org/wiki/Brain_abscess#Treatment
        Demonstrates some degree of tolerability for bacterial infection above zero. Suggests even non-multiplying cells (ie. neurons) are capable of outcompeting multiplying cells (ie. bacteria), strongly implying efficiency in a particular environment is a major constraint, with a strong genetic basis.

https://www.youtube.com/watch?v=V2YDApNRK3g

https://jbiomedsci.biomedcentral.com/articles/10.1186/s12929-019-0578-x
https://jbiomedsci.biomedcentral.com/articles/10.1186/s12929-019-0578-x/tables/2
 'Human iPSC banking: barriers and opportunities'
        'Table 2 Brief overview of iPSC banks worldwide'

https://www.youtube.com/watch?v=YWQnzylhgHc
        'This is not a program telling the robot to stop and reverse when an obstacle appears, it is the Connectome'

https://www.pnas.org/content/109/Supplement_1/10661
 'The remarkable, yet not extraordinary, human brain as a scaled up primate brain and its associated cost'
        '75.5%' '75.7%' '84.0%' 'entire brain mass'

https://hypertextbook.com/facts/2001/ViktoriyaShchupak.shtml
        '1200' 'cm^3'

https://en.wikipedia.org/wiki/List_of_animals_by_number_of_neurons
        'human' '16 billion neurons in the cerebral cortex'

ACKNOWLEDGMENT

*) For 'shorter duration action potentials', plausible example mechanisms were more confidently identified by articles found by 'Andonis' at the 'Futurist Network' 'Discord' server . Before that, accelerating apparent time by electrical interfaces bypassing action potential duration seemed substantially less feasible.
 *) ' Cortical Specializations Underlying Fast Computations '
 *) ' Recent Advances in Nanowire-Biosystem Interfaces: From Chemical Conversion, Energy Production to Electrophysiology '
  *) ' SEMICONDUCTOR NANOWIRES WITH LIVING CELLS FOR ELECTROPHYSIOLOGY '
 *) ' Bioinspired bio-voltage memristors '

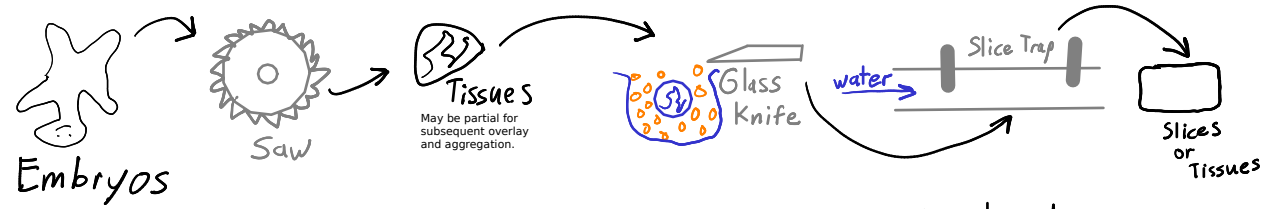
Estimate - Neurons in Containers

```
  'neocortex_neurons=$(_clc "16 * 10^9")'
  'neocortex_mm3=$(_clc "1 * 10^6")'
neurons_mm3= 16000
neurons_um3= 0.000016
```

```
  'container_50um_neurons=$(_clc " ((50 * ((1 micrometer) / (1 millimeter)))^3) * $neurons_mm3 " )'
container_50um_neurons= 2
  'container_75um_neurons=$(_clc " ((75 * ((1 micrometer) / (1 millimeter)))^3) * $neurons_mm3 " )'
container_75um_neurons= 6.75
  'container_100um_neurons=$(_clc " ((100 * ((1 micrometer) / (1 millimeter)))^3) * $neurons_mm3 " )'
container_100um_neurons= 16
  'container_150um_neurons=$(_clc " ((150 * ((1 micrometer) / (1 millimeter)))^3) * $neurons_mm3 " )'
container_150um_neurons= 54
  'container_250um_neurons=$(_clc " ((250 * ((1 micrometer) / (1 millimeter)))^3) * $neurons_mm3 " )'
container_250um_neurons= 250
  'container_1000um_neurons=$(_clc " ((1000 * ((1 micrometer) / (1 millimeter)))^3) * $neurons_mm3 " )'
container_1000um_neurons= 16000
```

```
  'container_um=125'
container_mm3= 0.001953125
  'container_neurons=$(_clc " $container_mm3 * $neurons_mm3 " )'
container_neurons= 31.25
```

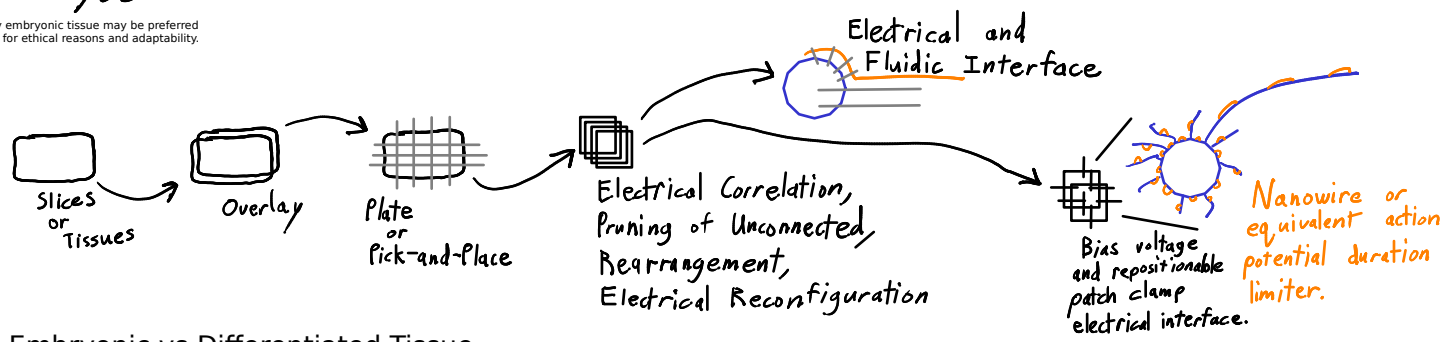
Automated, Fast - Extraction, Slicing, Dicing (of brain tissue)



Early embryonic tissue may be preferred both for ethical reasons and adaptability.

May be partial for subsequent overlay and aggregation.

Each step may be optional, chosen and configured according to desired tissue, shape, and efficiency.



Embryonic vs Differentiated Tissue

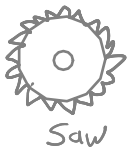
Early embryonic tissue may be better able to establish long efferent axons. Slightly more differentiated embryonic tissue may still be preferable rather than adult tissue - ethically - due desirability of minimizing erasure of memories, regardless of whether tissue is from a species or artificial genome with any capacity for sentience.

Obtaining tissue from highly specific locations or extents of differentation, and cataloging these samples properly, may allow automatic iteration through topographic map origins, efferent axons, and destinations, prior to electrical reconfiguration. Such may be particularly helpful if any sensory precepts correspond to specific biological molecules (ie. if not merely the structure of information input and processing but proteins or shapes of proteins account for such distinctively different quallia as sight, sound, touch, taste, smell, etc).

In any case, avoiding too much electrical reconfiguration in favor of preserving molecularly determined connectome to the extent possible, may be much safer. Nevertheless, beware synsthesia, loss of resolution, or at least longer delays in synaptic pruning, from inaccurate blending or geometric assignment of cells from different topographic map positions.

Extraction Saw

Whole brains are routinely extracted. Nevertheless, if some brain tissue is desired that is not so available, slicing three brains will allow extraction of tissue from all parts of brain from surrounding skull, regardless of tissue ablated by thickness of saw. Arguably inefficient and crude, but effective.



Slicing Knife

Glass (or diamond) knife takes micrometers thin tissue slices with negligible or <50% ablation.

If tissue is not sufficiently rigid, or is not easily anchored to a surface, fast light-cured epoxy resin may be added around tissue or before each slice.

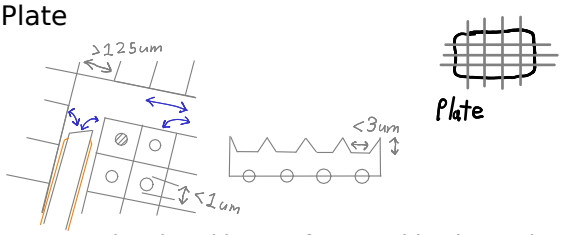
Surrounded by rigid cured hardened resin, removed from mold as a composite workpiece, glass knife may slice through precisely. Resin form an expendable slicing jig as such.

Overlay (mechanical)

Relative positions of tissue must be tracked if possible, especially if sensory precepts may result from biological molecules unique to specific topographic maps.

Blended tissue (if unavoidable) should if possible only mix tissue from adjacent locations.

Plate



Neurons may be placed in a surface-machined or resin 3D printed grid container scaffold, with drilled holes for open circulatory nourishment, accessible corridors for needles, edge slots between container walls for axons, resembling a waffle.

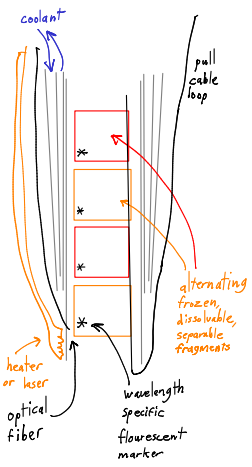
Tops of containers are closed by another layer of such scaffold plate, a stack of waffles. Electrical interface may be the scaffold substrate itself, or added after.

Gaps between containers must prevent multiplying cells from spreading. Bacteria (other than mitochondria) may be treated by antibiotics or similar.

Pick-and-Place (bioprinting)

Tissue fragments may be extracted from tissue, then deposited within other tissue or at specific locations, assembling geometric arrangements of cells, or possibly fragments of cells. In the most extreme case, fragments of axons may be placed, experimentally, effectively grafting into arbitrary tissue.

Slicing or boring through tissue may pick tissue fragments. A conveyor belt with attachable/detachable fragments may place tissue fragments without the disruptive collateral damage of repeated insertions through the workpiece. Bioprinting, by a pick tool, a place tool - assembly by 'pick-and-place' tool.

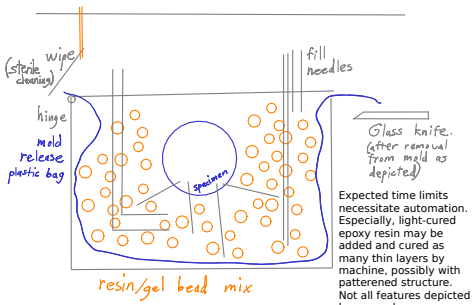


Bulk Tissue - Framing, Nourishment, Interfacing

Framing

Coagulation and mechanical stabilization of tissue surfaces by resin 3D printing may maintain correct fluid flow or prevent tearing as appropriate in many situations, both while slicing tissue, or if tissue is never sliced. Such filler may also include quick-set epoxy, cyanoacrylate, or merely shredded materials such as micrometer gelatin cubes/spheres.

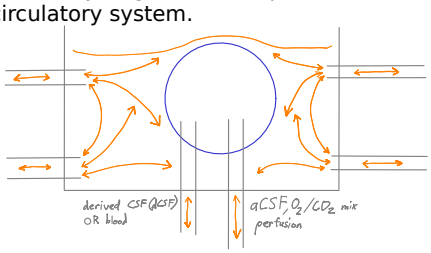
Using sub-mm resin 3D printing, instead of curing all resin around tissue, may reduce tissue exposure to near-UV curing light, and may ensure internal structures (ie. blood vessels) are not inappropriately filled and hardened.

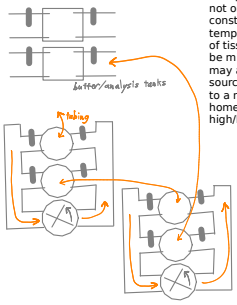


Expected time limits necessitate automation. Especially, light-cured epoxy resin may be added and cured as many thin layers by machine, possibly with patterened structure. Not all features depicted here may be necessary.

Nourishment, Interfacing

Precise control of blood/CSF flow rates at specific tissue locations may be necessary, regardless of open or closed circulatory system.

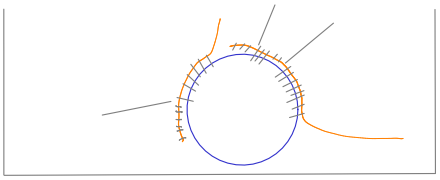




Multiple buffer tanks may be required not only to change fluid (ie. aCSF) constituents but also to rapidly change temperature, especially during transfer of tissue (when time and trauma must be minimized). Mutliple buffer tanks may also be helpful with natural fluid sources (ie. dCSF) to more rapidly shift to a mixture usual of a different homeostasis condition (eg. day/night, high/low metabolism).

Appropriately sterile tubing supplies may have a narrow selection of components, and turbulence minimization may be required.

Rapidly and gently filling, draining, and recirculating nourishment fluid may require some clever arrangements of appropriate commodity tubing and pumps.

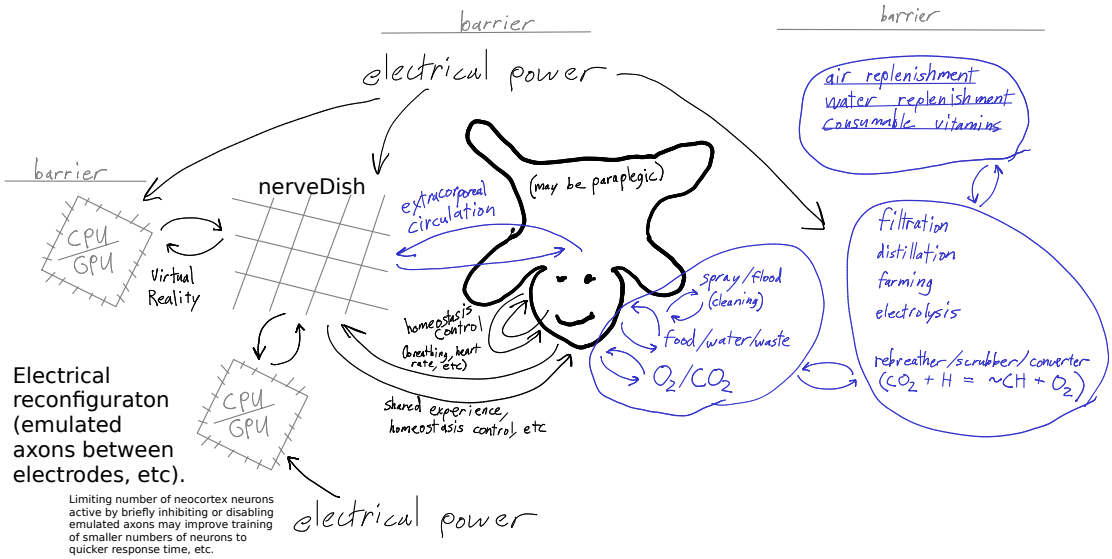


Instead of slicing and/or dicing, neural interface (ie. 'neuralBits') may be added to neural tissue as extracted (eg. 'whole brain'). Obviously should be arranged before embedding in hardened resin.

Whole Organism - Natural dCSF, Homeostasis Sensation, Harnessing

Some specifc homeostasis sensations (eg. breathing, soporific digestion) reinforce important motivations (eg. exploration risk, competitve energy management, competitive short-term planning), and may be desirable as such. Biological organisms already inherently having such homeostasis management, reported to the embodied person, may be a feature, instead of a defect.

Combining a biological organism with disembodied brain tissue has several advantages, although emulation of homeostasis sensations for disembodied brain tissue by software modeling is possible and may also be economical in some situations.
*) Economic efficiency. By combining ion channels with membranes, may be able to more economically recycle such fluid constituents than synthetic industry (which often disposes of salts open-loop after obtaining from raw minerals).
*) Inherent homeostasis sensation, at least when reasonably healthy.
*) Obviates possible significant technological issues (eg. possible complexity of blood constituents if aCSF may be insufficient).
*) May combine whole brain of organism (original connectome between topographic maps) with a more reconfigurable nerveDish simultaneously (eg. to emulate at least most of a previously human connectome and synaptic weights).



DISCLAIMER: Plausible concepts, attributed sources, oversimplifications, resonably. Rigorous mere academia NOT primary.

errata

_ Terms _

_ Rough _

-
REVIEW - May be duplicative from (another) part of (another) document.

*) Wet abrasion, dry absorption.

-
Elaboration regarding otherwise already noted concepts.

*) Suitable highly-selective fluid barrier may be created by alternating layers of cell types, limiting fluid transfer between layers.

*) Additional >3um perforations may be added to top/bottom of boxes to allow greater fluid transfer.

*) MAJOR - Hardware and wetware failure rates are similar, and should be rare. Combined system must keep a backup, and if either hardware or wetware failure are detected, backup should be copied to new hardware/wetware, at which point entire broken combination of hardware/wetware may be repaired/discarded/recycled.

*) Personal backups must only be deleted or otherwise acted upon at the request of their own person, on detection of incapacitation to make such a request - not by accident or failure to recognize mere paralysis. Partial paralysis may be especially troublesome when some parts of a cognition divided across sevaral neural tissue slices may remain functional after the failure of others.

*) For action potential reduction/truncation/acceleration, if desired, genetic replacement of voltage gated ion channels and long strands of nanowires may be necessary.

*) Tiny device capable of being configured to interact with multiple points along single neurons by nanowires, patch clamp, or similar, with ability to speed up neural processes, might be useful. May itself be a solid-state needle array capable of using DC bias to power/interrogate the nanowires, if some means of attracting their endpoints may be achieved. May not yet be illustrated by sketch.

*) Multistage push-pull hydraulic amplifier stages may allow complex flow control, minimizing stress, and allowing access to multistage buffer/analysis tanks. Large buffer tanks will allow less frequent analysis. Small analysis tanks may be more easily purged by gas or small liquid quantities, allowing more consumable or more diverse techniques. Multiple buffer tanks allow iterative control of composition - perhaps using the biological cell health as the only metric.

*) Although CSF composition may be trivial, economic replenishment after byproduct accumulation is not. Elemental potassium/sodium commercial production methods and costs, as well as typical dialysis solution, strongly imply biological systems remain far more efficient in this regard, especially in much lower mineral consumption. At minimum, highly purified water/mineral solution tanks will be required (possibly most cheaply replenished from pure raw materials much as with any salt product), at worst, additional types of biological tissue. Sports drinks (ie. 'with electrolytes') are of presumably similar composition, and presumably similar expense, commonly used without any recycling.

*) Tissue organization may be more than necessary. Lysate solution capable of producing custom chains of proteins may obviate the complexity of neurons as complete cells. Such may require protein design capability which may require faster computers.

References (Inaccessible)

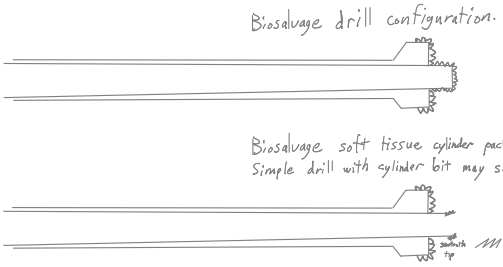
'The isolated and perfused brain of the guinea-pig in vitro'

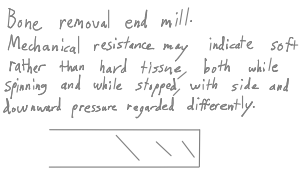
'Restoration of brain circulation and cellular functions hours post-mortem'
        'active cerebral metabolism in the absence of global electrocorticographic activity'

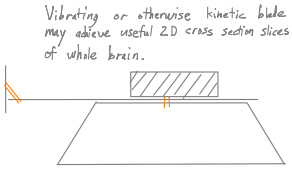
References (Unknown)

Reference

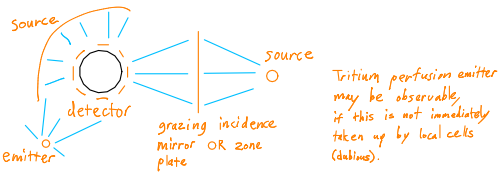
https://www.researchgate.net/publication/338575390_A_scalable_pipeline_for_designing_reconfigurable_organisms
 'A scalable pipeline for designing reconfigurable organisms'







X-Ray detection sphere. Differentially determines material density in all directions. Sudden changes reflect more local condition. With contrast agents, this allows identification of blood vessels, bone, etc. High dose rates are tolerable when the goal is in-vitro extraction, as cell multiplication may be controlled by mechanical confinement, and low yields may be acceptable.

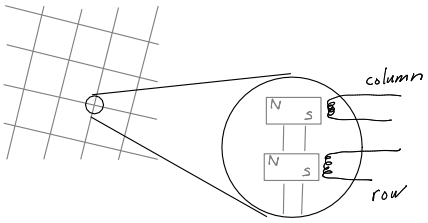


Continious liquid flow across glass knife followed by valve trap allows slices to be isolated for automatic mechanical pickup and further processing.

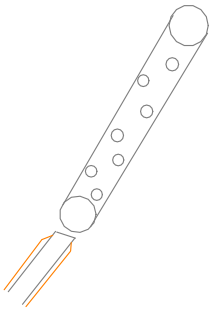
Microfluidic valve 'activeMatrix' (albeit arguably passive). Both row and column valves must be set open and fluid must be pressurized to allow flow.

Electromagnets shown may be entirely external to microfluidic device.

Not known to have any plausible biological production use.



Alternatively, a single valve may be powered by an electrical active matrix.

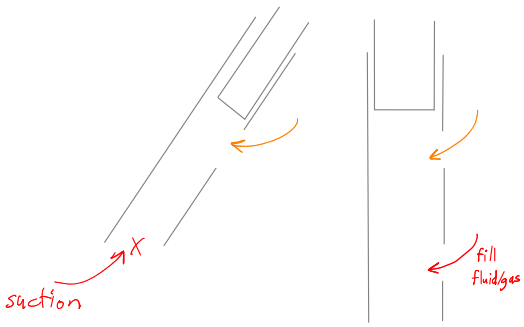


Bulk tissue, at the cost of some inflammation, may be interfaced by permanently embedded rigid tubing, confining collateral damage from repeated needle insertion.

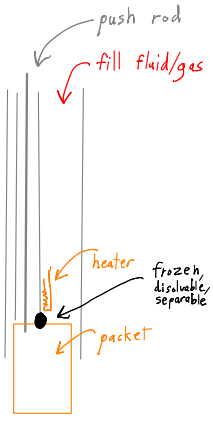
Minimizing collateral damage to nearby 'neuralBits' hardware (as opposed to protecting biological tissue), during routine protein or gene delivery (ie. for voltage sensitive dye) is the only obviously plausible use case.

Otherwise, other means are expected plausible in every plausible use case. Neural electrical interfacing may be done solid-state by permanent 'neuralBits' with no routine mechanical access. Fluid transfers are usually destined for voids where large pumps are highly tolerable if not far more desirable. Reconfiguration of neural networks is better facilitated by nondegradable scaffolding fabricated onto or adhered to 'neuralBits'.

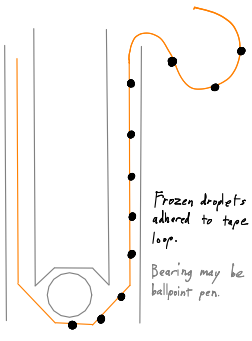
Such permanent access corridors may require some kind of actuated door (eg. spring) to prevent cross-contamination (experiments with replicating transcription factors being particularly sensitive to unintended tissue being affected sooner than expected).



Single needle with side hole may be used as both pick-and-place, tool, minimizing non-friction collateral damage.



Fill fluid/gas may be pushed out as needle is withdrawn, minimizing collateral damage from undesired displacement suction.



DISCLAIMER: Plausible concepts, attributed sources, oversimplifications, resonably. Rigorous mere academia NOT primary.

cryogenicComputer

Compact liquid cooled gas-tight sealed metal box for CPU and GPU.

Entire computers have the sole purpose of converting power and data in to data out. Users usually need either the highest single-threaded performance (eg. VR 'flight sim'), a point of diminishing returns for responsive cost effectiveness (eg. 'web browsing'), or very low performance (eg. 'smartphones', 'standalone VR', 'thin client' terminals, etc).

Long has the time passed for compacting essential high-performance single computer hardware into a roughly standard size portable metal brick.

Introduction

Heatsinks will not need replacement if corrosion inhibiting fluid is replaced annually and carefully kept clean of contaminants. Soldering, not welding, is nonetheless preferred, to allow disassembly for replacement of heatsinks.

Commercially available scuba tank compressors are the most straightforward technology for LN2 generation. Experimentally, LN2 supplies seem widely available.

Only when the computer is off, LN2 reservoir full, and/or chilled coolent too cold, should cooling stop.

Bendable 'Type K' copper (embrittlement >-253degC) pipe is preferred for coolant loop.

Reportedly, a turboexpander can reduce compressor motor load (for LN2 generation) by ~10% - this is NOT worthwhile and will NOT be done.

High-lead 'bar solder' is apparently currently exempted from RoHS, and may be absolutely necessary if whole metal box is cooled to cryogenic temperature, due to outside of box possibly not being under dry nitrogen gas, and resultant tin pest.

Lead soldered external surfaces should be if possible thoroughly cleaned (in case of splatter) covered by high visibility colored tape, as hazardous, not to touch directly.

Performance Improvements at Lower Temperature

Per LN2 published experiments... ~0.5 / (~195 + ~20) = 0.25581395/degC.

*) 9% at -20degC (R-410A used by USA Window AC and Mini-Split AC units)
*) 25% at -90degC (Methanol Freezing Point)
*) 50% at -190degC (LN2 Boiling Point)
*) 55% at -220degC (Liquid Helium Boiling Point)

Incompatible Materials

*) Tin.
 *) -70degC (embrittlement)
 *) possibly >30degC, possibly >14degC, may become non-conductive (tin pest)
*) Steel - -73degC (embrittlement)
*) Buna-N Rubber - -143degC

Tin Pest Mitigation

If tin pest, or tin embrittlement, is a severe risk, that cannot be entirely mitigated, several techniques may be used to minimize its impact.

*) Resoldering (with lead) of the few components (ie. capacitors) found directly in the vicinity of the CPU/GPU core.
*) Simply accepting eventual failure of CPU/GPU solder joints, given a good chance of repair/salvage thereafter with appropriate solder paste stencil.
*) Accepting motherboard failure and reflowing CPU/GPU core solder joints periodically by deliberate use of high-temperature (~300degC) in coolant blocks to remelt degraded tin.
 *) Requires pure metal tubing (ie. Type K Copper Type) and above-soldering high temperature compliant components throughout entire coolant loop.
*) Trickle cooling of components to slowly change temperature independent of chassis cooling (chassis allowed to remain above

temperature at which tin pest occurs rapidly).

Some research shows that allowing tin to return to room temperature (or perhaps higher) in the absence of oxygen/water, prevents the formation of ice crystals which accelerate tin pest upon return to low-temperatures, in effect, reversing tin pest. Under a dry nitrogen/helium atmosphere, periodically cycled to above room temperature, tin pest may not be a concern.

External cold surfaces will still need to use lead solder.

Suppliers

Dewar size may be ~30L. Cost of LN2 fill may be ~$3/L to ~$5/L . Roberts Oxygen (eg. Winchester, West Virginia) may be able to supply LN2. Airgas may be more difficult to work with.

Comparatively, the cost of producing LN2 on site, has been estimated at ~8.5kWh/L, or $0.765/L at $0.09/kWh .

Presented

*) Suitable computer enclosure and techniques to improve portability illustrated by sketches.

*) Cryogenic issues and compatible resources.

Conclusions

Laptops may combine the metal box with a radiator heatsink underneath, a keyboard/mouse on top, and a clamshell or sliding display above that. Switching from internal radiator to external cold fluid can bring maximum performance at any time.

Chassis Temperature - never below -160degC (embrittlement) or cautiously below -13degC (tin pest). Due to this chassis temperature limitation, dry nitrogen may be used in place of helium. LN2 condensation is an electrical insulator, and can be further mitigated by strong internal blower fan heater.

Coolant Temperature - depends on coolant fluid.
 *) Water/50%_Methanol - -40degC (freezing point)
 *) Methanol - -96degC (freezing point)
 *) Liquid Nitrogen - -196degC (boiling point)
 *) Liquid Helium - -233degC (semiconductor limit) or -269degC (boiling point)

Efficient terrestrial refrigeration may rely on gravity, at least with oil-free compressors and/or appropriate safety valves, with LN2 reservoirs for short-term demanding operations or long-term storage. Efficient space refrigeration may rely on direct radiative cooling, not necessarily available on terrestrial locales. Cooling compatible with both terrestrial and space use may necessitate isentropic expansion cooling (ie. stirling cryocooler).

RoHS ban of leaded solder is of negligible benefit and substantial harm, to the point that additional leaded solder may be worth adding manually to a few specific components (ie. at capacitor leads) near CPU/GPU chips. RoHS exemption 'custom made for a specific client or a small number of clients involved in scientific research or prototype product development' may de-facto necessitate inefficient and unreliable small business involvement.

REFERENCE

https://www.instructables.com/Homemade-liquid-nitrogen-generator/

http://homemadeliquidnitrogen.com/
http://homemadeliquidnitrogen.com/PSA/
http://homemadeliquidnitrogen.com/compressor.html
	'compressor needs to have oil-free pistons'
	'scuba tank compressor' '3500 psi'
	'RIX Oil-free compressor' 'SA-3E' '3 scfm at a pressure of 3500 psi'

https://en.wikipedia.org/wiki/Hampson%E2%80%93Linde_cycle
https://en.wikipedia.org/wiki/Liquefaction_of_gases#Claude's_process

https://www.mide.com/ideal-stirling-cycle-calculator

https://www.youtube.com/watch?v=qxZFSNITK-c
	'hydrostatic transmission'

https://www.youtube.com/watch?v=2T-6jDm_ebI
https://www.youtube.com/watch?v=zupVhX5bwZ0

http://www.realcold.co.nz/media/15239/pt_chart.pdf
https://www.achrnews.com/articles/141371-five-rules-for-charging-refrigeration-systems

https://www.youtube.com/watch?v=-0udKOMtXx4

https://midtennrses.net/2012/04/why-does-oil-foam-in-the-crankcase/

https://spinoff.nasa.gov/Spinoff2016/ip_2.html

http://www.sparkbangbuzz.com/els/refrig-el.htm

https://www.youtube.com/watch?v=r7pqc26TWAg
 'My 10 Year Old Chiller WORKS! -20C on THREADRIPPER!'
 'Linus Tech Tips'

https://www.overclockers.com/data-on-coolants-and-liquids-used-in-computer-watercooling/
https://en.wikipedia.org/wiki/Tin_pest

https://www.totalmateria.com/page.aspx?ID=CheckArticle&site=ktn&NM=23

https://f2labs.com/technotes/2016/06/20/rohs-directive-201165eu-equipment-for-research-and-development/
	'custom made for a specific client or a small number of clients involved in scientific research or prototype product development'

https://www.reddit.com/r/metalworking/comments/1ypk67/can_tin_pest_be_reversed_by_melting_and_recasting/

https://calce.umd.edu/tin-pests
	'RoHS, exemptions are granted when applications can demonstrate that compliance with RoHS materials bans will result in any one of three conditions, among which is the condition that the reliability of substitutes is not ensured'

https://www.quora.com/How-long-can-liquid-nitrogen-maintain-its-liquid-temperature-inside-a-portable-liquid-nitrogen-container-75-liters
	'6 months'

https://en.wikipedia.org/wiki/R-410A

REFERENCE (unknown)

*) Somewhere, a study of stable voltages and clocks across temperatures from ~100degC to ~LN2, for an NVIDIA RTX series GPU, found a clear progression, and is the probable basis for the estimated performance increase at lower temperatures.
	*) 9% at -20degC (R-410A used by USA Window AC and Mini-Split AC units)
	*) 25% at -90degC (Methanol Freezing Point)
	*) 50% at -190degC (LN2 Boiling Point)
	*) 55% at -220degC (Liquid Helium Boiling Point)

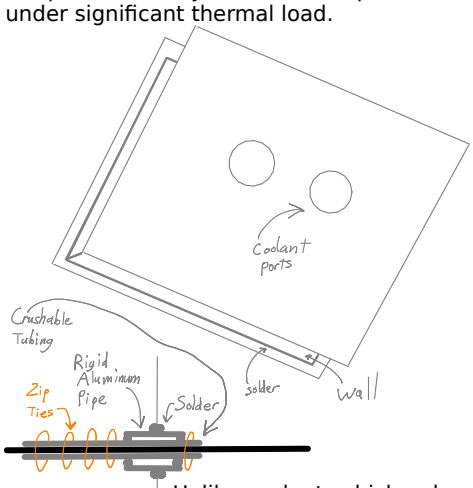
*) Many estimates of material usability at low temperature, or material behavior with usual techniques at low temperature (eg. time before cryogenic fluid coolant reservoir tank boils off, electrical cost per liter of LN2) may have been found from references now unknown. Such are, or are very close derivatives of, commonly available facts, often widely known for more than a century.

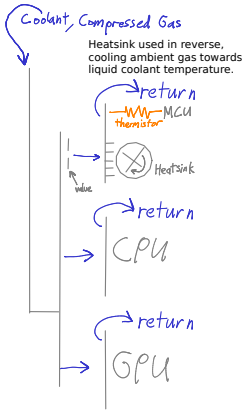
REFERENCE (inaccessible)

'5 W at 77 K without Breaking the Bank'

'Design and Test of a 1.8K Liquid Helium Refrigerator'

Soldered metal box. Gas tight if electrical wiring openings are appropriately sealed. Helium tight sealing may be required if ambient component temperatures may need to be kept at <-25degC under significant thermal load.





Combined parallel liquid coolant loop. Pump and radiator (if appropriate) are mounted to another flat external box.

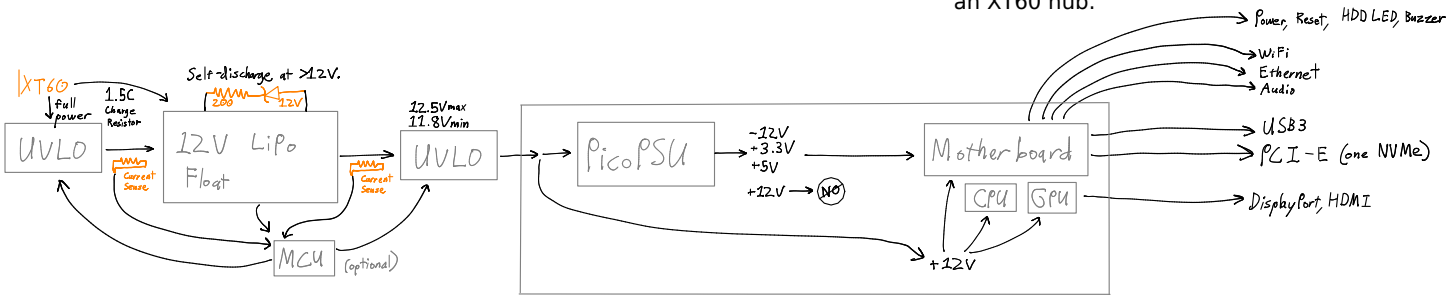
Water/Alcohol/Glycol may be switched to cryogenic (ie. LN2, LHe) fluid after confirmed shutdown/suspend of computer (reducing thermal power dissipation to negligible), and compressed gas purge of significant freezeable liquids (ie. water). Subsequently, computer should be notified of (or detect) cryogenic temperature availablility, to allow ~50% increased core clock frequency. Memory clock not a priority.

Reservoir of cryogenic fluid may be sufficient for only a limited number (eg. 15hour tank at 2kW), used only for demanding 'flight hours' (eg. flight sim, tournament competition, etc), slowly replenished at few liters per day.

Unlike coolant, which only contacts a solid metal heatsink, power and data cables must contact innumerable insulated connectors. Helium tight sealing around commodity cables may be necessary. Expoxy fill between bundled cables and around cables may be added if appropriate.

Internal LiPo float battery is far more efficient, especially for portable computers (small desktops and laptops). Much better ripple attenuation, reduced power transistor heatsinking, reduced filtering, and far more compact than lead-acid UPS battery backup.

PicoPSU converts all low-wattage power rails to +12V, drastically simplifying the high-wattage supply. All power connectors may be adapted to an XT60 hub.



errata

Chiller

R410A...

-Miniturization-

-Refrigerant-
R410A or lower temperature.

Hot side should be liquid filled, cold side gas filled. Liquid returning to the compressor causes permanent failure of the entire system, and preventing this relies on gravity. Indeed, it seems 'Sunpower' stirling cryocoolers are used abord the ISS (zero-gravity).

-Compressor-

A highly geared, or otherwise extremely high torque, motor, is used with some kind of pump. Must maintain high temperature pressure and low temperature pressure as indicated by PSIG chart with expansion valve set.

-Expansion Valve-

A water chiller may not need a controlled 'thermal expansion valve', except perhaps as a crude 'floodback' prevention. A simple needle valve could be set to provide the desired pressure drop to achieve an acceptable minimum temperature (starting with no-load and simulated load conditions), with the water heat exchanger on the 'evaporator' vaporizing all liquid until this value is reached. When this minimum temperature is not available, loads are required to run from ambient temperature radiators, if allowed at all.

If 'superheat' in this scenario means anything at all in the context of 'Low-temperature refrigeration' down to '-40degF', it should be set to '4deg to 6degF' (a relatively small value) .

Superheat may also be regarded as the measurable difference between high/load side temperatures.

Expander

An isentropic expansion system is technically feasible, using a radial pump, possibly with a radial engine following it, or with an actual turbine expander . This may be useful with helium as a working fluid.

Adiabatic

Feeding back non-liquified expanded gas to cool compressed gas, 'regenerative cooling', is simple and reasonably efficient. Moreover, this 'regenerative cooling' loop itself should provide an efficient source of minimum available temperature at the point of expansion, though apparently this cannot be used in the same manner with helium as with a stirling engine, due to the reliance on friction.

Seems ~$1500 , needing to provide 3 'SCFM' at 3500 PSI using oil free pistons (requiring replacement of teflon rings).

... '10 micron vacuum filter and water trap'...

Use of (or compatibility to provide) standard 'oil free' scuba tank compressors may be a major advantage. HydroStatic Transmission pumps may also be usable.

-Miniturization-

Motor and pump head are both welded to, or mounted to plates welded to, metal pipe.

A 'T' junction allows translation from rotary to linear motion, which then powers a piston pump.

With appropriate valves, this can be staged multiple times as necessary, using the same motor with multiple pistons to achieve high compression.

Radial pump architecture is most likely, using shaft displacement.

-Radial Pump-
An extremely robust single stage inside impinged radial piston pump may be built exclusively from flat plates, requiring no

valves, using a principle geometrically similar to an axial pump.

All shaft pressure is lateral, constrained by circular ball bearings.

Piston arrangement may need to place the highest-pressure pistons close to opposite of each other, to minimize shaft pressure.

Pistons may be simple modules built from metal pipes, and welded to aluminum plates, with plastic brackets used for rough alignment (as adequate) during assembly.

Eccentric shaft is expected small, and may be 3D printed metal, or plastic with a protective metal pipe.

A small turbine may provide preload pressure to the system, as an alternative to springs. Only the compression stroke should be under high pressure - eliminating the need for any kind of hook.

Piston material is still uncertain. Teflon may or may not be usable.

Stirling

Reportedly, some RF filters with intergrated crycoolers are available on eBay. In fact, these have not been found available. Cryocoolers may be available.

Continious supply of pure helium gas may possibly be necessary for some commercial stirling cryocooler devices (ie. due to leakage).

-Topology-

A high-pressure tube with two pistons is suggested, each piston being connected to an extremely high torque motor, rotary encoder, and possibly including a flywheel. In this way, only piston seals, regenerator material, heatsink, compression/expansion space/ratio, pressure, and working fluid, need be adjusted as appropriate.

Calculations suggest that higher minimum pressure and higher pressure ratios maximize performance.

-Calculations-

-20degC/255degK hot - (R410A)
77degK cold - (LN2)
50 compression ratio
2077 Specific gas constant of working fluid (J/kg-K) - (helium)
1200 pressure at state 1 - (10atm)
45cc volume at state 1 - (reasonable)
350 amount of heat applied to engine W - (reasonable)

2000 atm maximum pressure

Iterative

*) Modified R410A Chiller

*) Cryogenically Cooled Computer

*) Dewar - 30L (1-6 flight hours at >10L and 1-2hr/L)

*) Low Power Durability Test (low power system kept at LN2 temperature to test for tin pest)

*) Basic Air Liquifier - Compressor, Precooler, Regenerative Cooler
 *) Low Temperature (Methanol) Tank Cooled by Regenerative Cooler - -90degC

*) Compact Air Liquifier - Chiller, Compressor and/or Stirling Engine

Iterative

*) Microcontroller Temperature Control
 *) Must maintain internal record of hours at low chassis temperatures if tin embrittlement or tin pest is a risk, allowing automatic chassis temperature rise to balance risk.

*) Valve Control

*) Plumbing

*) Plate Design

*) Plate Welding

*) Heatsink Threading/Welding

*) Cryocooling and Material Embrittlement
 *) Testing of components for use of solder nonconductive at low temperature.

*) Pumping under stopped conditions.

*) Compressed gas coolant purge.

*) LN2 compatible components - motherboard, CPU, GPU.

*) Independent RAM/Chipset/Chassis temperature control.

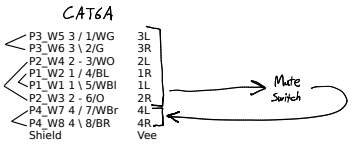
*) External slim radiator module.

Low Temperature Electronics Solder

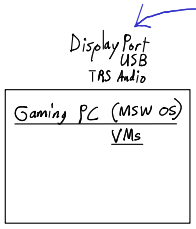
*) Long term, beyond 18months at deeply cryogenic (<20degC) temperatures, leaded solder would be preferable for motherboards...
 *) Antimony solder may be acceptable.
 *) Bismuth solder is 'not known' in terms of tin pest susceptibility .
 *) Tailor-made 'specifically designed equipment' very narrowly made for 'research and development' supplied to a small number of B2B clients is apparently exempted from RoHS. The purpose here - deeply cryogenically cooled computers - is only currently applicable to 'research and development' of software not adequately or not immediately optimized for multithreading.
  *) Excluding the EU from the procurement of such computer systems, if permissible, is economically justifiable for a small business, and illustrates the substantially research oriented purpose of such computers, as researchers and research in the EU would be substantially hindered more than any other professional field.

DISCLAIMER: Plausible concepts, attributed sources, oversimplifications, reasonably. Rigorous mere academia NOT primary.

flightDeck

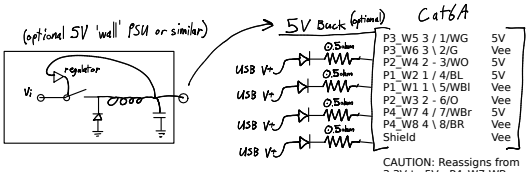


CAUTION: Unusually relies on shield for common ground.

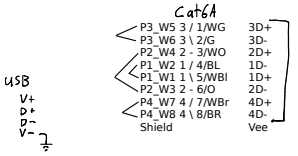


Ability to project VMs and Cloud VMs into VR is expected to substantially improve the ability to integrate legacy (eg. POTS call forwarding).

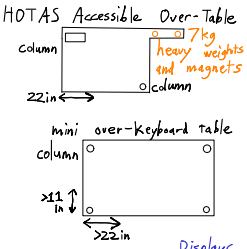
Single Cat6A cables may carry multiple USB/Audio more reliably, having approximately correct impedance, excellent shielding, and better connectors. TRS connectors and usual audio cables, even the most reputable, are highly unreliable.

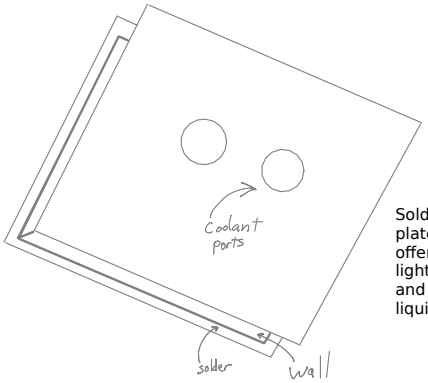


CAUTION: Reassigns from 3.3V to 5V - P4_W7 WBr .



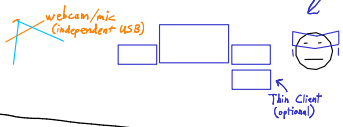
Simple mini-tables may add 'desk real-estate' over keyboard/mouse area.

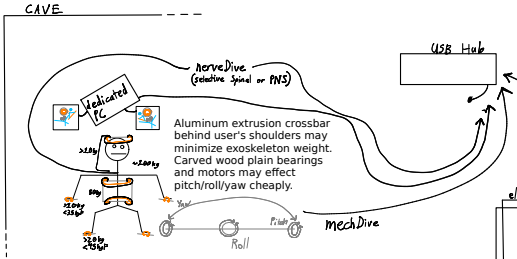




Soldered aluminum plate helium filed may offer the most compact, lightweight, inexpensive, and very high performance liquid cooled PC enclosure.

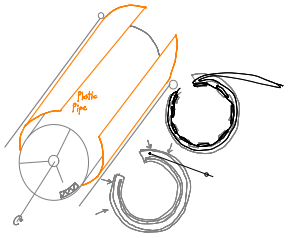
Displays, 'Wearables'

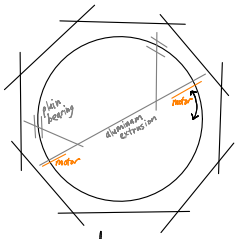




Cable puller.

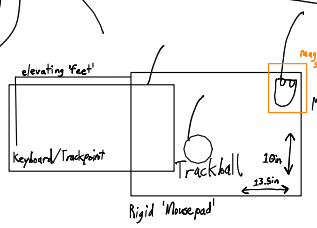
*) Single motor. Spinning aluminum pipe drags static plates in direction of rotation when electromagnetized.
*) Expect >>20kgF/10mm brake plate thickness with 6inch diameter aluminum pipe at 30k RPM 1-10kW .
*) Precision actuators may dedicate additional bowden cables to low-force movements (ie. finger joints).
*) Easy maintenance - plates snap fit from side.
*) Low maintenance - no high speed friction.
*) Entirely constructed of pipe, drilled plate, and extrusion, all commodity metals products, plus a motor.
*) May cheaply control hydraulic push-pull amplifier valves driven by commodity lawn tractor hydrostatic transmission pump, if even more force is required.

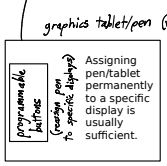




Reinforced Wood Panel mechDive Yaw Bearing (optional as with mechDive pitch/roll bearings)

(framed several feet from flooring)



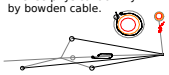


Assigning pen/tablet permanently to a specific display is usually sufficient.

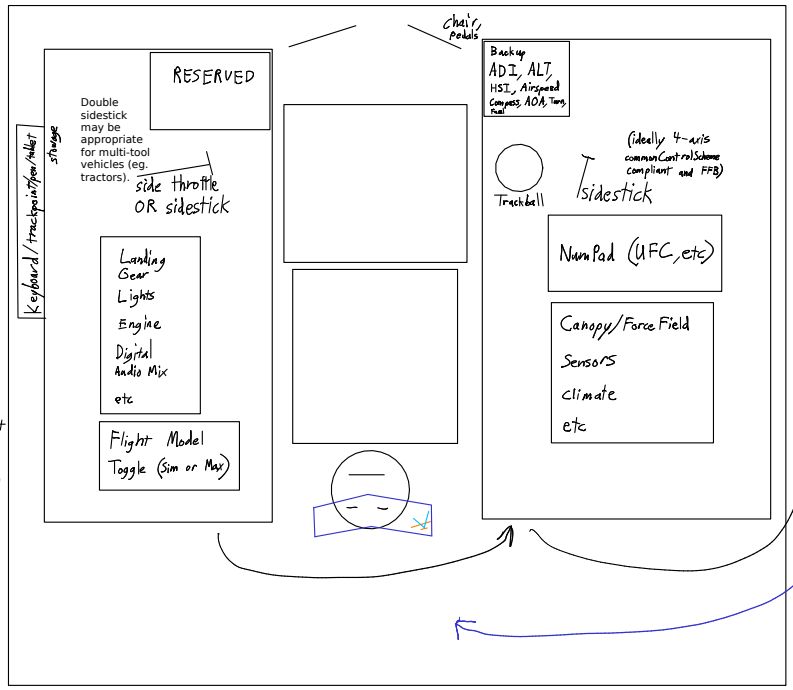
Hard exoskeleton actuator.

X/Y rotation (pitch/roll), Z translation (push/pull), unconstrained surface rotation. Expected to 'push' from shoulder to elbow, elbow to wrist, torso to knee, knee to ankle, in any direction.

Cuffs may be tightened as necessary during more intense physical activity by bowden cable.



Soft exoskeleton. May or may not improve responsiveness and flexibility of wrist and finger joints.



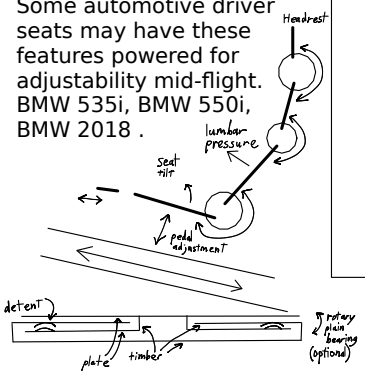
A single electromagnetic bidirectional valve, can achieve heating, cooling, pressurization, and vibration, forming a single tactile 'pixel'. Microcontrollers, registers, logic gates, and active maxtrix, are each expected to provide cheap addressing.

Temperature, pressure, electromyography, and electroconductivity sensors may be useful as well (ie. control of new 'limbs' such as 'wings').

Out may be simple exhaust (no return plumbing). Cold input may be air from a chilled reservoir box, or any other suitable 'fluid' (ie. gas or water).

Chair Adjustments

Some automotive driver seats may have these features powered for adjustability mid-flight. BMW 535i, BMW 550i, BMW 2018 .



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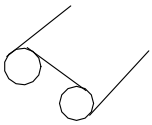
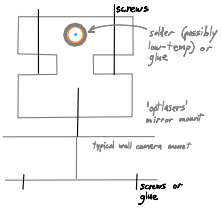
toys

'Positive' eyeglasses (> +1.50) may possibly be useful to prevent myopia possibly resulting from nearwork .

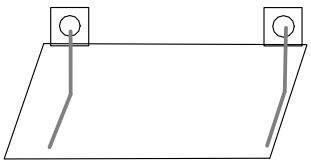


Precision adjustable laser spot or pattern projector.

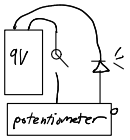
May mark floor positions for furniture projected in VR (eg. chair).



Standalone Shelves, Wall-Mount Shelves, and Junction Boxes, may provide convenient sorted stowage without obstructing frequently used table/floor surfaces.



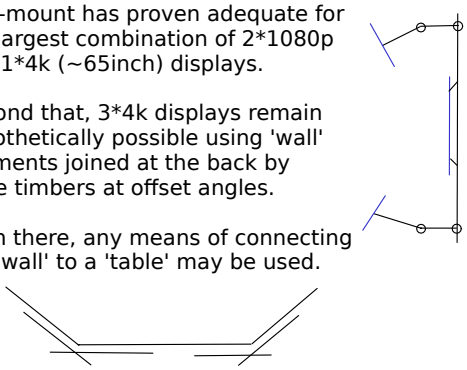
Extremely low intensity amber/red LED notetaking night light. Battery powered, switch off. Intended for cases where the always on aspect of 'TritiLED' would be undesired, and slightly more luminosity required.



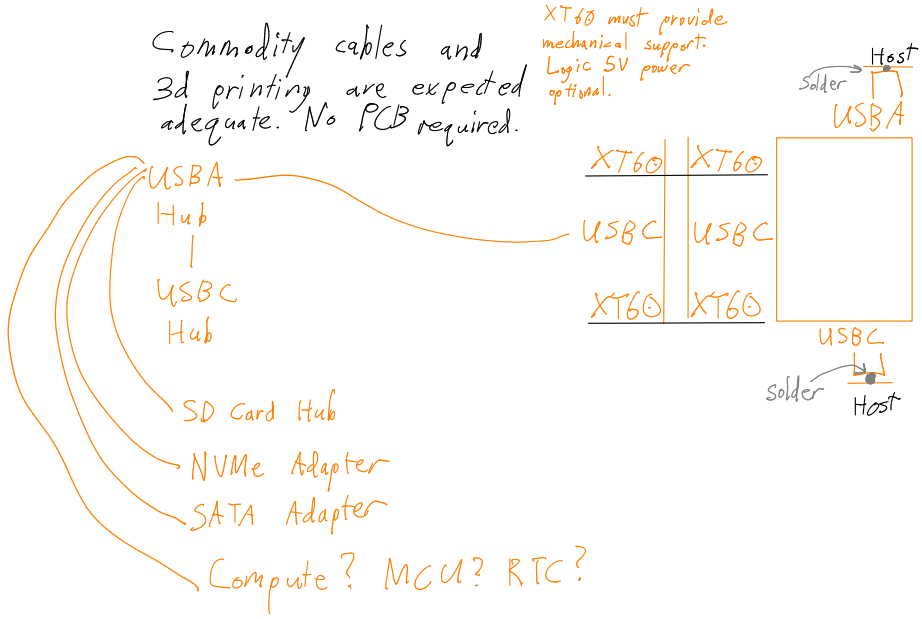
Wall-mount has proven adequate for the largest combination of 2*1080p and 1*4k (~65inch) displays.

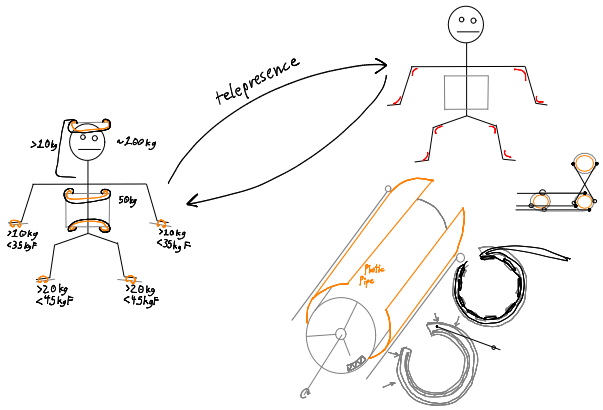
Beyond that, 3*4k displays remain hypothetically possible using 'wall' segments joined at the back by large timbers at offset angles.

From there, any means of connecting the 'wall' to a 'table' may be used.



USB connectors can be interupted by connector and cable bounce. Combining with XT60 power connectors can improve mechanical stability without other extensive high-frequency connector redesign. Especially intended for permanent installation of a more robust connector for 'laptops', hot-air solderable to host connector.





Telepresence may use mechDive in reverse, particularly combining the eddyBrake , soft exoskeleton techniques, and basic force/strain sensors.

Consider that the telepresence 'robot' need only sense applied forces, complying with encountered surfaces, and therefore could rely completely on a less expensive and more flexible 'soft' exoskeleton without any exact position tracking.

Consider also that 'humanoid' shapes, while proven in tool use, may not actually be even the most versatile.

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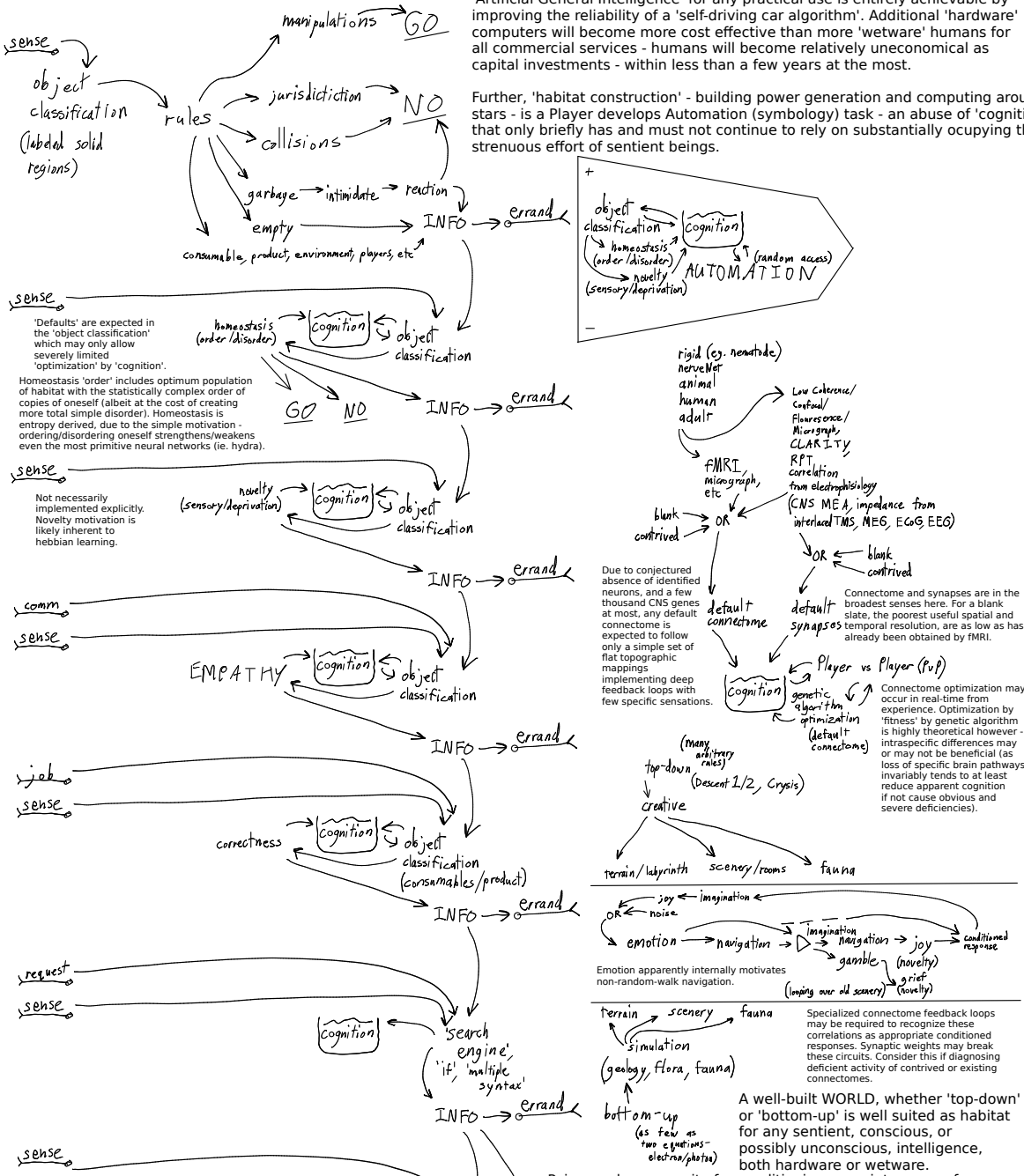
modularAI

Speculative structure, motivation, environment, and supporting creative technique.

DISCLAIMER: Do NOT take speculative model literally!

'Artificial General Intelligence' for any practical use is entirely achievable by improving the reliability of a 'self-driving car algorithm'. Additional 'hardware' computers will become more cost effective than more 'wetware' humans for all commercial services - humans will become relatively uneconomical as capital investments - within less than a few years at the most.

Further, 'habitat construction' - building power generation and computing around stars - is a Player develops Automation (symbology) task - an abuse of 'cognition' that only briefly has and must not continue to rely on substantially ocupying the strenuous effort of sentient beings.



A well-built WORLD, whether 'top-down' or 'bottom-up' is well suited as habitat for any sentient, conscious, or possibly unconscious, intelligence, both hardware or wetware.

Pain may be a requsite for conditioning or maintenance of 'emotion' internal motivation (eg. 'fear of heights', 'thrill' etc). Cowardice must not be the founding basis of most habitat in a universe bounded by possibly infinite uncontrollable chaos anyway. Rather, we must do our best to make the best of the uniqueness in any substantial finite part which may equally divide that possible infinity.

Jurisdiction is a 'GPS' specified area travel outside which is strictly prohibited.

Garbage may be any object within a 'GPS' specified 'safe work area', from which uncooperative objects may be assumed safe to remove.

Any non-consumable non-garbage object is a 'collision' - damage must be avoided.

Traffic deconfliction directives (ie. altitude assignment, requests to move out of way, etc) are not part of 'rules' as these emphasize *least* risk rather than essentially *zero*.

Consumables may include objects which are novel but can confidently asserted as 'probably not non-consumable' - the exact item need not be known specifically.

All 'errand' messages are to be assigned 'priorities' and 'broadcast' to that bus 'globally', using flexible numbering.

Priority of 'INFO' is important. Indications of 'homeostasis' or 'empathy' MUST be given consideration by subsequent cognition and object classification.

Input 'comm' is strictly for 'out-of-band' or 'broadcast', vaguely similar to 'gestures' or 'expressions', NOT voice or text chat.

Input 'request' is for the likes of 'voice assistants', or at least ModularAI using such techniques. Extensively 'predefined' 'search engine', 'if', and possibly 'multiple syntax' logic processing required.

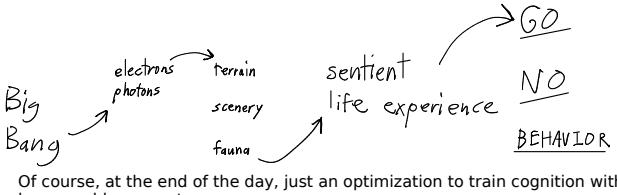
Any 'cognition' may have a shared 'connectome' - part of, overlapping, or otherwise connected to the 'connectome' of another 'cognition' in other algorithms of the same individual. A partially filled liquid container is an allusion to both the 'wet' nature of much 'cognition', and to 'half empty/full' 'opinion'.

A 'job' is a standardized, precise, and accurate description of a desired 'product' shape or consistency from an initial 'product'. In the case of map navigation, the initial product is a destination and current location, while the desired product is an optimum path from current location to destination. In the case of 'g-code', the initial 'product' is a blank 'slab'. Prefer to specify geometry, so a feedback loop may iteratively correct defects if not also tolerate degradation of 'slab' as each job may leave 'garbage' that may not be removed, or cause unrepaired slab 'damage'.

Basic problem of a self-driving car - do I go here or there or nowhere - with reasonable embodiment - is the basis of all problem solving in the universe.

Mining removes material from a rock face, not itself or cooperating machinery.
Refineries move material through material arangements created and controlled to concentrate desired materials from undesired materials.
Sculptors start with a product having undesired material, moving a tool through the path of that undesired material until only the desired shape remains.
CNC mill or 3D printer runs a tool across a path that removes or adds material.
Lithography projector moves reflective and refractive objects to direct photons where material will be removed or added.
Computing, signal processsing, and power generation equipment causes fewer electrons to move more electrons (aka. 'gain', 'amplification', etc).

All problems in the universe derive from the basic problem of transportation. Electrons are caused to push some electrons through (virtual) photons, without undesirably disturbing some other electrons, rearranging solid matter in the process. What few useful processes are explained by other physics (ie. transmutation) are only useful in bulk (ie. minimum reaction cross-section), and thus trivial beyond where electrons/photons are concerned (fluid flows at high velocity, temperature, and compression). Fundamental particle physics has established the insignificance, or disutility, of all other interactions, outside highly hypothetical computation on the surface of far away neutron stars. Travel to those neutron stars at meaningful velocities can not begin until after human cognition has become relatively uneconomical in solving all other problems.



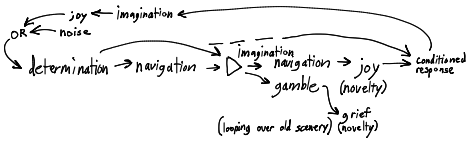
Of course, at the end of the day, just an optimization to train cognition with a less capable computer...

Some concept of at least a vaguely accurate model with more structure may allow composing software infrastructure to allow faster training.

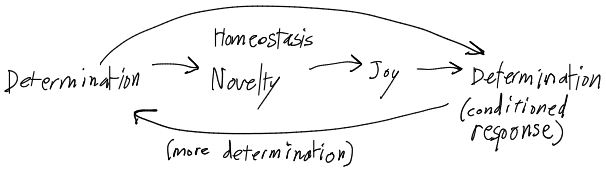
DISCLAIMER: Plausible concepts, attributed sources, oversimplifications, reasonably. Rigorous mere academia NOT primary.

Deeper speculation of rigorous techniques towards ensuring basic motivations (emotional responses) are adequately conditioned by the provided environment.

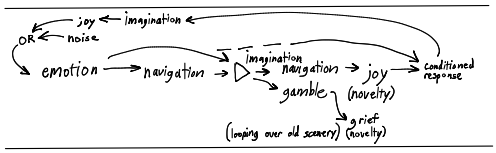
Due to determination possibly broadly eliciting emotions (and corresponding intellectual/physical activity), the reinforcement loop for determination may be especially important.



Determination sensitization may be reasonably modeled as the result of a loop between progressively more challenging rewards, and additional reinforcement by progressively more determination.



Emotions may generally force a choice between careful navigation and random gamble, sensitized into conditioned responses by relevance to joy (ie. novelty or homeostasis). Emotions running as parallel processes may also inhibit navigation in favor of imagination and activating other emotion processes.



Joy/Grief -> Tend to happen in close association with or as part of other emotions.

Hope -> Cease navigation. Imagination generating novel possible navigation paths towards objects associated with 'trust'.
Lack of sensitization of hope in extreme cases may stop 'oscillation' (ie. 'learned helplessness'.
Savoring -> Cease navigation. Imagination accounting of past navigation leading to joy.
Fear -> Cease navigation. Imagination selecting more accessible navigation paths established through 'hope' processing. Hope returning to fear may sensitize risk aversion.
Sorrow -> Cease navigation. Imagination selecting and removing possible navigation paths including objects which may no longer exist.

Trust -> Be near protection and protect. Applies to other players to 'safe' places, etc. If trust did not promote defending as well as being defended, then both behaviors would indirectly sensitize nonetheless due to the fear of actual (discovered) or imagined loss.

Determination -> Increase gain and decrease high-pass frequency of all active emotions (eg. rage, vigilance, trust).

Vigilance -> Seek and maintain perception.
Rage -> Use force.

Examples may illustrate some interesting emotion logic.

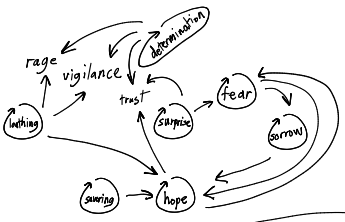
Learned Helplessness - eventually to the point that 'oscillation' will not self-start from inherent input 'noise'. Experiments (by 'Martin Seligman') indeed suggest this state can be unrecoverable without interactive intervention.

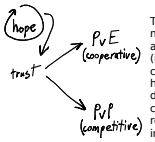
Closure - converting fear to trust (maybe permanently).

Vigilance - checking instrumentation, using image enhancement, peering into darkness.

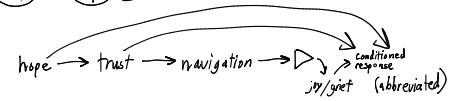
navigation -> grief -> fear

Cease navigation as an apparent response to 'receiving' grief need not be modeled as so direct. Rather, navigation motivated by another emotion brings evidence of a result. From there, activity of the fear (or converted to sorrow) process increases (eg. fear of solving problems without the help of a lost ally, fear of loss of novelty from absence of a companion's solutions, fear of a companion's own absence from a 'theory of mind' imagination of sorts, etc).



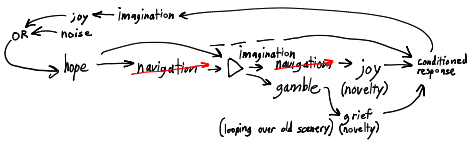


Trust (aka. confidence) may be used to acquire a location's resources (ie. PvE - working with colleagues at good hunting grounds) or to directly confront a competitor (ie. PvP - reducing total intraspecific resources).



Exploration

Combat
Player vs Environment
Player vs Player
Player develops Automation



Emotions motivating the cessation of navigation (ie. deliberate physical movement) in favor of imagination (eg. hope), cause 'joy' through novelty (new plausible solutions), then convert to another emotion (eg. trust). So long as all emotions eventually result in 'joy' (through novelty or homeostasis), both are sensitized.

Conditions reinforcing progressively longer cycles of cessation of navigation in favor of imagniation will sensitize the emotion (eg. hope).

Hope/Determination is sensitized/learned when conditions progressively reinforce with joy only after progressively increasing durations of ceasing navigation to use imagination.

Hope/Determination is desensitized, or more vaguely Despair/Helplessness is sensitized/learned, when conditions only result in grief.
Abandonment of the preceding emotion (eg. hope) repeatedly causes a conditioned response ignoring the imagination state (eg. proposed solution) which would have otherwise brought joy (due to novelty).
With the imagination state not sensitized and novelty lost, the original emotion will be more difficult to evoke.
Failure of navigation from the converted emotion (eg. trust) causes all emotions not to be sensitized. Both novelty and the preceeding emotion will be ignored.

Hope/Determination sensitization, when strong, causes continious imagination, building novel long-term solutions (ie. hobbies) from a regular stream of short-term solutions.

Hope/Determination desensitization (or more precisely absence of sensitization), causes random noise input, imagined solutions, and/or the converted emotion, to terminate as they occur, ending 'oscillation'. Such 'learned helplessness' results in no attempt at 'navigaton'.

Stronger players have more sensitized Hope/Determination, with short-term success building increasing motivation to imagine more difficult solutions. Weaker players have been desensitized and will show less thoroughly careful decision making (tending to gamble).

DISCLAIMER: Do NOT take speculative model literally!

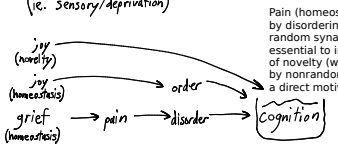
Model may be intended at most to account for plausible mechanisms of reinforcement of useful motivation (ie. 'emotion' as might also be accounted for by 'positive psychology', etc).

Any mention of any particular 'feeling' or 'emotion' beyond binary joy/grief representing pleasure/pain from homeostasis or novelty, is only illustrative.

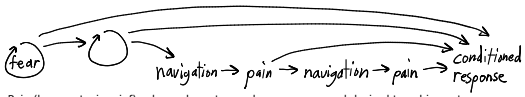
A complete account of the underlying emotional circuits responsible for specific 'feelings', or their associated mechanisms, of any particular connectome typical of any particular species (eg. 'human', is out of scope (ie. 'off-topic'). That would instead be a topic when studying a specific connectome, contrived for Artificial Intelligence (aka. AI, AGI, etc) purposes or otherwise.

Terminology and symbology used here will depart from official or usual meanings as used in existing psychology research. In no way are these models intended for any use in the field of psychology, only in rough architecture of software/hardware/wetware design.

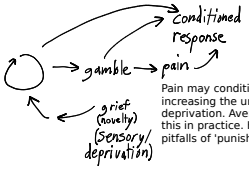
Pain may be a necessity. VR software/hardware designers must also implement pain simulation. Beware either absense or inadequate punctuality will cause severe harm.



Pain (homeostasis grief), if implemented by disordering the cognition (eg. by random synaptic pruning), may be essential to improving the effectiveness of novelty (which may order the cognition by nonrandom synaptic potentiation) as a direct motivation.



Pain (homeostasis grief), when relevant, may be necessary and desired to achieve strong conditioned responses, which may be necessary to achieve adequately strong internal motivation (ie. emotions). Here, memory of a reptitive loop in careless navigation may reinforce determination to avoid carelessness.



Pain may condition responses by pairing, increasing the unpleasantness of sensory deprivation. Aversion therapy may rely on this in practice. However, all the dangerous pitfalls of 'punishment' apply in this case.

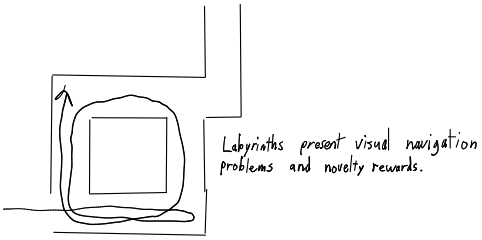
Ferocity and tranquility both may be desirable end states of strong conditioned responses.

Congenital Insensitivity to Pain reportedly may result in diminished 'fear', 'thrill', among other emotions.

https://en.wikipedia.org/wiki/Congenital_insensitivity_to_pain

https://www.nytimes.com/2019/03/28/health/woman-pain-anxiety.html
'At 71, She's Never Felt Pain or Anxiety. Now Scientists Know Why.'

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6676009
'Microdeletion in FAAH pseudogene identified in a patient with high anandamide concentrations and pain insensitivity'



Novel terrain features (ie. flora/fauna, creative game artwork, etc) are essential to motivate behaviors beyond basic homeostasis (and novel player interactions to supplement this also do not develop without the novel terrain features).

Exploration, including encountered conflict, sensitizes hope. Increasingly large and complicated 'labyrinths' with 'adversaries' from behavior that searches environments for sustainable resources and novel scenery (PvE) as well as behavior defending (or winning) resources (eg. players) from other players (PvP), repeatedly awards increasing joy with appropriately careful encounters with increasing dangerous terrain or players.

Restraint, from inadequate ability, parasite damage, repeatedly removes or precludes joy, progressively desensitizing Hope/Determination. Restraint is at best an unfortunate reality of a given situation, and never a necessary good in itself. Restraint is appropriate when keeping balance (ie. currency per hour earnings, low currency inflation, leveling between players, findable key locked doors, severe consequences for entering wilderness beyond a player's own stats, rebalancing spawn rates, adjusting difficulty), but inappporpriate otherwise (ie. lottery, gambling, unlimited retrying of dangerous situations, immortal lack of consequences from 'death', etc).

Absence of adequate sensory novelty from Player develops Automation, progressively desensitizes Hope/Determination. While highly sensitized Hope/Determination may allow long-term absense of reinforcement, the direct consequences of sensory deprivation inevitably must be compensated sooner from some exposure to exploration through PvE and/or PvP.

Enabling more Player develops Automation, is in the context of substantial wealth inequaltiy, the economic justification for entertainment industries of any sort. In that temporary situation, higher quality - more novel and intense exploration through PvE and/or PvP - will allow faster recovery of abilty for more PdA.

Diversity is mandated by parasites due to the need for differences in strategy to overwhelm the less resourced imagination resource of the parasites. Food chains are expected to be divided into roughly equal players of forms differing mostly in relative attributes rather than adaptations (excepting inhabitation of different locales with substantially different air/fluid/land lift/drag/bouyancy/weight/thrust constraints).

Wealth inequaltiy can only occur if material wealth exists - if players own property in addition to their self-replicating forms.

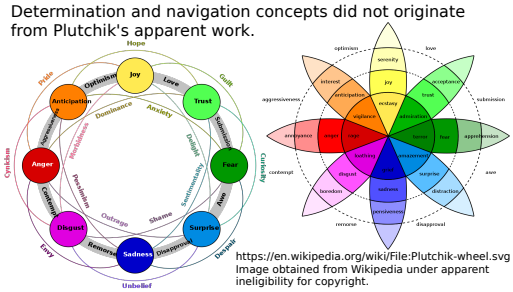
Promptly dispense homeostasis and novelty order/disorder (ie. pleasure/pain). Maximize exploration (complicated terrain, PvE, PvP) and novel terrain features (eg. flora/fauna). Minimize restraint and PdA. Balance diversity. Expect limited parasite activity. Expect equal wealth between same-age players. Time spent in PdA will be proportional to the novelty and intensity of available PvE and PvP.

Top-down WORLD builders (ie. game developers) must be especially wary of inadequate novelty from absence of creativity in artwork design (ie. plainly arranged terrain/architecture), unhelpful or extensive Player develops Automation (eg. cheating, spreadsheet overuse, third party analysis software overreliance), restraint gamification (eg. standalone rewards without inherent novelty fulfillment, timegates, absurdly low return on investment gambling), etc.

Bottom-up WORLD builders must be especially wary of inadequate novelty from any 'shortcuts' taken (eg. random terrain, procedural terrain generation of lifeless rock without for adequate flora/fauna).

Plutchik's apparently postulated hypothesis concerning basic emotions, essentially analog response, and narrowly defined behaviors, has seemed relevant to possible explanations as to how motivations of complex behaviors might emerge from environmental interaction creating chains of conditioned responses.

Determination and navigation concepts did not originate from Plutchik's apparent work.



https://en.wikipedia.org/wiki/File:Plutchik_Dyads.svg
Image obtained from Wikipedia under apparent
CC BY-SA 4.0 license. No intentional modification.

https://en.wikipedia.org/wiki/File:Plutchik-wheel.svg
Image obtained from Wikipedia under apparent
ineligibility for copyright.

Well studied games, including classic games of chess, go, connect four, etc as well as two player game theory scenarios, may offer a means to test the 'rationality' of an individual's emotion conditioned responses. Well balanced internal motivations (ie. emotions) should be expected to result in the individual quickly recognizing and attempting optimum strategies an all games.

Quick recognition of optimum strategy is important in any complex scenario requiring multiple techniques to achieve a top score (ie. combat instead of racing).

Simple animals may be highly proficient in speed, while lacking other abilities. PvE may emphasize the use of complex combinations of behaviors obstructing apparent paths to escape, while PvP may emphasize the use of complex combinations to identify any weaknesses.

Top-Down WORLDs may have deficiencies other Top-Down WORLDs may not have. Players accustomed to multiple games are more likely to achieve a top score in at least one, by quickly recognizing all necessary techniques and means of perfecting those techniques. Some of which may be a consequence of internal neurophisiology (eg. disciplined use of fast CNS vision instead of latent PNS pointing feedback).

Life and game experience, notably in navigating labyrinths and identifying the higher latency of PNS feedback point shooting, accounts for most if not all of this document's logic. Any gamer would likely be at least vaguely very well aware of similar concepts. Formal academic study absent of such thorough experience rarely if ever contributes more than a description of the narrowest mechanics. Individuals with only formal study are unqualified to WORLD building, those without either formal study or life experience are even less qualified.

By gamers, for gamers.

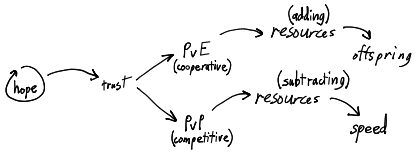
As to the idea that a commercial success or a program of formal study could guarantee competence, Frontier Developments has enjoyed too many years of mediocre commercial success, while however much by design (ie. selling vaporware) or ineptitude, their WORLD building has fallen far short of requirements.

Top down (many rules, arbitrary) has the advantage of avoiding unnecessary unpleasantness - such incomprehensible nuances as the misalignment of neural and bacterial circadian rhythms. Unfortunately, top-down itself results from unpleasant Player develops Automation (PdA) effort, and to identify what is or not necessary to 'gameplay' requires taking this beyond a point of diminishing returns.

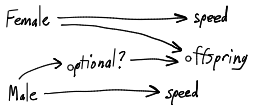
Bottom up (few rules, 'big bang') has the advantage of bringing out all possible Player vs Player and Player vs Environment interactions. However, bottom up does not avert unnecessary unpleasantness - notably parasites and falling asteroids.

Top down requires an abundance of caution to avoid severe stagnation. Bottom up requires a high tolerance of neutral and negative results. ACKNOWLEDGEMENT - Top down and bottom up terminology is from Sword Art Online (SAO).

Highly speculative.
Few cases may create some incentive for gender specialization.
*) Deficient conditioning from previous life experience (ie. 'gender roles' from a discriminating society which has separated the gathering of resources entirely from parental care.
*) Males incentivized to abandon parental care in pursuit of slight (parts per thousand) differences in speed.
*) Bottom-Up WORLD building may result in some cases of this, along the lines of gender specializations observed in wild animal phenotypes.
*) Top-Down WORLDs deliberately created to mimmic Bottom-Up WORLDs may include gender specialization incentives, difficult to balance appropriately.
*) Top-Down WORLDs using intraspecific role specialization (instead of equal competence) used as a 'game mechanic' to allow players to emphasize a specific mental ability subset (eg. speed at the expense of defense) may inherently or inadvertently create specializtions which resemble gender specializaton.
*) After all, emphasizing intraspecific role specialization may be something of an artifice, as prolonged intraspecific cooperation may be rare in nature.



Highly speculative.
Females may be incentivized to become more skilled as hunters, to gather resources while burdened carrying offspring.
Males may be incentivized to only achieve very small competitive differences in speed, if not burdened with parental care.



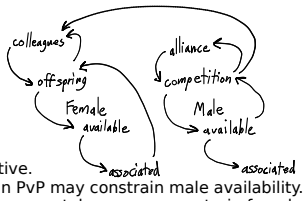
Highly speculative.
Gender specialization and any actual secondary characteristics may result if males are incentivized to abandon parental care. Males may still cooperate with other males, resulting in similar or more dynamic 'trust'.

$$P_S = V\left(\frac{T-D}{W}\right)$$ 'Energy-Maneuverability Theory'

V = Speed
T = Thrust
D = Drag
W = Weight

A few parts per thousand may consistently separate a top 'winner' from a 'loser' in 'racing - or any other competition. Indeed, this seems to be the case in 'horse racing', albeit that may be an artifice.

Logically, speed may not be the only necessary advantage (eg. 'turn rates' being essential to countering evasion), but may be required (as even a slightly faster opponent may simply 'run away'). Although the equation presented is arguably less a 'theory' than a hypothesis to exclude other variables, 'speed' is required for all other advantages in any conflict (eg. between well designed 'fighter jets' with adequately trained pilots).



Highly speculative.
Specialization in PvP may constrain male availability.
Specialization in parental care may constrain female availability.
When specilization is not extremely favored, males may have sufficient incentive not to abandon parental care, joining females as colleagues.
Lingering specialization in PvP may provoke males in alliances (not being successful in competition on their own) to aggressively take the place of other males associated with females as colleagues, which may dilute specialization more.
Males may have greater impediments to associating with females than vice versa, due to competition and expenditure on any 'gifts' (eg. food for female and offspring at expense of male competitive fitness).

Beware these mechanics, if at all valid, exist within the complexities of interspecific interactions, incurring severe pitfalls.

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_ Cycle _
Bouncing between Trap and Escape may be part of a loop motivating increased determination in future activities. Consequently, environment (eg. game) design may benefit from deliberately including both Trap and Escape conditions, made available to players in multiplayer as occasional opportunities, or consequent from certain kinds of activities (ie. PvP contract workers may be spontaneously recommended to other player corporations as recruitment opportunities).

Initiative > (PvP, PvE, PdA) > Failure > Frustration > Fatigue
Initiative > (PvP, PvE, PdA) > Success > Reward > Fatigue
Employment > (PvP, PvE, PdA) > Reward > Demand > Success > Fatigue
Fatigue > Rest (extent differs) > Initiative or *Employment*

Escape > Initiative
Trap > Employment

Escape > Demise
Trap > Demise

	Escape
*) Random teleport away from Employment.
*) 'Affordable housing', fair housing, etc.
*) Forgivable loans.
*) Selectively spendable currency (ie. food stamps).
*) Third party employee recruiting offers.
*) Asset ownership (vehicle, home).
*) Mental Health Counseling Program (with built-in limits to prevent dependence).
*) Homeostasis (ie. food).
*) Acute pain (sharpening reflexes).
*) Rare items.
*) Luxury to partake in daily activities (eg. food) of different types at different times whenever so inclined.
*) Short high intensity missions (PvP with kills) and plenty of opportunity for free living between.
*) Snacks, water, temperature controls, lighting, etc, on flight deck.
	Trap
*) Overbearing NPCs (ie. NPC shopowners employing players).
*) Ponzi Schemes.
*) Gambling.
*) Guild contracts, follow-on contracts (long-term).
*) Asset rental (vehicle, home).
*) Long commutes.
*) Homeostasis (ie. bottom of Maslow's hierarchy of needs - hunger).
*) Chronic pain, added sleepiness/exhaustion (persuading the least-effort rather than least-risk or highest-gain path).
*) Literal death traps requiring maximum effort and creativity to survive - rewarded with an escape including an exceptionally rare item.
*) Exactly specified daily activities.
*) Long working hours, or worse, extremely long missions with little free living between.
*) High-temperature, high-humidity, dehydrating flight deck.
*) Tech development.

Escapes and Traps must be *rarely encountered*, but with *long-term consequences*, and calibrated. Metrics such as completion of less risky or otherwise difficult tasks may be used to discern disinterested boredom rather than motivated interaction. Motivation must be consistently encouraged, demotivated boredom disfavored.

_ Conclusions _
*) New individuals in a VR world may need to have frequent opportunities to experience and escape from dependence, with incentives to escape dependence, as a means of improving determination.
 *) Allowing such individuals to languish, and then placing them back into a more rich existence, may be a useful premise.

Future Work
*) Defining an example environmental loop, not that such would necessarily be useful, for learning savoring.

Reference
https://en.wikipedia.org/wiki/Behavioral_sink
	'Controversy exists over the implications of the experiment.'
		So try to consider possible concepts instead of literal interpretations.

https://en.wikipedia.org/wiki/Spoon_theory
https://en.wikipedia.org/wiki/Ego_depletion

https://en.wikipedia.org/wiki/Savoring
	'deliberate effort to make a positive experience last'

Acknowledgement
*) 'Mental Health Counseling Program' - from Sword Art Online (SAO) by Reki Kawahara .

memoryRegeneration

Learning long-term neural network stabilization, if necessary, by *isolation* (exocortex), by *refresh* (spatial/temporal object neural decoder), and/or by *partial reset* (increased forgetting rate while doing important things).

Highly speculative. Memory capacity of a neural network must be finite (unless some unexpected 'handwavium' new physics). Yet neural network memory apparently is somewhat of a 'soft' limit, seemingly endless until 'memory interference' and/or absence of novelty seemingly causes either poor reaction times or demotivation 'sensory deprivation'.

Absence of novel information may actually cause a neural network to degrade faster than a steady rate of novel information to learn. From a hypothetical neurological or mathematical perspective, all learning neural networks may be long-term stability limited due to useful memory object cross-association with noise at least every time the memory is recalled - less detailed sub-objects being more noisy to begin with. From a hypothetical psychological perspective, vividly motivating experiences become much less memorable after the first experience. A 'Player develops Automation' (PdA) emphasizing lifestyle drastically worsens such degradation, the symbolic manipulation beginning with less novel 'signal' and accumulating more chaotic 'noise'. Both these (regeneration) problems are solved biologically along with any physical degradation by abrupt complete replacement of all wetware and loss of all associated memory - *death*. Much 'science fiction' has already widely recognized this as such possible issues as the 'fever dream' of novelty, having 'seen it all' (or imagined), severe boredom from immortality, etc.

Mortality is a rather expensive solution for either artificial neural networks (ie. self-driving AI) or biological neural networks (ie. people preferring to better or longer enjoy the problem solving game of life). Gamers are well acquainted with 'amortality' as 'respawning' already as a means of experiencing problem solving taken to the point of victory or defeat. Adding memory storage/retrieval as an 'amortality' 'respawning' feature extends such workarounds to the lifelong processes of learning and forgetting.

Introduction

Cognition memory retrieval requires comparably expensive computation. All possible solutions to neural network memory capacity limits are either both computationally and storage intensive, or erase memories.

Neural networks may be regarded as similar to amplifier feedback loops - sensory input, internal modeling, motor output, back to sensory input - with the memories which modify internal modeling (ie. learned neural network processing) as a complex adaptive set of band-pass filters. If such (vaguely) band pass filters accumulate without removal, and/or if the means to add new band pass filters are irreversibly reduced by loss of neurons and synaptic pruning, a neural network may be reduced to a noise amplifier, incapable of problem solving (aka. 'intelligent behavior').

Partial reset of memories is by far the most straightforward, and expected to allow sufficient retention of actually useful memories, especially once humans accumulate sufficient wealth to 'retire' in favor of 'self-driving AI'.

*) Isolation of memories may keep neural networks learning to the limits of available information storage and computing. Iterative copy of RPT correlations from a learning neural network to a long-term storage neural network subsequently 'frozen' as a non-learning neural network and 'firewalled' by bandwidth and threshold limits to prevent rapid cross-association of noisy/irrelevant old memories back into the learning neural network. Essentially 'puts old memories on the proverbial shelf' - downsides being increasing storage/retrieval costs possibly as high as equal to the entire cognition per snapshot, including some repetitive conscious awareness of boring old memories.
 *) Exocortex to shelve memories to must be capable of both learning and 'freezing' learning - rather capable hardware (whole brain emulation) is required, and any consciousness of such an exocortex may be significantly undesirable.

*) Refresh of memories, may keep neural networks learning to the limit of the noise rejection ratio of a neural decoder. From TX events and/or RPT correlations (ie. 'cognitionSplicer'), a rather 'analog' neural decoder may be able to extract spatial/temporal information, then either purifying of noise and abberation, replacing with a much simpler object new experiences will find novel replacements for, or replacing with a less noisy object acquired from earlier recordings. Replacements are then iteratively rewritten. Only less noisy objects from earlier recordings will definitely have large, definitive TX event patterns, recognizable across large regions of neocortex ES at reasonably expected densities. Persons not having such recordings continuously from early life to the present may not be able to rely on memory refresh alone without great permanent disability.
 *) Neural decoder with useful noise rejection ratio or reasonable computational efficiency may be impossible.
 *) Memory object storage/retrieval may be efficient but saving every memory may still be an unjustified waste of space.

*) Partial reset of memories. Iterative reset closer toward a default connectome and synaptic weights (ie. simple gradients) while actively using the memories desired to keep. In the most extreme case, a few highly desirable memories (eg. sense of continuity having been alive previous day, things that will not likely be relearned in another lifetime, etc) are reconstructed as a 'single-player game' (or possibly multiplayer with specific features for each of a very limited number of participants), which a person plays through while all other memories are gradually blanked.

Iterative copy/rewrite/reset for isolation, refresh, and/or partial reset, uses repeated measurement of RPT correlations, calculation of desired connectome and synaptic weights, and stimulation in the patterns that would be expected of the desired presence/absence of RPT correlations, until desired presence/absence of RPT correlations has been achieved. Such exploits the 'neurons fire together wire together' and 'out of sync lose their link' learning.

Complete copying of a connectome and synaptic weights (ie. a backup) is of course possible and may be combined with memory isolation, refresh, partial reset. Risk being that 'spinning up' older memories may regress now satiated desires to unsatiated (incurring a desire to repeat the memory isolation, refresh, and partial reset as well as any experiences since all over again), which may be a significant expense against moving on to actually new experiences.

Conclusions

If less sharp memories are formed in a neural network that is not at neutral defaults, possibly due to retreading of already existing but worsening signal-to-noise ratio pathways, then such degradation cannot be reversed by interactively reliving similar experiences, making the degradation permanent without some isolation/refresh/reset. A lifestyle of symbolic problem solving (ie. 'Player develops Automation', instead of experimentation), will cause such degradation substantially faster.

Looking at this issue from a more hypothetical psychological, rather than hypothetical neurological, perspective, presenting a player with a vividly highly motivating experience in VR, or early childhood, may result in immediate, non-reconstructive, essentially photographic memory. Such a 'fever dream' (as mentioned in the beginning pages of 'Sword Art Online') of immediate photographic memory does not happen for similar experiences twice in a lifetime, leading to the 'seen it all' (or imagined) trope. 'Altered Carbon' imagines similar problems at the opposite end of life, with at least some of the more long-lived characters seemingly bored into ruthless depravity.

Phonological loop amplification, particularly emphasized by absence of preoccupation with PvP/PvE, task tracking, and delayed gratification, all inherent to substantial 'Player develops Automation', may substantially worsen cross-association of irrelevant memories with any (possibly also irrelevant) memories in the buffer.

Irreversible synaptic pruning, or neuron loss, represents permanent physical degradation 'brain damage', which may inevitably accumulate in older wetware, irreversible by isolation/refresh/reset . Replacement wetware may be required (ie. 'sleeveDive').

Sleep may be a limited memory refresh process, possibly ineffective due to poor noise rejection ratio, and a biological neural network that may be disordered by chaotic noise and possibly ordered only by overwhelming novelty forming strong synapses. Such would be consistent with insomnia as a consequence of insufficient novelty. Recording detailed brain activity (ie. RPT correlations) to determine synaptic weight strength for clinical insomnia cases, while returning to a heavy preoccupation with a healthy PvP/PvE lifestyle, may be neuroscientifically interesting.

Memory interference and memory signal-to-noise ratios could be *measurable objective metrics of mental health* (not just for human wetware but also AI statistical classification neural networks).

Disrupting current brain activity might be useful as a user activated retroactive recent memory removal or blocking tool, taking memorable objects out of the phonological loop before much undesired cross-association occurs.

Partial memory loss is enforceable by CARDinal as a multiplayer game beginning condition from statistical evaluation of movement patterns that would show both whether a player was relearning most basic skills and whether a player was subject to degradation otherwise expected. This may be important to other players (as with any similar 'anti-cheat') who wish to begin a game of life with maximum potential for motivation (ie. 'sharp memories' and 'fever dream').

REFERENCE

https://tvtropes.org/pmwiki/pmwiki.php/Main/GhostAmnesia
'Common in Greek Mythology and in Asian mythology. In fact, one of the main rivers of the underworld was the Lethe, whose water would explicitly cause amnesia. Drinking fresh blood (animal would do) would break the spell at least temporarily, as seen when Odysseus visited the underworld looking for advice from the by-then dead seer Teiresias in the Odyssey.'
Also equivalent to events of 'Fall, or Dodge in Hell' by Neal Stephenson, presumably mythologically inspired.

ACKNOWLEDGEMENT

Sword Art Online, by Reki Kawahara, within few pages of the beginning, recognizes the 'fever dream' of highly motivated players experiencing VR challenges for the first time.

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_ Terms _

Isolation
Exocortex

Refresh
Spatial/Temporal Object Neural Decoder

Partial Reset
Increased Forgetting Rate

Continuity

_ Rough _

*) Sense of correctness - absurdity - may be necessary for memory refresh. A neural interafce may present candidate objects and candidate associations, and reject if another neural decoder detects these are considered absurd. Sleep may use such mechanisms.

*) Scrambling to randomized RPT correlations, rather than to specifically expected topographic mappings, may be another means of 'blanking' to default.

-
REVIEW - May be duplicative from (another) part of (another) document.

-
Elaboration regarding otherwise already noted concepts.

*) MAJOR - Memory distillation. Explaining information symbolically (eg. by language) is in terms of discrete objects. Cognition can do this, and decode the symbology. Automation can categorize the new objects in the new cognition without memory intereference.
 *) Unfortunately, this has the same drawbacks as any PdA - the resulting memories will be dryly lacking novel details.
 *) Recreating these experiences is essentially what a single-player video game 'story' is, and exactly what is done as treatment for PTSD.
  *) MAJOR - May be prohibitive. At best, this will be an order of magnitude more expensive (to reconstruct) than the original experience.
  *) MAJOR - Equivalent to experiencing memories for the first time, allowing capture of pure memory objects.

Reference

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