

CPE/EE 322
Engineering Design VI
Lesson 11: Implementation

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2023-04-17

Outline

1. Transforming a design concept into reality
2. Concurrent engineering and design for X
3. Poor implementation can lead to failure
4. Materials selection in design
5. Common fabrication materials
6. Importance of material testing
7. Manufacturing processes
8. Construction processes

Objectives

[G. Volland, Engineering by Design, Chapter 11](#)

- Explain why poor [implementation](#) of a design concept may lead to failure or disaster
- Describe why engineers should determine the process, materials, and equipment for [fabrication](#), [assembly](#), and other manufacturing operations
- Apply the basic principles and guidelines that one should follow to design for X, where X may represent manufacturability, assembly, reliability, quality, packaging, maintainability, disassembly, and recyclability
- Recognize that materials chosen for an engineering design must match the product's performance, environmental, processing, and financial requirements
- Distinguish between the general characteristics of metals, polymers, plastics, ceramics, and composites
- Describe some of the fabrication processes commonly associated with metals and polymers
- Select materials for a design by considering the various relevant properties of material candidates, together with the fabrication processes that may be required
- Describe some of the obstacles that may confront an engineer during the [construction](#) of large-scale, one-of-a-kind systems

Assignment 11 — Implementation

Refine the system and process diagrams in Assignment 6 based on Assignments 7-10 and provide

11.1 Design diagrams

11.2 Gantt chart

11.3 Senior design plan

Program Outcome 1: (Complex Problem Solving)

1.3 (Engineering foundations) Students will be able to use block diagrams and a hierarchical representation of the project and use detailed circuit diagrams and interconnected component diagrams with technical specifications on inputs, outputs, and control to describe the detailed operation of components in the project.

Program Outcome 2: (Design)

2.6 (Design assessment) Students will be able to understand and apply the principles of concurrent design in the breakdown of tasks and project plans and will understand and apply Gantt chart and PERT/CPM (either or both) in the creation of a breakdown of tasks and planning the activities to complete the project.

Program Outcome 5: (Teaming and Leadership)

5.1 (Teamwork) Students will be prepared to effectively participate in and manage a multidisciplinary design team.

Senior Design Projects

- Bookmark and review the following pages:
 - [ECE senior design site](#), [Google sheet](#) and [TABER form](#)
 - Senior design [roadmap](#)
 - Interdisciplinary project [rubric](#)
 - Stevens [MakerCenter](#)
 - [Environmental Health and Safety](#) (EHS)
 - Stevens Annual [Innovation Expo](#)
- Stevens Ducks app > find and open the Innovation Expo Guide
- Download a collaboration app, e.g., [Asana](#), [Discord](#), [Flock](#), [Lucidspark](#), [Slack](#), and [Trello](#)

Transforming a Design Concept Into Reality

- The world around us is filled with objects and systems that have been fabricated or constructed to satisfy needs and improve the quality of life
- Fabrication and construction often require a series of tasks to be performed with great precision and consistency
- Certain designs such as [infrastructure](#), [high-speed rail](#), [ships](#), [airplanes](#), [rockets](#), and [spacecraft](#) are produced in limited quantities because of substantial costs, limited demand, and size
- The engineer must consider the practical challenges associated with the implementation and production of a design during the earlier phases of the iterative design process

Minimum Viable Product

- A [minimum viable product](#) (MVP) is a version of a product with just enough features to satisfy early customers and provide feedback for future product development
- Gathering insights from an MVP is often less expensive than developing a product with more features, which increases costs and risk if the product fails, for example, due to incorrect assumptions
- The term was coined and defined in 2001 by Frank Robinson, CEO of [SyncDev](#), and then popularized by
 - [Steve Blank](#), creator of [Lean Launchpad](#)
 - [Eric Ries](#), author of [The Lean Startup](#) and [The Startup Way](#)
- An MVP must include these key elements in production quality
 - Functionality: the set of features must deliver clear value to the user
 - Design: the design of the MVP must be up to the highest industry standard
 - Reliability: production quality standard needs to be achieved by rigorous testing
 - Usability: the MVP must be easy to use and intuitive

Concurrent Engineering and Design for X

- [Concurrent engineering](#) is simultaneous development of all aspects of a design from the initial concept to its manufacture, maintenance, and disposal
- [Design for X](#) or DFX seeks to achieve
 - Superior or at least satisfactory performance of all design functions, i.e., the customers' needs
 - Minimum cost, maintenance, and repair
 - High level of quality and reliability
 - Fastest time to market
 - Environmentally safe products and processes
 - Design that can be updated and upgraded as necessary

Design for Manufacturing and Assembly

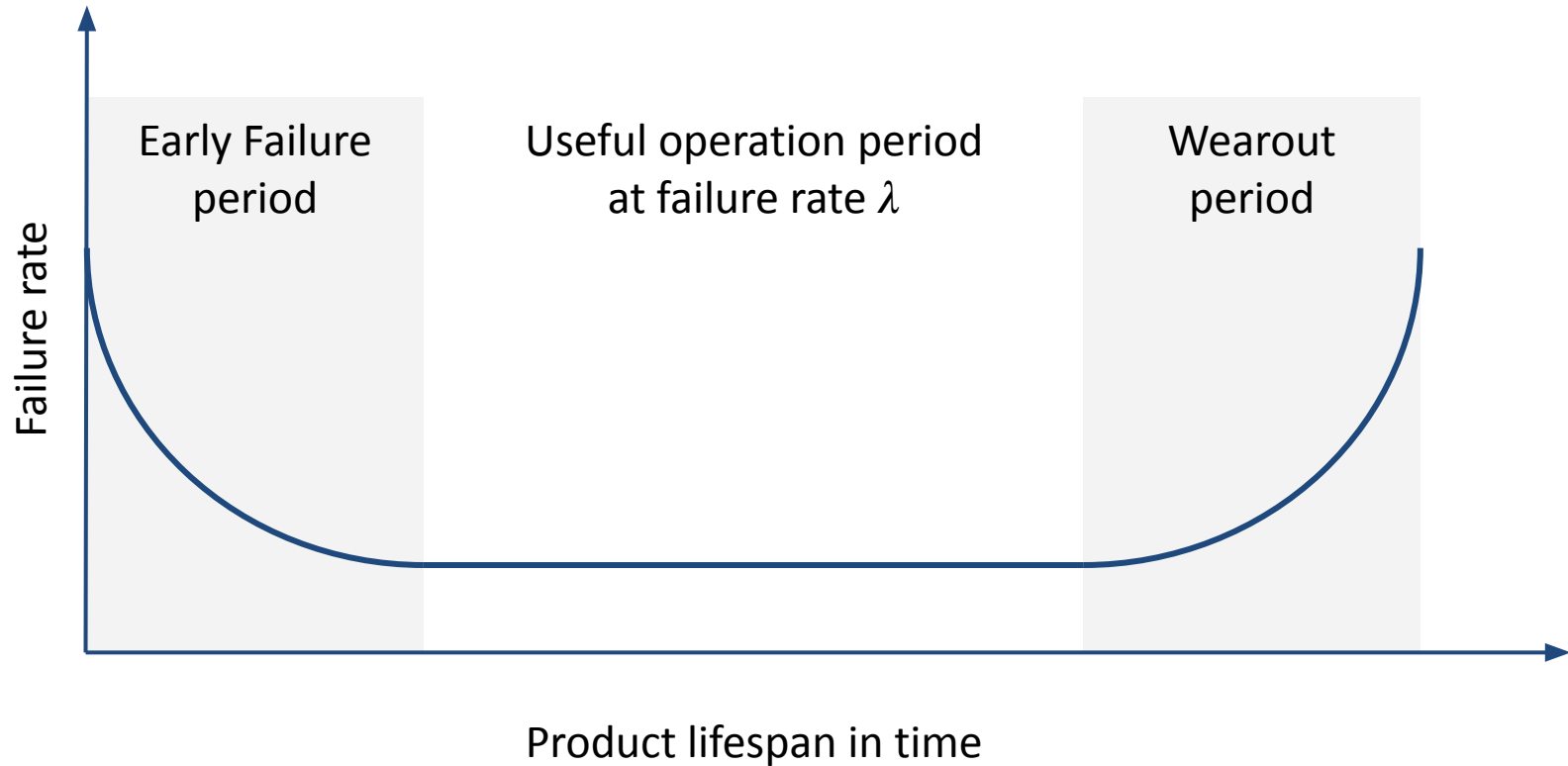
- Employ a division of labor
- Use interchangeable or standardized parts
- Use [assembly line](#) operations
- Use machine whenever appropriate
- Use modular design and subassemblies
- Use rapid prototyping
- Minimize the number of parts
- Minimize part variations
- Design parts to be multifunctional
- Avoid separate fasteners
- Minimize the number of assembly operations
- Maximize tolerance for easy assembly
- Provide access for easy assembly

Design for Reliability

- [Reliability](#) is the probability that a device will satisfactorily perform a specific function for a specified period of time under given operating conditions
- A high number of units fail early in their expected operating lifetime because of manufacturing defects, damage while in distribution or storage, or errors in installation
 - Many of potential early failures can be identified before entering the marketplace by a series of stress tests
- During the product's expected useful operating lifetime, some units can be expected to fail at a constant rate λ resulted from the stress or load to which the unit is subjected is greater than its strength or capacity to perform at that level
 - The engineers shall anticipate most of the operating demands and performance limitations of the design through data collection, experimental investigation, and analysis
- During the last phase of the product's expected operating lifetime, most of the long-term surviving units will fail because of wear and deterioration

Bathtub Curve

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



Design for Repairability

- [Repairability](#) is a measure of the degree to and ease with which a product can be repaired and maintained, usually by end consumers
- Repairable products are put in contrast to [obsolescence](#) or products designed with [planned obsolescence](#)
- [Electronics right to repair](#) is proposed legislation that would provide the practical means for electronics equipment owners to repair their devices

Mean Time Between Failures

- Mean time between failures ([MTBF](#)) describes the expected time between two failures for a repairable system
- Failure rate λ is the number of failures per unit of time
- $MTBF = 1/\lambda$
- Mean time to failure (MTTF) denotes the expected time to failure for a non-repairable system
- Mean downtime (MDT) is the mean time that the system is down after the failure

$$MTBF = \frac{\sum (\text{start of downtime} - \text{start of uptime})}{\text{number of failures}}$$

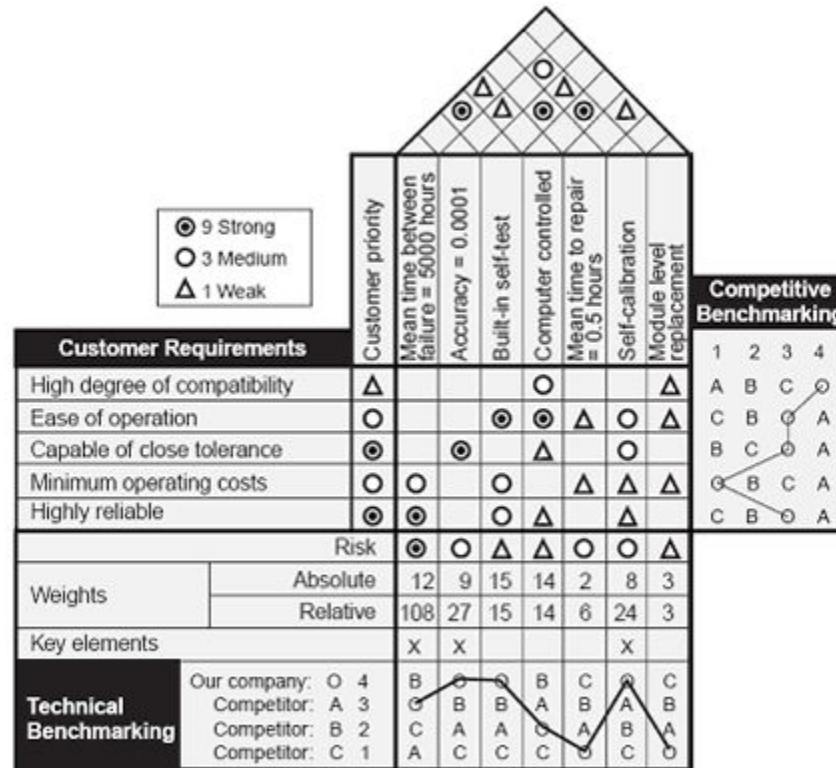
$$MDT = \frac{\sum (\text{start of uptime} - \text{start of downtime})}{\text{number of failures}}$$

Design for Quality

- Quality is the total composite product and service characteristics of marketing, engineering, manufacture, and maintenance through which the product and service in use will meet the expectations of the customers
- Design for quality aims at minimizing the potential impact of variations in a product's manufacture and operation
- Proactive [quality assurance](#) tools include
 - Failure mode and effects analysis ([FMEA](#))
 - Ishikawa cause-and effect diagrams
 - Fault tree analysis ([FTA](#))
 - Taguchi engineering method to reduce any undesirable variability in the manufacture of a system at three levels of sequential development: system design, parameter design, and tolerance design
 - Benchmarking to examine and adapt the best practices within the company, at competing firms, and throughout the world
 - House-of-quality charts to correlate customer and technical requirements

House-of-Quality Chart

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



Design for Packaging

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

- Provide aesthetic appeal and brand name recognition for the product
- Protect the product contents from spoilage or damage
- Provide the customer with a broad range of product sizes and formats
- Help establish a set of product standards and measures of quality
- Prevent the misuses of the product
- Provide closures that are inexpensive to manufacture and easy to open

Design for Maintainability, Disassembly, and Recyclability

- Design for [maintainability](#) ensures that a product will continue to operate properly with only minimum maintenance and repair, perhaps through periodic preventive maintenance
- Design for disassembly and design for recyclability focus on the end of a product's operating life to select materials, fasteners, and sequential assembly operations that allow obsolete or deteriorated units to be safely and economically reused, recycled, or discarded

Dependability

- In systems engineering, [dependability](#) incorporates availability, reliability, maintainability and since the 1980s, safety and security have been added to measures of dependability
 - Availability: readiness for correct service
 - Reliability: continuity of correct service
 - Maintainability: ability for a process to undergo modifications and repairs
 - Safety: absence of catastrophic consequences on the user(s) and the environment
 - Security is a composite of Confidentiality, Integrity, and Availability
 - Confidentiality: the absence of unauthorized disclosure of information
 - Integrity: absence of improper system alteration
- Security is sometimes classed as an attribute but the current view is to aggregate it together with dependability and treat dependability as a composite term called dependability and security
- In software engineering, dependability is the ability to provide services that can defensibly be trusted within a time-period

Storyboarding

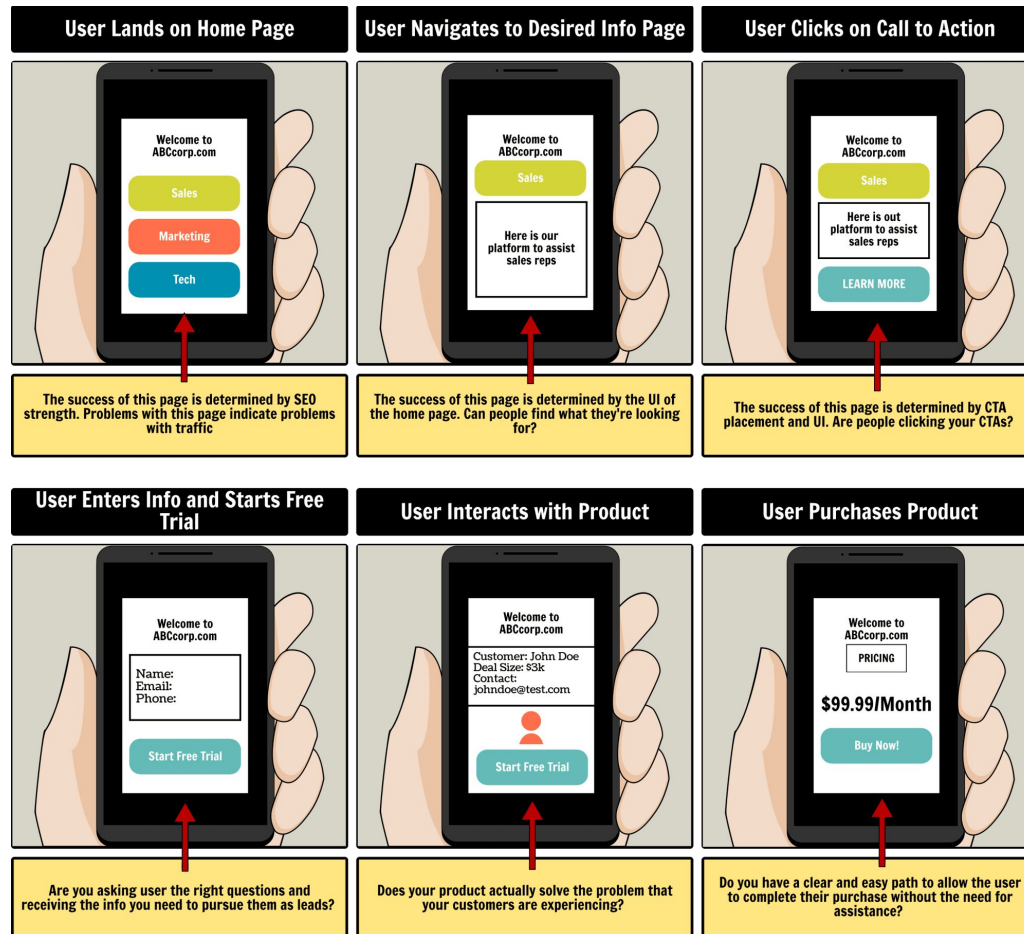
- A [storyboard](#) is a graphic organizer in the form of illustrations or images displayed in sequence for the purpose of pre-visualizing a motion picture, animation, motion graphic, or interactive media sequence
- The storyboarding process, in the form it is known today, was developed at [Walt Disney Productions](#) during the early 1930s, after several years of similar processes being in use at Walt Disney and other animation studios
- More recently, the term storyboard has been used in the fields of web development, software development, and instructional design to present and describe interactive events with audio and motion, particularly on user interfaces and electronic pages
- Storyboarding is used in software development as part of identifying the specifications for a particular set of software, e.g., screens that the software will display are drawn, either on paper or using [storyboard software](#), to illustrate the important steps of the user experience
- It usually costs less to make changes to a storyboard than an implemented piece of software

User Experience (UX)

- [ISO 9241](#) on ergonomics of human system interaction—Part 210: human-centred design for interactive systems defines [user experience](#) as
 - A person's perceptions and responses that result from the use or anticipated use of a product, system or service
- Recent advances in mobile, ubiquitous, social, and tangible computing technologies have moved human-computer interaction into practically all areas of human activity including not only the traditional [usability](#) metrics of efficiency, effectiveness, and basic subjective satisfaction but also users' feelings, motivations, and values
- In website design, user experience provides a platform to cover the interests of all stakeholders in marketing, branding, visual design, and usability, making websites easy to use, valuable, and effective for visitors

Design for User Experience

The Value of Storyboarding for Product Design

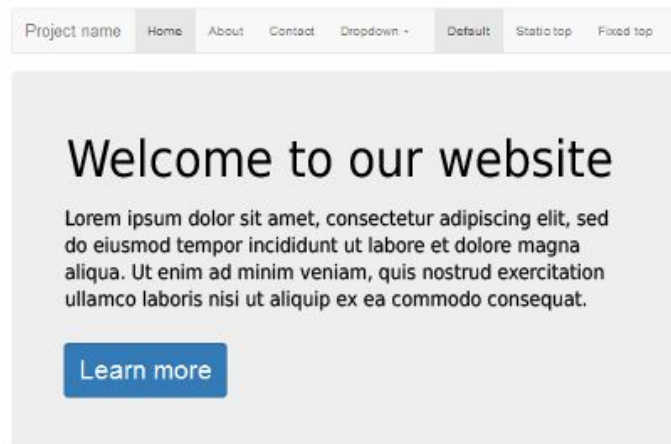


Software Testing

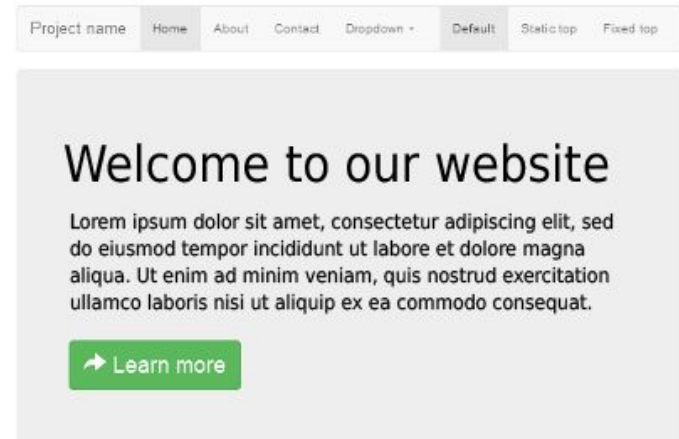
- [Software testing](#) involves the execution of a software component or system component to evaluate one or more properties of interest:
 - meets the requirements that guided its design and development
 - responds correctly to all kinds of inputs
 - performs its functions within an acceptable time
 - is sufficiently usable
 - can be installed and run in its intended environments
 - achieves the general result its stakeholders desire
- Testing approaches include [static](#), [dynamic](#), passive, [exploratory](#), [white-box](#), [black-box](#), [gray-box](#), component interface, and visual
- Testing levels include [unit](#), [integration](#), [system](#), and [acceptance](#)
- Testing types include [installation](#), [compatibility](#), [sanity](#), [smoke](#), [regression](#), [acceptance](#), alpha, beta, [functional](#), [non-functional](#), [continuous](#), [destructive](#), [performance](#), [usability](#), [accessibility](#), [security](#), [internationalization and localization](#), [development](#), [A/B](#), [concurrent](#), [conformance](#), output comparison, property, and playback

A/B Testing

- [A/B testing](#) is a way to compare two versions of a single variable, typically by testing a subject's response to variant A against variant B, and determining which of the two variants is more effective
- By randomly serving visitors two versions of a website that differ only in the design of a single button element, the relative efficacy of the two designs can be measured



Click rate: 52 %



72 %

Design Tools

- [Adobe InDesign](#) app and [Adobe XD](#) vector-based user experience design tool
- [Affinity Designer](#) vector graphics editor
- [Appy Pie](#) no code application development platform
- [Axure RP wireframing](#), rapid prototyping, documentation and specification software tool
- [Canva](#) and [Kittl](#) graphic design platforms to create social media graphics, presentations, posters, documents, and other visual content
- [Figma](#) cloud-based design and collaboration tool
- [Fluid UI](#) browser-based wireframing and prototyping tool to design mobile touch interfaces
- [GIMP](#) (GNU Image Manipulation Program) [free and open-source raster graphics](#) editor used for image retouching and editing, free-form drawing, converting between different image formats, and more specialized tasks
- [Inkscape](#) free and open-source vector graphics editor
- [InVision Studio](#) screen design tool
- [OmniGraffle](#) diagramming and digital illustration application
- [Open Broadcaster Software](#) (OBS Studio) cross-platform streaming and recording program
- [Sketch](#) for designing UI and UX of mobile apps and web
- [SketchUp](#) 3D modeling computer program for architectural, interior design, landscape, civil and mechanical engineering, film and video game design

Mobile Development Framework

- A [mobile development framework](#) is a [software framework](#) designed to support [mobile app development](#) in three categories
 - Native frameworks for platform-specific development
 - Mobile [web app](#) frameworks ([MIT App Inventor](#))
 - Hybrid apps ([Ionic](#), Google [Flutter](#), Microsoft [Xamarin](#), etc.)
- [React](#) is a [JavaScript](#) library for building user interfaces by rendering data to the Document Object Model ([DOM](#)) with a logical tree structure
- [React Native](#) is an open-source mobile application framework to develop applications for Android, iOS, Web, and Universal Windows Platform ([UWP](#)) by enabling developers to use React along with native code in languages such as [Java](#) for Android and [Object-C](#) or [Swift](#) for iOS
- [Qt](#) is a free and open-source [widget toolkit](#) for creating graphical user interfaces and cross-platform applications that run on various software and hardware platforms such as Linux, Windows, macOS, Android, or embedded systems with little or no change in the underlying codebase while still being a native application with native capabilities and speed

Mobile Video Editing Apps

iOS and Android

- Quik by GoPro
- Adobe Premiere Rush
- InShot
- KineMaster
- WeVideo
- PicPlayPost
- Horizon
- Videoshop
- VivaVideo
- VideoShow
- Magisto
- Boomerang
- Anchor
- FilmoraGo

iOS

- Slice
- iMovie
- LumaFusion
- Filmmaker Pro
- Hyperlapse
- Clips

Source

Thomas J. Law, "[The 20 Best Mobile Video Editing Apps You Must Use in 2021](#)," Oberlo, 2020-11-22

Privacy Management

Privacy management for fair and authorized processing of personally identifiable information ([PII](#))

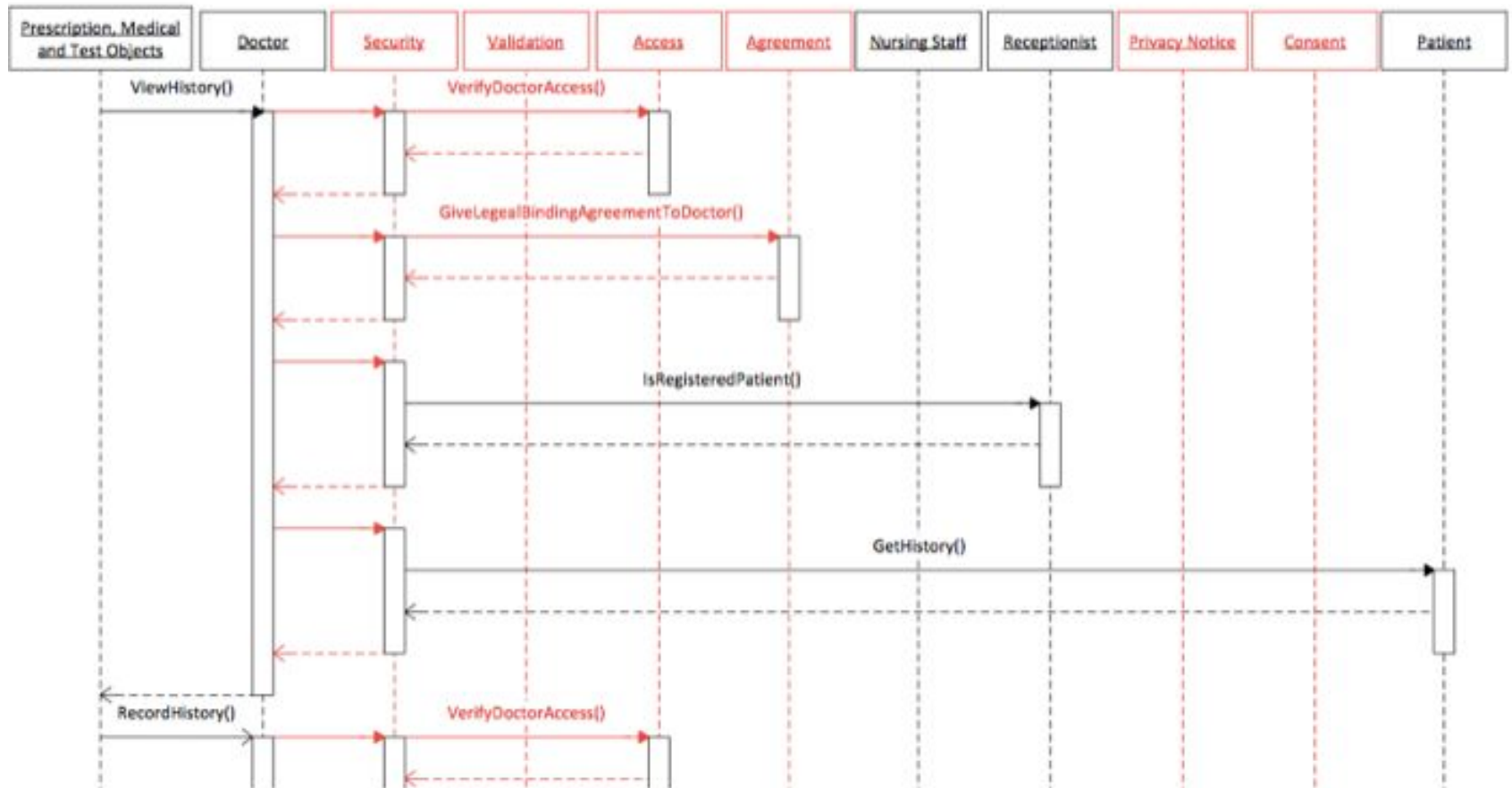
- Collection, storage, use, organization, recording, alignment, combination, disclosure by transmission, consultation, erasure, destruction, and alteration
- Any data that identifies an individual or from which identity or contact information of an individual can be derived

OASIS Technical Committees

- [OASIS](#) is Organization for the Advancement of Structured Information Standards
- Privacy Management Reference Model ([PMRM](#))
- Privacy by Design Documentation for Software Engineers ([PbD-SE](#))
- Cross-Enterprise Security and Privacy Authorization ([XSPA](#))

Privacy Management Sequence

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



Privacy by Design



OASIS Privacy by Design Documentation for Software Engineers (PbD-SE) TC

RACI Definitions

R

• Who is Responsible

• The person who is assigned to do the work

A

• Who is Accountable

• The person who makes the final decision and has the ultimate ownership

C

• Who is Consulted

• The person who must be consulted before a decision or action is taken

I

• Who is Informed

• The person who must be informed that a decision or action has been taken

RACI Chart for OASIS PbD-SE Methodology (WIP)

PbD-SE Methodology Step	Documented Activity	Software Engineer	Privacy Resource	Project Mgmt.	Mgmt.	Third Party	User
3.1 Assess Organizational Readiness	Document Privacy Policy Document	C	RAC	C	AC	I	C
	Document Privacy Roles/Training Program in Organization	I	RA C	C	AI	I	I
3.2 Scope Privacy Requirements & Reference Architecture	Document Functional Privacy Requirements & hooks to Reference Architecture	RA	RA C	AC	AI	RAI	C
3.3 Conduct Risk Analysis on Use Cases	Document Business Model with Personal Data Flows	C	RAC	C	AC	C	-
	Document Risk analysis (incl. threat models, PIA)	C	RA C	C	AC	C	-
3.4 Identify Privacy Resource Allocation	Document privacy resource allocation to SE team	I	RACI	R	AI	I	-
3.5 Create RACI for Producing Artifacts	Document RACI assignment to artifact production	RC	C	RAC	AI	-	-
3.6 Customize Privacy Architecture	Document Privacy Architecture	RA	AC	AC	AI	I	-
3.7 Conduct Periodic Review	Document Review of Artifacts throughout the PDLC	RA	C	RAC	AI	-	-
3.8 Execute Code Testing & Privacy Evaluation	Document testing and evaluation for privacy usability - metrics	RA	RC	RAC	AI	-	C
3.9 Create Retirement Plan	Document plan for retirement of software solution	C	RA C	RAC	AC	I	I
3.10 Sign-off	Document sign off with checklist	RAC	RA C	RAC	AC	-	-

Privacy-Preserving Contact Tracing

- [COVID-19 apps](#) with privacy-preserving contact tracing can help [flatten the curve](#) by reducing the spread of the [SARS-CoV-2](#) virus that causes [COVID-19](#) [[Research](#)]
- Google and Apple released with [exposure notification](#) specifications including Bluetooth, cryptography, framework API, and frequently asked questions
 - Exposure notification apps: [COVID Alert NJ](#), [COVID Alert NY](#), etc.
- [CovidSafe](#) created by Microsoft and University of Washington to alert people in close proximity to someone infected
- Other frameworks, protocols, or apps for contact tracing and exposure matching based on voluntary symptom sharing and/or confirmed COVID-19 test results: [Antidote](#), [Care19](#), [Check-In](#), [CoEpi](#), [COVID SafePaths](#), [COVID Trace](#), [Covid Watch](#), [DP-3T](#), [NextTrace](#), [PACT](#), [Private Kit: Safe Paths](#), [TCN Coalition](#), etc.
- Singapore [BrueTrace](#), [TraceTogether](#)
- India [Aarogya Setu](#)
- Norway [Smittestopp](#) (data are deleted every 30 days)
- Pan-European Privacy Preserving Proximity Tracing ([PEPP-PT](#))
- [COVID-19 Digital Rights Tracker](#)

Software Release Life Cycle

A software release life cycle includes the following phases of development:

- **Pre-alpha** activities include requirements analysis, software design, software development, and [unit testing](#)
- **Alpha** test is the first software testing that usually ends with feature [freeze](#) or feature complete
- **Beta** test focuses on reducing impacts on users
- **Release candidate** (going silver) is code complete that no entirely new code to be added
- **Stable release** or production release has passed all tests
- **Release to manufacturing** (going gold) is ready to be delivered
- **General availability** (gone live) for commercialization and purchase
- **Release to the web** uses the internet for distribution
- **Support** [patch](#) and [service pack](#) include a set of updates, fixes, or enhancements
- **End-of-life** as software to be deprecated and no longer supported

Materials Selection in Design

- What materials are available for selection?
- How will each material, if selected, aid or hinder efforts to achieve the performance requirements and specifications?
- Which manufacturing processes are available?
- For each material under consideration, how would the corresponding manufacturing process affect the production of the design in terms of costs, precision of work, fabrication time, assembly, plant space and equipment, use of personnel, and waste of raw materials?

Mechanical Properties

Property	Interpretation	Common or related measure
Strength	Ability to resist breaking	Yield stress
Stiffness	Ability to resist bending	Modulus of elasticity
Ductility	Permanent deformation before breaking	% elongation
Toughness	Ability to withstand impact or resist breaking	Energy or work necessary to fracture material
Hardness	Ability to resist abrasion or scratching	Scores on hardness tests
Creep	Gradual, continuing deformation under an applied constant stress	Creep strength

Electrical Properties

Property	Interpretation	Common or related measure
Resistance	Opposition to passage of electrical current	Electrical resistivity R
Conductance	Ability to conduct electrical current	Electrical conductivity $C = 1 / R$
Dielectric strength	Highest voltage that can be applied to insulator without electrical breakdown	$DS = \text{Breakdown voltage} / \text{Insulator thickness}$

Thermal Properties

Property	Interpretation	Common or related measure
Thermal conductivity	Ability to conduct heat	Amount of heat per second flowing through a temperature gradient ΔT
Specific heat capacity	Heat per unit mass needed to raise temperature T by an amount ΔT	Amount of heat / (mass $\times \Delta T$)
Coefficient of linear expansion	Amount of expansion ΔL with increasing temperature ΔT	$\Delta L / (L \times \Delta T)$
Melting point	Temperature at which change of state from solid to liquid occurs	T_m = Melting temperature

Other Properties

Appearance	Flammability	Odor
Availability	Mass oxidation	Texture
Corrosion	Permeability	Toxicity
Cost	Porosity	Transparency
Density	Reflectivity	Viscosity

Ingress Protection (IP) Code

- Defined in IEC 60529, [IP code](#) classifies and provides a guideline to the degree of protection provided by mechanical casings and electrical enclosures against intrusion, dust, accidental contact, and water
 - The first digit (0-6) or letter X represents solid particle protection
 - The second digit (0-8) or letter represents liquid ingress protection
 - For example, a cellular phone rated at IP67 is "dust resistant" and can be "immersed up to one meter depth of freshwater for up to 30 minutes"
- The US [National Electrical Manufacturers Association](#) defines NEMA enclosure types for electrical equipment in [NEMA 250](#)

Common Fabrication Materials

- Metals: aluminum, copper, iron, magnesium, nickel, steel, titanium, and zinc
- Polymers
 - Thermoplastics: acrylics, cellulose, fluoroplastics, nylons, polyethylene, polypropylene, polystyrene, polyvinyl chloride, and vinyl
 - Thermosets: phenol formaldehyde, melamine formaldehyde, and urea formaldehyde
 - Elastomers: natural rubber and synthetic rubbers
- Ceramics
- Composites formed from two or more constituent materials that, when combined, exhibit a combination of the individual constituents' characteristics
- The European Union adopted in February 2003 the Restriction of Hazardous Substances ([RoHS](#)) Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment that took effect on July 1, 2006

Fabrication Processes

- Metals
 - Casting
 - Forging
 - [Sintering](#) (powder metallurgy)
 - Stamping and forming
 - [Extrusion](#)
 - Machining
- Polymers and plastics
 - Blow molding
 - Injection molding
 - Laminating
 - Thermoforming

Manufacturing Processes

- Solidification
- Deformation
- Material removal
- Polymer
- Particulate
- Joining
- Heat and surface treatment
- Assembly

3D Printing and Additive Manufacturing

- [3D printing](#) is any of various processes in which material is joined or solidified under computer control to create a three-dimensional object, with material being added together such as liquid molecules or powder grains being fused together
- Unlike material removed from a stock in the conventional machining process, 3D printing or additive manufacturing (AM) builds a three-dimensional object from computer-aided design ([CAD](#)) model, Additive Manufacturing File ([AMF](#)), or stereolithography ([STL](#)) file usually by successively adding material layer by layer
- Patents, [industrial design rights](#), copyright, and trademark may apply
- Although no occupational exposure limits ([OELs](#)) specific to 3D printer emissions exist, certain source materials used in 3D printing, such as carbon nanofiber ([CNF](#)) and carbon nanotube ([CNT](#)), have established OELs at the [nanoparticle](#) size
- [3D bioprinting](#) is the utilization of 3D printing and 3D printing–like techniques to combine cells, growth factors, and [biomaterials](#) to fabricate biomedical parts that maximally imitate natural tissue characteristics
- [3D printing filament](#), materials [guide](#), and the "[top ten materials](#) for 3D printing" by the American Society of Mechanical Engineers ([ASME](#))

Product Testing



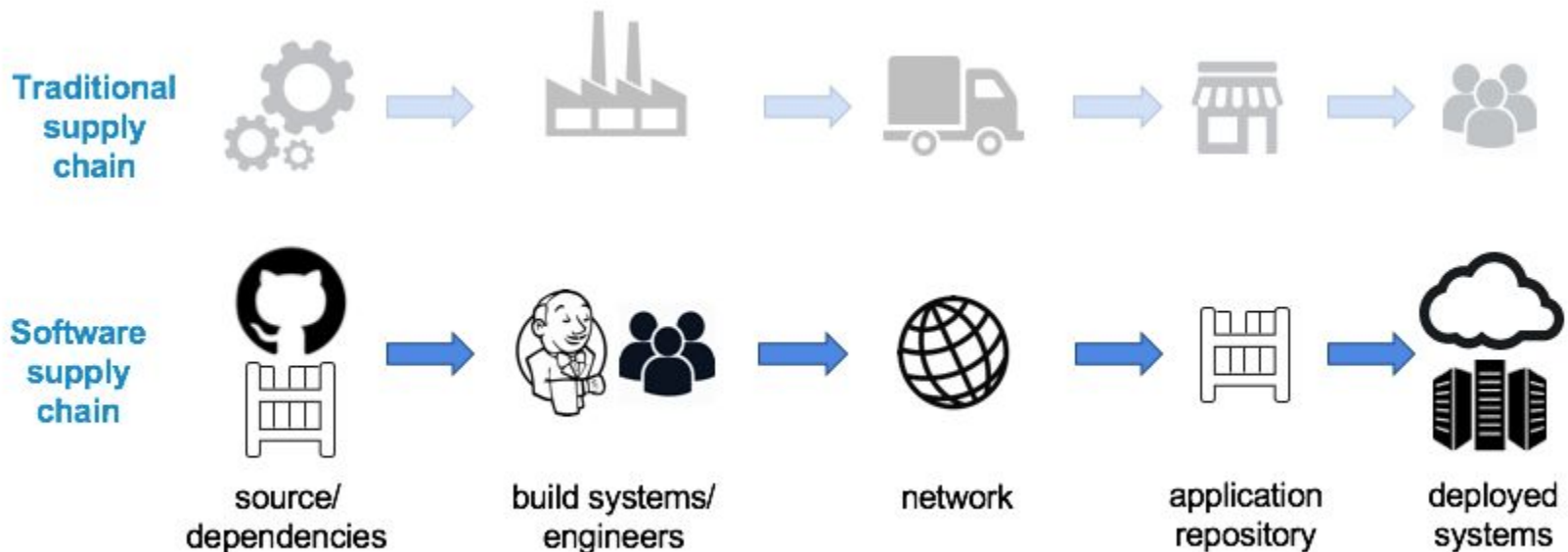
- [Product testing](#) is a process of measuring the properties or performance of products
- Product testing might be accomplished by a manufacturer or a Nationally Recognized Testing Laboratory ([NRTL](#)), e.g., [UL](#) and [Eurofins Scientific](#)
- Often an existing formal [test method](#) is used as a basis for testing
- Other times engineers develop methods of test that are suited to the specific purpose
- [Consumer Reports](#) was founded in 1936 to provide unbiased product testing, [investigative journalism](#), consumer-oriented research, public education, and [consumer advocacy](#)
- Jon Love and Chris Ward founded [Electric Teeth](#) in 2015 to test dental care products including [mouthpiece toothbrush](#) products such as [Y-Brush](#)

Supply Chain

Securing Enterprise Software Supply Chain Using Docker

The software supply chain maps similarly to the [supply chain](#) for a physical product

- Source the raw materials (code, dependencies, packages)
- Fabricate and manufacture (build) the product (systems)
- Ship them by sea, land, or air (network) to a store (repository)
- Sell (deploy) the item (application) to the end customer



Industry 4.0

[Industry 4.0](#)

	Year	Industrial Revolution
1.0	1784	Water- and steam-powered mechanical production facilities
2.0	1870	Electrically powered mass production based on division of labor
3.0	1969	Electronic and information technology systems that further automate production
4.0	2010	<u>Cyber-physical systems</u> (CPS), the <u>internet of things</u> (IoT), <u>cloud computing</u> , and <u>cognitive computing</u>

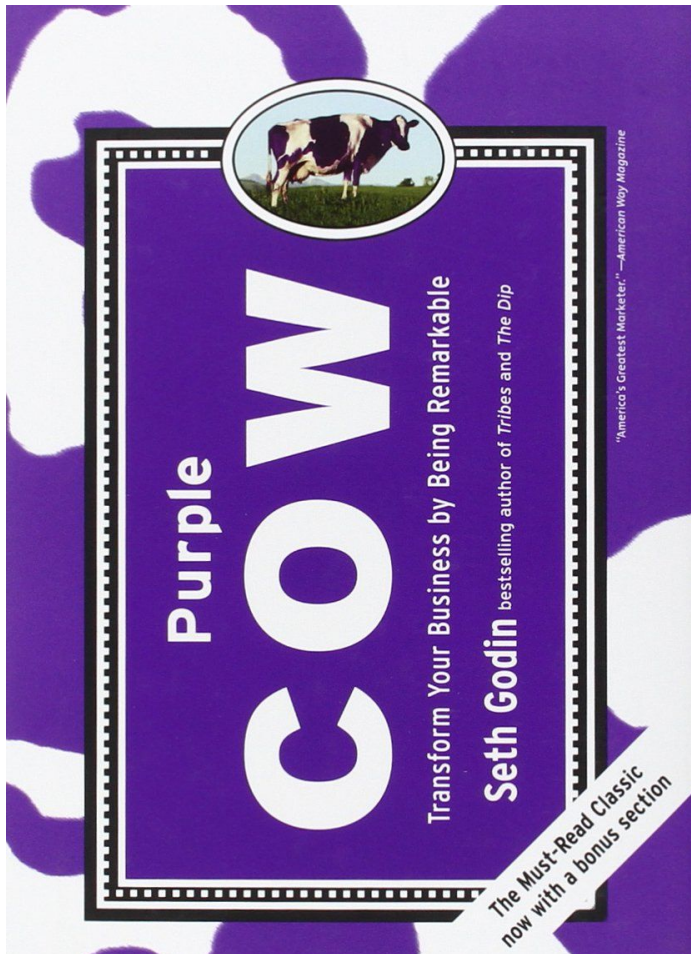
Construction Processes

- Canals, e.g., the [Suez Canal](#) was constructed between 1859 and 1869, and the [Panama Canal](#) was attempted between 1881 and 1894, constructed between 1904 and 1914, and expanded between 2007 and 2016
- Concrete dams, e.g., [Hoover Dam](#) was constructed between 1931 and 1936 during the [Great Depression](#)
- Highway systems, e.g., the [Interstate Highway System](#) was authorized on 1956-06-29 and completed on 1992-10-14
- Tunnels, e.g., the [Channel Tunnel](#) began construction in 1988 and opened in 1994
- [Boat lifts](#), e.g., the [Falkirk Wheel](#) began construction in March 1999 and opened on 2002-05-24
- High-rise buildings, e.g., the [Taipei 101](#) started construction in 1999 and finished in 2004, and [One World Trade Center](#) began construction on 2006-04-27 and opened on 2014-11-03
- Airports, e.g., [Beijing Daxing International Airport](#) started construction on 2014-12-26 and opened on 2019-09-26

Lesson 11 Summary

- Poor implementation of a design concept can lead to failure or tragedy
- Determine the the processes, materials, and equipment that will be used in fabrication, assembly, and other manufacturing operations when developing the design concept itself
- Materials chosen for an engineering design must match the performance, environmental, processing, and financial requirements of the product or system
- Design for X (DFX) provides valuable guidelines for developing successful products
- DFX seeks to achieve
 - Superior, or at least satisfactory, performance of all design functions
 - Minimum costs, maintenance, and repair
 - High levels of quality and reliability
 - Fastest time to market
 - Fundamentally safe products and processes
 - Designs that can be updated and upgraded as necessary
- Apply basic principles and general guidelines for effective fabrication
- Consider important aspects of packaging

Purple Cow



- *Purple Cow: Transform Your Business by Being Remarkable* is a 2003 [book](#) by [Seth Godin](#)
- The first, self-published edition came packaged in a milk carton and was sold for just shipping and handling charges
- The cover is [purple](#) and [white](#), and the words are printed sideways
- The book advocates that companies produce remarkable products and target people who are likely to spread [word of mouth](#) about the product
- "Today, the one sure way to fail is to be boring"
- "The one chance for success is to be remarkable"
- Seth Godin's [blog](#), [quotes from the book](#)

Hack Versus Kludge

	Hack (cf., Hacker)	Kludge or Kluge
Definition	A usually creative solution to a computer hardware or programming problem or limitation	A system and especially a computer system made up of poorly matched components
Connotation	A real solution is possible but requires changes	No one is proud of a kludge
	Hard to reuse, maintain, and extend	Sloppy, hasty, shoddy, or inelegant

Polyhedron Seal

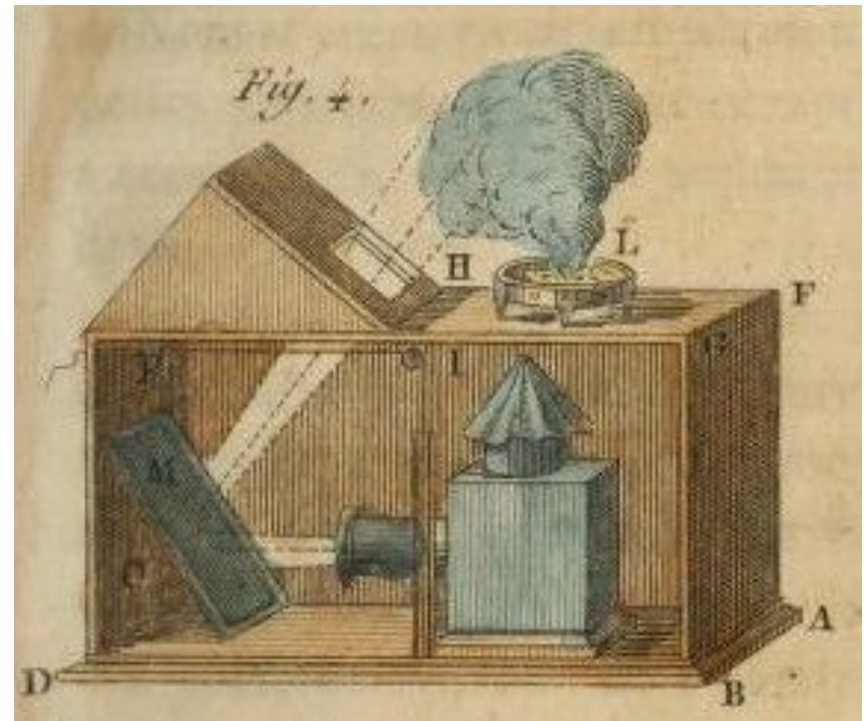
[Dugu Xin](#) 503—557 used a [rhombicuboctahedron seal](#) made of [jet](#) with 18 square faces (of which 14 stamps for signing documents) plus eight equilateral-triangle faces



Smoke and Mirrors

- [Smoke and mirrors](#) in magical illusions rely on a hidden projector (known then as a magic lantern) to reflect an image off a mirror into a cloud of smoke
- The phrase "smoke and mirrors" has entered common use to refer to any proposal that proves to be an illusion when examined closely
- "[Mirror Flower, Water Moon](#)" is a Chinese proverb meaning a flower reflected in a mirror that can be seen but not touched or the moon reflected on the water surface that is beautiful but unattainable like a mirage

Source: *Nouvelles récréations physiques et mathématiques* (1769) by [Edmé-Gilles Guyot](#) 1706—1786



Vaporware

- [Vaporware](#) is a product, typically computer hardware or software, that is announced with few details about its development being released to the general public but is never actually manufactured nor officially cancelled
- Developers have been accused of intentionally promoting vaporware to keep customers from switching to competing products that offer more features
- [InfoWorld](#) magazine wrote that the word is overused and places an unfair stigma on developers
- "Vaporware" was coined by a Microsoft engineer in 1982 to describe the company's [Xenix](#) operating system and first appeared in the [1983-11-28 issue of RELEASE 1.0](#) by entrepreneur [Esther Dyson](#)
- It became popular among writers in the industry as a way to describe products they felt took too long to be released [[list](#)]

Michelangelo's Unfinished Works

- [Michelangelo](#) di Lodovico Buonarroti Simoni 1475—1564 carved 42 pieces of marble sculpture, 24 of them are unfinished in entirety or in part
- Michelangelo worked between 1547 and 1555 on [the Deposition](#) that he tried to smash in a fit of rage
- Prof. [Juergen Schulz](#) 1927—2014 wrote "discontent or dissatisfaction in one form or other did stop Michelangelo from completing all of the foregoing works"
- Keep [propensity](#) for perfection in check



Senioritis and Student Syndrome

- [Senioritis](#) describes an ebbing of motivation and effort by school seniors as evidenced by tardiness, absences, and lower grades
- [Student syndrome](#) is first coined by [Eliyahu M. Goldratt](#) 1947—2011 in [Critical Chain](#) to highlight the habit of leaving a lot of work until the last moment, while originally working at a very relaxed pace with lots of slack
- Success is only reserved for a few who overcome the innate habit of [procrastination](#) in any person (and pigeon)
- The common causes of procrastination are [intertemporal choice](#), task [averseness](#), and certain personality traits such as indecisiveness and distractibility
- Further reading: "[Understanding and Overcoming Procrastination](#) [1]–[2]."

References

- [1] The [McGraw Center for Teaching and Learning](#), Princeton University.
- [2] Dominic J. Voge, "Classroom Resources for Addressing Procrastination," *Research and Teaching in Developmental Education*, Vol. 23, No. 2, pp. 88-96, 2007.

Open Source Robotics

- [ROS](#) ([Robot Operating System](#)) provides libraries and tools robot applications
- [TurtleBot](#) is a ROS standard platform robot with [open-source software](#) [[GitHub](#)]
- [Robotis Bioloid](#) is programmed with RoboPlus, a C language based software solution comparable to the [LEGO Mindstorms](#) and [VEX Robotics](#)

TurtleBot 2 Family



TurtleBot 2



TurtleBot 2i



TurtleBot 2e



TurtleBot Euclid

TurtleBot 3 Family

Burger



Waffle

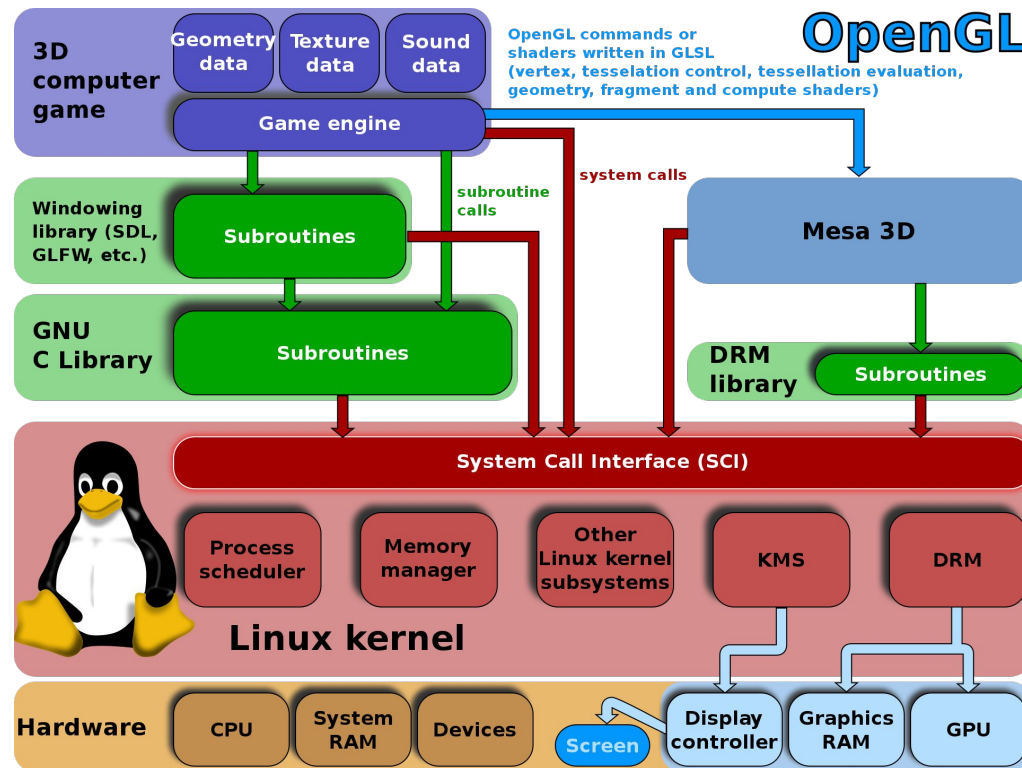


Waffle Pi



OpenGL

Open Graphics Library ([OpenGL](https://www.khronos.org/opengl/)) is a cross-language, cross-platform application programming interface (API) for rendering 2D and 3D vector graphics

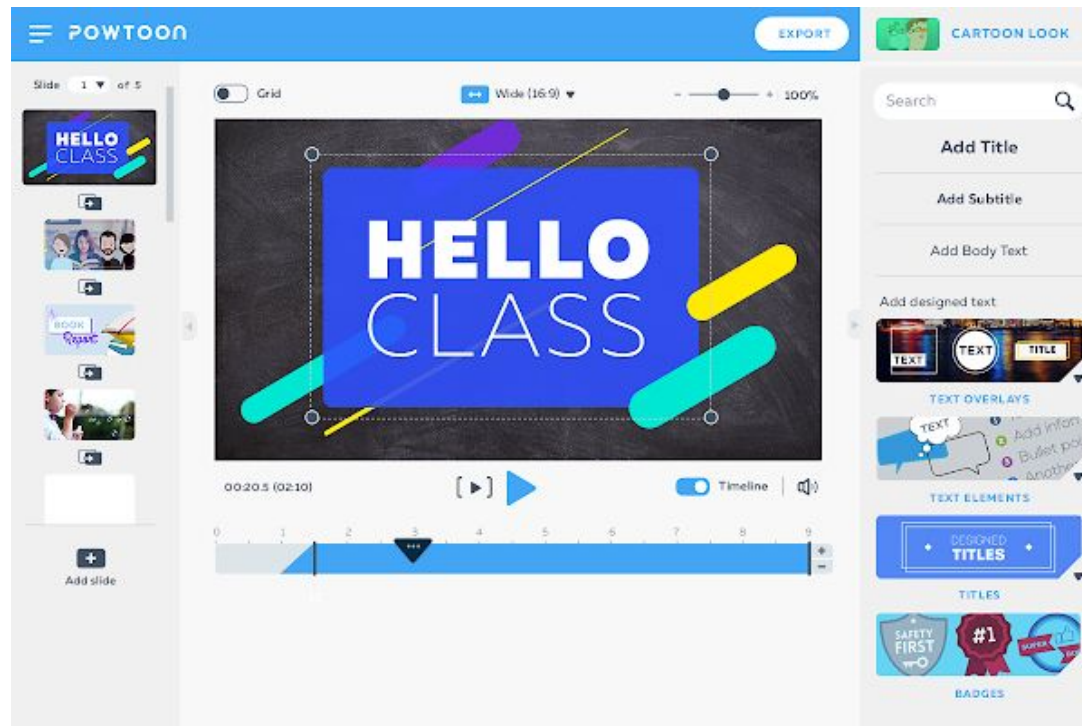


OpenAI and GPT-3

- [OpenAI](#) was founded on 2015-12-11 by Elon Musk, Sam Altman, and others
- Considered a competitor to [DeepMind](#), OpenAI conducts research in the field of artificial intelligence (AI) with the stated goal of promoting and developing [friendly AI](#) in a way that benefits humanity as a whole
- OpenAI has created Generative Pre-trained Transformer (GPT) series, including [GPT-3](#), the third-generation autoregressive language prediction model, which uses deep learning to produce human-like text
- Microsoft announced on 2020-09-22 that it had licensed exclusive use of GPT-3
- Although others may join the waitlist to use the public [OpenAI API](#) to receive output, only Microsoft has control of the source code
- Unlike most AI systems that are designed for one use-case, the API today provides a general-purpose “text in, text out” interface, allowing users to try it on virtually any English language task
- [OpenAI Codex](#) has been used to power [GitHub Copilot](#) since 2021-06-29

Powtoon

- [Powtoon](#) uses an [Apache Flex](#) engine to generate an XML file that can be played in the Powtoon online viewer, exported to YouTube, or downloaded in [MP4](#)
- Powtoon also has an application on [Edmodo](#)



Sustainable Materials

- [Hemp](#) is used to make a variety of commercial and industrial products, including rope, textiles, clothing, shoes, food, paper, bioplastics, insulation, and biofuel
- The bast fibers can be used to make textiles that are 100% hemp, but they are commonly blended with other fibers, such as flax, cotton or silk, as well as virgin and recycled polyester, to make woven fabrics for apparel and furnishings
- The inner two fibers of the plant are woodier and typically have industrial applications, such as mulch, animal bedding, and litter
- When oxidized (often erroneously referred to as "drying"), hemp oil from the seeds becomes solid and can be used in the manufacture of oil-based paints, in creams as a moisturizing agent, for cooking, and in plastics
- Hemp seeds have been used in bird feed mix as well
- A survey in 2003 showed that more than 95% of hemp seed sold in the European Union was used in animal and bird feed

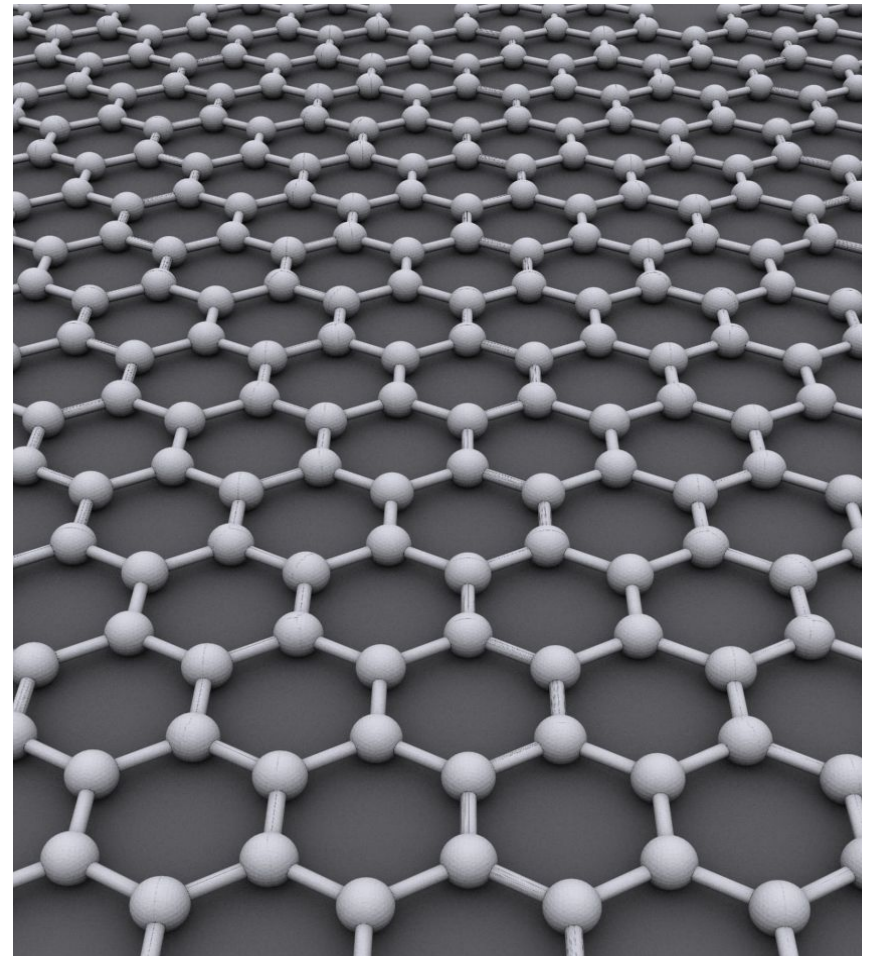
Graphene

[Graphene](#) is a single layer of carbon atoms bonded together in a honeycomb lattice that is electrically and thermally conductive, and transparent

- 0.335 nm in thickness
- 0.77 mg per square meter
- 42N/m of [tensile strength](#)
- 31 Ω of [sheet resistance](#)
- 5000 W/(m · K) [thermal conductivity](#)

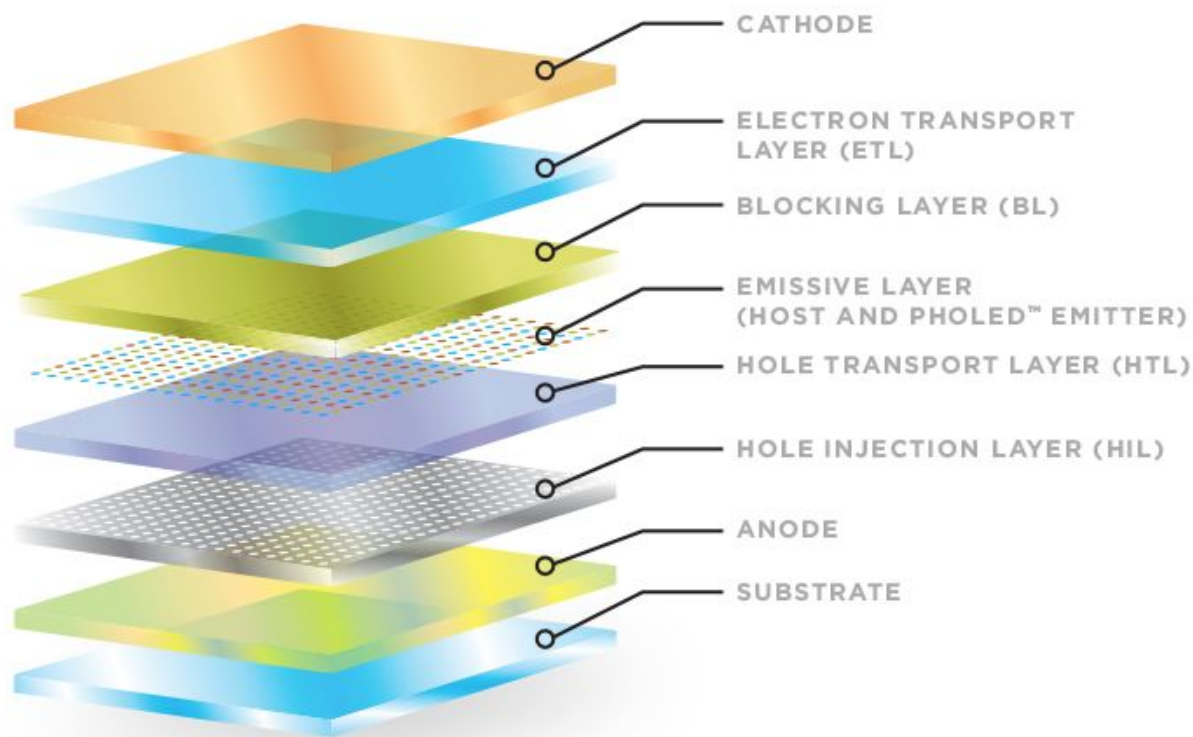
[Applications](#) of graphene include

- Biomedical
- Composites and coatings
- Electronics
- Energy
- Membranes
- Sensors



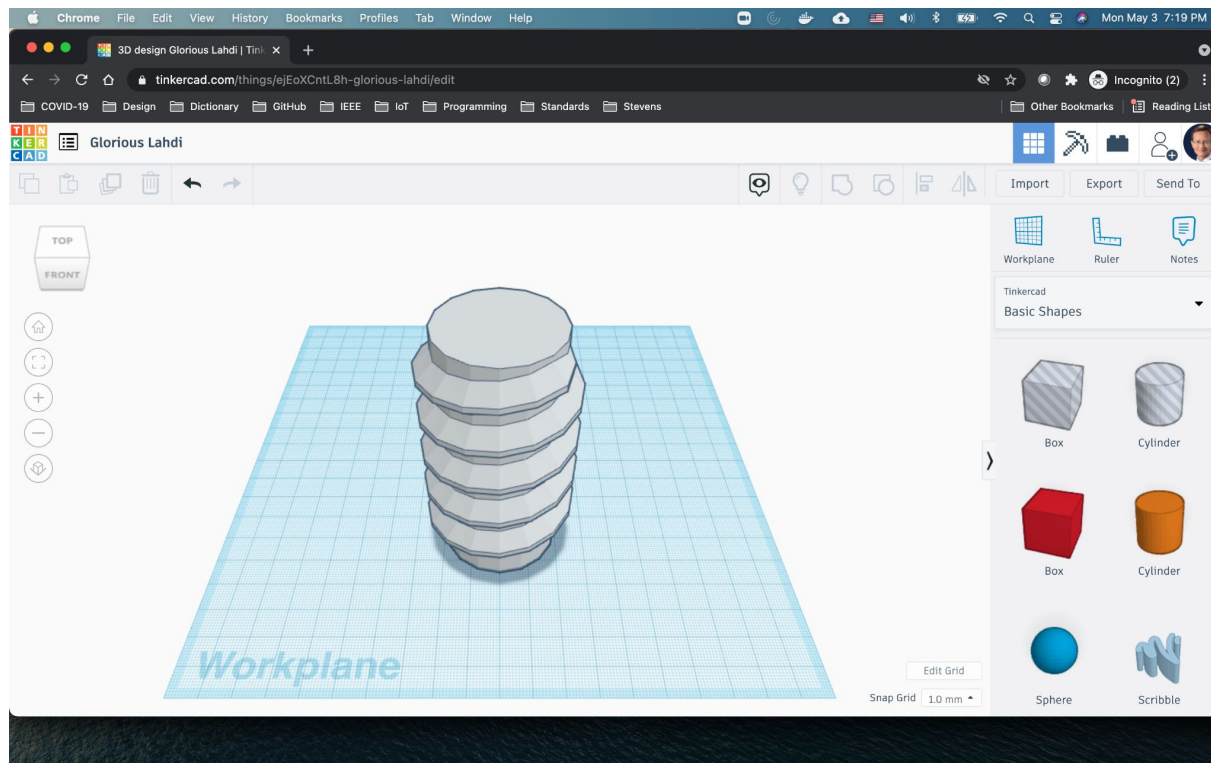
Organic Light Emitting Diodes

[Organic light-emitting diodes \(OLEDs\)](#) are monolithic, solid-state devices that consist of a series of organic thin films sandwiched between two thin-film conductive electrodes



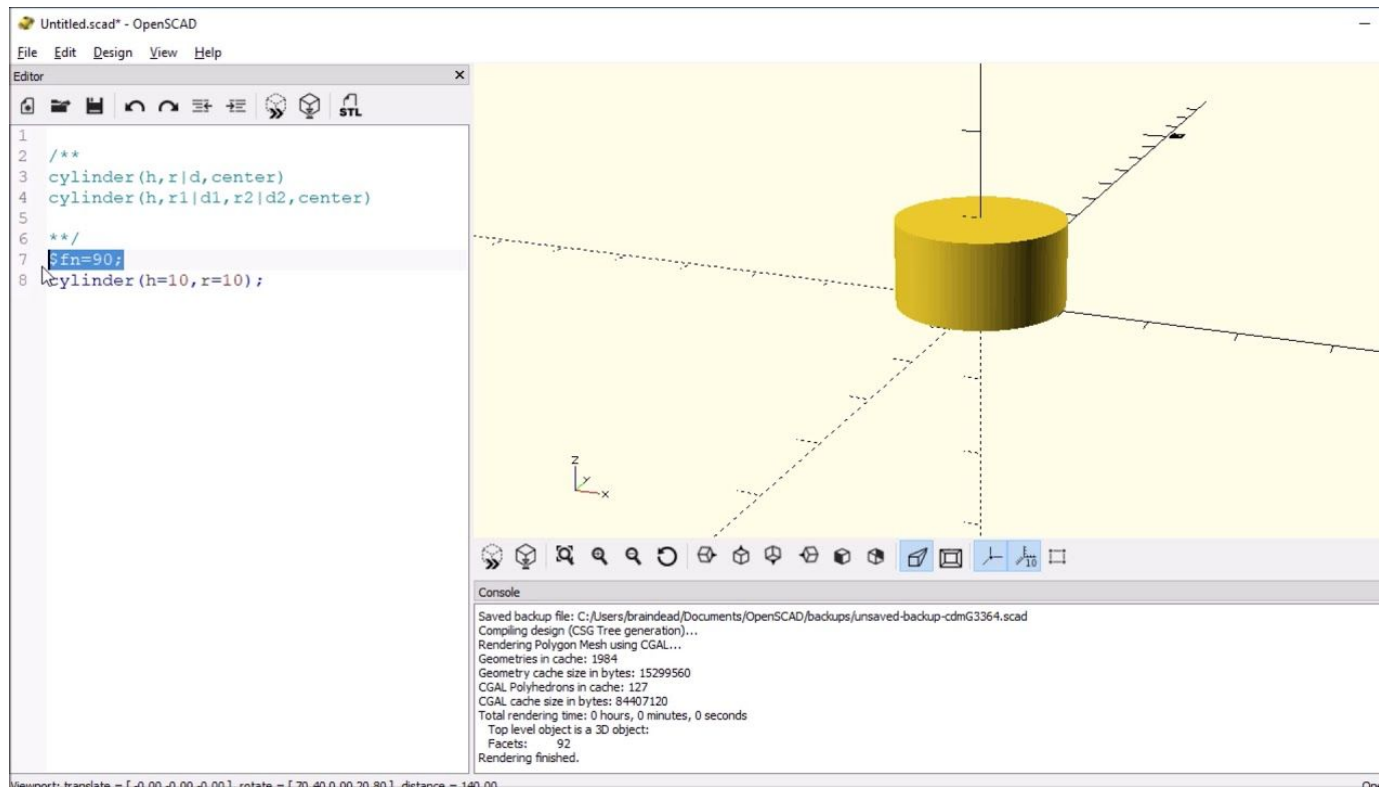
Tinkercad

- [Tinkercad](#) is an online 3D modeling program that runs in a web browser
- Tinkercad exports models in STL or [OBJ](#) formats, ready for 3D printing



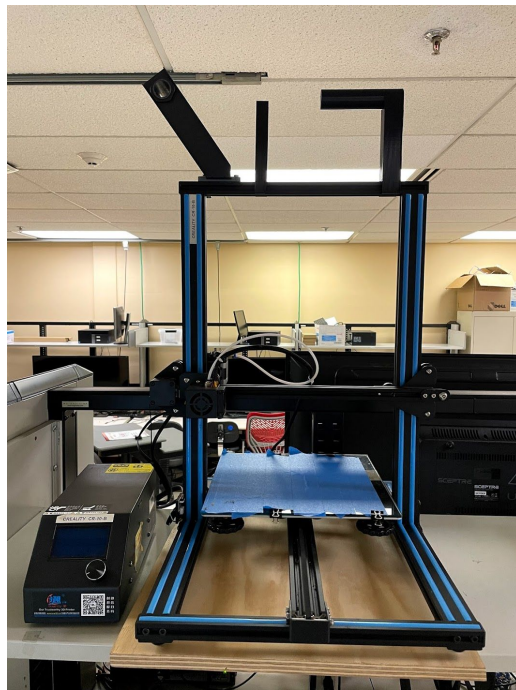
OpenSCAD

- [OpenSCAD](#) is a software for creating solid 3D CAD objects
- OpenSCAD GitHub [repository](#)



3D Printers at ECE Lab

- Founded in 2014, Shenzhen [Creality](#) 3D Technology Co,. Ltd. released the [CR 10](#) 3D printer in 2017 and the [Ender 3](#) 3D printer in March 2018
- In July 2018, Creality released all Ender 3 hardware specification, CAD files, board schematics, and firmware files



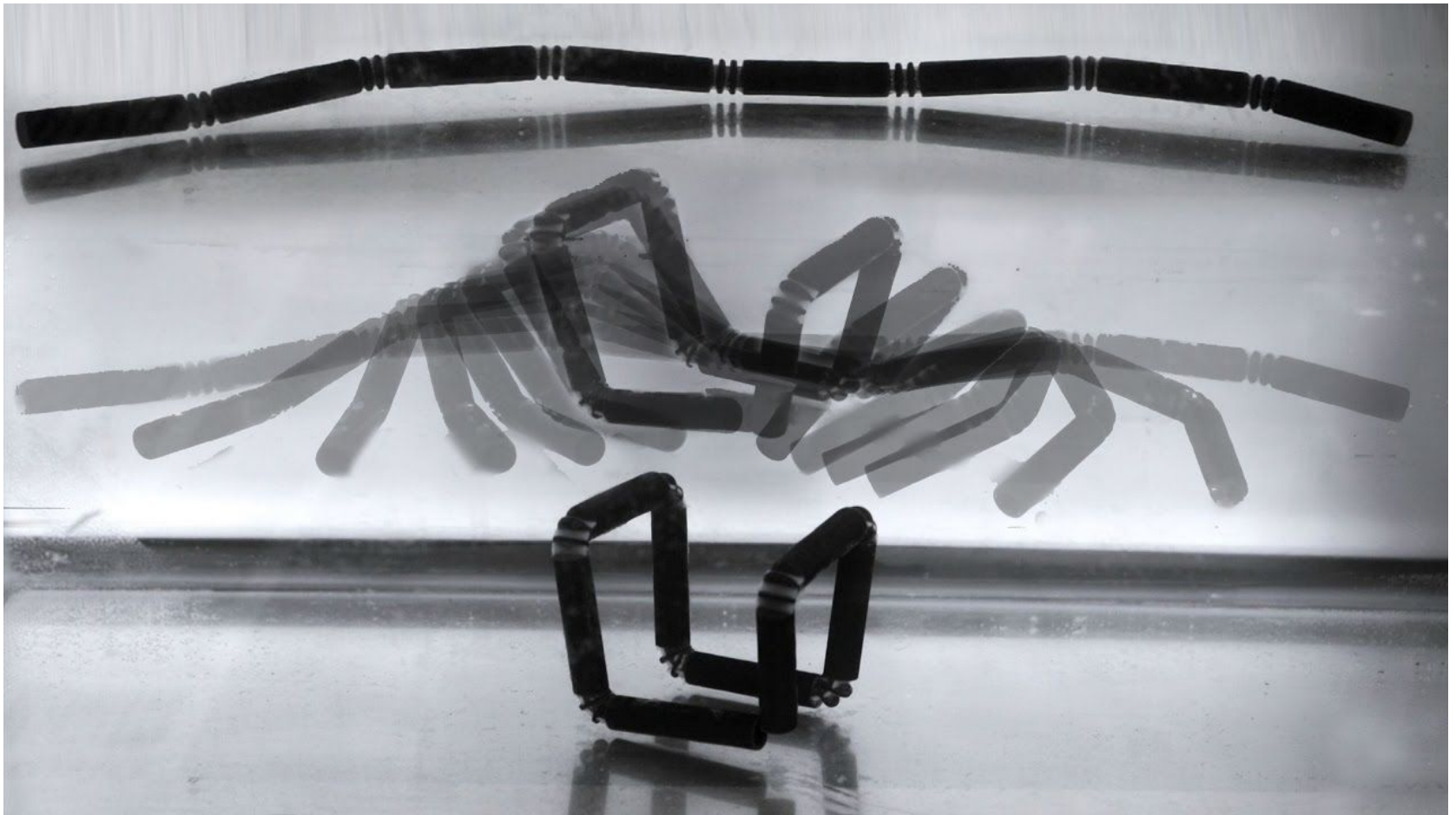
5-Axis 3D Printing

<https://etherealmachines.com>



4D Printing

https://en.wikipedia.org/wiki/Four-dimensional_printing



Clifford Holland 1883—1924

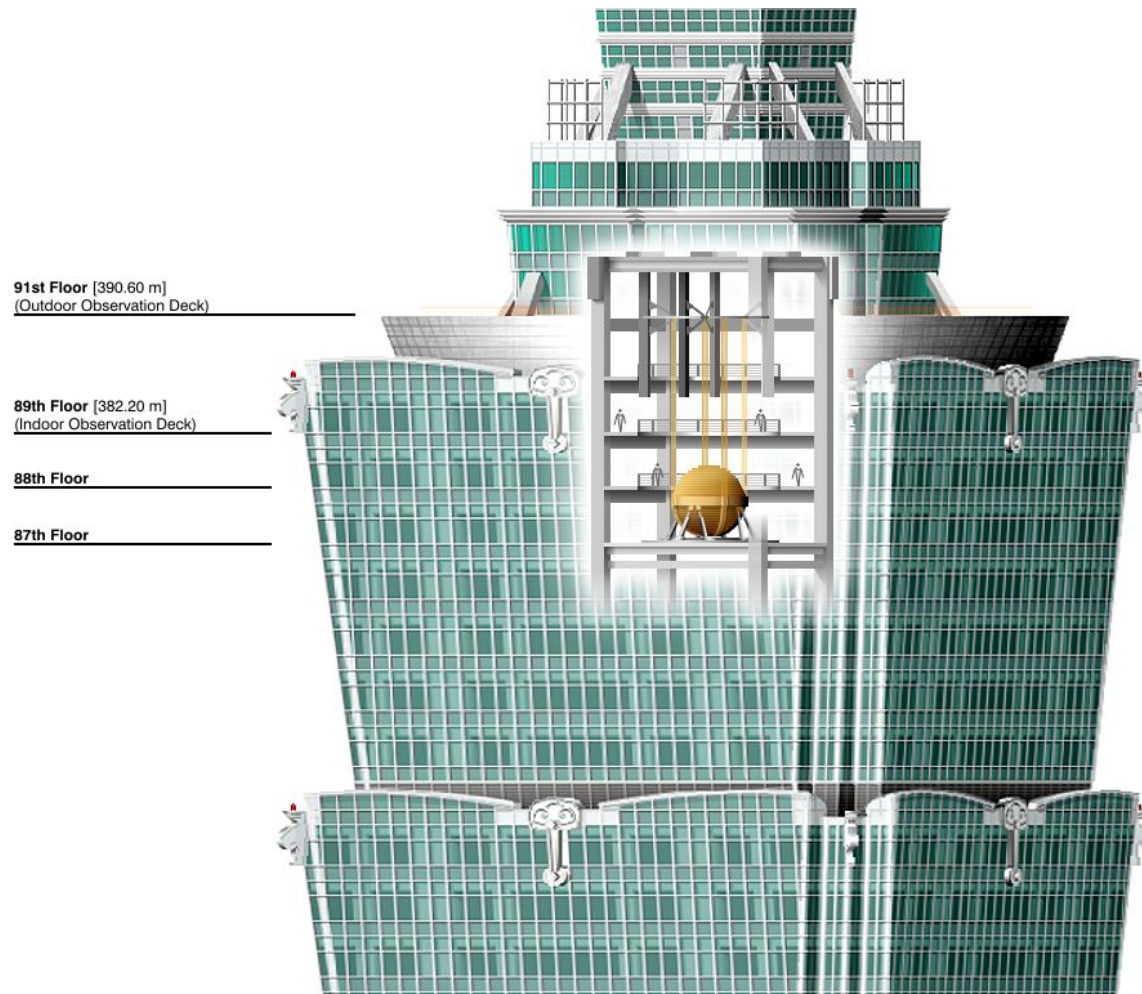
- The [Holland Tunnel](#) opened in 1927 was named in memory of its chief engineer, [Clifford Milburn Holland](#)
- Tunnel construction required workers to spend large amounts of time in the watertight [caisson](#) under high pressure to prevent river water from entering before completion of the tubes
- The Holland Tunnel ventilation system for supplying fresh air and evacuating the carbon monoxide emissions from vehicles was designed by [Ole Singstad](#) 1882—1969, a Norwegian-American civil engineer who designed the [Lincoln Tunnel](#) with the center tube opened in 1937, the north tube in 1945, and the south tube in 1957



Falkirk Wheel



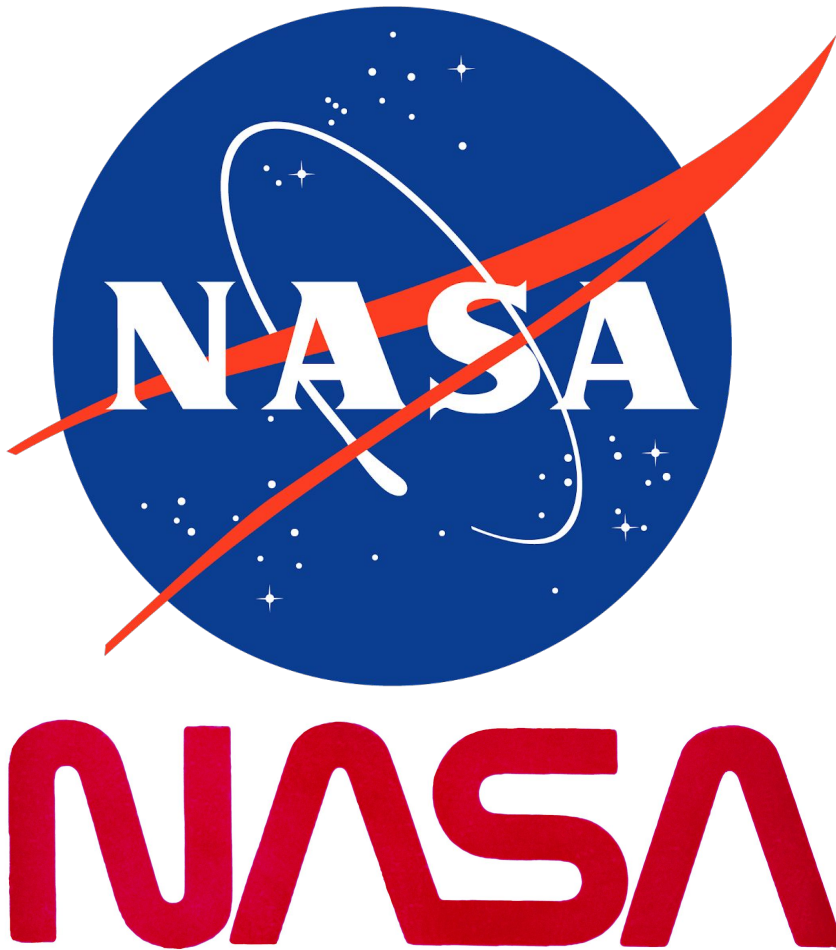
Taipei 101 Damper



Sea Grant and Space Grant

- The US congress established the [National Sea Grant College Program](#) in 1966 and transferred it from the National Science Foundation in 1970 to the National Oceanic and Atmospheric Administration ([NOAA](#))
- The US Congress established the [National Space Grant College and Fellowship Program](#) in 1988 and transferred it in 1989 to the National Aeronautics and Space Administration ([NASA](#))
- Prof. Joe Miles of Stevens serves as Program Coordinator for the New Jersey Space Grant Consortium ([NJSGC](#))
- The [Colorado Space Grant Consortium](#) (COSGC) has national programs including
 - [RockSat-C](#) is a program for students to design and build a sounding rocket payload, and launch the payload on a rocket out of [Wallops Flight Facility](#) ([WFF](#)), Virginia
 - [RockSat-X](#) has an ejectable skin and nose cone that will expose experiments to the space environment fully at an apogee of 150-170 km
 - The [RockSat-XN](#) payload deck is a modular system based around decks designed for suborbital flights with WFF and [Andøya Space Center](#), Norway

NASA Insignia and Logotype



- The NASA "[meatball](#)" [insignia](#) designed in 1959 by [James Modarelli](#) 1915—2002 included a red [chevron](#) wing piercing a blue sphere representing a planet, white stars, and an orbiting spacecraft
- The NASA "[worm](#)" [logo](#) was created in 1974 by Richard Danne and Bruce Blackburn 1938—2021 for its zigzag lettering with crossbar-less A's reminiscent of rocket nosecones
- The [NASA Graphics Standards Manual](#) outlined how the logo and the rest of the graphics system should be implemented on everything from spaceships to stationery

Serial Number

- A [serial number](#) is a unique identifier assigned incrementally or sequentially to an item, to uniquely identify it
- Serial numbers need not be strictly numerical; they may contain letters and other typographical symbol, or may consist entirely of a character string
- Serial numbers identify otherwise identical individual units
- Serial numbers are a deterrent against theft and counterfeit products, as they can be recorded, and stolen or otherwise irregular goods can be identified
- Some items with serial numbers are automobiles, electronics, and appliances
- Banknotes and other transferable documents of value bear serial numbers to assist in preventing counterfeiting and tracing stolen ones
- Serial numbers are valuable in quality control, as once a defect is found in the production of a particular batch of product, the serial number will identify which units are affected
- A [vehicle identification number](#) (VIN) is a unique code, including a serial number, used by the automotive industry, as defined in ISO 3779 (content and structure) and ISO 4030 (location and attachment)

Hull Code and Number

- The United States Navy, United States Coast Guard, and United States National Oceanic and Atmospheric Administration (NOAA) use a [hull classification symbol](#) (sometimes called hull code or hull number) to identify their ships by type and by individual ship within a type
- The [Naval Vessel Register](#) (NVR) maintains an online database of U.S. Navy ships
- [United States Ship](#) (USS) is a ship prefix used to identify a commissioned ship of the United States Navy and applies to a ship only while it is in [commission](#)
- In-service but non-commissioned Navy ships go by the prefix USNS, which stands for [United States Naval Ship](#)
- If a ship's hull classification symbol has "T-" preceding it, that symbolizes that it is a ship of the [Military Sealift Command](#), with a primarily civilian crew
- A [hull number](#) is the serial identification number of a boat or ship
 - For the military, a lower number implies an older vessel
 - For civilian use, the hull identification number (HIN) is used to trace the boat's history
 - The precise usage varies by country and type