Mathematics, Science, and Technology Education Partnership

IRG Section VIII

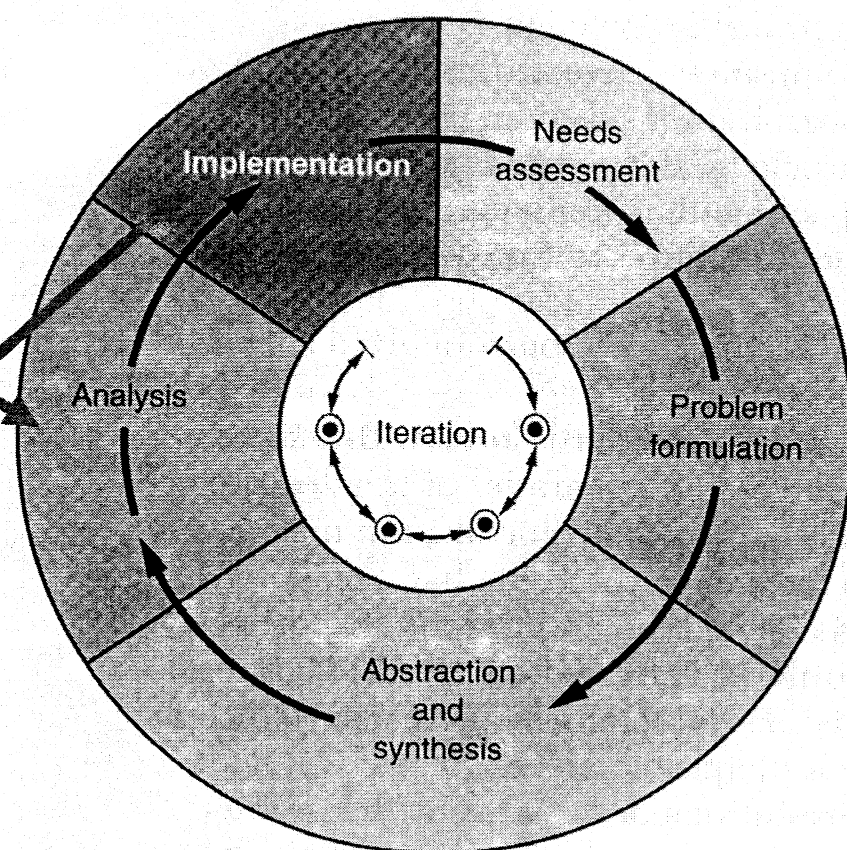
Role of Stem Faculty

Table of Contents

The Engineering Design Process:

Analysis:
-- Compare and evaluate alternative designs
-- Choose basis for comparison (i.e. needs)
-- Consider ergonomics, ethics, hazards, failure modes
-- Build and test models (prototypes)
-- Optimize the results

Implementation:
-- Develop final solution and distribute to client/customer/user
-- Beta prototype testing
-- Production ramp-up
-- Reflect on results and process for feedback to improve the design process



FI
ne

STEM Faculty

College faculty can serve key roles in the design, planning, execution and assessment of STEM education programs on the middle school level. As has been found through the MSTP program, these roles can take a number of forms that take advantage of the backgrounds and interests of the faculty members involved. For example, faculty involved in teaching mathematics or engineering can bring their knowledge of these fields to development of activities for curricula enhancement. Faculty with specializations in pedagogical research can directly explore the impact of STEM activities on both the teaching and learning environments at the middle school level. Furthermore, college faculty roles in STEM projects are shaped by the program itself, by the nature and design of teams, and by the college faculty themselves. Roles can include: participation in Collaborative School Support Teams with middle school teachers, administrators and social workers helping to provide leadership and create activities which link learning opportunities and match curricula to State standards; evaluating the roles of administrators in support and institutionalization of STEM curricula developments; mentoring both student-teachers and middle school project teachers in promoting the goals of STEM teaching enhancement; designing and conducting workshops for middle school teachers and administrators on development of linked STEM learning experiences; assisting in transfer of such activities to the classroom and evaluation of the results; and combinations of the above.

The common thread through all these activities is twofold – first, that college faculty involvement provides multiple opportunities for STEM teaching and learning enhancement at the middle school level, and, secondly, that through involvement in STEM teaching programs like MSTP, college faculty can enhance their own teaching and pedagogical skills at the college level. MSTP university participants have gained an understanding of middle school learning standards as well as an enhanced comprehension of student learning styles and exposure to a diverse set of teaching activities. In turn, these faculty members have been able to incorporate concepts of linked, problem-based and active learning and student learning-focused pre and post assessment of learning goals and outcomes into their own teaching and course and curriculum development. These developments represent institutional change that ensures the sustainability of project impact on the college learning environment.

The following examples of workshop activities developed by college faculty and pedagogical developments for college classrooms demonstrate the nature and variety of college faculty involvement in the MSTP program, and serve as examples for college faculty involvement in STEM programs in general.

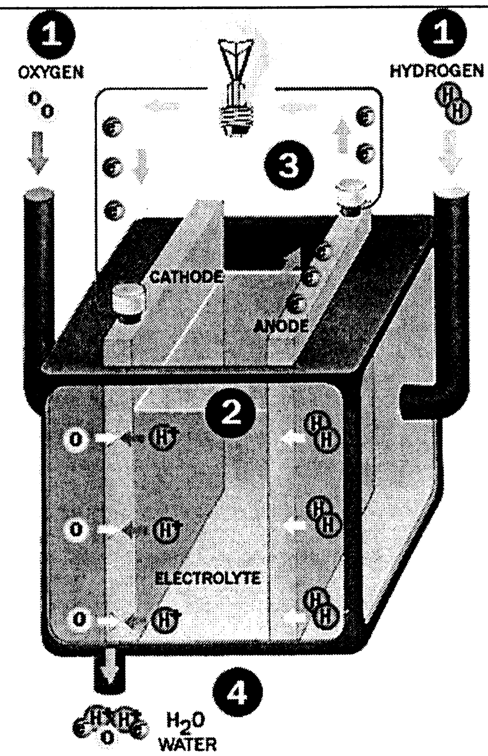
The Future of Power: *How Fuel Cells Work, and How We Can Make Our Own*

Gary P. Halada
Department of Materials Science and Engineering
Stony Brook University
ghalada@notes.cc.sunysb.edu

New clean, efficient and cheap power sources will be in high demand in our future, for everything from our homes to our cars and even our personal electronic devices, such as cell phones. It is important that these power sources be light weight, safe and cheap enough so that we can afford them. Batteries are a great technological development to store and transport small amounts of power, but, as we know, batteries eventually drain and have to be replaced. A petroleum powered generator, on the other hand, will provide power as long as there is a source of fuel – unfortunately it also turns out a number of pollutants which can injure us and poison our environment.

A fuel cell can provide the best of both worlds – a simple chemical energy conversion device which will run as long as there is a source of fuel, but which produces little (if any) pollution. If we supply hydrogen (either as a gas or as part of a simple hydrogen-containing fuel) to one side of a fuel cell and air or oxygen to the other side, a simple chemical reaction occurs on surfaces called catalysts which provide ions which travel through the inside of the fuel cell. The electrolyte, which is the material the ions flow through, does not allow the other product of the reactions to flow through it – electrons. These are forced to flow through a circuit on the outside of the cell where they will be able to do work (like run an electric motor, or light bulb). As long as we can supply hydrogen (for example from the hydrolysis of water by use of a solar cell), we can get power from a fuel cell.

How a Fuel Cell Works, from http://fossil.energy.gov/programs/powersystems/fuelcells/



1: Hydrogen gas is extracted from natural gas or other hydrocarbon fuels and permeates the anode. Oxygen from the air permeates the cathode.
2: Aided by a catalyst in the anode, electrons are stripped from the hydrogen. Hydrogen ions pass into the electrolyte.
3: Electrons cannot enter the electrolyte. They travel through an external circuit, producing electricity.
4: Electrons travel back to the cathode where they combine with hydrogen ions and oxygen to form water.

Making your own gas fuel cell:

For this we need two graphite pencil 'leads' (actually made from a form of carbon called graphite -- graphite is important because it acts as our catalyst – a material which enhances a chemical reaction but is not consumed by it!), a beaker, some salt water (a little NaCl in water), a voltage source (of about 9 volts), and a simple voltmeter. (Art pencil leads work best, but students can vary the type and number, as noted below, to 'optimize' their fuel cell operation).

The two graphite electrodes (pencil 'leads') are situated side by side so only about 3 cm extends into the solution. They are then fixed at the edge of the glass and connected by clip leads coming at the top. The electrodes should not be too far from each other (a few millimetres is ideal), but should not touch.

The next few paragraphs are adapted from the website http://www.fuelcellstore.com/products/martin/DL48fuelcellkiteng.pdf:

The electrodes are connected to the voltmeter (polarity is unimportant). The very first time one will measure no voltage, even in the most sensitive VDC range (except for small effects from stray electromagnetic fields). On repetition of the experiment, however, the electrodes may be no longer identical (adsorbed traces of gas from the previous experiment) and one can already see very small effects. The voltmeter is switched to the 0-20 VDC range and the battery connected to the electrodes (plus to plus, minus to minus pole). One observes vigourous gas evolution at the electrodes (the chlorine gas can be smelt when close enough). The gas mixture is in principle explosive but the small quantities make the experiment harmless. The voltage of the battery is measured on the voltmeter (9 V).

The battery is disconnected, preferably without shaking the glass so that as many gas bubbles as possible remain adhered to the electrodes. Now we have no more electrolysis but the voltmeter still shows a voltage of about 1.4 V which slowly sinks (switch voltmeter to a more sensitive range as needed). Our cell now functions as a gas battery or fuel cell! It is true that it cannot drive anything other than a voltmeter, but the effect is clearly observable (for higher power, e.g. to drive a lamp or motor, one needs larger vessels and greater electrode areas). By reconnecting the battery for a short time (after switching the voltmeter to a suitable range), one can recharge the gas battery as often as desired and repeat the experiment.

The reactions in the cell are as follows:

First, with the battery connected (to generate our "fuel"):

Anodic reactions
Electron release (oxidation) Cl - -> Cl + 1 e -Formation
of chlorine (gas) molecule 2 Cl -> Cl_2
Overall reaction 2 Cl - -> 2 e - + Cl_2

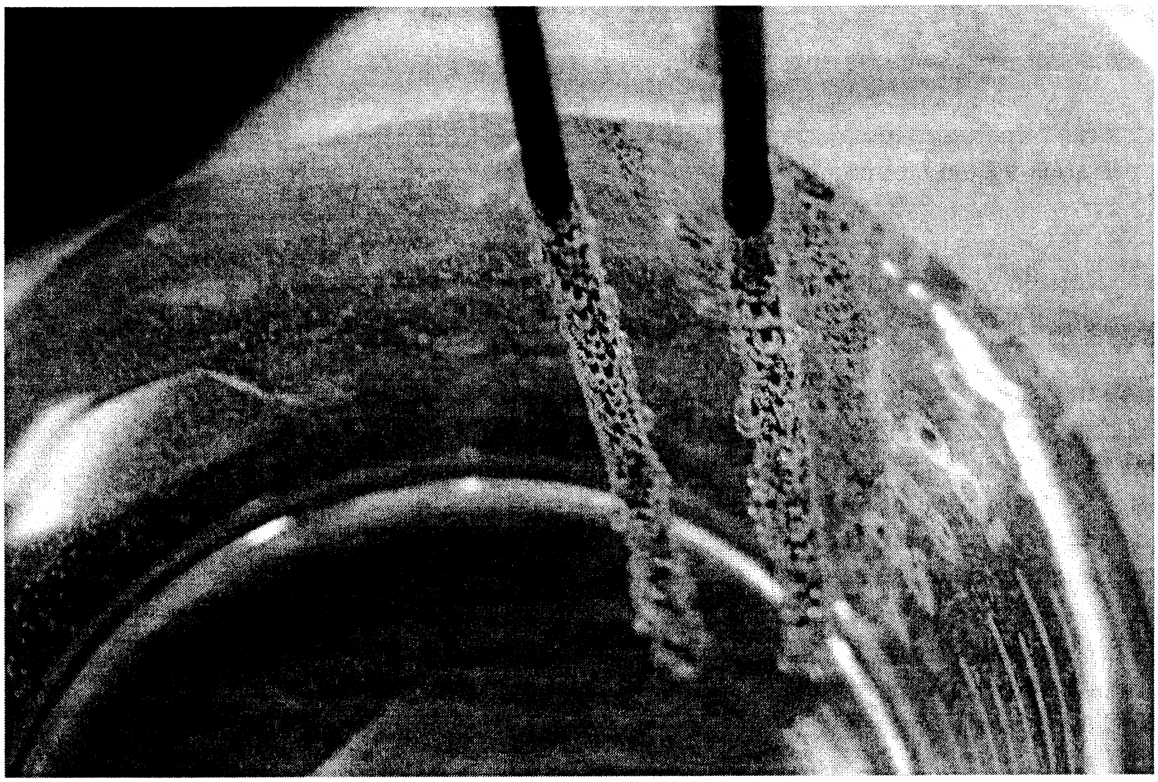
Cathodic reactions
Electron acceptance (reduction) Na + + 1 e - -> Na
Secondary reaction: formation of caustic soda Na + H_2O -> NaOH + H
Formation of hydrogen (gas) molecule 2 H -> H_2
Overall reaction 2 Na + + 2 e - -> 2 NaOH + H_2

And then, with the battery disconnected:

Overall reaction H2 + Cl2 -> 2 HCl

Electron acceptance (reduction) $Cl_2 + 2e^- \rightarrow 2Cl^-$ E 0 (Cl_2/Cl^-) = 1.36 Volts
Electron release (oxidation) $H_2 - 2e^- \rightarrow 2H^+$ E 0 (H_2/H^+) = 0 Volt (by definition)

This is the reaction that produces our voltage!



Gas fuel cell experiment showing evolution of hydrogen and chlorine gas at graphite electrodes.

Classroom/homework activities:

- Step one: establish research/design teams
- Identify experimental parameters: solution and electrodes
- Measure surface area per unit length of graphite electrodes; make notes of any other differences in the surface texture or shape of the electrodes
- Calculate the surface area of graphite which extends into the solution.
- Try creating more surface area under the surface of the solution by
    - Using several electrodes bundled together
    - Using thinner or thicker electrodes
    - Extending the electrodes only 1 cm into the solution instead of 3 cm
- Keep records – what was the effect of each of these changes on your gas fuel cell performance?
- Write lab report on the gas fuel cell experiment
- Describe what was done, what chemical equations/reactions are involved, and what the results were.
- Include a graph of results, showing the voltage versus time for each change made in the amount of electrode surface area in the solution.
- Explain importance of the experiment in terms of improving the fuel cell performance.

Learning objectives (science and technology):

Understanding how a fuel cell works and how it is different from a battery
Understanding and writing a chemical reaction, including balancing charge and numbers of atoms
Understanding the role of a catalyst and the importance of surfaces in reactions
Understanding design of experiments

Additional mathematical objectives (various grade levels):

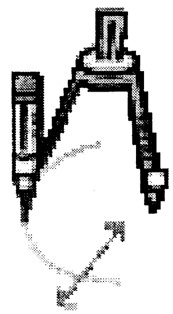
Measuring/using a ruler and other measurement tools (length, time, voltage)
Calculating surface area, volume, circumference
Graphing data

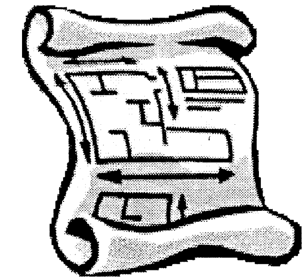
5th – 7th Grade Related mathematical standards (from http://www.regents.nysed.gov/2004Meetings/November2004/mathstandards-part2-nov04.doc

5.M.3 Measure to the nearest millimeter
5.M.6 Calculate elapsed time in hours and minutes
5.M.8 Determine the tool and technique to measure with an appropriate level of precision: lengths and angles
5.S.2 Display data in a line graph to show an increase or decrease over time
5.S.4 Formulate conclusions and make predictions from graphs

6.G.4 Calculate the area and circumference of a circle, given the radius
6.G.5 Identify radius, diameter, and chords of a circle
6.G.7 Understand the relationship between the circumference and the diameter of a circle
6.M.1 Measure capacity and calculate volume
6.M.8 Estimate volume, area, and circumference
6.S.6 Read and interpret graphs
6.S.7 Justify predictions made from data

7.G.4 Calculate the surface area of prisms and cylinders, using a given formula and a calculator
7.M.15 Estimate surface area
7.S.8 Interpret data and justify predictions
7.S.10 Predict the outcome of experiments
7.S.11 Design and conduct an experiment to test predictions
7.S.12 Compare actual results to predicted results





Math by Design:

Alignment of Mathematical Concepts in the Engineering Design Process with NYS Standards

Technology Workshop

Stony Brook University

March 4, 2006

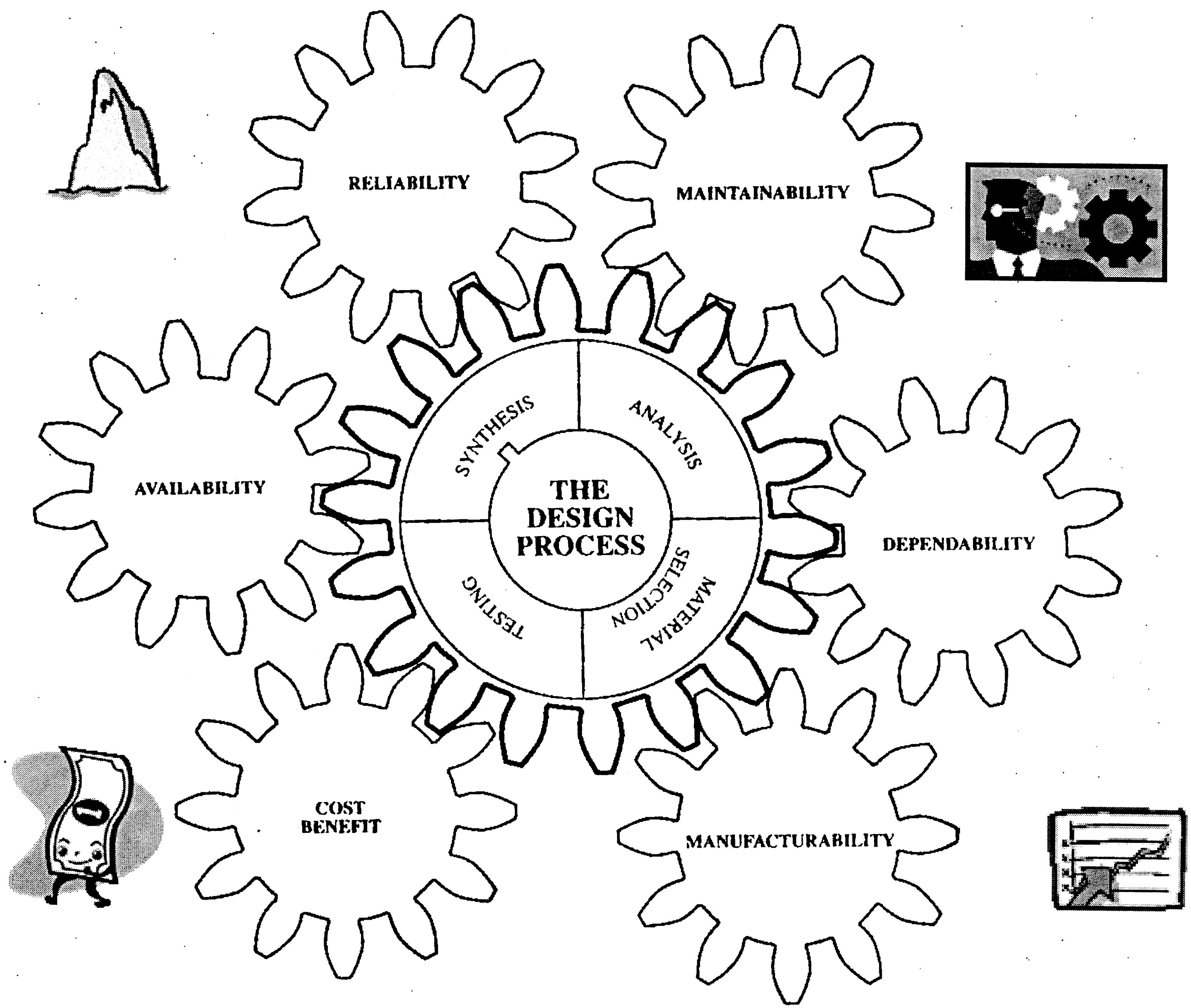
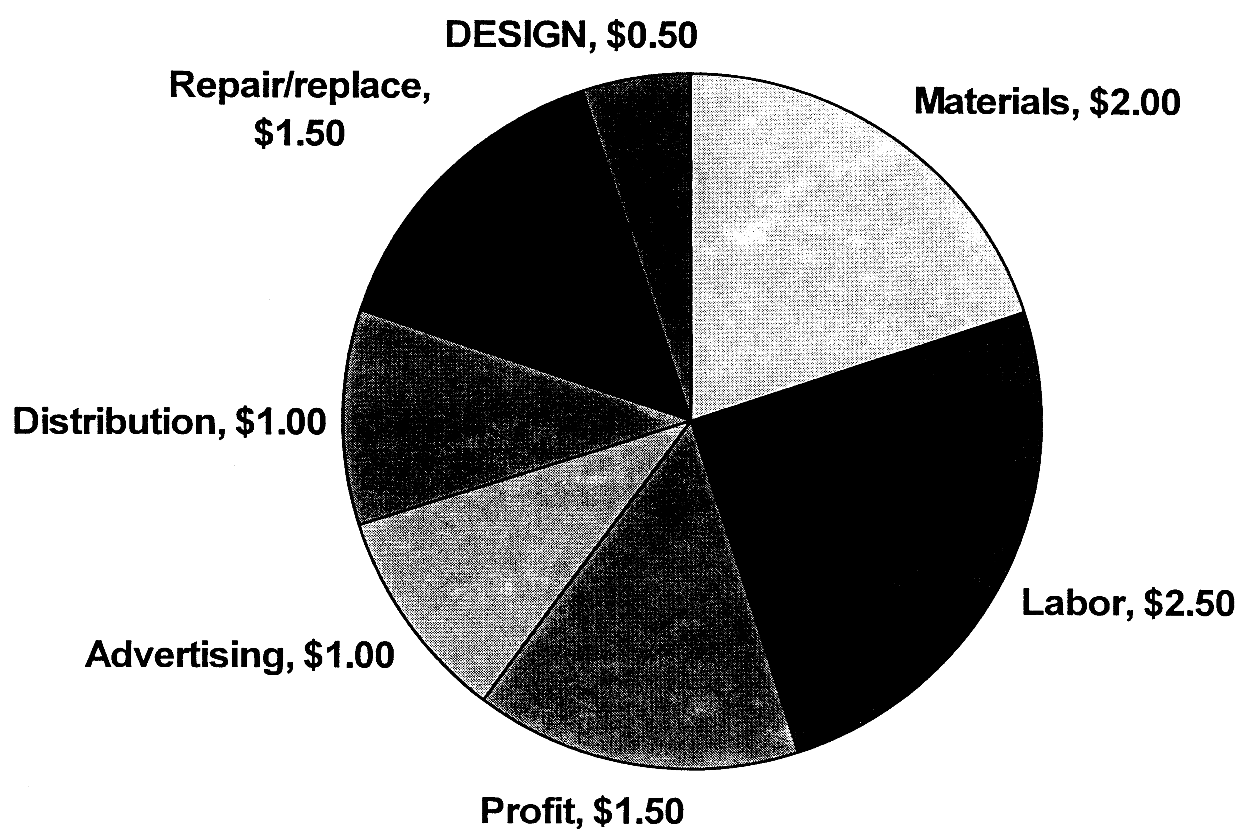


Figure 1.12 Important design parameters.

Design = meeting needs.

- Whether we are designing a toy or nanotechnology, we are striving to meet the needs of the customer, the government, ourselves, etc.
- Success depends on clearly understanding those needs
- Success also depends on our ability to understand the ***trade-offs*** involved in our designs

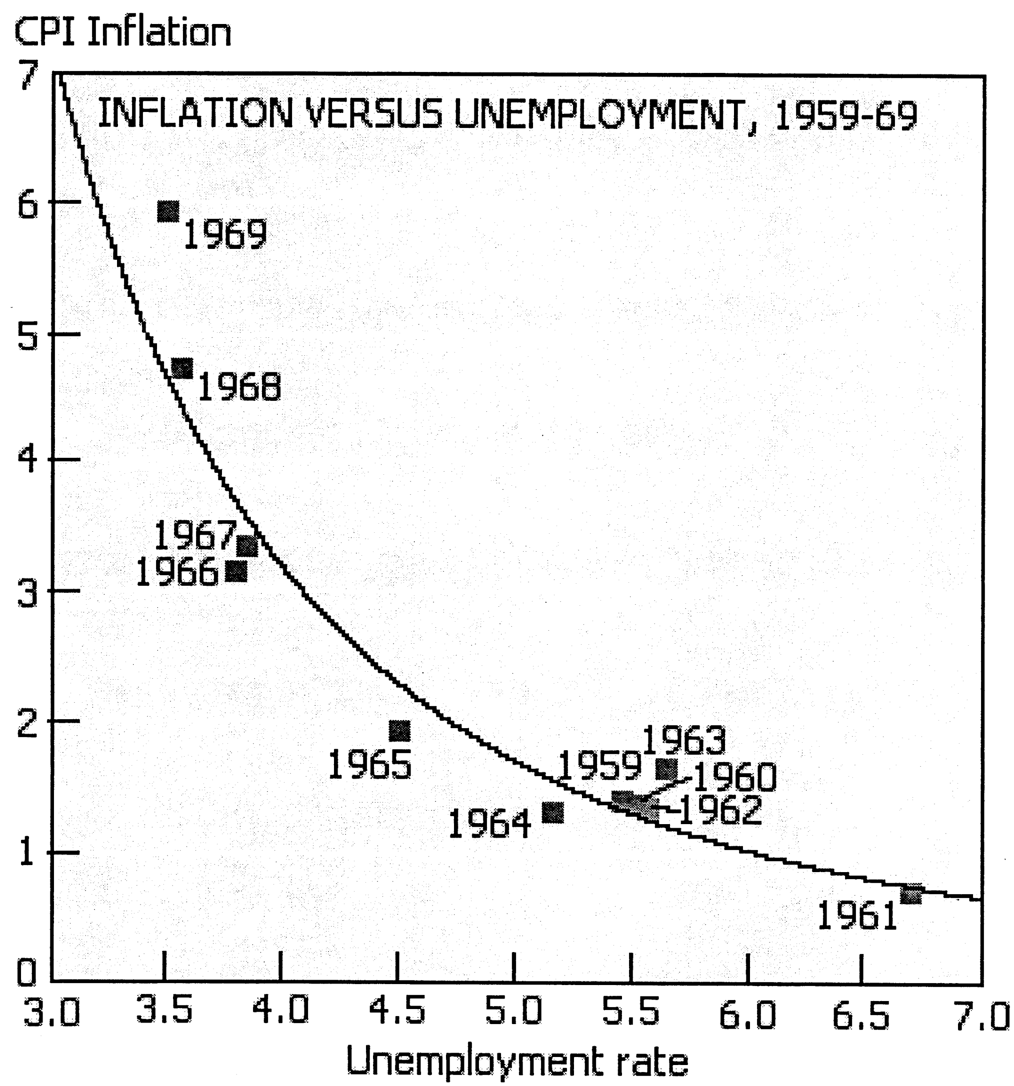
How might we typically divide up the cost of a $10.00 consumer electronics product?



How can Design affect the costs of other categories in a product price?

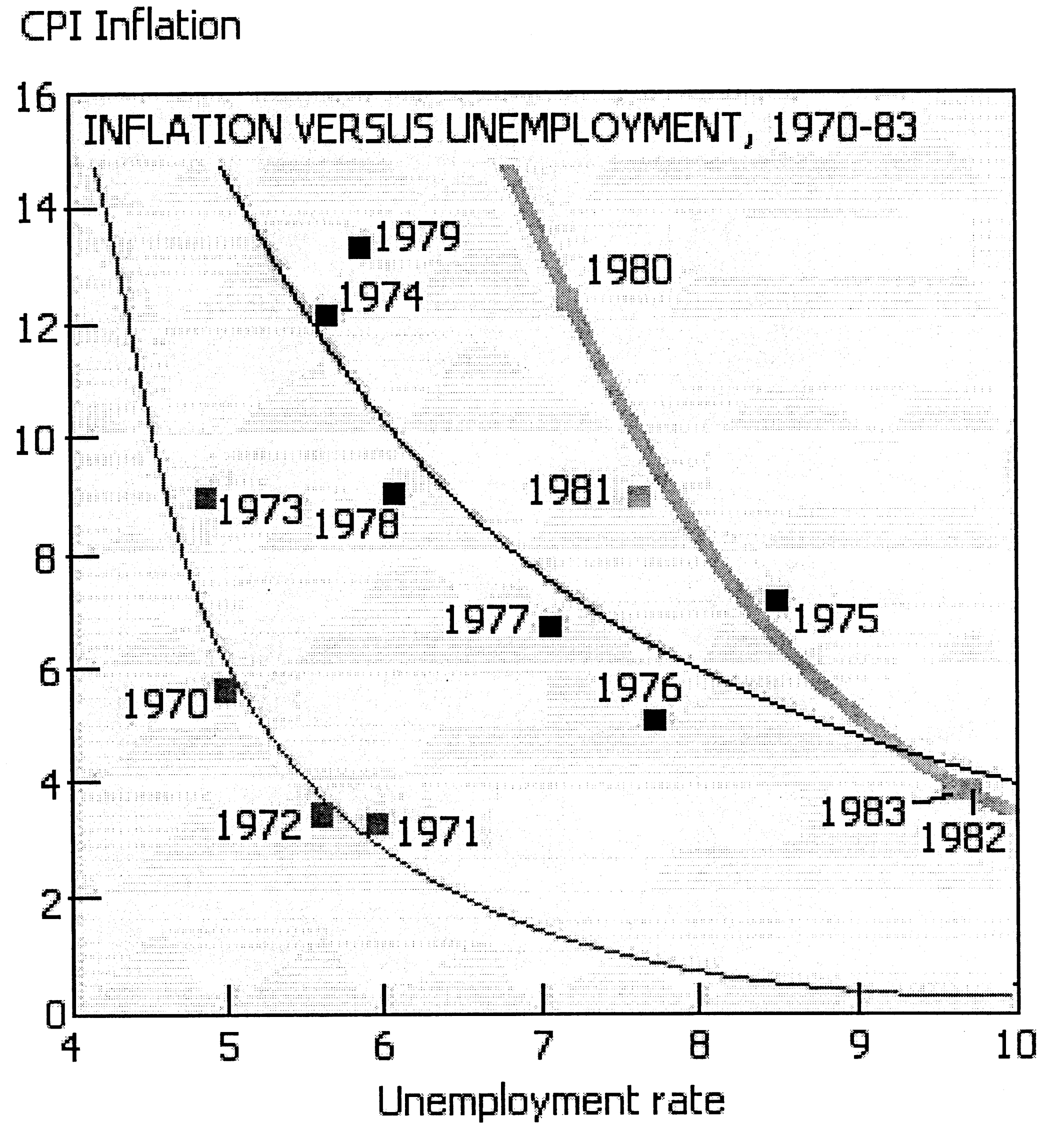
- Materials?
  - Selection of costly materials, or materials which result in more waste generation during manufacturing or high disposal costs
- Labor?
  - Difficult to assemble parts, high complexity results in higher costs
- Profit?
  - Slow design team increases “time-to-market” resulting in loss of sales
- Advertising?
  - “Ugly” design, fewer features = harder to sell!
- Distribution?
  - Bulky packaging, poor shelf life, lack of ‘robust’ design results in expensive shipping
- Repair/replacement?
  - Lack of “Design for Reliability”, quality control results in warranty costs, law suits, loss of customers

Figure 11-2.



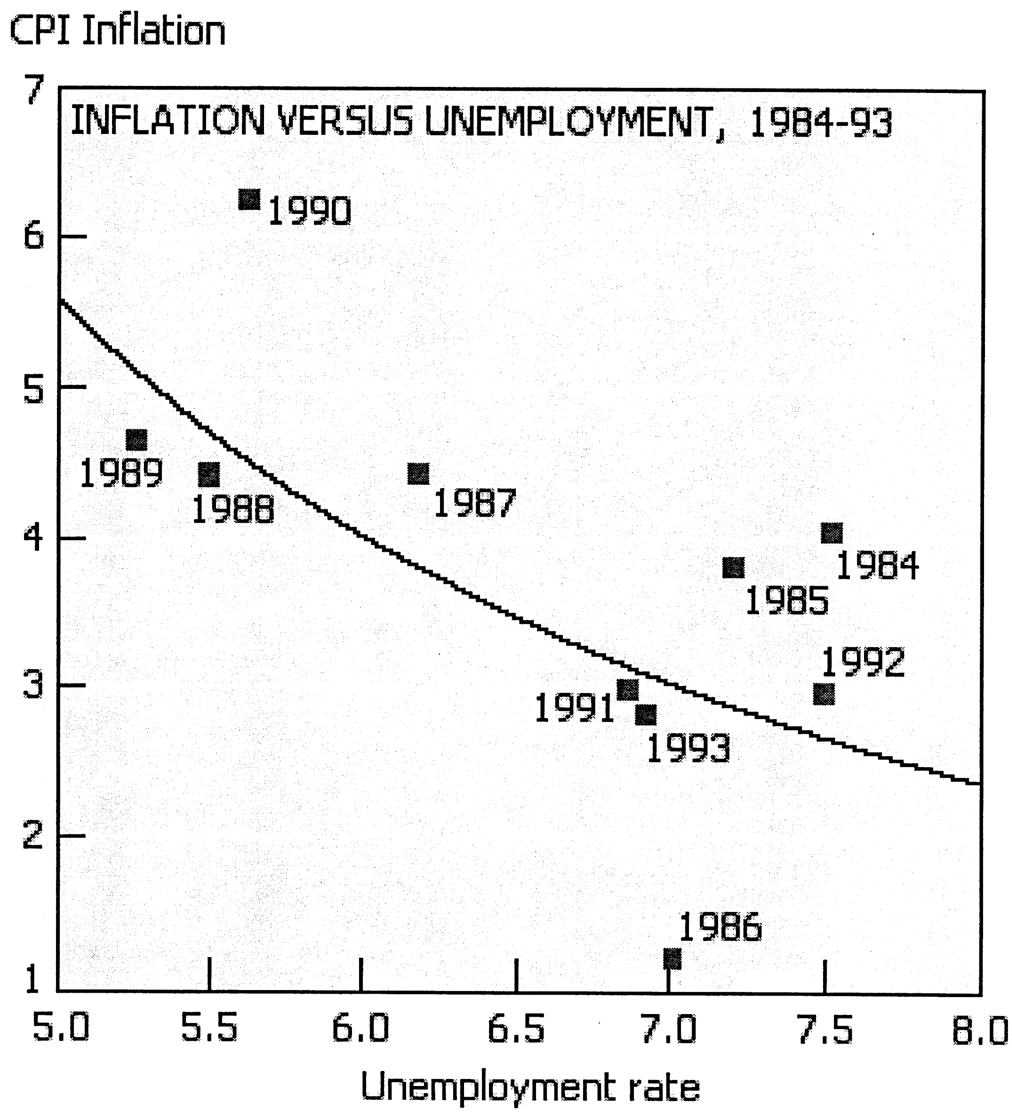
Source: *Economic Trends*, Federal Reserve Bank of Cleveland, December 1997, page 5.

Figure 11-3.



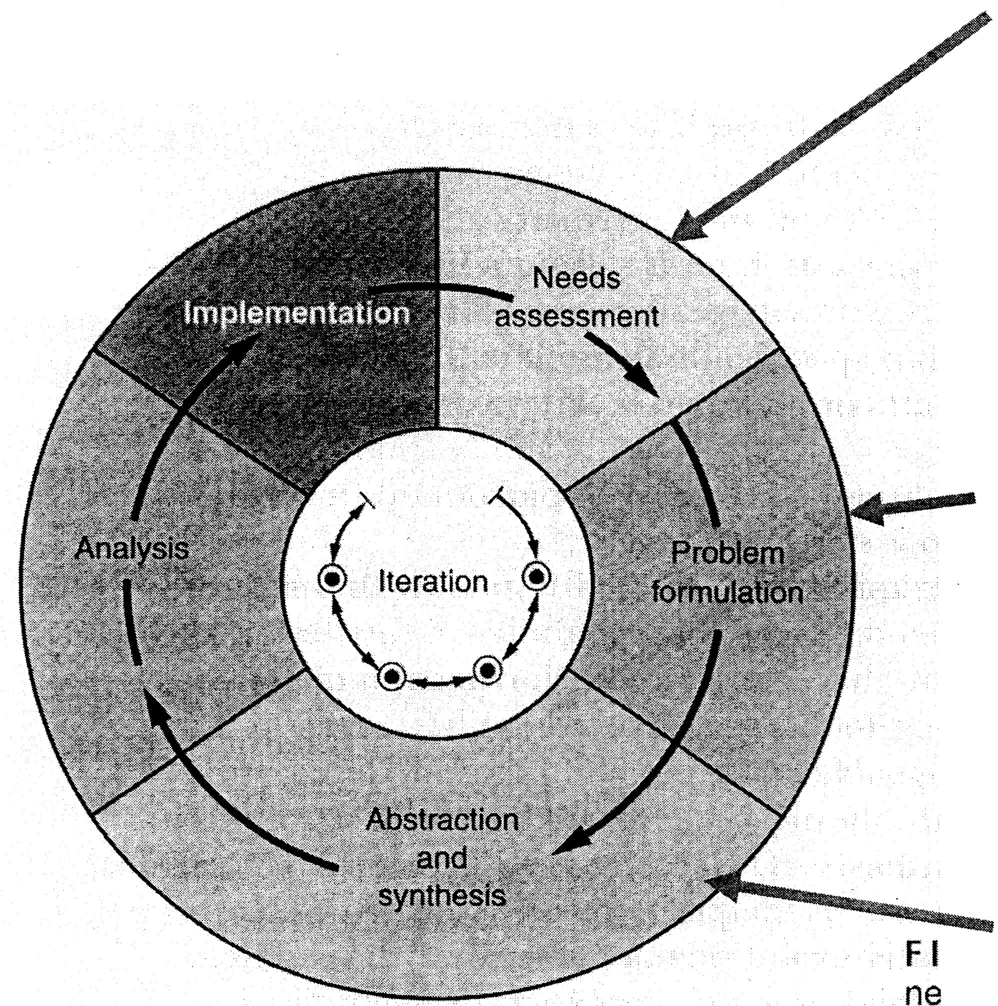
Source: *Economic Trends*, Federal Reserve Bank of Cleveland, December 1997, page 5.

Figure 11-4.



Source: *Economic Trends*, Federal Reserve Bank of Cleveland, December 1997, page 5.

The Engineering Design Process:



Begin with needs assessment:
– identify problem, stakeholders, markets, goals

Problem formulation:
– identify the ‘real’ problem (fully understanding the problem is half the work of solving it!)
-- create design specifications, based on needs and goals
-- identify resources and prioritize goals

Abstraction and synthesis:
-- Concept generation
-- Use of problem decomposition and creativity, brainstorming

The Engineering Design Process:

<u>Analysis:</u>

-- Compare and evaluate alternative designs

-- Choose basis for comparison (i.e. needs)

-- Consider ergonomics, ethics, hazards, failure modes

-- Build and test models (prototypes)

-- Optimize the results

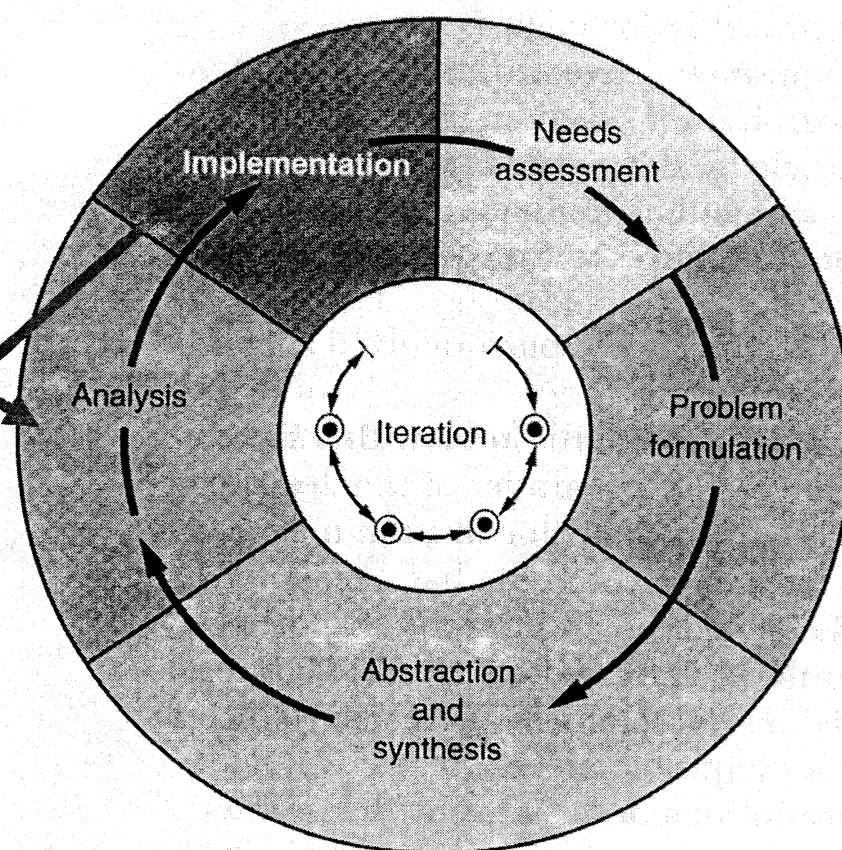
<u>Implementation:</u>

-- Develop final solution and distribute to client/customer/user

-- Beta prototype testing

-- Production ramp-up

-- Reflect on results and process for feedback to improve the design process



FI
ne

Case History 1.1: Incomplete design: The Early Quest for Manned Flight

pp. 29-34

-- haphazard

Relied on trial and error

Based on individual inspiration, but no methodical approach over the centuries (starting with manned kites in medieval China).

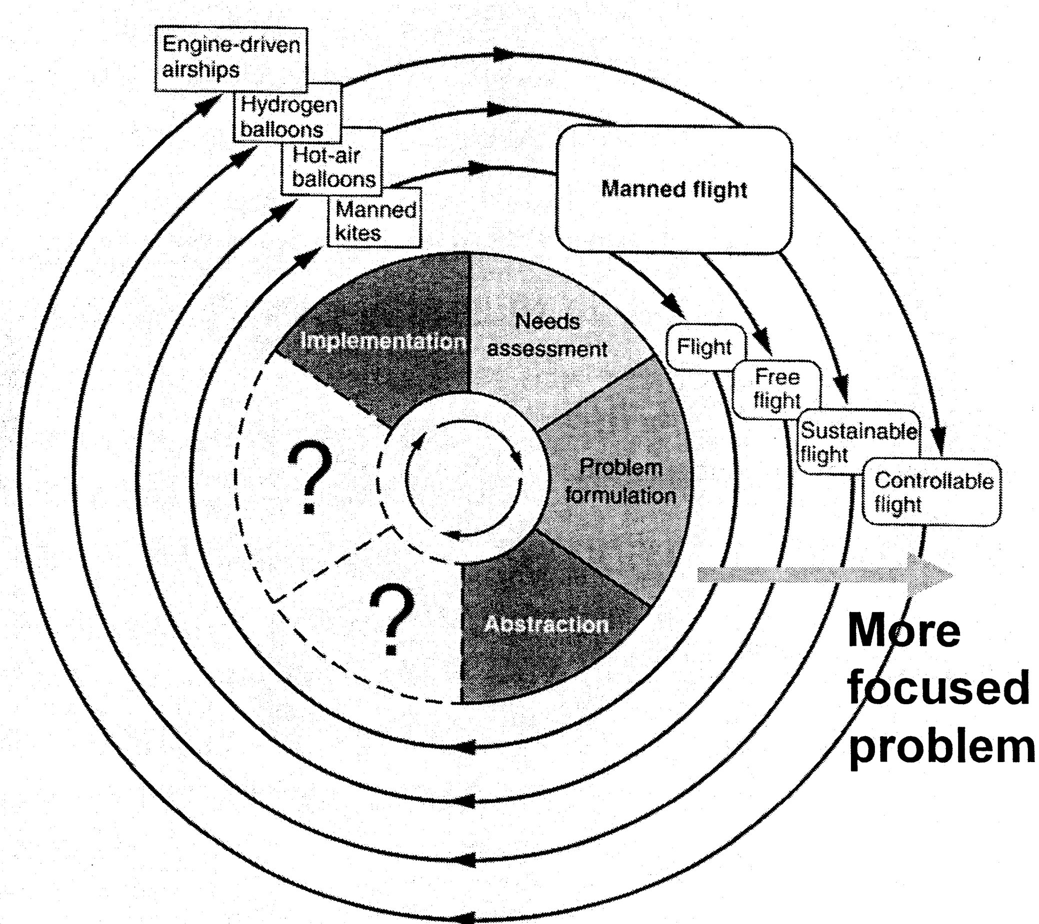


FIGURE 1.5 The use of an incomplete design process led to limited success in achieving manned flight.

Stages in early manned flight developments:

- 1200's: Manned kites in China (reconnaissance)
- 1500's: da Vinci's designs
- 1783: Montgolfer brothers hot air balloon
- 1783: Jacques Charles hydrogen balloon (unmanned)
- Nov. 21, 1783: first manned free-flight in a hot air balloon (Jean-Francois Pilatre de Rozier – also first casualty)
- 1849: Balloon crossing of the Alps, 1862 – 20,000 feet ascended
- 1852: Giffard adds steam engine to hydrogen balloon
- 1897 – 1937: Zeppelins (after ferdinand von Zeppelin) with metal frames.
- 1856: first manned glider flight (Jean-Marie le Bris)
- 1890's: Otto Lilienthal develops curved wing gliders (after birds) and attempts to add engine
- 1890: Clement Adler achieves take-off (a few inches for 160 ft.)
- 1903: Samuel Langley (govt. funded) gasoline powered plane crashes, had earlier flown unmanned version 0.75 miles.

So – after seven centuries, limited success.

Case History 1.2: Methodical Engineering Design: The Wright Brothers' Success in Manned Flight

pp. 34 - 48

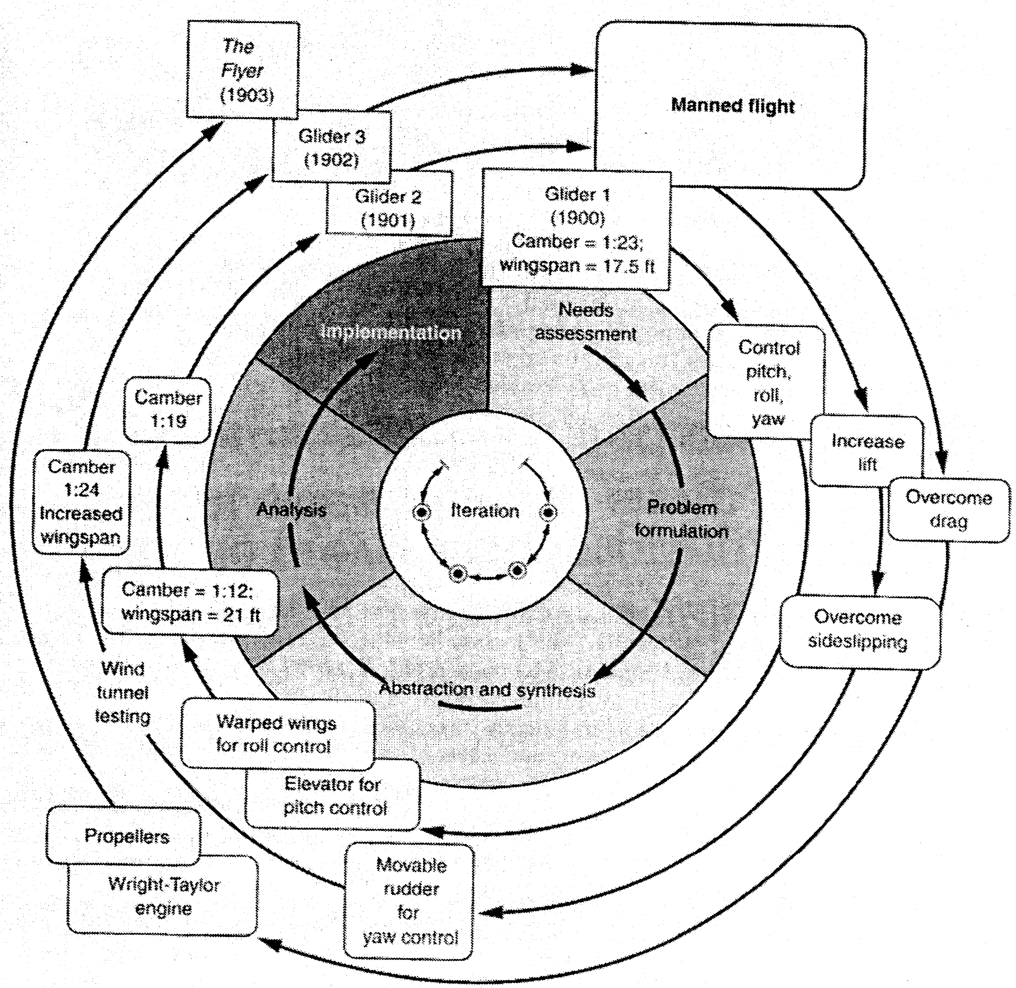
Only five years of methodical development

Studied bird flight, fluid dynamics

Used mathematical models (i.e. Lift is proportional to square of velocity times surface area of wing times a coefficient based on wing shape and curvature.)

Also account for drag and that power of the engine can be related to drag times velocity.

FIGURE 1.6 Their use of complete design process led to the Wright brothers' success.

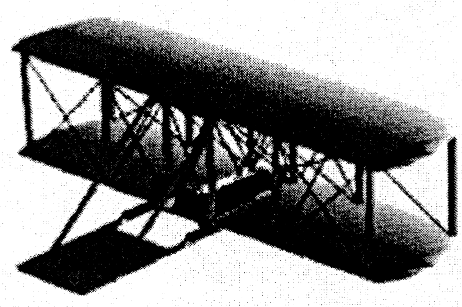


The Wright Brother's Methodical Design Process

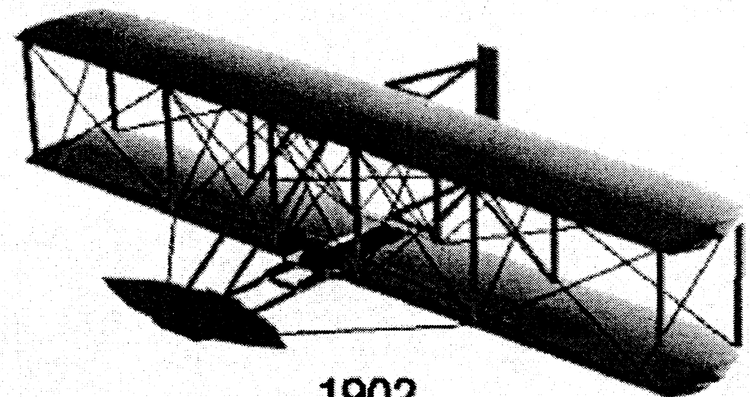
- 1900: development of gliders, calculation of lift versus velocity
- Prevent stalling by controlling rotation about the pitch axis (killed Lilienthal) – install flat horizontal elevator
- Use twisting or warping of wings to control roll (saw buzzards do this)
- Construct wind tunnel, flying 'wings' as kites to test theories (1901) – spent one year testing 200 designs, find improved value for coefficient
- 1902: use fixed vertical rudders to prevent sideslipping, but then develop a moveable one to better preevnt sideslipping in sharp turns
- 1903: After 1000 successful controlled glides, need powerful, lightweight internal combustion engine
- Developed by their mechanic, Charles Taylor (needed at least 8.4 hp but weigh less than 200 lbs. – engine developed had 12 hp and weighed only 180 lbs.)
- Wrights develop their own countrarotating, rear-mounted propellers (eliminates turbulence and torque from propellers themselves)
- Dec, 17, 1903 – first flight at Kitty hawk, NC (131 feet, 10 feet high, 12 sec.)
- Within 2 years – flew over 24 miles, non-stop

Wright Brothers' Aircraft

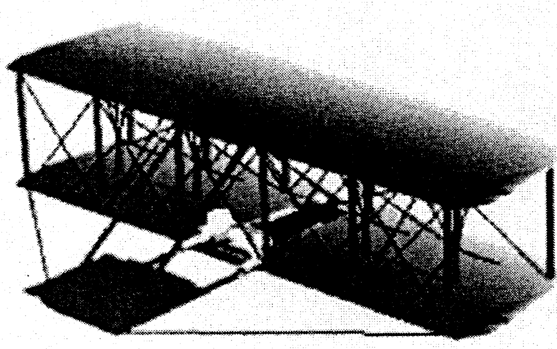
Glenn
Research
Center



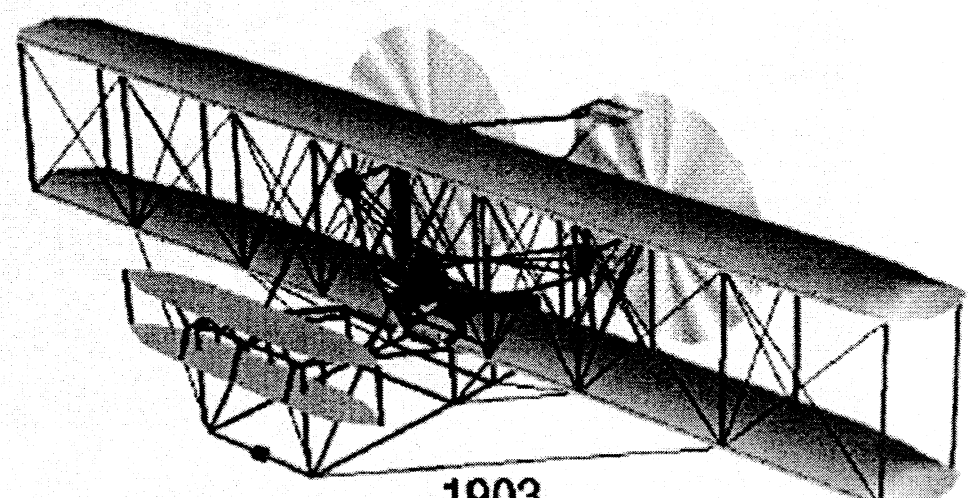
1900



1902

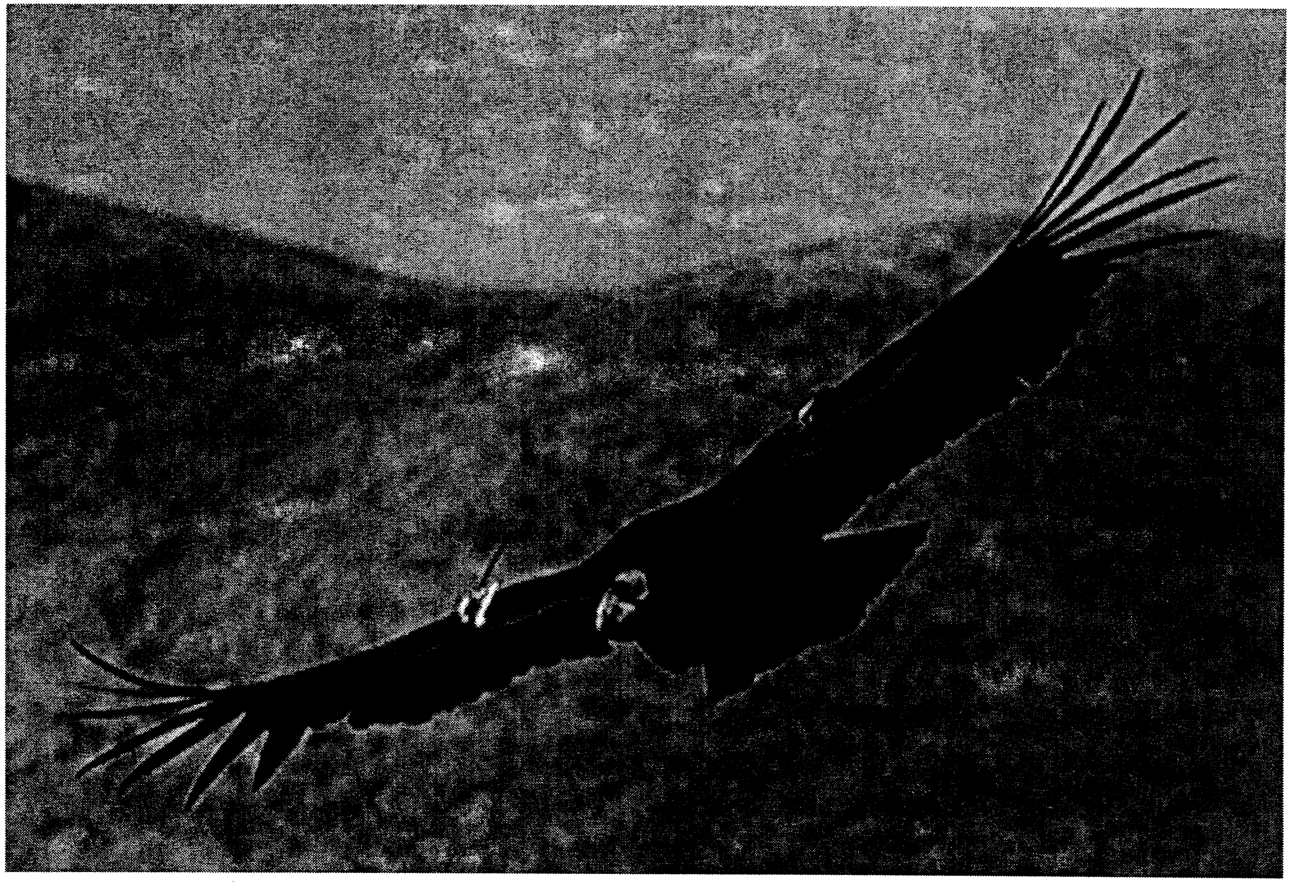


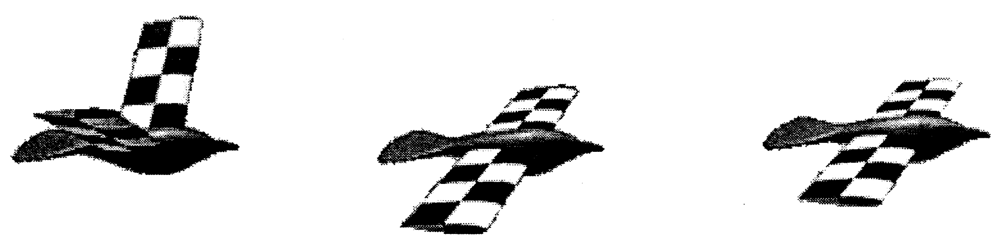
1901



1903

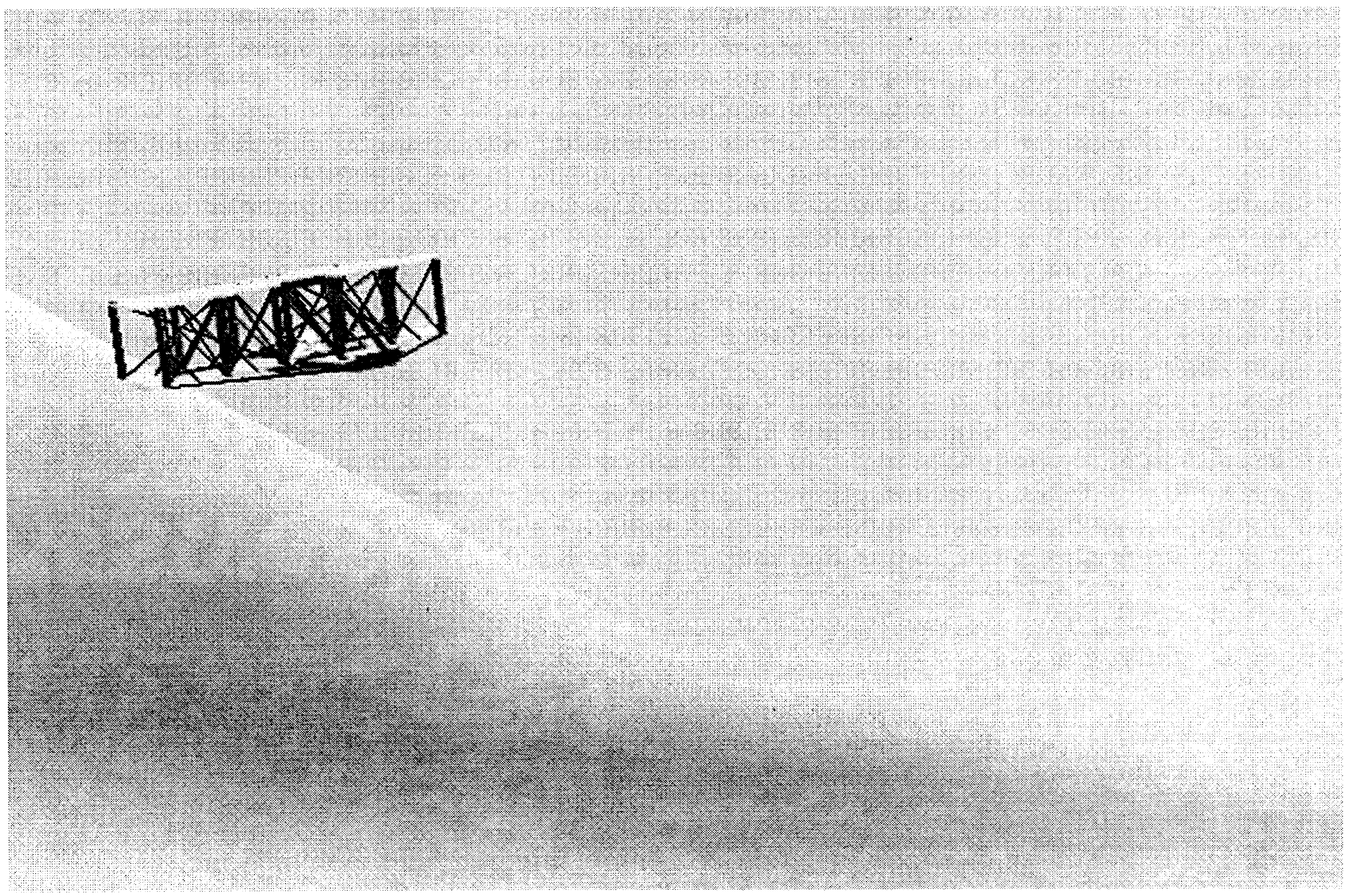
http://www.grc.nasa.gov/WWW/Wright/airplane/planes.html





http://www2.unil.ch/biomapper/opengl/BirdFlight.html#Model

The process which lead to the first successful airplane is the same process used by engineers today to solve problems. The brothers first performed a **literature search** to find out the state of aeronautical knowledge at their time. They read about the works of Cayley, and Langley, and the hang-gliding flights of Otto Lilienthal. They corresponded with Octave Chanute concerning some of their ideas. They recognized that **control** of the flying aircraft would be the most crucial and hardest problem to solve. From the observation of soaring birds, they believed that they could obtain **roll control by warping**, or changing the shape, of a portion of the wing.



CAMERON SINCLAIR, NEW YORK: Sinclair, 29, laid off from a straight architecture job, now devotes himself to raising the profile of his Architecture for Humanity nonprofit. With competitions for shelters in Kosovo and mobile AIDS clinics in Africa, he's roped in socially activist firms like Gans & Jelacic.

MARTIN FISHER, SAN FRANCISCO AND NAIROBI: Fisher, 44, a Stanford Ph.D., went to Kenya on a Fulbright in 1985. His nonprofit ApproTEC conceived a human-powered irrigation pump—think StairMaster—for struggling Kenyan farmers. Now 24,000 locals use it, increasing their income more than tenfold.

SHIGERU BAN, TOKYO: From the land of the paper house, Ban, 46, came up with an ingenious cardboard-tube shelter, with a tent top and Kirin beer-crate foundation. Each unit can be put up in six hours in disaster areas, like Kobe after the 1995 earthquake. Eventually the materials can be recycled.

Ban's cardboard-tube houses

Honor Roll

NOT EVERY GIFTED DESIGNer aspires to craft high-tech trophy houses or high-end toenail clippers. Meet some folks who make a difference.

Bargmann

JULIE BARGMANN, CHARLOTTESVILLE, VA.: Instead of the "cap and haul" approach to toxic mining and industrial areas, UVA landscape-architecture prof Bargmann, 45, favors "holistic" land reclamation. She's working with the EPA on Superfund sites.

Good Housekeeping

OK—WE ADMIT THAT CLUMSY, PLUG-UGLY kitchen gadgetry doesn't even rank among the top 100 problems of the human race. But why should cooks have to suffer when relief is right here in plain sight? Check it out.

Jenn-Air Attrezzi mixer

DON'T THAT BEAT ALL? Jenn-Air's sleek new American-designed Attrezzi (Italian for "tools") kitchenware line includes this 10-speed mixer, governed by an "innovative touch wheel." Bowls in upmarket colors—e.g., Aqua Beach, Merlot Red.

TOAST OF THE TOWN: In homage to its classic 1919 stand mixer, KitchenAid has developed a new line of neo-retro countertop appliances. This Pro Line toaster, with stainless-steel midsection, has two or four extrawide slots.

KitchenAid toaster

Oxo Good Grips scoop

THE INSIDE SCOOP: Oxo has built its rep on ergonomic correctness. Its new i-Series, by Smart Design, features an ice-cream scoop with nonstick finish, shovel-like point and hair-trigger ejection. Burns fewer calories!

The Way-Coolest New Car

TOYOTA'S SCION XB IS A BOOMBOX ON WHEELS—OR A BREADbox with six speakers and optional subwoofer. A hit in Japan, it's the ravers' ride of choice in California, the one state where it's now sold. What's up with *that*? It goes nationwide next summer.

Toyota's Scion xB

OCTOBER 27, 2003 NEWSWEEK 69