ENGINEERING
Professional Development

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Mechanical and Aerospace Engineering

ENG190 W’13
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(II)

Agenda (II)

Creativity in Engineering

Approaches to Creativity

The Development of Design

Engineering Design

Brainstorming

Team Work

Free Exchange of Ideas

Industrial Design

Inventions and Creativity

We have discussed examples of inventions in the previous class. We can easily name example of inventions. But what defines an invention? And what defines creativity?

Invention

An invention has an identity as a new distinctive device, process, or system.

Creativity

Nearly everyone can recognize creativity instantly, yet it is difficult to define the word in a fully acceptable manner.

Creativity

From the Oxford Dictionary:

The use of the imagination or original ideas, especially in the production of an artistic work.

From the Oxford Thesaurus:

inventiveness, imagination, innovation, innovativeness, originality, individuality

Design

From the Oxford Dictionary:

A plan or drawing produced to show the look and function or workings of a building, garment, or other object before it is built or made.

Creativity and Design

Technical Design as opposed to Aesthetic Design

…

Some examples:

Artistic (Henry Moore)

Fashion (Yves Sait Laurent)

House-hold objects (Italy)

Commercial (Packaging)

Industrial (Porsche)


Two flagship Sapper designs for Alessi: coffee pot 9090 (the first coffee pot manufactured at Crusinallo, awarded the 11th Compasso d'oro and on display at the MoMA in New York), and the majestic *Kettle with a singing whistle*, inspired by the sound


ayola
sspack
Crayola
12
COLOURING
PENS
Crayola


Breguet
Depuis 1775
nnovator.
urbillon, 1801
ation Tourbillon 5317 provides the perfect
tacular invention and undeniably the most
plications, developed over 210 years ago
of gravity. On the back, the "B-shaped"
eauty of the meticulously hand-engraved
g written...

Engineering Design

"Engineering Design is the process of applying the various techniques and scientific principles for the purpose of defining a device, a process or a system in sufficient detail to permit its physical realization…

A design may be simple or enormously complex, easy or difficult, mathematical or non mathematical; it may involve a trivial problem or one of great importance"[1]

(1) "*Report on Engineering Design*", Journal of Engineering Education", April 1961, pp. 645-660.

(2) "*Engineers and their Profession*", John Kemper and Billy Sanders, 5th Edition.

Samsung Example

Samsung has 60,000 staff members working in 34 research centers across the globe.

Their range of products run from cellular phones to household appliances, and everything in between.

It employs thousands of designers with different backgrounds in psychology, sociology, economy management, and of course engineers from all fields.[(1)]

(1) The New York Times, *Samsung Challenges Apple's Cool Factor, But in Its Own Way,* 2/11/13

Engineering Design Process

The engineering design process starts with the

formulation of a plan

to help an engineer build a product with a specific function and performance:

Research
Conceptualization
Feasibility
Assessment
Design Requirements
Preliminary Design
Production Planning
Tooling and Manufacturing

Playing "Devil's Advocate" at all stages, all the time

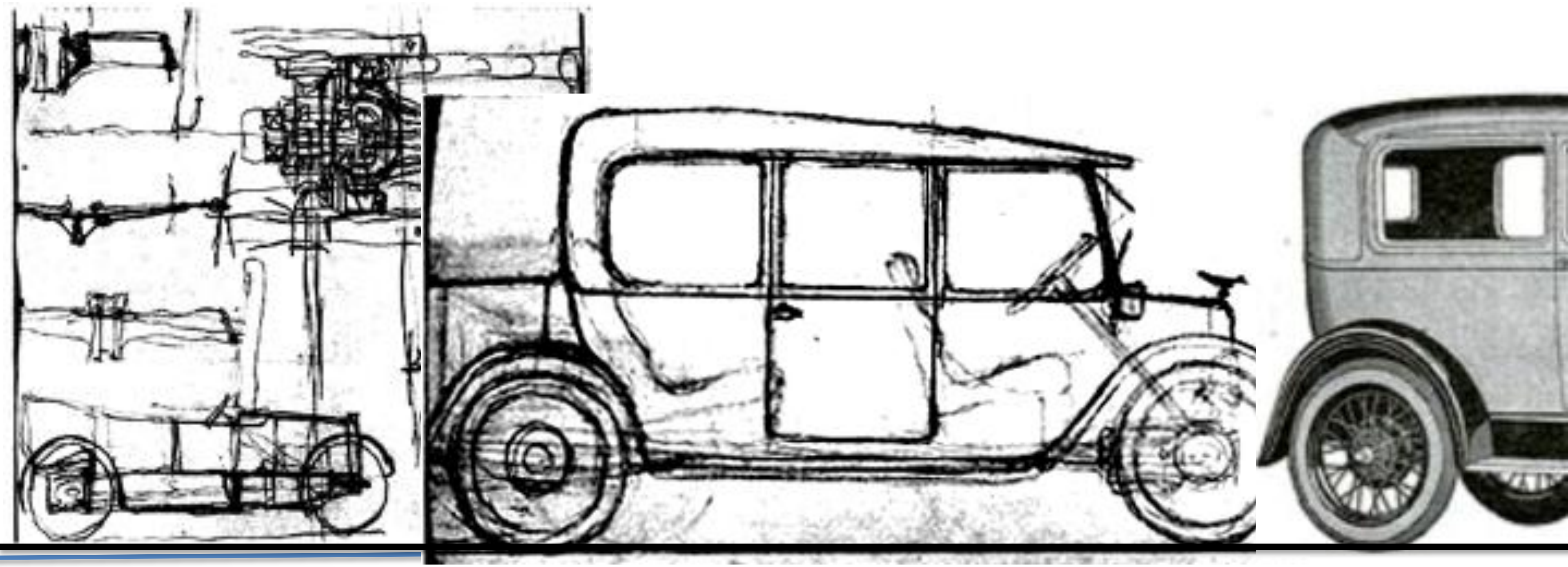
From Ideas to Prototypes

Creativity leads to Ideas.

Ideas materialize into Designs.

Designs lead to Prototypes.

From Prototype to Manufacturing.

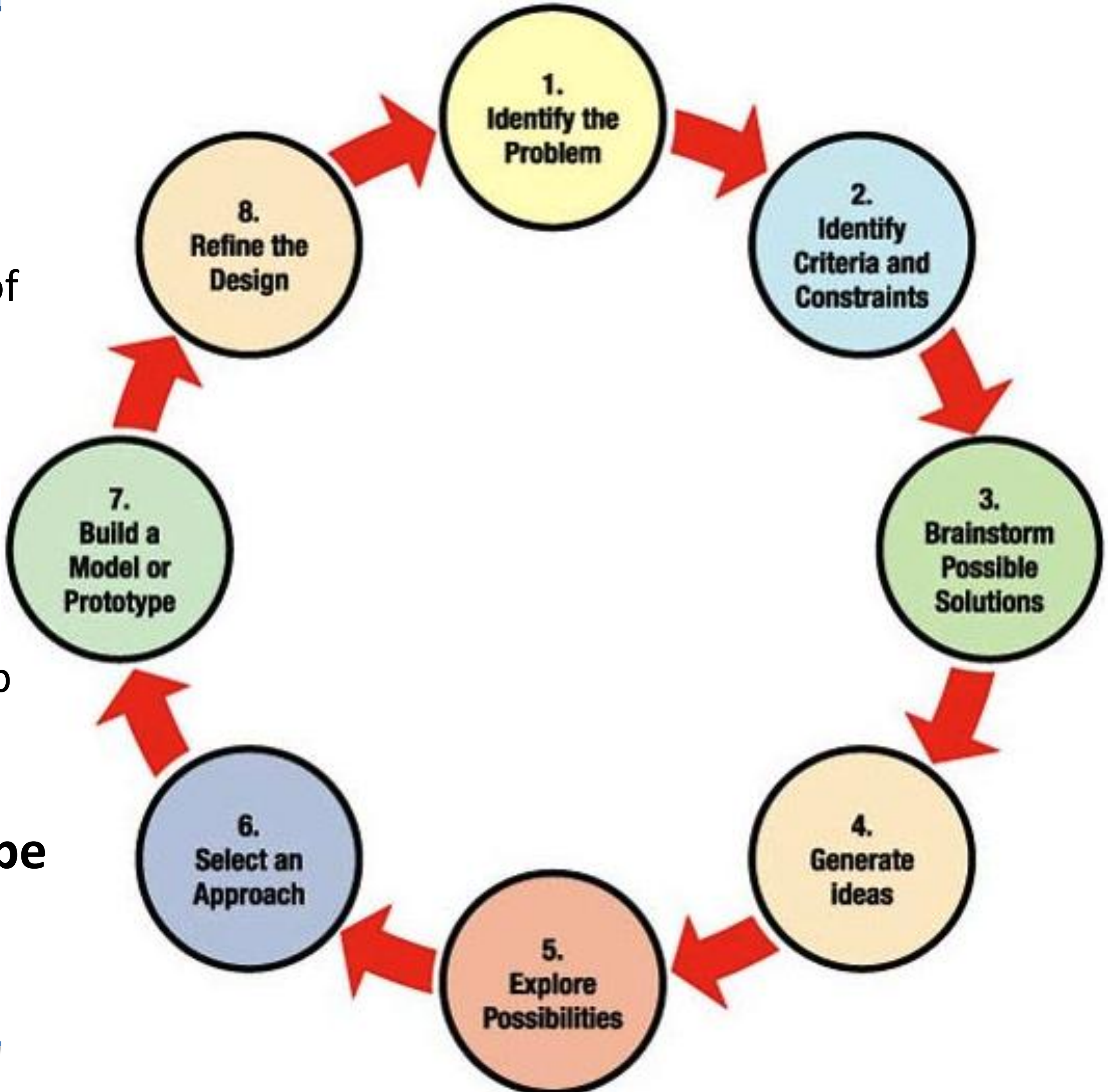


NASA Engineering Design Project

Lunar Plant Growth Chamber

The Engineering design process involves a series of steps that lead to the development of a new product or system.
In this design challenge, students are to complete each step and document their work as they develop their lunar plant growth chamber.

The students should be able to do the following steps:



Creativity in Science and in Engineering

There are **multiple levels of creativity** used in science, engineering, and technology.

Different from invention, many creative endeavours do not constitute a tangible thing or outcome.

e.g. The Theory of Relativity,

as opposed to

The Golden Gate Bridge.

Different kinds of Technical Creativity

Galileo (1564 – 1642) **:** Tilted Plane Experiments

Newton (1642 – 1772) : Theory of Gravitation

Einstein (1879 – 1955) : Theory of Relativity

Shockley, Bardeen, Brattain (1047) : The Transistor

E.O. Lawrence (1901 – 1958) : Inventor of the Cyclotron

Henry Phillips (early 1930s) : Phillips Head Screws

Silver, Woodland (1948) : Barcode [1974, chewing gum]

Symbiosis of Science and Engineering

Engineering Driven Science

Science Driven Engineering

Frontier Creativity

Creativity in Science (Basic Research)

The creativity used in identifying and studying natural phenomena.

This level of scientific creativity is mostly the domain of scientists.

Creativity vs. Discovery

Interpretation as Creativity

Two Aspects of Creativity in Science

Theoretical: The creativity used in identifying and **studying natural phenomena**.

(The Theory of Gravitation, Maxwell Equations, etc.)

Experimental: The creativity of **designing techniques and diagnostics** to obtain information from nature.

(e.g. Galileo Galilee's Tilted Plane)

Frontline Research

The creativity used in expanding scientific knowledge and novel applications of this knowledge.

….

In frontline research there is **no clear transition between science and engineering.** There is a large area of overlap regarding creativity.

…

This level of creativity is both the domain of scientists and engineers.

Two Examples of Frontier Research

The Laser

Invented in 1960, with combined contributions from

Scientists (Stimulated Emission, Population Inversion) and **Engineers** (flash-lamp, optical cavity).

(originally, a hammer without a nail)

The Heart Pace Maker

Invented in 1928 by the combined creative effort of **Medicine** and **Engineering**.

Commercialized in 1960.

Science Driving Engineering

When scientific research drives the development of new technology.

e.g.: **High Energy Physics and Particle Accelerators** (as the case of E.O. Lawrence)

e.g.: **Nuclear Physics and Nuclear Engineering** (nuclear reactors, nuclear submarines)

e.g.: **Controlled Fusion and Laser Technology** (National Ignition Facility)

Lawrence’s Cyclotron

The cyclotron is a good example of creativity where a scientist, **E.O. Lawrence**, did engineering (designed the cyclotron) in order to continue with his scientific research on High-Energy Physics.

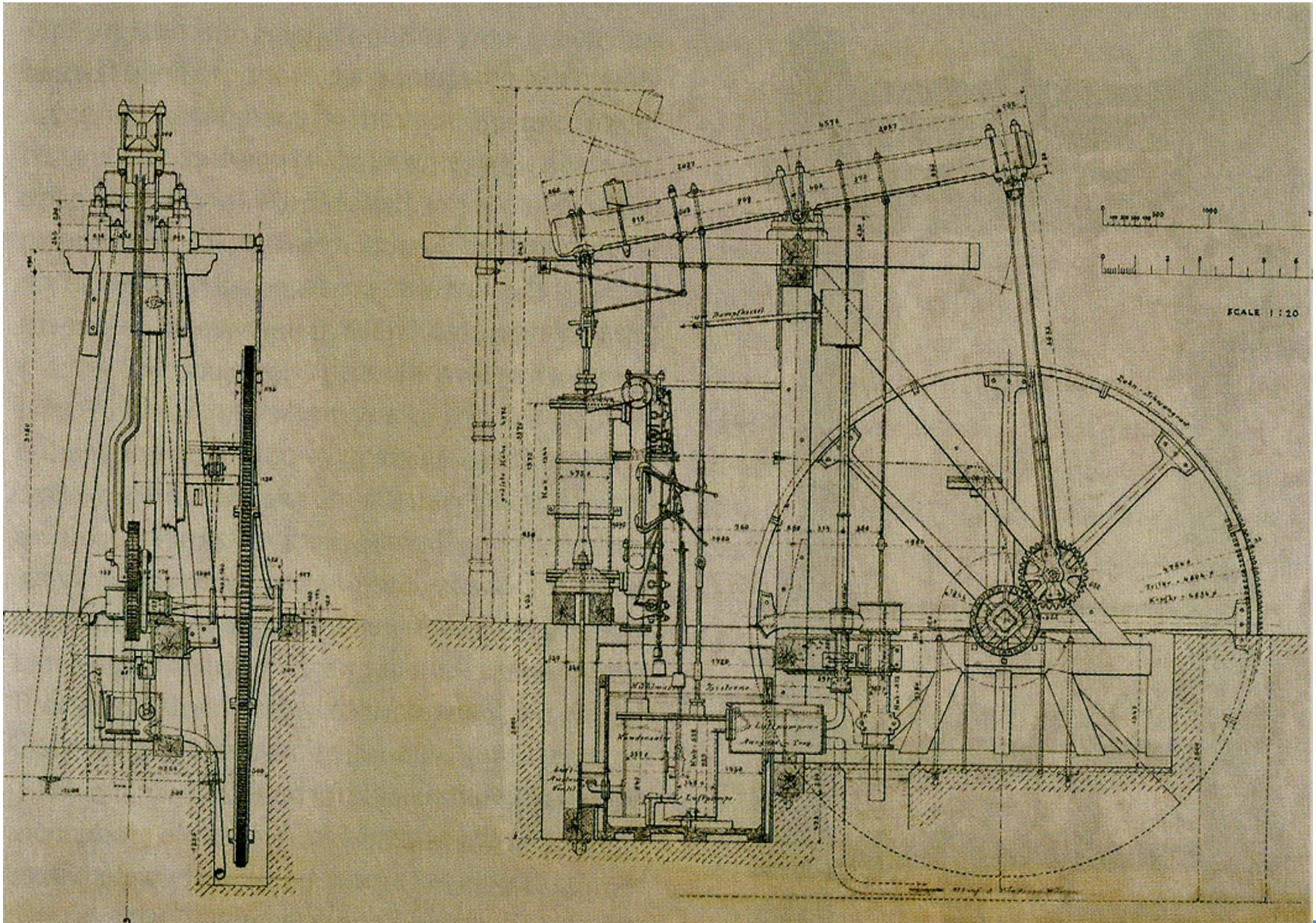
Cyclotron (1929)

Lawrence accelerates particles to greater velocities than ever before.

A modern cyclotron for radiation therapy >>

Technology Driving Science

From Steam Engine to Thermodynamics



Steam Engines and Thermodynamics

The Steam Engine and Thermodynamics

The need to improve efficiency of steam engines and fabrication of canons gave rise to the development of Thermodynamics, a **branch of Physics**.

The Laws of Thermodynamics

a) Determination of an absolute temperature

b) Conservation of Energy

c) Principle of Irreversibility

(*James **Watt**, James Prescott **Joule**, Sadi **Carnot***)

The Birth of the Industrial Revolution

Thermodynamics and the steam engine led to

the Industrial Revolution

followed by achievements in other fields, such as **electricity, hydrodynamics**, and others.

This in turns brought **Modern Engineering** into the picture.

Evolution of Applications: Semiconductors

Creativity is also at the heart of the development of **new devices**, systems, and structures.

This level of creativity is mostly the **domain of engineers.**

e.g.: a) From semiconductors to transistors

b) From transistors to integrated circuits

c) From analog to digital technology

d) From integrated circuits to computers

Developing Ideas

Three important components on the process of developing an idea:

Brainstorming

Exchange of Information

Team Work

The Idea Behind Brainstorming

Brainstorming:

Multiple Engineers and/or Scientists working as a team to develop the best approach to solve a problem, design a device, etc.

This involves teams developing ideas with the expectation that **one team member's creativity will stimulate another's** in the hope that the group as a whole will be able to expand and refine the best idea.

Brainstorming

Depending on the situation, there are times when brainstorming is effective, and others where **individual work is more effective** in pursuing a solution of a particular problem.

Studies have been done to determine if brainstorming is a useful creative tool, but **no conclusive evidence has been found either way.**

Nevertheless, it leaves you thinking…

Free Exchange of Information

The Institutional **Environment** in which **research and design is conducted** is thought to be the most important factor in creative stimulation. Access to a free **exchange of scientific and technological information** facilitates the crystallization of ideas.

Bell Labs

Bell Laboratories (also known as **Bell Labs)** are at present the research and development subsidiaries of the French-owned Alcatel-Lucent.

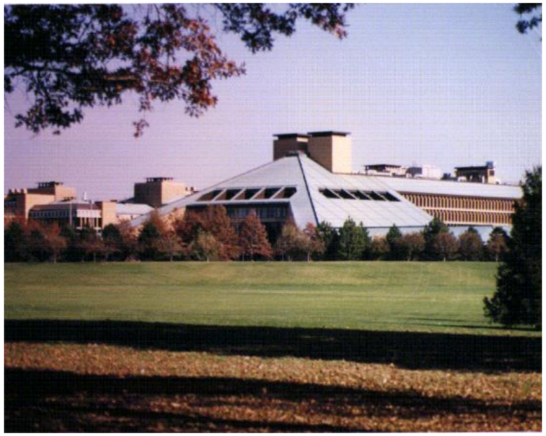
Bell Labs are credited with the development of **Radio Astronomy**, the **Transistor**, the **Laser**, the **Charge-Coupled Device (CCD)**, **Information Theory**, the **UNIX Operating System**, the **C and C++ programing languages**, and many more.

Seven Nobel Prizes have been awarded for work completed at Bell Laboratories.

Bell Labs Free Exchange

Bell Labs were extremely successful.

This success is attributed to a set of recommendations for the encouragement of individual effort.



Bell Laboratory in Murray Hill, New Jersey

Bell Labs Recommendations (I)

- (1) Organizational Systems should allow **engineers to pursue individual work**.
- (2) Individuals should be **encouraged to study unknown phenomena** which could lead to a new invention or discovery.
- (3) **Incentives** should be adequately rewarding and based on merit.
- (4) **Information exchanged** and coordination for research should be facilitated. Engineers should have **access to information** outside of their specific field.

"Engineers and their Profession", John Kemper and Billy Sanders, 5th Edition.

Bell Labs Recommendations (II)

One of the most famous examples is the invention of the **transistor** by William Shockley, John Bardeen, and Walter Brattain.

This unique invention become the building block of the digital age.

These policies are now widely used, although **with limitations**, within various institutions, companies, etc., around the world.

Edison : American Businessman

Edison was one of the first inventors to apply the principles of **mass production** and large-scale **teamwork** to the process of invention.

Because of that, he is often credited with the creation of the first **Industrial Research Laboratory.**

Edison’s Menlo Park Research Lab

Team Work

Engineers typically work in teams in order to utilize the advantages of having various specialists tackling a project.

However, there are many differences between team work done under Academic and under Professional settings.

The LLNL development team for the High-Average Power Wavelength Converter

Team Work Experience

*"**Do engineering schools do a good job in preparing their graduates for working in a team environment ?** In most cases the answer is **no** because the classroom experience for undergraduate students is more representative of one-on-one competition than team participation."* (*)

(*) *Engineers and their Profession*, John Kemper, and Billy Sanders

Team Work in Academic Setting

Students are often competing with each other for the top grade.

Even in team projects, student will mostly likely have to give an individual report.

The overall grade earned by a student is predominately based on the work the student has produced individually.

ABET and the “Capstone” course.

Team Work In Professional Settings

Team Work is essential in professional settings.

It is likely that a team of engineers will be evaluated equally on their collective performance regardless of individual contribution.

It is common practice for engineering firms to reward teams equally for outstanding performance.

However, this does not preclude distinguishing individuals for specific contributions.

The team leader is responsible for the last point.

Team Building

(1) The time a team will spend working together is determined by the **duration of the project**.

(2) Members of the team are not necessarily of the same field, typically each member may have their **own specialty**.

(3) For larger projects, a team member will take on the role of **Financial Administrator**. This team member will have to monitor the finances of the project at every step to assurance that the project ends on budget.

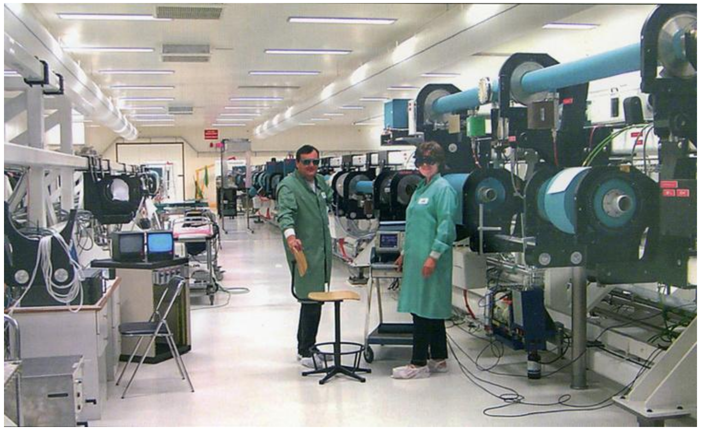
(4) Each team will have a **Team Leader**. The team leader should have a reasonable amount of knowledge of **each of the fields** involved in the project. [1]

(1) *Engineers and their Profession*, John Kemper, and Billy Sanders

Example: Team Leader

The team leader for a particular project involving High Power Lasers would have to be knowledgeable in:

- Optical Engineering
- Laser Technology
- Electronic Devices
- Mechanical Structures
- Programming/Software
- Control Systems
- And more…



Quality Control in Manufacturing

Manufacturing and Quality Control

Quality has to be introduced at every step in the design and manufacturing process.

- Setting standards
- Tolerances
- Focus on final product

- Baseline Design Reviews
- Prototype Design Reviews
- Product Design Reviews
- Manufacturing Plan Reviews

Evolution of Manufacturing Sequence

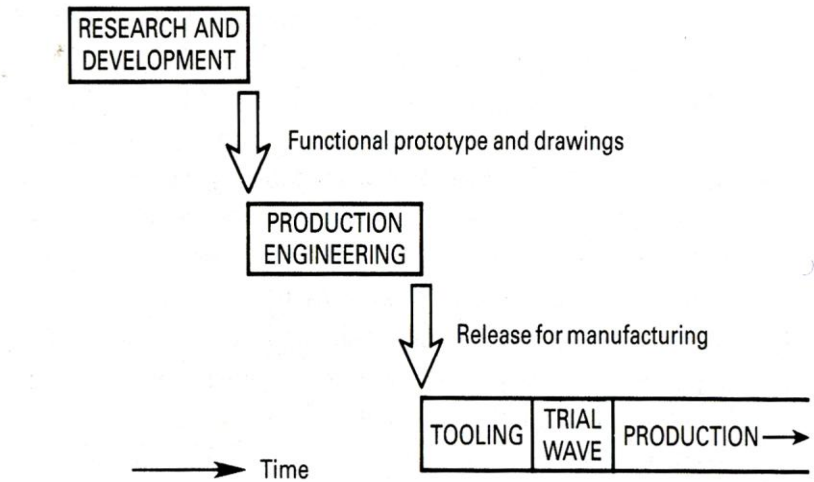


Figure 3–1

The "classic" view of the sequence from research and development, through production engineering, to manufacturing. This view is being superseded by the one shown in Figure 3–2.

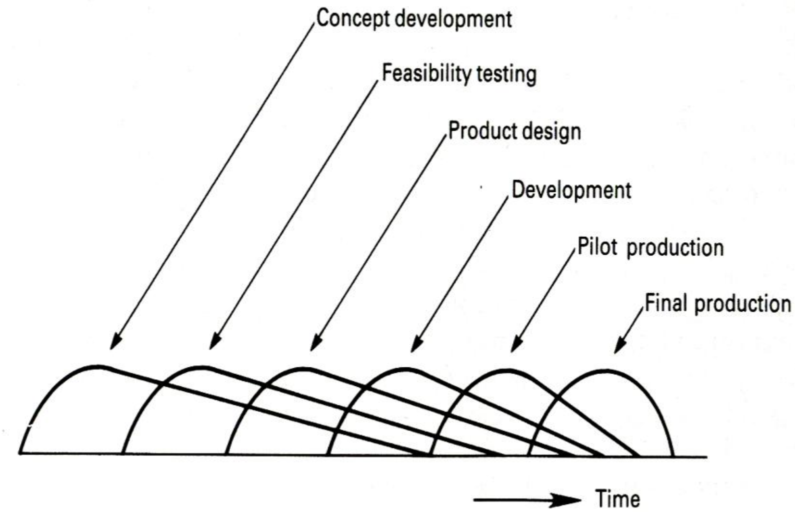


Figure 3–2

The "overlapping" model of the product development sequence. (Source: H. Takeuchi and I. Nonaka, "The *New* New Product Development Game," *Harvard Business Review*, January–February 1986, pp. 137–146.)

In the new style of **Simultaneous Engineering** many problems associated with manufacturing and quality never arise.

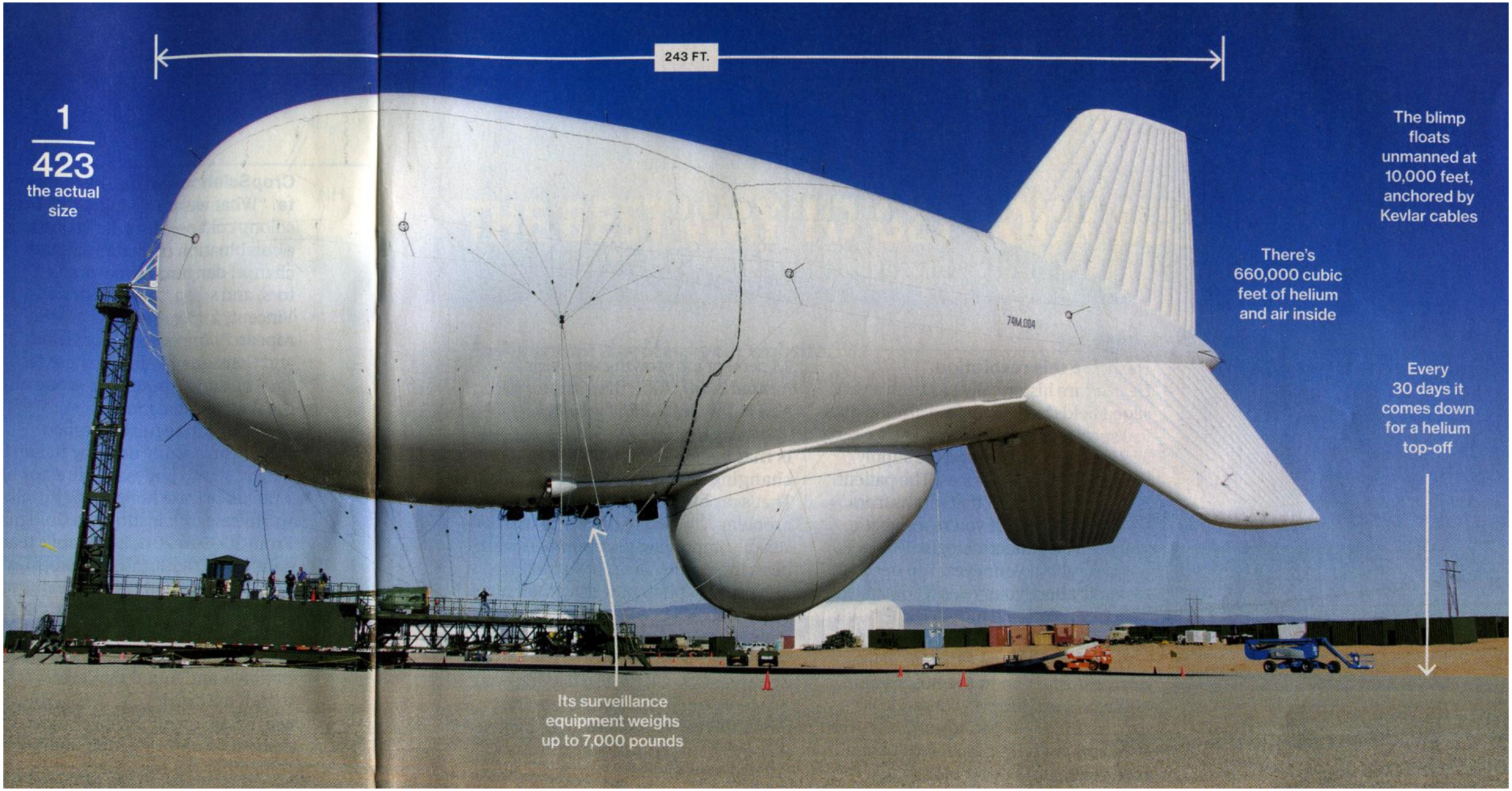
Quality has to be built in at all stages

Medicine Driving Science and Engineering

Positron Emission Tomography (PET)

(Nuclear Medical Imaging)

Government Driving Engineering



Raytheon's Missile-seeking Blimp will get a test guarding the Capitol

Bloomberg Businnessweek, March 4-10, 2013

Science Driving Engineering (CERN)

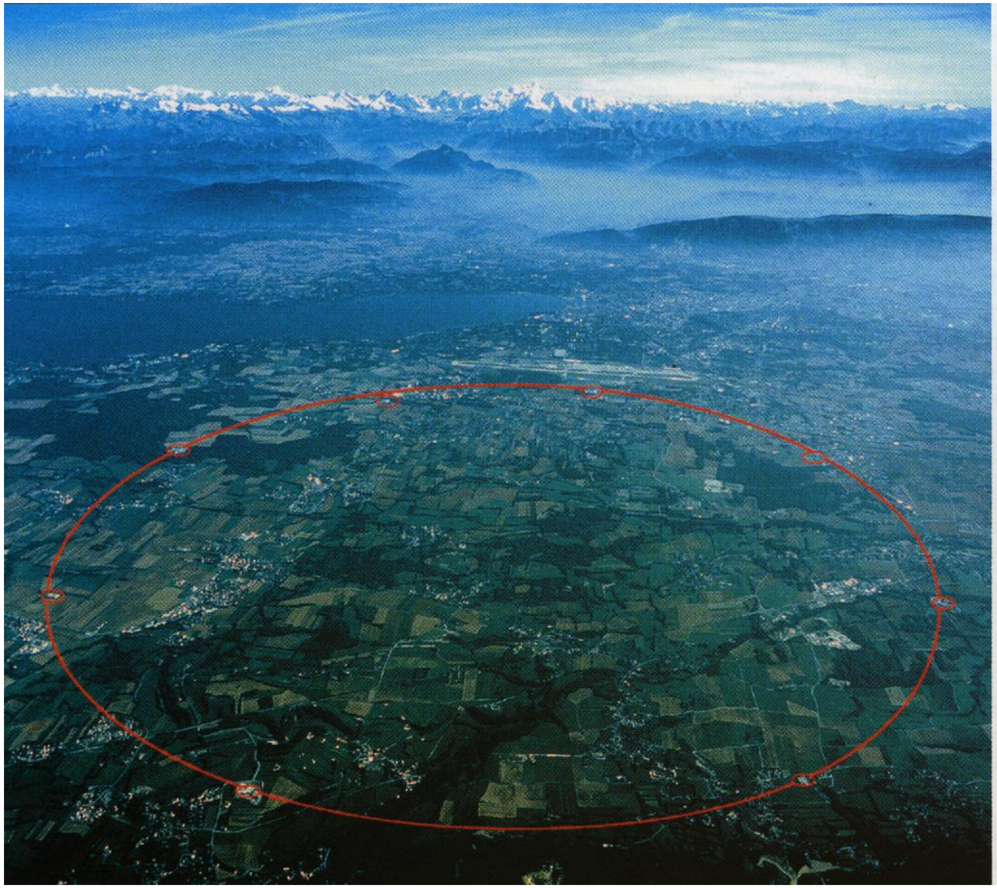


Fig. 6.5 An overview of the European high energy physics laboratory CERN. Superimposed on the photograph is an outline of the ring (deep underground, of course) of LEP, this tunnel later to be used for the Large Hadron Collider (LHC) described later in this chapter. In the background are Lake Geneva, the airport and Mont Blanc.

CERN European High Energy Physics Laboratory. Largest electron-positron storage ring of all times: 27 km in circumference.

Engines of Discovery, A. Sessler, E. Wilson, 2007 (World Sci. Pub.)

Science Driving Engineering (CERN)

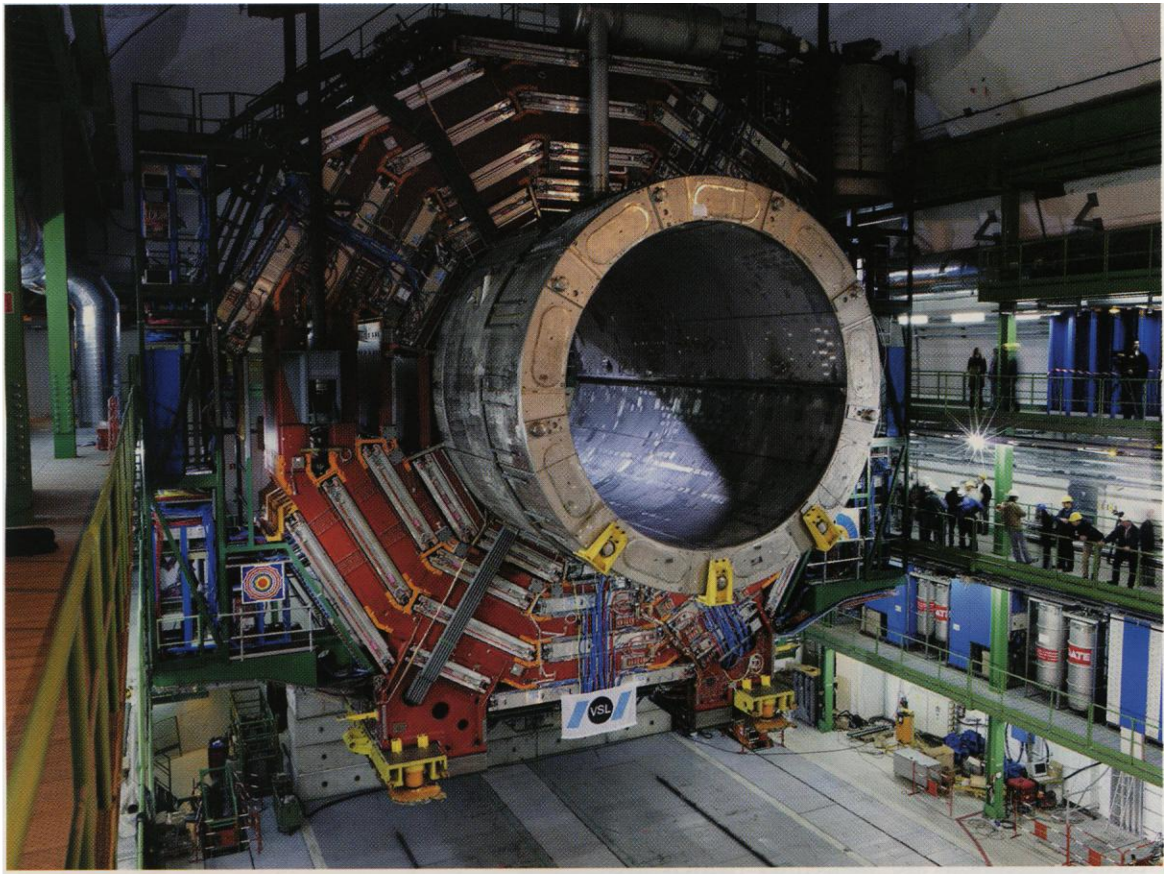


Fig. 7.8 A picture of a modern detector; in this case the central solenoid of the mammoth CMS detector at CERN. One can easily imagine that these detectors are as complicated as the accelerator itself.

A Modern Detector: the central solenoid of detector to identify mass of particles.

Engines of Discovery, A. Sessler, E. Wilson, 2007 (World Sci. Pub.)

Stanford Linear Accelerator Center (LINAC)

Fig. 8.6 Aerial view of the Stanford Linear Accelerator Center showing the Linac Coherent Light Source (LCLS).