**For the Ellen MacArthur Foundation Summit: June 13th 2019**
An oral talk doesn't work well for this quantity and kind of ideas. Instead this draft white paper presents them to be read before the live Q and A session.

DRAFT

# How?

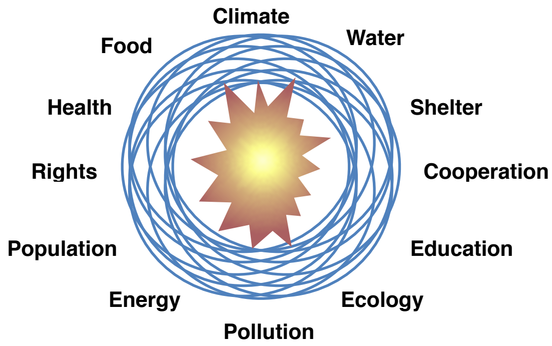
## *When "What Will It Take?" Seems Beyond Possible, We Need To Study How *Immense Challenges* Have Been Successfully Dealt With In The Past*

Alan Kay

## Introduction

**Many of today's "Immense Challenges" are Intertwined Complex Systems**

We cannot solve our problems with the same kinds of thinking we used when we created them
—Albert Einstein




Insanity is doing the same kinds of things over and over and expecting different results
—Albert Einstein

*Immense Challenges*:

… are too large, complex, different, etc., for commonsense thinking

… are too large, complex, different, etc. for a leader, or a committee, to try to identify problems and solutions

… are often intertwined and barely stable *systems* that need very different approaches

Just as one person can't make an automobile from ore, but 1000 can, *a well organized community of top people* can be qualitatively and exponentially more powerful than simple top-down hierarchical tactics/strategies and general voting.

Need higher levels of qualitatively different thinking than the thinking that caused the challenges

… including how to set up and nourish the communities of top people

This has been done successfully a number of times in the past—mostly when "normal" feels under great enough desperation to allow very different approaches.

*How* such successful "immense challenge" communities can be set up is the main content of this note.

Many of the most successful methods for organizing "immense challenge" communities were employed in most of them, regardless of the particular immense challenges they were dealing with.

We will look at some of these methods using seven historical examples; two of them in some detail.

Key idea: both "rational" and especially "non-rational" approaches and combinations need to be supported

> "Rational" means within an accepted "normal" context; "non-rational" means to find and use a context that is not considered "normal" and could be considered "crazy".
>
> Since "normal" and "rational" for most people is commonsense reasoning, most of science and much of engineering will be "non-rational" and even "crazy".
>
> Within science and engineering, "non-rational" is a different qualitative context than "normal practice" — getting out of the "normals" here for scientists can be almost as difficult as for most people to deal with normal scientific and engineering thinking.

We'll finish up with a short survey of barriers to successful efforts, mostly caused by many aspects of "human nature"

## Systems

Many of what we consider our "immense challenges" have come about from our genetic heritage of hundreds of thousands of years of coping at small scales, projecting our beliefs on our perceptions, etc. These have made it difficult for us to imagine the consequences of the new powers brought by the extremely recent inventions of modern engineering, science, the industrial revolution, and *progress* itself.

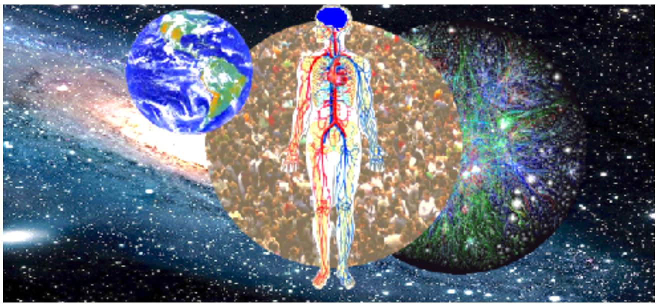
Even what we call "modern thinking" was a series of inventions. "Normal thinking" for us is "remembering and recalling" for short term concerns, often in the form of proverbs, stories, and simple rules and rituals. As new ways to think were gradually invented they had to co-exist in human minds more like new tools on old minds rather than to create brand-new greatly improved minds.

One of the most recently invented perspectives is *whole systems thinking*. It is a very useful lingua franca for "looking at most things at most scales and complexities", but it is so new that it is not yet taught generally in schools, and most people, especially decision makers, voters, planners, etc., are not fluent.

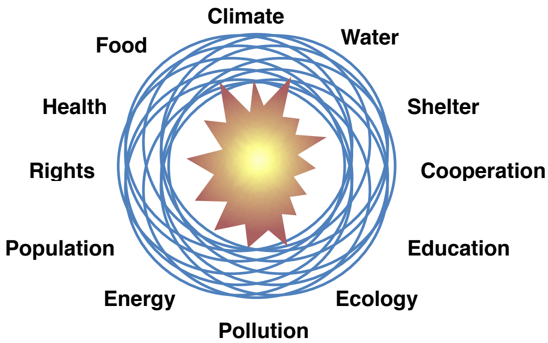
The complexities of systems were starting to be realized but were difficult to model and predict until the invention of the computer—itself a complex system—but also a kind of "language machine" that can represent complex systems and move the models over time—especially into the future—to make a new kind of imagination amplifier. And to make a new kind of early warning apparatus for many of "the systems we live in and the systems we are".

**The Systems We Live In And The Systems We Are**

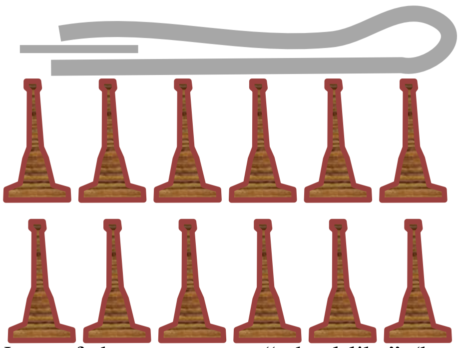
**Universe Planetary Biological Mental Social Technological**



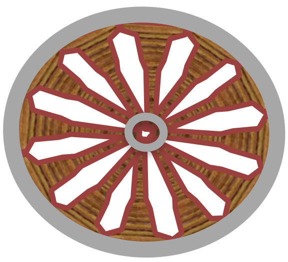
**Many of the "Immense Challenges" are Intertwined Systems**




**Parts organized well together can create a system with different and more powerful properties**



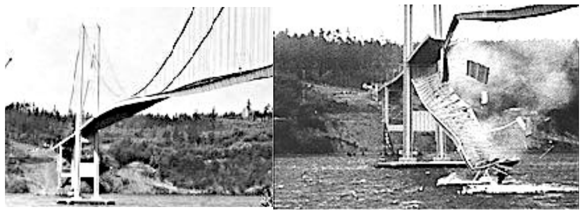
None of these parts are "wheel-like" (however, it's fun to note that 12 of them are kind of "leg-and-foot-like"). But they can be organized to do something really powerful (the "power" comes from the extra information/knowledge required to assemble the parts).



**A spoked wheel from 2100BC.**

**Stability and Toppling**

Even things that seem to be completely stable are actually systems that are "only somewhat dynamically stable".



**The Tacoma Narrows Bridge**

Just a 55 mile-per-hour wind plus a bridge that seemed too large and strong to fail.

A good way to think about most systems, no matter how stable they seem to be, is to compare a push on a bottle, and then upside down, and to see that the energy needed to topple can be many times less than the energy needed to restore.

In other words, *we humans may have enough power to topple our critical systems but may not be able to restore them*. (In short: *<u>don't</u> topple them*!)

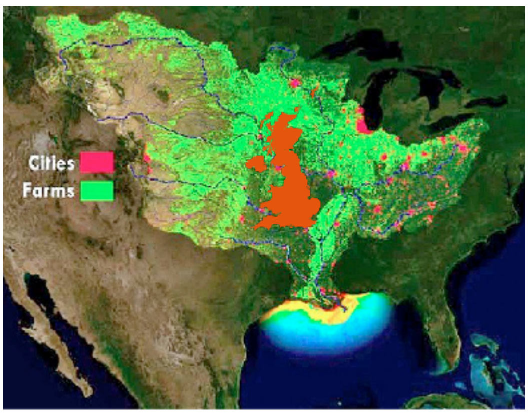
Many of "the systems we live in, and the systems we are" have only partial dynamic stability, so we have to be very careful about nudging them. *You can fix a clock, but you have to negotiate with a system*.

### Very Small Changes Can Topple

Bark beetles eat the bark of pine trees and their reproduction rate is tied to the average temperature of their environment. Recently, there has been just a 1° rise in their climes, and this has led to the toppling devastation of millions of acres of forest land in the northern latitudes. As they say in New York City "who knew?"

### Independent Small Actions That Combine To Topple

In the US, the Mississippi and Chatahoochie rivers drain much of the runoff of the entire middle of the country into the Gulf of Mexico. The use of fertilizers over the last 50 years has helped millions of individual farmers, but runoff and the rivers have combined to send the fertilizers to the Gulf, which has caused algae to bloom, and then to remove most of the oxygen from an area as large as several states and to kill almost all life to create a dead zone.

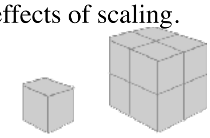



**A map of the UK is overlaid to aid scale comparisons**

This disaster is entirely human made. Besides the lack of imagination of the farmers and local governments, it happens that each state on a river controls only its part of a river; there is no overview of an entire river.

### Scaling

With a few sugar cubes we can experience several of the surprising effects of scaling.



We can see that doubling the linear dimension of a sugar cube will require 8 cubes: the mass/weight has gone up by a factor of 8. If we look more closely, we can see each surface has gotten 4 times larger. This explains why an ice cube will quickly melt, while a glacier (or the massed ice in an ice house) takes much longer.

**Anyone can build a doghouse from almost anything.**

**Almost no one can build one just 100 times larger**

This is because the mass of the doghouse has increased by one million, and the strength of its materials (more or less proportional to cross section) have only increased by a factor of 10,000 — so the structure has gotten weaker with respect to gravity by a factor of 100. The New Orleans Superdome is about 200 times the size of the doghouse, and had to be made *very differently*! In fact, scaling things up only 10 times larger is very often quite difficult.

### Internet

A scaling example used many times every day by billions of people is the Internet.

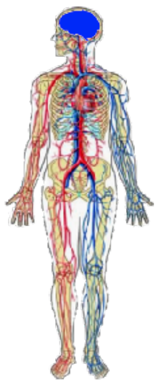
**Self-portrait of a small part of the Internet**

The aim was to connect everyone on our planet with a system that would be "too large to control" and "could not be taken down to fix or grow". Thus it was a qualitatively differently scaled "immense challenge" than the much smaller and more fragile switched telephone networks.

The quite different outlooks and enormous scalings of system biology were factors in the success of this design with many billions of nodes and trillions of interconnections. As we will see in a bit, the Internet was designed by a large cooperating community of top researchers: it took a lot of perspectives and design work to get it to turn out "so simple it could grow large and powerful".

**Societies**

Perhaps the ultimate examples of complex systems are humans and human societies.



This is because they carry around their own mental universes that are not always in accord with what is actually going on—and based on these, they much too often carry out disastrous actions (including doing nothing if they find ways to believe there are no threats to them and the future).

One of many problems here is in economics where, despite Adam Smith, "the Invisible Hand has not enough Brain" in order to deal with the actual levels of complexities and lightning swift feedback systems coupled with very difficult to predict delays in intercommunication.

Other kinds of scalings are in *kind*. For example, everyone can put a band-aid on a small wound, but almost no one can (or should) do a heart transplant. And for certain kinds of small wounds—such as those on the feet where lower circulation can aid infections, a band-aid can conceal what needs to be carefully tracked.

Another qualitative scaling where big changes happen without much warning is in *methods*. In order to scale up a doghouse or a band-aid — or make a Superdome, or do a heart transplant — radically different *methods* have to be learned and carried out.

**To deal with scalings we have to move from tinkering to learning engineering, maths, science and systems.**

An important idea here is that most human minds are *terrible* at imagining scalings that are large — even if proportional — and are *really terrible* when the scalings are exponentials rather than proportional.

Historically, we moved from the "tinkering instincts" we share with other animals to "more principled making"—Engineering—to powerful "symbolic engineering"—Mathematics—to the deeply powerful ways of thinking that make up Science, and finally to unite all through systems relationships.

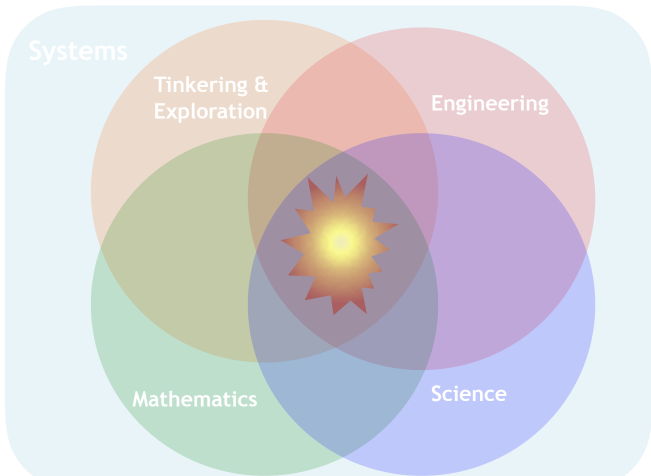
One way to visualize this is to imagine someone much smarter than average—such as Leonardo—being born in 10,000BC. Even if he had twice his IQ, he would not get far (he couldn't even invent the engines his vehicles needed because he was born into the wrong century as it was).

Henry Ford wasn't as smart as Leonardo but was born into a more fruitful century for motor vehicles, and did what Leonardo couldn't. Ford's century of stronger knowledge was the result of a bigger change in the whole context of human thought, called modern mathematical sciences, invented most especially by Newton.

In short: IQ is not effective without Knowledge, and creating useful Knowledge requires Contexts containing powerful perspectives and world views.

**"Context is worth 80 IQ points!"**

Most modern practitioners are adept at all five of these, and will endeavor to do their work in a sweet spot that keeps all five perspectives in view.




Besides being able to extend our thinking with the qualitatively new methods, one of the greatest benefits of this kind of training is internalizing a much deeper sense of how limited our thinking actually is — this helps promote "anti-fooling" when real thinking needs to be done.

Most people haven't trained in engineering, mathematics or the sciences, especially most politicians, business people, financiers, and voters. This makes the societal handling and judgements about a large number of crucial issues very difficult to intractable.

More deeply, this is partly what Einstein meant when he said: "We cannot solve our problems with the same kinds of thinking we used when we created them."

| | |
|---|---|
| The projects we will glean to extract methods and principles are all large to very large group efforts that addressed problems previously thought impractical or impossible, were accomplished surprisingly quickly, involved a wide range of top talents with unfettered choices how to find and solve the problems, and had somewhat random funding support. | **The Empire State Building ('30s)**<br>**Radar (WWII)**<br>**Code-Breaking (WWII)**<br>**Manhattan Project (WWII)**<br>**SAGE Air Defense System ('50s)**<br>**ARPA computing research ('60s)**<br>**Xerox Palo Alto Research Center ('70s)** |

It's important to note that one of the main reasons that the highly unorthodox methods used in the examples were tolerated was that all had a considerable sense of urgency connected with them — many from being in a war or war footing, several others from the sense of "this is the very last chance for quite a while".

## 1930s

### Engineering: The Empire State Building

The design, planning, site demolition, construction by about 3400 workers, and occupancy of the Empire State Building in a little over a year, ahead of schedule, and under budget, has the least amount of added science to its first class engineering. But this will make it a little easier to discuss the addition of deep science in the next examples and "what engineering is all about" here.

The exhibit on page 7 shows that the framing and cladding took place at the rate of 4 1/2 floors per week from the groundbreaking in early June 1930 to the almost finished structure just 6 months later.

## WWII

### Maths + Engineering: Bletchley Park Codebreaking

This is one of the best examples of "try everything with every kind of talent, no matter how nutty or unlikely", and despite quite a few attempts by "reasonable management" to limit the scopes of the attempts.

Anticipating a war with Germany, Alistair Dennisston, the head of "Codes and Cyphers" for Britain, pushed for setting up a large site at Bletchley Park. The government said it "did not have the funds", so Admiral Paul Sinclair bought it "for the sake of the country" with his own money.

Recruitment of top "weird thinkers"—e.g. Alan Turing, Gordon Welshman, etc.—also started before the war. There were many different uses of the German Enigma encoder, and the later much more difficult Lorenz cipher machine.

One of the main problems was to try to determine the almost daily settings of the cipher machines (using a combination of complex playing with organizations of codes and a bit of luck from occasional carelessness on the part of the enemy). The actual decoding could then be done relatively straightforwardly using transcription machines such as the "Typex".

A central problem was to deal with the astronomical number of combinations for initial settings in a timely enough fashion to allow the decoded messages to be used while the advantage was ripe. This initially led to the design and construction of electro-mechanical "bombe" machines (both adapted and newly invented from already existing examples). These worked but were still slow, and led to a number of much more controversial proposals for mostly electronic machines using valves (vacuum tubes) to do computational and logical operations.

The Bletchley Park chain of command was against the idea of using large systems of electronic vacuum tubes (valves) in their code-breaking machines, mainly on the grounds that valves kept burning out and it seemed impossible that a system that had a large number of them could be reliable.

The legendary Tommy Flowers had done early experimentation with the UK Telephone system, and had found that the main reason for burnout was turning the valves on and off. If they were kept on, and especially at a low power setting while "resting", they had considerably longer life.

Flowers ignored the official fetter, and instead almost singlehandedly created in less than a year the remarkable Colossus computer using thousands of valves, which worked perfectly to defeat the German Lorenz cipher machine. This amounted to almost inventing and building a digital computer from scratch, and Colossus predated the American ENIAC by several years.

### Science + Maths + Engineering: Manhattan Project

The science had started with Einstein's famous equation, and the realization that splitting — fissioning — large nuclei would likely yield some of the energy that had been holding the nuclei together. This was found by Meitner, Hahn, Frisch et al in Germany in 1938.

The actuality of fission, plus its location in Germany, was turned in the late 30s into a warning letter by Einstein to President Roosevelt, who then got Vannevar Bush to initiate what became the Manhattan Project. Maj. General Leslie Groves, an engineer who had helped build the Pentagon, was put in overall charge. He soon found that a fission bomb would likely be fairly easy to make given enough special fissionable materials. There were several ways to refine the materials, none of which were easy or tested.

Groves saw that while the science part of the project was critical, the overall effort would have to be a massive undertaking to set up at giant scale all the possible ways to refine fissionable material. Over the few years the US was in the war, he spent 1% of the war build entire functioning cities and had over 600,000 people involved in a project that might not work (or get done in time).

#### Science + Maths + Engineering: Radar

In the 19th century, Maxwell's equations indicated a "whole piano" of radiation of which light was just one octave. Hertz looked to make non-visible radiation that would reflect and refract like light, and found it. This produced not just radio, but also the start of detecting objects by bouncing and detecting radio waves.

In the UK, early pioneers included Robert Watson-Watt and Arnold Wilkens, whose work was the basis for the CHAIN system of radar early warning systems in the mid-thirties which were decisive in the Battle of Britain. In the US during this time Alfred Loomis, Karl Compton and others experimented with radar detection, especially with the shorter wave lengths that would be able to "see" smaller objects.

A key invention in the UK was the cavity magnetron by Randall and Boot which could produce short wave length radar waves at very high power.

Henry Tizard (UK) and Vannevar Bush (US) were two scientists/politians who had considerable government influence, and were key to the sharing of the magnetron and also atomic research results.

Building 20 at MIT was set up to house the development of more than 150 radar systems of every scale and power. 9 Nobel Prize winners in physics (before, during and after) worked at Building 20 along with thousands of other top scientist/engineers.

### Cold War

#### Science + Maths + Engineering: Whirlwind and SAGE

The aftermath of WWII was an almost immediate entry into the Cold War via the 4 powers problems in Germany/Berlin and the Russian atomic bomb in 1949. During this transition, there was great interest in going from useful but awkward plug-board computers to fully stored program machines. The first successes happened in the UK at Manchester and Cambridge.

One of the many developments in the US was "Whirlwind" at MIT, an early attempt to build a very fast parallel computer that could work in real-time (for flight simulators, then airplane tracking, computer graphics, etc.).

"Whirlwind II" in the mid-50s morphed into the SAGE air defense early warning system, a massive undertaking with 24 football-field-sized paired 50,000 vacuum tube computers — with 150+ graphic terminals each — in distributed 4-story concrete blockhouses connected by several kinds of networks. This almost impossible large scale project also yielded a number of research computers, some of massive size, and also a number of companies, one of whose first product was the PDP-1, that was very like the original Whirlwind but now via transistors of "minicomputer" size.

The image of SAGE and the PDP-1 prompted several far-thinkers to imagine "a SAGE graphics terminal in every home" as part of an "information utility" as an analogy to the water and electricity utilities already connected.

#### Science + Maths + Engineering: ARPA-IPTO (and other DoD funding)

Following the visual exhibit on page 11, I will explain in some detail how ARPA and other DoD funding—and then the addition of Xerox Parc—worked to produce so many of the inventions of our major computer technologies today.

In 1962 "spare funds" at ARPA as the space program shifted to NASA were given to JCR Licklider, a visionary psychologist who (with a few others) could see in the computers of the day something very different. His vision: *"Computers are destined to become interactive intellectual amplifiers for all humans pervasively networked worldwide"*.

This major funding was joined with smaller sources to eventually create an entire community of about 20 large "projects"—about 3/4 were at universities, the rest at think-tanks—devoted to formulating problems from the vision and inventing working results that wound up constituting many of the basic technologies for the computing of today.

### ARPA Add-on

#### Science + Maths + Engineering: Xerox Parc

In 1970, when Congress blindly started to curtail ARPA, Xerox Parc was set up to "finish the job" with most of its computer researchers (all young) drawn from the ARPA projects.

The Xerox Parc exhibit on page 11 shows a whole system of different technological inventions and adaptations for Licklider's vision. These created entire new industries across the planet, gave rise to many 10s of trillions of dollars of new wealth, and are now used by about 5 billion people over most of the Earth. A deep result is that almost all science and engineering today and into the future was in part catalyzed by these inventions, and requires them for future progress.

With regard to the "immense challenges" we face, part of the solution processes of "new levels of thinking" has to be reflected by inventing "new levels of thinking-helper-tools" and much better education processes to help more people learn how to use them (this is a strong parallel to the powers of writing-reading, and the need to actually teach them). Basically: re-engaging with Licklider's visions and lifting them above the "consumer mire" that has keep them from helping global citizens outside of science and engineering (if you run an intelligence amplifier "backwards" it will attenuate intelligence rather than boost it!).

JUN 3, 1930

Groundbreaking


JUN 26, 1930

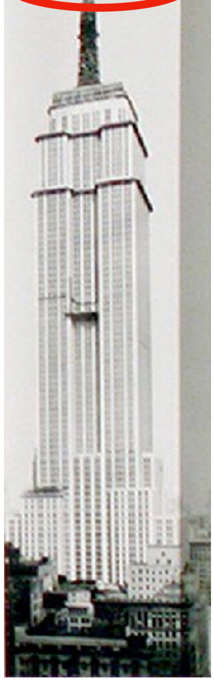
JUL 7, 1930

JUL 24, 1930

AUG 18, 1930

SEPT 8, 1930

NOV 10, 1930



"The design, planning and construction of the Empire State Building took just 20 months from start to finish.
After demolishing the Waldorf-Astoria hotel—the plot's previous occupant—contractors Starrett Brothers and Eken used an assembly line process to erect the new skyscraper in a brisk 410 days. Using as many as 3,400 men each day, they assembled its skeleton at a record pace of four and a half stories per week—so fast that the first 30 stories were completed before certain details of the ground floor were finalized".*

280 ENGINEERING NEWS-RECORD *August 21, 1930*

# Planning and Control Permit Erection of 85 Stories of Steel in Six Months

**Empire State Building in New York City Involving 57,000 Tons Goes Up in Record Time—Nine Derricks Starting Work on 425x198-Ft. Site Reduced to Five Above Twentieth Floor—Relay Platforms Necessary in Hoisting Steel—All Hoists Inside of Building**

FIG. 1—EMPIRE STATE BUILDING, NEW YORK CITY

THE PLACING of more than 57,000 tons of structural steel in an 85-story building between the months of April and October is the task which has confronted the steel erector on the Empire State Building in New York City. Eighty per cent of this total tonnage was in place on Aug. 1, when the building had reached to about the 50th story. During July, 22 stories of steel were placed in 22 working days, involving regular hours and no night work. As progress has averaged about 10,000 tons of steel per month (working five days a week), it seems probable that the difficult schedule will be met.

This article is devoted to an account of the steel erector's methods and equipment which are of interest and value both because of the magnitude of the project and the careful planning and control which has been exercised. The steel tonnage in the Empire State Building exceeds by a large margin that used in any comparable structure. The Chrysler Building utilized 21,000 tons and the 70-story Manhattan Company Building, both in New York City, required 18,500 tons. The Merchandise Mart in Chicago, recently characterized as the world's largest building, required only 38,000 tons. The principal roof of the Empire State Building is 1,043 ft. above the curb, and latest plans contemplate the addition of a combination airship mooring mast and observation tower approximately 200 ft. tall above this point. The building's completed height will exceed that of the Chrysler Building, now the tallest stfucture, by something over 200 feet.

In preparing a plan of procedure for the steel erection, it was necessary to consider four major problems: (1) steel supply, which had to take into account the fabrication schedule and methods of delivery; (2) plant layout, including number, size and location of derricks and hoisting engines; (3) steel-handling methods at the job, which necessarily had to be considered as complementary to plant layout in the planning; and (4) actual erection procedure, including methods of setting, fitting up and riveting.

*Steel Supply*

The large tonnage in the building and the urgency for completion made it advisable to divide the fabricating contract between two firms, the American Bridge Co. and the McClintic-Marshall Co. Alternate sections from the basement to the roof, comprising from two to eight floors each, were assigned to each fabricator. All steel is shipped to a joint waterfront supply yard near Bayonne, N. J., and steel for erection is ordered from this supply yard one lift (two floors) at a time, as needed. Because of possible delays in loading and shipment it is necessary for the steel erector to order steel two days in advance of the time it is to be used. Since there is no storage space at the building site, it is absolutely necessary that everything be in readiness to erect the steel when it arrives.

Steel is delivered from the supply yard to docks on the East River waterfront by derrick-equipped lighters. Columns and heavy members are transferred to trucks at 23d St. while the smaller material comes ashore at 19th St. Since the Empire State Building is between 33d and 34th St. on Fifth Ave., the haul through city streets is not long. The largest shipping pieces were the two bottom column sections, the lower one 15 ft. 8 in. long, weighing 44 tons, and the upper one having about the same weight but being 33 ft. long. By using a two-wheel trailer, the trucks were able to handle these sections as easily as the smaller ones.

At the beginning of the job steel was delivered to the 33d St. side of the building; an unusually wide sidewalk on 34th St. made it impossible for the derricks standing in the excavation to reach trucks on this side. When erection had reached the second floor, however, the derricks could reach either street and steel was delivered on both the 33d and 34th St. sides until erection reached the 46th floor, when unloading on 34th St. was discontinued. All steel is now being received along 33d St. which, although narrow, is a westbound street permitting the trucks to reach the building from the East River waterfront in the most direct manner.

The erection plant is divided into two main parts—

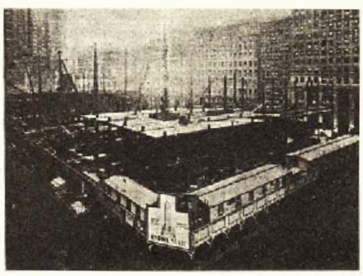
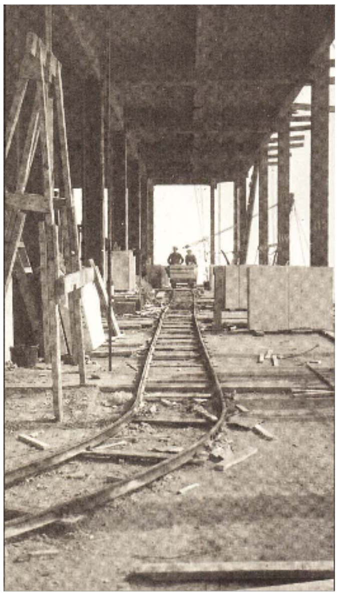


FIG. 2—EARLY ERECTION VIEW OF EMPIRE STATE BUILDING

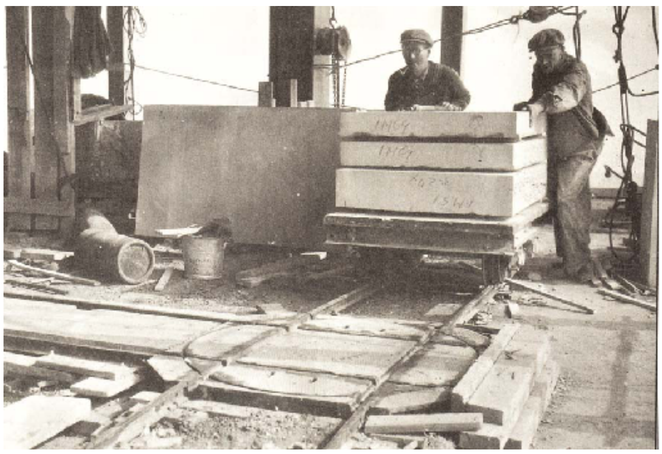
At stage shown almost 8,000 tons of steel had been erected. Note extent of site which is 198x425 ft. General contractors' offices on bridge over 5th Ave. in foreground. Note complete planking of top floor forming a safe working platform for the steel erectors. Also at left, trucks unloading steel and materials along 33rd St. side.

**"Mr Starrett, what tools do you have for this job?"**

**"Not a blankety blank thing! Not even a pick and shovel. "Gentlemen, this building of yours is going to present unusual problems. Ordinary building equipment won't be worth a damn on it. We'll buy and make new stuff, fitted for the job … That's what we do on every big job. It costs less than renting secondhand stuff, and it's more efficient."**

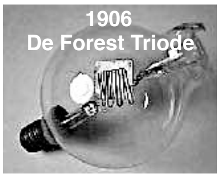


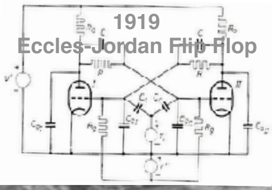
**A narrow gauge railway on every floor, etc.**

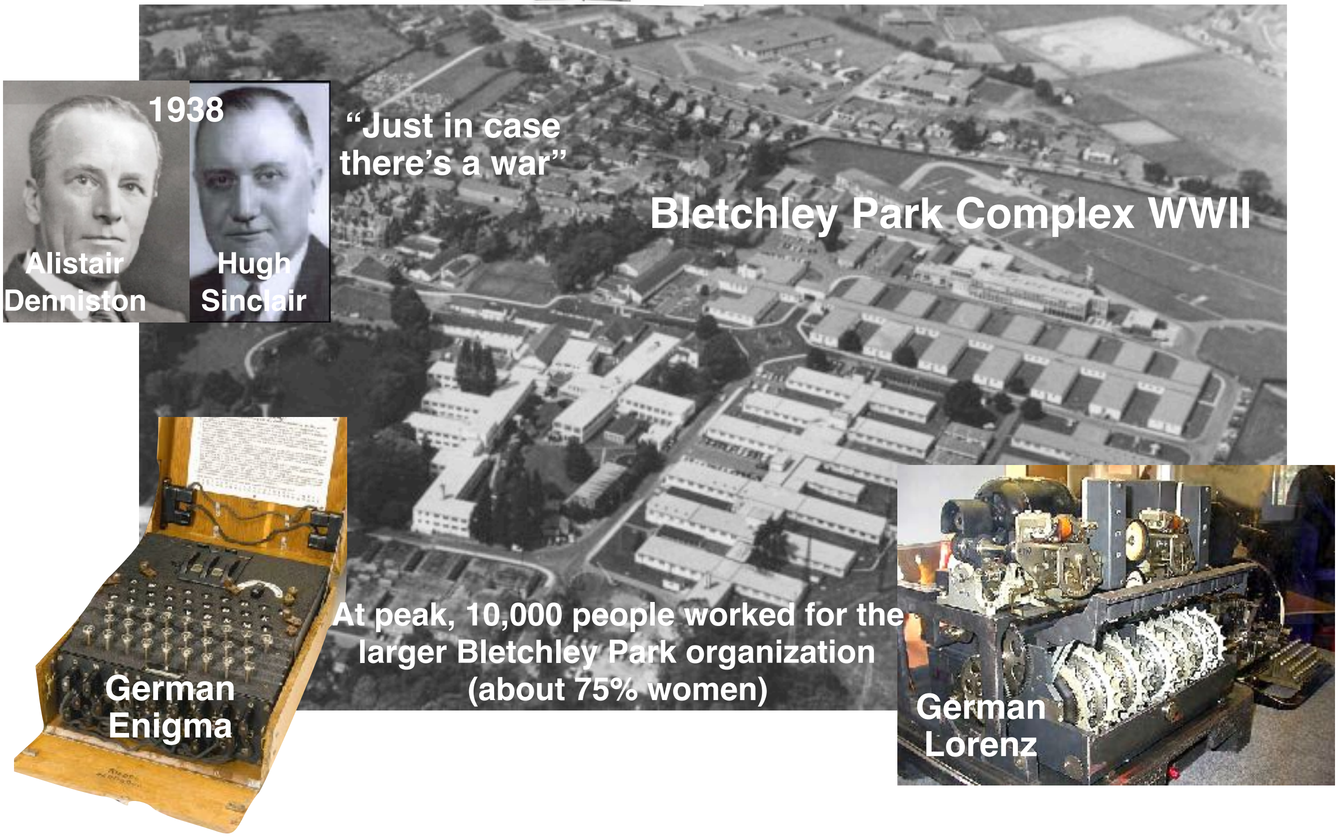


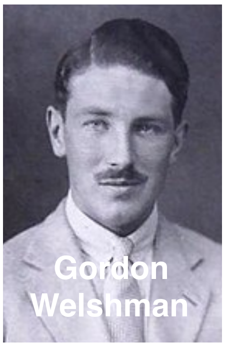
*https://rarehistoricalphotos.com/empire-state-building-1931/

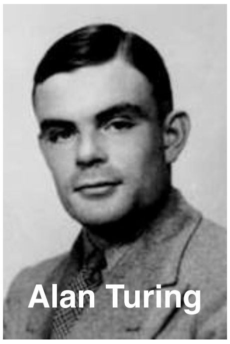
# SERIOUS MATHS ADDED TO ENGINEERING — CODEBREAKING



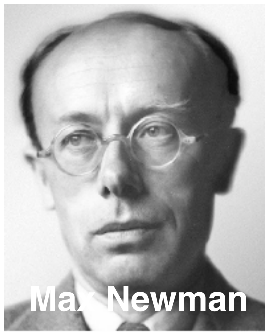



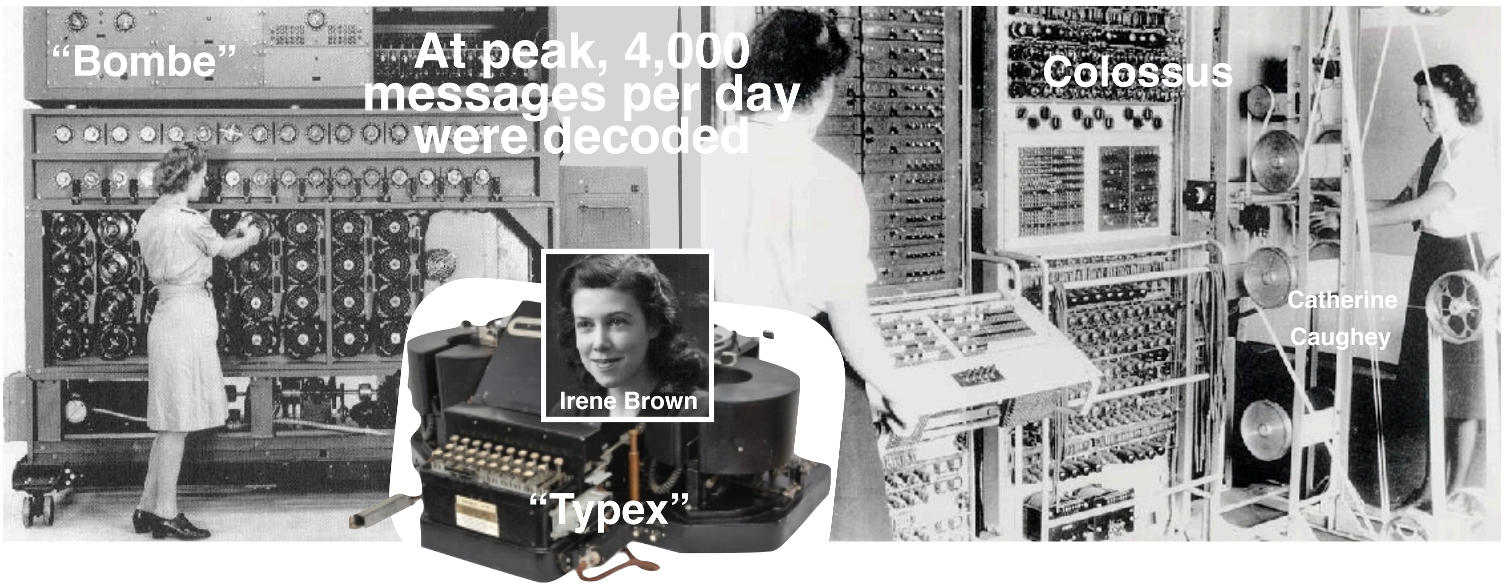





# SERIOUS SCIENCE ADDED TO ENGINEERING






Albert Einstein
Old Grove Rd.
Nassau Point
Peconic, Long Island

August 2nd, 1939

F.D. Roosevelt,
President of the United States,
White House
Washington, D.C.

Sir:

Some recent work by E.Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable - through the work of Joliot in France as well as Fermi and Szilard in America - that it may become possible to set up a nuclear chain reaction in a large mass of uranium,by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable - though much less certain - that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

-2-

The United States has only very poor ores of uranium in moderate quantities. There is some good ore in Canada and the former Czechoslovakia, while the most important source of uranium is Belgian Congo.

In view of this situation you may think it desirable to have some permanent contact maintained between the Administration and the group of physicists working on chain reactions in America. One possible way of achieving this might be for you to entrust with this task a person who has your confidence and who could perhaps serve in an inofficial capacity. His task might comprise the following:

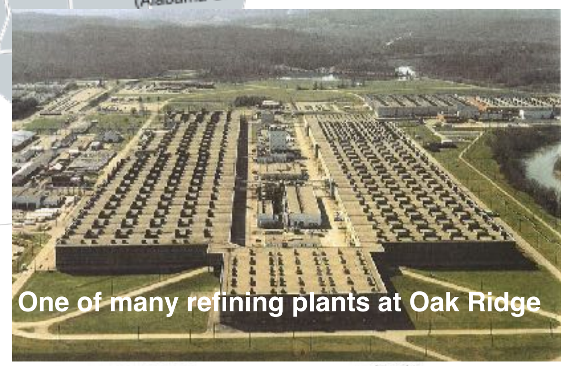
a) to approach Government Departments, keep them informed of the further development, and put forward recommendations for Government action, giving particular attention to the problem of securing a supply of uranium ore for the United States;

b) to speed up the experimental work,which is at present being carried on within the limits of the budgets of University laboratories, by providing funds, if such funds be required, through his contacts with private persons who are willing to make contributions for this cause, and perhaps also by obtaining the co-operation of industrial laboratories which have the necessary equipment.

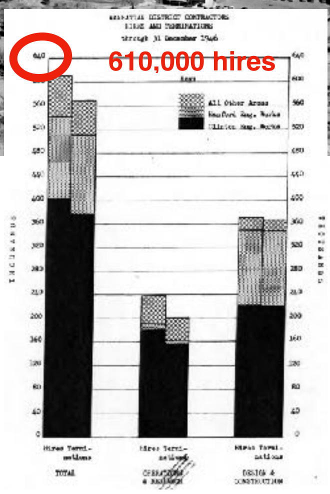
I understand that Germany has actually stopped the sale of uranium from the Czechoslovakian mines which she has taken over. That she should have taken such early action might perhaps be understood on the ground that the son of the German Under-Secretary of State, von Weizsäcker, is attached to the Kaiser-Wilhelm-Institut in Berlin where some of the American work on uranium is now being repeated.

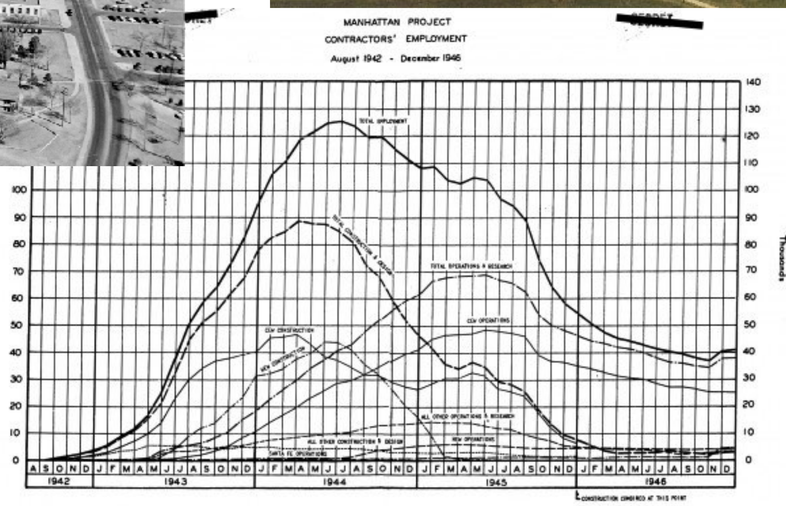
Yours very truly,
A. Einstein
(Albert Einstein)


Los Alamos Laboratories



One of many refining plants at Oak Ridge

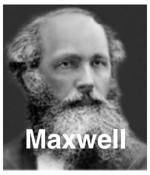



http://blog.nuclearsecrecy.com/2013/11/01/many-people-worked-manhattan-project/

# MORE SERIOUS SCIENCE ADDED TO ENGINEERING

## RADAR



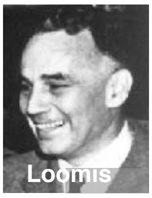


Radar in the UK

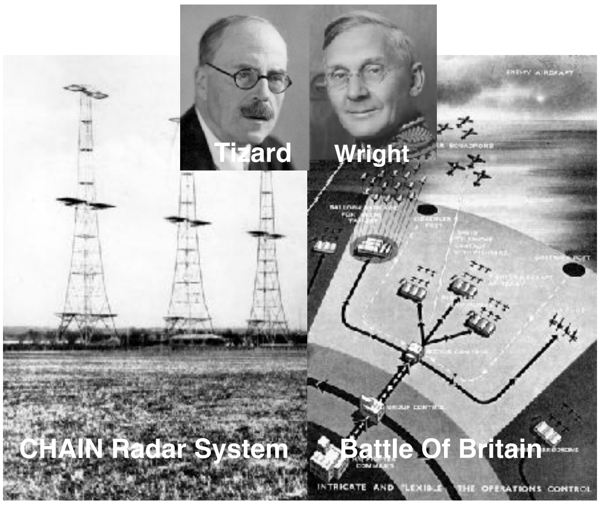
Radar in the US

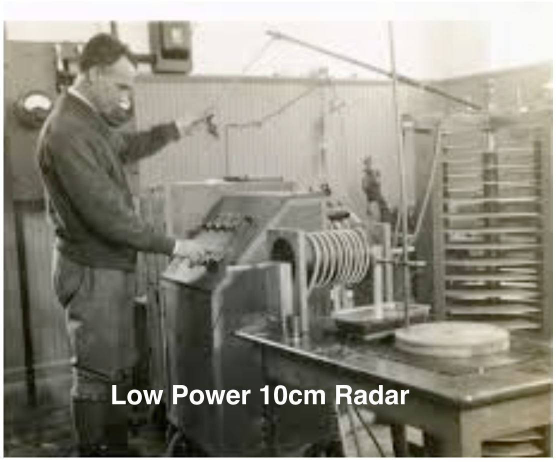
1930s



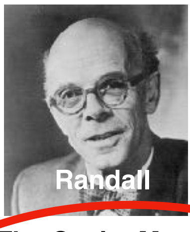







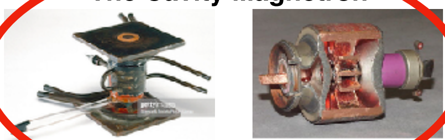




1940

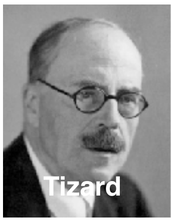


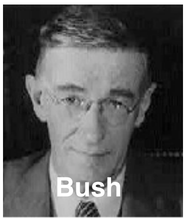


The Cavity Magnetron

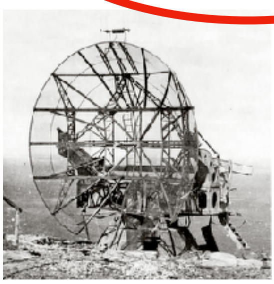


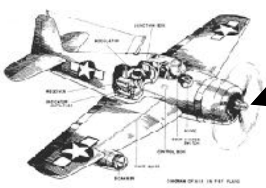
Very High Power

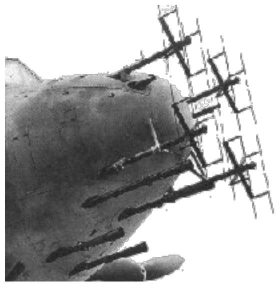


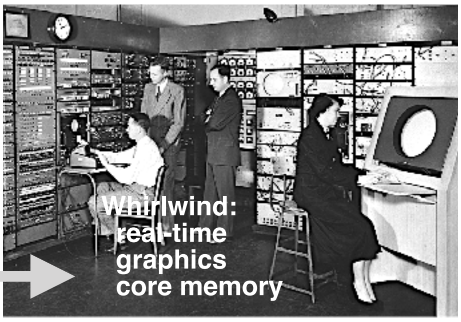


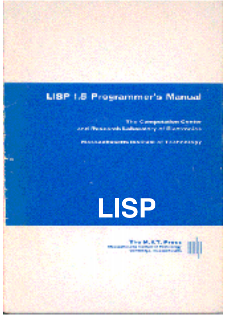


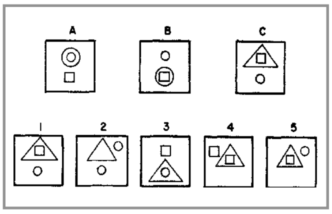


## US Cold War Pioneering Early Work ‘50s & ‘60s

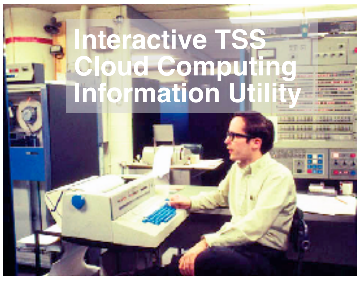






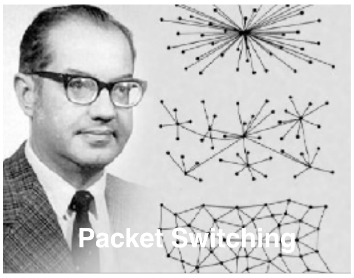




AI

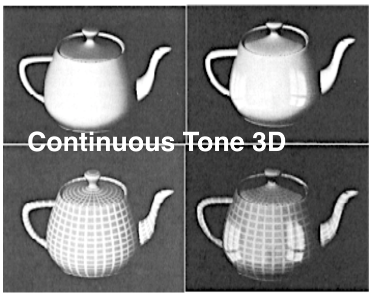


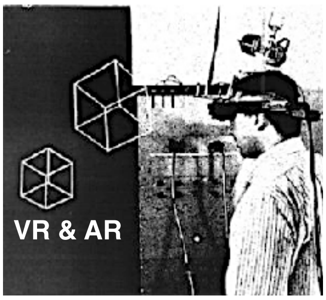




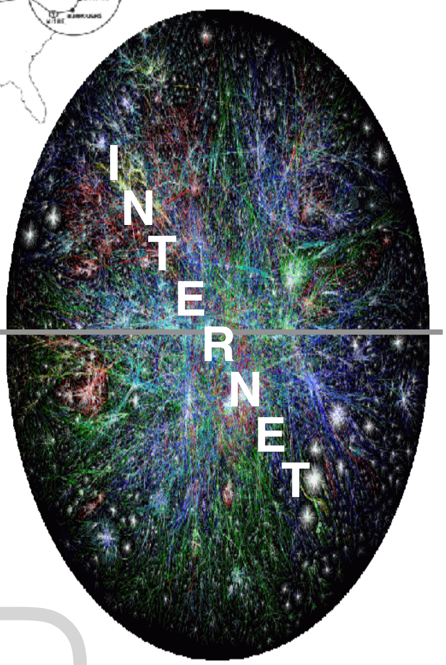




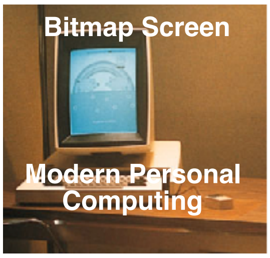



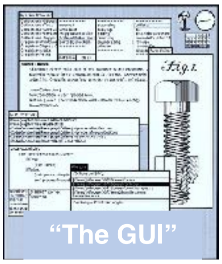




ARPAnet




## Xerox Palo Alto Research Center ‘70s





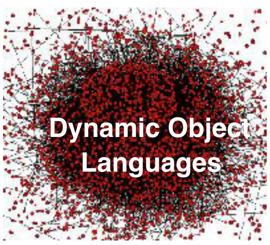
EtherNet

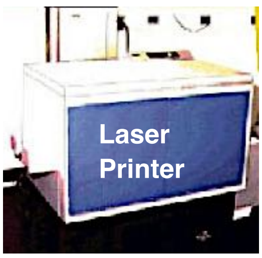
~ 25 Researchers ~ 5 Years

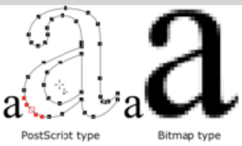
~ cost $12M-$15M/year today’s dollars

~ return $35++ Trillion Dollars and counting

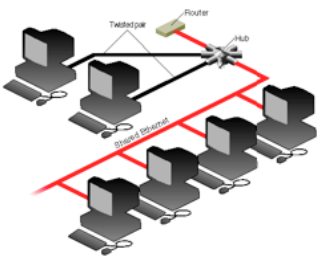
~ an “Industry” rather than an “Increment”




Outline Fonts - Postscript



Peer-Peer & Client-Server
Architectures

## ARPA + Xerox Parc Research

**1. The goodness of the results correlates most strongly with the goodness of the funders.**

The Advanced Research Projects Agency (ARPA without the "D") was set up in response to the Soviet launch of the Sputnik satellite, and among many activities initiated the Kennedy Moon Shot program to get it quickly started while NASA was formed. As this was being handed off to NASA in 1962, there was a discussion about what to do with the remaining ARPA funds from the space program. The first suggestion was "Why don't we give it to Lick?" (JCR Licklider was a psychologist they liked, who had written a paper that proposed the future of thinking would be a "symbiosis" of humans and interactive computers.)

The response was "OK, that's a good idea. Next?"

This was not a lot of money by ARPA standards, but it was a lot of computer research funding, and Lick first used it to set up a large project at MIT called "Project MAC" (Machine Aided Cognition), and its first results were to create the first really usable interactive time-sharing system in the US (CTSS), along with a number of other research projects concerning interaction with computers.

Soon, Lick had funded about a dozen projects, later growing to about 20 at 16 venues, at major universities (Carnegie-Mellon, Stanford, Illinois, etc.) and several government research think tanks (RAND, Mitre, etc.)

**2. Visions instead of goals**

Whenever he was asked what he was doing, he would only say:

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**"Computers are destined to become interactive intellectual amplifiers for all humans pervasively networked worldwide".**

---

This came to be known as "The ARPA Dream". Lick would not say specifically what he thought this meant, nor how this was to be accomplished. When asked why, he said that visions are more open then goals, especially at the beginnings of things where we don't know the best questions to ask or the best problems to solve.

**3. Cosmic metaphors really help imagination**

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ADVANCED RESEARCH PROJECTS AGENCY
Washington, D.C. April 23, 1963

MEMORANDUM FOR: Members and Affiliates of the
                Intergalactic Computer Network
FROM:           J.C.R. Licklider
SUBJECT:        Topics for Discussion at the
                Forthcoming Meeting
```

When asked why he used "Intergalactic" in this early memo, he said "Engineers always give you the minimum. I want an world-wide network, so I asked for an 'Intergalactic' one!"

**4. Fund people not projects**

How then? "We will accomplish this by finding and funding *special* people who will have their own ideas about how to go about realizing the vision. They will come up with *their goals* and *their processes*."

**5. Fund problem-finding, not just problem-solving**

As the UK's Henry Tizard remarked in the early 20th century: "The secret of science is to ask the right question, and it is the choice of problem more than anything else that marks the man of genius in the scientific world."

**6. No peer review**

We have to be able to do this without the usual kinds of peer reviews, in part because we need to allow "unreasonable" projects as well as "reasonable" ones. Peer reviews tend to be "too reasonable" and it is also very difficult to find "real peers".

**7. It's baseball, not golf!**

When asked about "failure" and "failure rate", Lick said "We're not playing golf!"

Meaning: we are not going to cry about losing a stroke here and there. We are playing something more like baseball, where successfully getting a hit 30% of the time is considered excellent. "But what about the 70% failure? Yikes!". Lick pointed out that in baseball getting a hit is the hardest thing in the sport — hitting a round thing with a round thing both going over 100 miles per hour and with less than 1/3 second to see and decide). So the 70% is not failure but <u>*the overhead required to get the 30% hits*</u>.

"Given what we are actually funding, if we are 30% successful we will revolutionize and change the world" (this is what happened). In other words, pay attention to <u>what</u> results, not the percentage of yield.

There is a concept of "error" in baseball: when something that one is technically trained to do is flubbed (like catching a fly ball, or an errant throw, etc.). Good baseball players are supposed to be about 98-99% accurate on all such actions. In Beethoven's scores, his scratched out sections are "overhead" for doing something really difficult, whereas most of the great composers almost never would make an "error" by writing a poor voice leading.

In the world of technology, this translates to: "If you are going to make a computer, or a programming language or an operating system or a display system, etc. you should pretty much always be successful".

**8. Fund great people (MacArthur for groups!)**

This means that only absolutely top people should be engaged to do the creative work. In the US this is pretty much only tolerated in sports, but is thought of as "elitist" in most other areas. The American MacArthur Foundation awards 5 year no strings attached "Fellow

Grants” (called “genius grants” in the popular press) to individuals in many different fields who have “shown promise” and are likely to advance civilization in some way.

**9. It’s a research community not a research project**

Lick’s grants were similar but were much larger: large enough so that big projects requiring many people could be supported. (This is also like a whole sports league with many teams.)

**10. Important results include new great people**

In addition, the funding also covered considerable “student and intern development”. The idea was to develop young people into more “great people” who could be principle investigators in the not too distant future. (For example, almost all of the computer researchers at Xerox Parc were results of this ARPA program.)

An important point here is to note that the variation of offspring each generation will produce a few super talents in every area. These grow up in a random assortment of cultures and schooling, and some get thwarted while others will find fertile soil to grow. A workable formula here might be:

Ability = Talent ⊕ Skills ⊕ “Ganas”

where ⊕ means “some kind of combination” and “Ganas” is a difficult to translate but great Spanish word that combines “desire” and “will”.

Even though the percentage of the most unusual types might be quite small, a large enough population will produce enough high ability prime contributors to fill out most needs.

**11. Separate responsibility from control**

Much rarer in my experience are great research managers and great funders. I’m not completely sure why, but they are possibly combinations of rarer types playing off against the very different kinds of pressures and routes that come with “managerial” kinds of processes.

In any case, managers of funds and people are also responsible in various ways—sometimes including legal responsibilities—for what happens. This plus deep cultural (even human genetic) propensities for “control” will tempt the managers to try to “command and control” the processes they are supposed to be helping.

**12. Synergy requires constant messaging**

A very important aspect of the young people development part of this funding was that the students and interns also wound up acting as the “messengers” and “cooperators” in the larger community. The principal investigators actually cooperated much more than engaging in rivalries, but there’s no question that the young people were much more ecumenical and interested in finding out what everyone was doing. This larger overview was another reason that Bob Taylor aimed at getting young ARPA researchers for Xerox Parc.

Bob Taylor was a large factor in ARPA-Parc. When at NASA in the early ‘60s, he was one of the original funders of Douglas Engelbart (of mouse fame, but with cosmic ideas far beyond the mouse), even before ARPA became the main underwriter. This brings up another principle: Lick used to say

**13. “No one can have good ideas inside the Beltway”**

Meaning: the “reality warp” of Washington, DC (or any concentration of wheeling, dealing and bullshitting). This was another reason he wanted to have his principal investigators run the research process instead of attempting top-down control. But he also applied this to his own job.

**14. Train your successor and get back to work!**

He felt it would be much more productive to continually bring in new directors from the research community. So, every two years there was a new director. It was a three year commitment (they would spend their first year assisting the existing director and then direct for two years, and train their successor in their final year).

The succession over the first 8 years was Lick, Ivan Sutherland (age 26, the inventor of interactive computer graphics), Bob Taylor (who later founded computing research at Xerox Parc), Larry Roberts (who built the ARPAnet and parts of the first Internet).

In a very important sense, that this worked was a microcosm of why this community worked. It is very often the case that a new executive will dismantle projects by the previous executive. Quite the opposite was the case with ARPA. In part because each new director bought into the “ARPA Dream” vision, the scope and perspective of the work was amplified in many ways, and left room for brand new projects.

An important principle that can be traced all the way back the WWII MIT Building 20 Radar Project is:

**15. Argue to make progress, not to win**

Teach all how to avoid “debating” but to be able to argue deeply about ideas without personal attacks. In ARPA-Parc, this cultural trait can be traced through the 50s Cold War, all the way back to the MIT Radar effort.

**16. If you have the ability to invent and make new tools that are needed for your problem, then you must.**

Another example of seeming “unreasonableness” was that the ARPA-PARC community made virtually all of their own tools from scratch — including giant computers, operating systems and programming languages. In fact, diving into extensive tool building has delayed and crippled many projects, and vastly run up the costs, so this had to be avoided. So this is an important example of a 1st order theory about something being true, and a completely opposite 2nd order theory also being

When the bidding started for the Empire State Building project, all the contractors stated they would use the standard tools they already had. When they asked the head of the Starrett Brothers firm: "Mr. Starrett, what tools do you have for this job?", Paul Starrett replied:

> "Not a blankety blank thing! Not even a pick and shovel! Gentlemen, this building of yours is going to present unusual problems. Ordinary building equipment won't be worth a damn on it. We'll buy and make new stuff fitted for the job . . . that's what we do on every big job. It costs less than renting second-hand stuff and its more efficient".

The Starrett Brothers got the job, and as chronicled on the Empire State Building page went up at the rate of 4 1/2 floors per day, and from demolition of the site until occupancy, the process took just a few days over a year. Much of this was due to the special tools and other inventions made by the builders to facilitate construction in ways no one had ever done before.

Much of the computing hardware and software used for computing research was made by the researchers themselves, and later adopted in parts or in whole by existing manufacturers. The computers that led from EDVAC in the late 40s to Whirlwind to TX-2 to Project Genie and NLS to the many different Xerox Parc architectures were all invented and built by the researchers.

As Paul Starrett pointed out, the results are both "fitted for the job" — without the clumsy and time-consuming workarounds required with vendor products — and also more efficient if the people involved can pull it off (a rule of thumb: "don't involve people who can't pull it off").

**17. Think and work in the future, not the present or past**

Most big projects extend over years to decades, and thus the results need to be developed in the context of what will likely be the case in the future. A field such as computing—or that heavily needs to use computing—has exponential changes in materials (a doubling of "everything good" every 18 months has produced pocket computers that are hundreds of thousands of times speedier and cheaper than supercomputers of 50 years ago). This means that development in the present somehow has to be "done in the future".

Because "any computer, given enough memory, can simulate any other computer" it is possible to "buy the future" by using and making supercomputers in the present that can be confidently predicted to be generally affordable in the future.

The ARPA-Parc community made heavy use of this idea. Sketchpad—the invention of interactive computer graphics—was done on the SAGE test computer, the size of a large building, with just one person using it. Most other systems in the 60s and 70s were done using similarly powerful expensive machines. Parc went very far by making 1000s of "personal supercomputers" (in today's money, costing about $130K each!), in order to invent the 80s and 90s in the 70s.

This led to an invention heuristic to get around "being too practical" when trying to have ideas.

**18. Take an idea immediately 30 years out to evaluate**

If *"it would be ridiculous if the idea weren't possible 30 years out"*, only then is it worth thinking about how to do it. The process is to "bring the idea back from the future", with the first stage being about 10-15 years out. What could be done then? What would the software be like? Could we build a supercomputer to simulate what could be done by then? The answer is often "yes". And this leads to short term plans for both SW and HW. If the software is thought about first—and partly simulated on existing machines—then the supercomputers can be optimized for the software (thus eliminating much viscosity and errors from busywork).

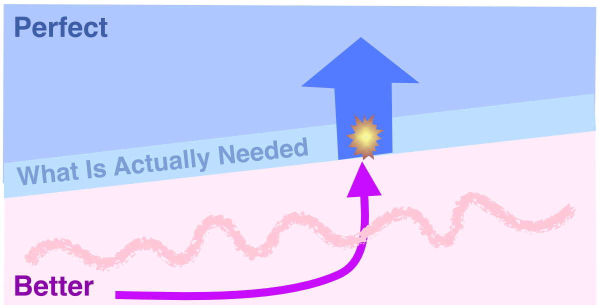
This is how graphical personal computers, laptops and tablet computers, and their GUIs came about. The idea of the personal computer of the future was thought up in 1968, it would be ridiculous not to have these by 1998, something good could be done by 1980-1985, personal supercomputers were made by 1973 that "could do the late 80s", and this created a whole development platform—and time—for the SW—and especially the needed GUIs—to be invented

**19. What Is Actually Needed (WIAN)**

It's worth looking at "aiming heuristics". Many processes are measure in a relative fashion, with "Better" being "Good" and "Worse" being "Bad". Over time this can look like a wavy graph of ups and downs. But, if we add the threshold of "What Is Actually Needed", we can see that many processes and their measurements are meaningless (for example: reading scores mean nothing if most of the population never achieves fluency).

Once we add WIAN, we can see that WIAN will rise for many things over time. This means that something that was once above WIAN can get below threshold just by maintaining itself. We can also appreciate that:

*"Better and Perfect are the Enemies of What Is Actually Needed"*




If we aim at WIAN and not just "better" then the process to get there might have a learning curve that starts worse than those striving for "better". But achieving WIAN crosses a qualitative boundary that opens the door to stronger and very different kinds of thinking.

## Barriers

Over the years, the question I've been most asked about "all this" is: *Given that the methods used in these and other examples have worked so astoundingly well, why don't funders, organizations, governments, universities, etc., set up similar processes to not only deal with our "immense challenges", but also just to generally make great improvements in many areas?*

Why does it seem to require a large sense of extreme danger—a war—or other kind of stress for most people to even pay attention to many of the challenges, and especially to get behind supporting large scale radical solutions?

This is especially puzzling, given that the returns were so enormous, reaching well beyond the original challenges (e.g. consider: information theory, radar, air traffic control, computing, pervasive networking, etc.) All of these have created new multi-trillion dollar industries from much smaller investments.

Another puzzling angle is the "black swan" paradox. People tend to discount disastrous events that seem to have low probabilities, but they miss that what's more important is the amount of devastation that might be wrought when such a low incidence event *does* happen.

The latter discountings have been termed "The Ostrich Paradox" (see the book of that title in the Reference section, which is a good introduction not just to this particular glitch in human thinking, but also will get the reader started on the many other thinking difficulties that we humans are born with and still struggle with).

These glitches were generally termed "cognitive biases" by Kahneman and Twersky, the founders of "Behavioral Economics" (how human beings actually behave when trying to think and evaluate and make decisions). About 150 "mental glitches" have been identified and studied so far. The "Six Core Biases" in the Ostrich Paradox are:

**Myopia in time and environment**

**Amnesia (quickly forgetting past difficulties)**

**Optimism ("things will work out")**

**Inertia (especially where there is uncertainty)**

**Simplification (cognitive load, etc.)**

**Herding (basing decisions on societal consensus)**

The first thing to appreciate about this list is that these were all pluses for almost all of human history where daily survival in an unkind environment was what needed to be given close attention. These helped human societies find ways to cope and survive at the expense of the dangers of experimentation and adding more risk. As with many other things that don't scale well, these don't either.

For example, "Herding" is pretty useful when there is very little powerful knowledge and technique available. But it needs to be reorganized in the age of science and engineering, where special knowledge almost always trumps both individual and general societal commonsense reasoning. Relying on "gut feel" about the state of the planet's global climate will work in the wrong direction until things are disastrously apparent almost every day.

The "gut feel" syndrome for most people often has them shy away from anything they don't understand, yet will nudge them into taking too much risk with things they think they do understand. A double whammy!

#### Other

Another related cognitive bias is against "other". This works in circles socially, where each circle outwards from an individual (family, neighborhood, town, state, country, etc) will cooperate within a circle to compete sideways to what seems to be "other"). A not so funny joke has posited that we need an invasion of aliens to unite humanity.

An interesting form of "other" is the otherness of things one didn't grow up valuing, and especially those who are very good at them. A good example: in the US, at least, almost the only people who are allowed to be publicly exceptional are sports stars. This has been attributed to the idea that most people grow up doing sports and they thus have a basis for fantasies that can be wrapped around exceptional sports stars. This is also the case with pop culture stars (who may be mostly fantasy personas, though some do have exceptional talents). Whereas those people who are intellectually exceptional are generally shunned and not valued, even when they could be a great boost to the society.

#### Loss Aversion

When we have something, we don't want to give it up, even if that will be much better for us in the end. We share this cognitive bias with most of our fellow primates. For example, if we want to catch most primates we simply need to make a container that is just the size of their hand, put something they like in it—such as some nuts—wait until they grab the nuts, and then just walk up and grab them. Remarkably, they cannot find the thought to let it go even in the face of much greater danger. A YouTube video of an example of this is in the References.

#### Dunning-Kruger

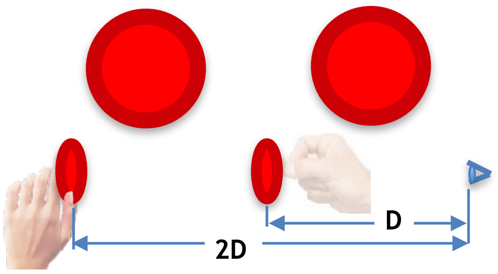
Another cognitive glitch is the Dunning-Kruger effect: examples are people who are ignorant but quite certain they are knowledgeable. Or are poor thinkers but believe they are great thinkers. Etc.

A big heuristic is "all humans exhibit the Dunning-Kruger effect to some degree!" Many of the most effective thinkers realize this and use it as part of their process to get around their own mental glitches. There is an enormous difference between those who realize it and those who don't!

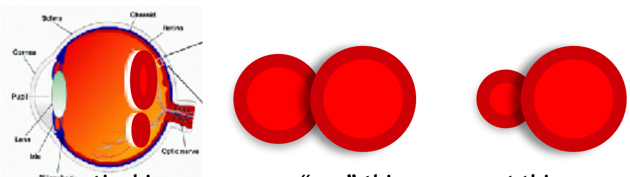
A larger insight is due to Korzybski, who pointed out that one way to characterize degrees of sanity was in how well internal beliefs and processes were in accord to the best findings of science and its relation to the universe. Using this measure, the best we humans can aspire to is “unsanity” because our internal maps don’t cover what’s around us very well. And “insanity” then is seen as larger more dangerous disparities between internal maps and outside processes.

It’s worth making and using some “sanity testers” to bring this home. An easy one is to take two coins or two small oranges, place one twice as far from the eye as the other and visually compare them.

The further away one will seem to be about 80% of the size of the closer one. If we check the geometry of the situation, we see that the angle subtended by the further away one is 1/2 the angle of the closer one, so we should expect that the images of the two objects on our retina should follow suit.




And in fact they do. (Descartes actually got an ox eye from a butcher and peeled off the back sclera to determine that animal eye lenses worked the same as the glass lenses of the day!) Why do we then “see” something quite different?



retinal images    we “see” this ...    not this ...

What is going on? The key is that we don’t actually *see* what’s out there. We just think we do. This illusion is called “size constancy” and it is another one of the almost 200 known cognitive biases. The problem is that we “know and believe” that the two poker chips are the same size, and we humans unfortunately mentally project our beliefs out on the world to help us “see” at all. Marshall McLuhan’s great line for this is:

**Until I believe it, I can’t see it!”**

If we were completely “crazy” we would see only our beliefs and would ignore all the evidence that our retinas have gathered for us. This is one of the manifestations of several kinds of “mental illness”.

Instead, for most people there is an invisible tussle between what we believe and the moment by moment evidence of our senses. The result is usually a compromise — as here — between the two, with beliefs usually winning over evidence to a goodly extent. The whole process can take as long as 1/4 second (this is why trying to hit a baseball is quite difficult — we only perceive where it *was* but think we are seeing where it *is*).

The deep conflict between beliefs and evidence is part of the source of Einstein’s definition of “insanity”.

Note the enormous difference between *knowing that this is happening for everything* vs. *not being aware* just how much of what you think you are experiencing are likely fairly compromised projections. Scientists experience the same kinds of illusions and cognitive biases as everyone else: the big difference is that (some of the time) they can keep this in mind well enough to be much more careful about what they think (and believe) might be going on. The result is that scientific revolutions have happened more quickly than other intellectual revolutions, but still usually lag by a generation or so “to let the older scientists die off”. The quip indicates that most scientists wind up believing too many things that — in science — are always provisional. The good news is that our human tendencies to create dogma have been resisted more successfully in science than in many other pursuits. Still, the field of science is comparatively quite a bit smarter than individual scientists.

An important point here is that science is not the be-all and end-all of all ways to try to think about our situations and issues. There are “careful excellent thinkers” who have found their way via other routes. The key idea: *we are biased in many ways, and we need to find and use methods that will help get around as many of our biases as possible*.

**Back to the issues at hand**

At this point we can “see” more clearly why we so often wind up acting against our best interests even when everything *feels* quite “reasonable” and reject suggested helpful actions that *feel* “unreasonable” and even “crazy”. Just being more self-conscious about our cognitive and emotional difficulties, and paying much more heed to good past knowledge, especially with regard to *method*, will make an enormous difference.

It’s worth noting that when a solution path doesn’t work out, it is rarely the case that just reversing what didn’t work will wind up working (there are 360 degree directions on compass, and there is also “look upwards” to add to “look outwards”).

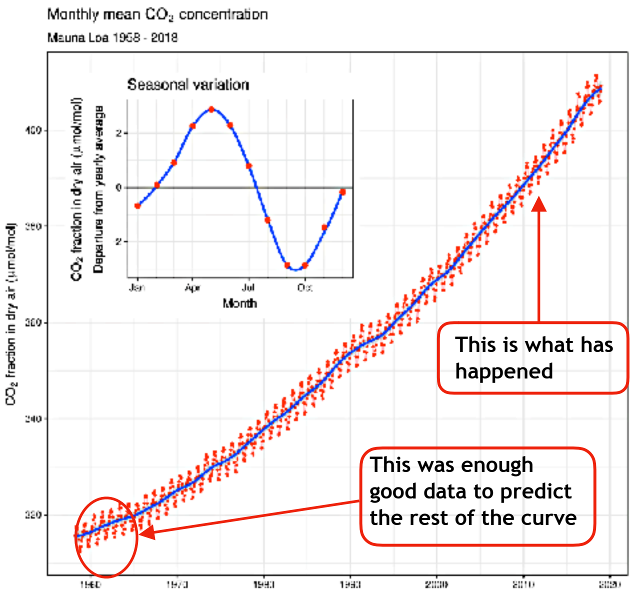
Also, the “Six Core Biases” (they are us!) are not abandoned in science, but they are drastically reworked. For example, the “herd” idea has to be used in science because of the “believing one’s own theory” Science has to be open to any and all ideas. Otherwise it would quickly become quite dogmatic like most other belief systems. One key is that science has a two level process: the first is a completely open forum, the second is the most critical set of methods that humans can devise to “actively doubt” what is in the forum. This allows “crazy” and “reasonable” to co-exist and synergize.

Another key is that acceptable scientific knowledge is most often in the form of dynamic models of the claims that produce complete enough results to be carefully tested against the phenomena under examination. The WIAN diagram in the previous section indicating needed thresholds and avoiding “perfect” (the “truth” is not possible in science) works well as a preliminary explanation.

**How Society Can Get Better At Dealing With “Immense Challenges” That Are Not Yet Like Wars**

The prime example of “immense challenge” in our time is the destabilization of many whole planetary systems by global warming and its consequences.

We’ve had plenty of time to do something about this catastrophe in the making. Charles Keeling, a chemist turned geologist, in the mid-50s devised the first highly accurate instruments for measuring the $CO_2$ content of the atmosphere. His first measurements were 310 parts per million (ppm) and rising on average year by year. *By the early 60s it was scientifically clear that the amount and pace of the rise was dangerous*, and the first warnings to the public and the government were given.




**The “Keeling Curve”**

Why warnings? $CO_2$ is the major "greenhouse gas". Without it to keep the Earth's heat—gotten mostly from the sun—from radiating back out into space, the planet would be about 60° colder.

Ancient air bubbles trapped in glaciers reveal that the level of $CO_2$ over the last million years has fluctuated between 200ppm and 300ppm, and today's ecosystems—and our civilizations—are accommodated to these levels. When greenhouse gases increase, the effect is to trap more of the heat from the sun and this will raise the overall average temperature of the Earth sufficiently to start changing the surface and the climate drastically and dangerously.

The additional $CO_2$ is mostly from industrialization, and the increase in another important greenhouse gas—methane—comes from both meat animals via agriculture, and from melting tundra from the increase in global temperatures. At the time of this writing the $CO_2$ level is 414ppm (an alarming increase of 33% in just 60 years) and the rate of increase is accelerating.

*The key point here is that 56 years after the first clear warnings, the general public, their governments, their industries, etc., still cannot summon enough informed imagination to see this as an approaching global disaster on many fronts*. This set of ostriches embodies all of the Six Core Biases, and many more.

Our planet is being poked by the finger of human blindness, and is wobbling. If the climate topples along the known dimensions (and more that are just starting to manifest), it is likely that human power will not be able to put Humpty-Dumpty back together again. The key—as in possible epidemics, flood control, etc.—is to be able to *vividly imagine the disaster well enough ahead of time* to keep the finger from being able to topple.

A dam broke in India and swept this car away. The man jumped in and saved the woman inside while he was in great danger of having the car toppling over on him. This is our species at its best. But the reason the dam broke was that the society could not imagine the broken dam well enough to “fix the dam before it broke”. This is perfectly *typical* human behavior, but it is *not at all reasonable* in this day and age.

**In Sum**

No one and no committee knows enough to lay out all the direct problem solving actions that are needed to deal with “immense challenges”. But past history of dealing successfully with a number of such challenges shows that processes involving many thousands of people can be organized well enough to yield enormous synergies of effort and produce new ways to understand the challenges and invent and build new ways to handle them. Like a vast epidemic (which will be one of the upcoming immense challenges) much needs to be done beforehand, in the immediate present, and longterm in the future, including training the next generations of problem finders, solvers—and—problem avoiders.

# SELECTED REFERENCES


**Systems**

Ludwig von Bertalanffy, “General Systems Theory”
Christopher Alexander, “Notes on the Synthesis of Form”
Peter Senge, “The Fifth Discipline“
Ken Webster, “What Might We Say About A Circular Economy?”, World Futures (2013)

**The Empire State Building**

Carol Willis, “Building The Empire State” (Foreman’s Log)
Deborah Hopkinson, “Sky Boys: How They Built the Empire State Building”
Geraldine B. Wagner, “Thirteen Months to Go: The Creation of the Empire State Building”

**WWII Radar**

Arnold Wilkins “The Birth Of British Radar”
Jennet Conant, “Tuxedo Park”
Robert Buderi, “The Invention That Changed The World”

**Code-Breaking**

Michael Smith, “Station X”
Gordon Welchman, “The Hut Six Story : Breaking the Enigma Codes”
Copeland and others, B. Jack, “Colossus: The secrets of Bletchley Park's code-breaking computers”

**The Manhattan Project**

Maj Gen Leslie Groves, “Now It Can Be Told”
Richard Rhodes, “The Making of the Atomic Bomb”

**The SAGE Air Defense System**

https://en.wikipedia.org/wiki/Semi-Automatic_Ground_Environment
Kent C. Redmond , et al, “From Whirlwind to MITRE: The R&D Story of The SAGE Air Defense Computer”
Bernd Ulmann, “An/Fsq-7: the Computer That Shaped the Cold War”

**ARPA computing research and Xerox Palo Alto Research Center**

Mitchell Waldrop, “The Dream Machine”,
Alan Kay, “The Power Of The Context”, http://www.vpri.org/pdf/m2004001_power.pdf
Alan Kay, “Two Stanford Lectures On ARPA-PARC Methods”, (Google this)

**Human Blindspots and “Bad Brains”**

Francis Bacon, “Novum Organum Scientia”
Daniel Kanneman, “Thinking: Fast and Slow”
Robert Meyer, Howard Kunreuthner, “The Ostrich Paradox”
https://en.wikipedia.org/wiki/List_of_cognitive_biases
Alfred Korzybski, “Science and Sanity”
YouTube: “How To Catch A Baboon” https://www.youtube.com/watch?v=ctol7JwpcuQ

**Exemplary Practices and Perspectives**

Amory Lovins, “Reinventing Fire”
E.F. Schumaker, “Small Is Beautiful”
Christopher Alexander, “Notes on the Synthesis of Form”