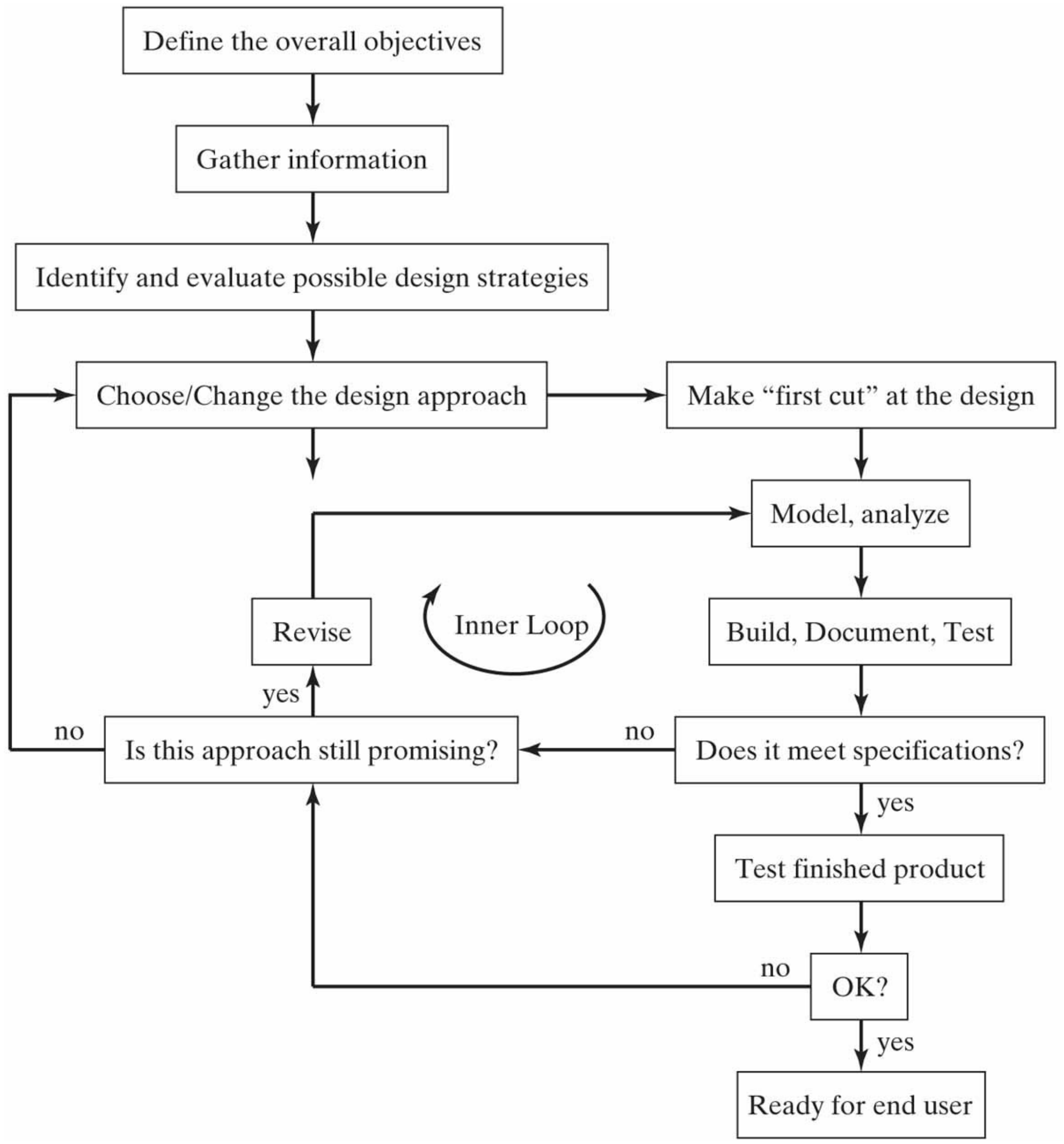
OSU Mercury Robotics

THE ENGINEERING DESIGN CYCLE

The Engineering Design Cycle

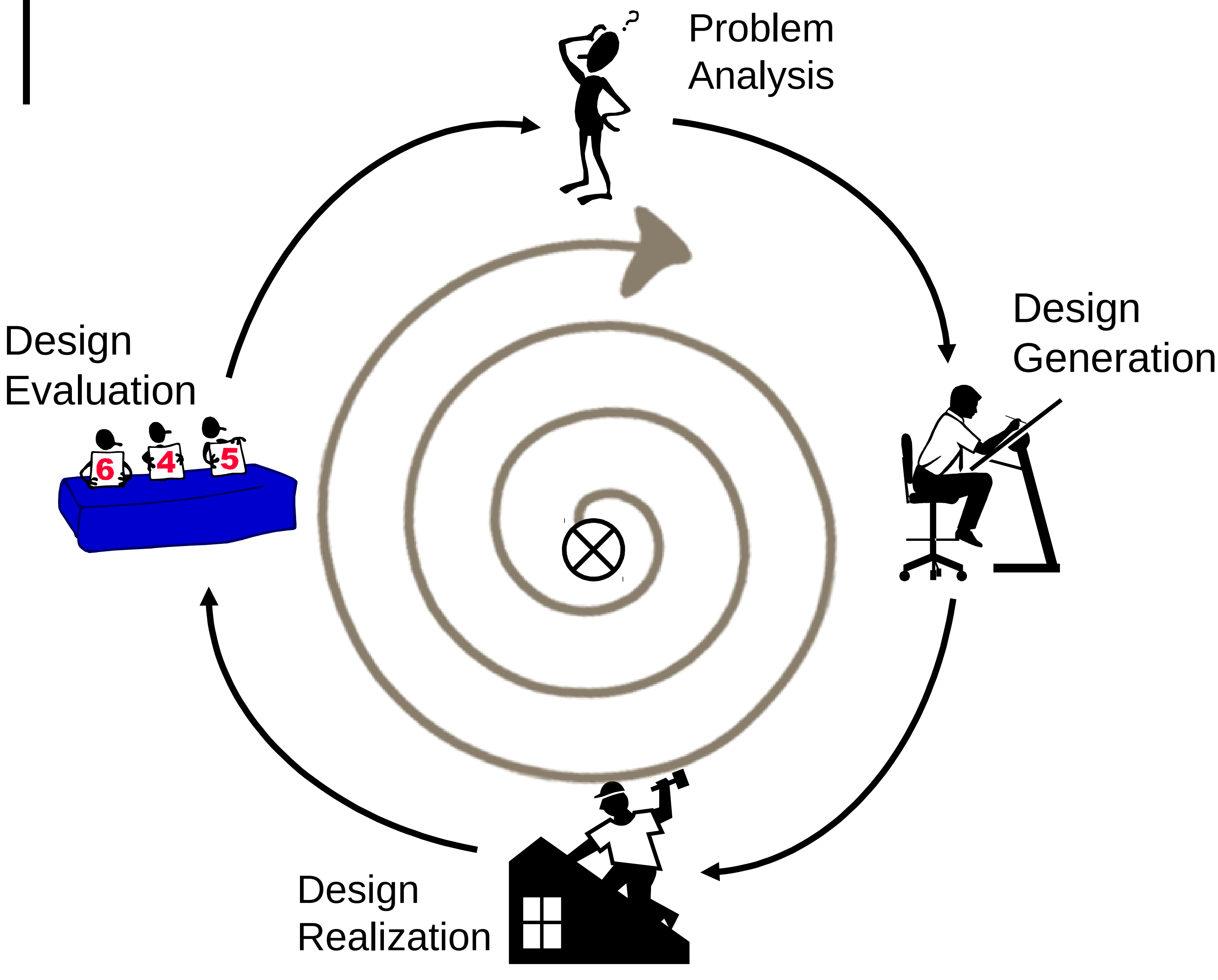
- Sequence of events from idea generation to finished product

- Flow chart representation . . .



Source: Horenstein, *Design Concepts for Engineers*

A simpler representation



Problem Analysis

- ***Goal:*** Clear and complete statement of problem to be solved.
  - Critical first step
  - What is the problem we are trying to solve?
  - What are our objectives in the design?
  - What are the constraints?
  - Have to have vs. nice to have
  - Do research – How have similar problems (or parts of the problem) been solved? What off-the-shelf components can help us?

Note: Invest the time here!!

Don’t solve the “wrong” problem!!

Problem Analysis, cont.

- ***Process***:
  - Clearly state the problem as given to us.
  - Identify all **given requirements**
    - Safety requirements, communications requirements, etc.
  - Identify additional requirements that emerge from the contest objectives, track, etc. (**“Derived” rqmts.**)
  - Prioritize from most to least important
  - Translate to Technical Requirements

Design Generation

- ***Goal:*** Come up with multiple candidate solutions for the problem and select "best" to carry forward.

- Techniques include:
  - Brainstorming (individual & group)
    - Some "guidelines"
      - No holding back – any idea, any time
      - No boundaries – no idea is "too crazy"
      - No criticizing – don't critique until the final discussion
      - No dismissing – don't discount an idea
      - No limit – one more idea is always good
      - No restrictions – draw from any field of experience
      - No shame – no one should ever be made to feel embarrassed about an idea

Design Generation

❖ ***Goal:*** Come up with multiple candidate solutions for the problem and select "best" to carry forward.

- Techniques include *(cont.):*
  - Benchmarking
    - How have other people solved the problem? (Don't reinvent the wheel!)
  - Back of Envelope analysis
    - Quick check using very simplified model to estimate performance
  - Tradeoff Analysis
    - Which idea will work "best"?
    - Weighted decision matrices can be helpful!

Design Generation
Weighted Decision Matrices

- To make confident and rational decisions when you have multiple options and multiple factors to take into account.
  - Step 1: List each option as a column heading and each factor/criteria as a row.
  - Step 2: Assign a "weight" to each criteria based on its relative importance.
  - Step 3: Work through the table, giving a *raw score* to each option for each criteria.
  - Step 4: Multiply raw scores by weights.
  - Step 5: Add up the *weighted scores* for each option and look for the highest.

Decision Matrix Example

Weighted Decision Matrix Example

	Concept	A		B		C		D		E	
Criteria	Weight	Raw	Wtd	Raw	Wtd	Raw	Wtd	Raw	Wtd	Raw	Wtd
I	1										
II	1.5										
III	1										
IV	2										
V	3										
		Totals:									

Scale for Weight Values:

4 Critical importance

3 High importance

2 Medium importance

1 Low importance

0 Minimum importance

Decision Matrix Example

Weighted Decision Matrix Example

	Concept	A		B		C		D		E	
Criteria	Weight	Raw	Wtd	Raw	Wtd	Raw	Wtd	Raw	Wtd	Raw	Wtd
I	1	2		3		1		0		2	
II	1.5	1		1		3		3		3	
III	1	4		4		3		4		2	
IV	2	2		2		4		2		3	
V	3	1		2		1		4		2	
		Totals:									

Scale for Weight Values:

4 Critical importance
3 High importance
2 Medium importance
1 Low importance
0 Minimum importance

Scale for Raw Scores:

4 Far exceeds requirement
3 Exceeds requirement
2 Meets requirement
1 Minor deficiencies
0 Does not meet requirement

Decision Matrix Example

Weighted Decision Matrix Example

	Concept	A		B		C		D		E	
Criteria	Weight	Raw	Wtd	Raw	Wtd	Raw	Wtd	Raw	Wtd	Raw	Wtd
I	1	2	2	3	3	1	1	0	0	2	2
II	1.5	1	1.5	1	1.5	3	4.5	3	4.5	3	4.5
III	1	4	4	4	4	3	3	4	4	2	2
IV	2	2	4	2	4	4	8	2	4	3	6
V	3	1	3	2	6	1	3	4	12	2	6
		Totals:	14.5		18.5		19.5		~~24.5~~		20.5

Scale for Weight Values:

- 4 Critical importance
- 3 High importance
- 2 Medium importance
- 1 Low importance
- 0 Minimum importance

Scale for Raw Scores:

- 4 Far exceeds requirement
- 3 Exceeds requirement
- 2 Meets requirement
- 1 Minor deficiencies
- 0 Does not meet requirement

Another Example

	A	B	C	D	E	F	G	H
1	Options (Alternatives)							
2	Citeria	Weighting	Vehicle A		VehicleB		Vehicle C	
3			Rating	Total	Rating	Total	Rating	Total
4	Purchase Price	5	6	30	4	20	3	15
5	Fuel Consumption	6	3	18	4	24	2	12
6	Reliability	4	4	16	4	16	5	20
7	Available Space	3	3	9	4	12	5	15
8	Engine Power	2	2	4	4	8	6	12
9	Total			77		80		74

Weighted Decision Matrix

source: https://www.infonautics.ch/blog/decision-matrix/

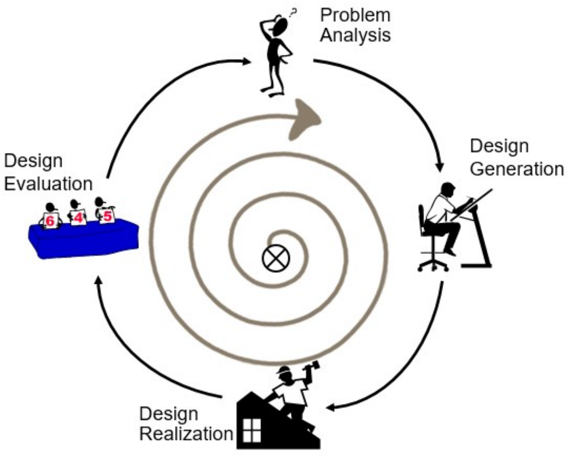
Another Example

A decision matrix for a self-administered syringe

Selection Criteria	Weight	CONCEPTS					
		A (reference) Master Cylinder		DF Lever Stop		E Dial Screw	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Ease of Handling	5	3	0.15	3	0.15	4	0.2
Ease of use	15	3	0.45	4	0.6	4	0.6
Readable settings	10	3	0.3	3	0.3	5	0.5
Dosage accuracy	25	3	0.75	3	0.75	2	0.5
Durability	15	3	0.45	5	0.75	4	0.6
Manufacturability	20	3	0.6	3	0.6	2	0.4
Portability	10	3	0.3	3	0.3	3	0.3
Total Score			3.00		3.45		3.10
Rank			3		1		3
Continue?			No		Yes		No

source: http://deseng.ryerson.ca/~fil/t/oldT/concept/evaluation1.html

Design Realization



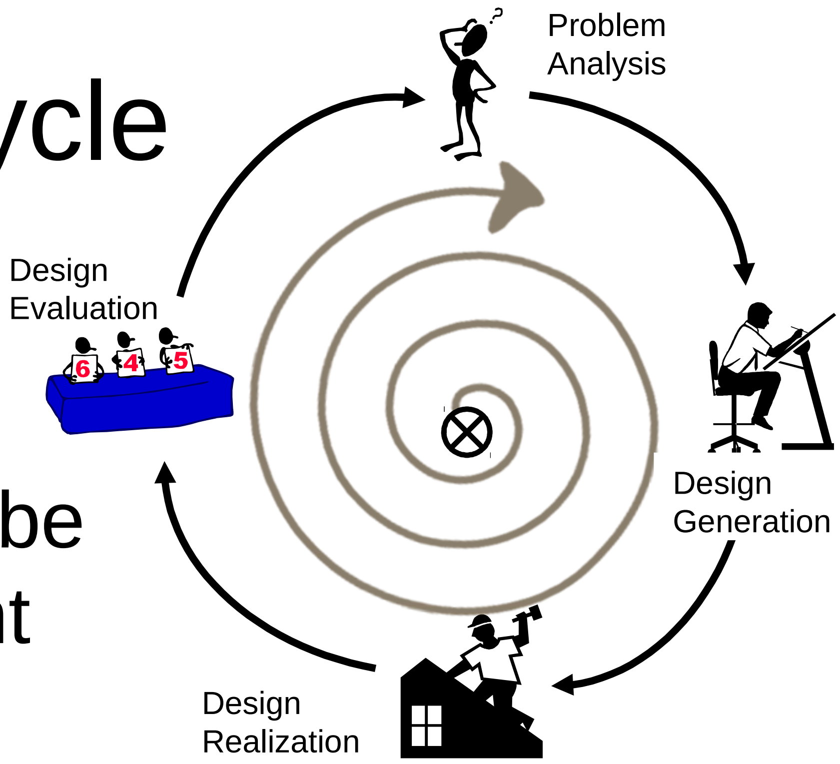
- Modeling / analysis / simulation
- Create a working prototype (if practical)
  - Needs to function, doesn't have to be pretty.
  - Use materials that are easy to work with.
  - Later prototypes may come very close to final design.
- Document throughout the process
  - What worked, what didn't work, design modifications, etc.

Design Evaluation

- Test thoroughly!
- Does it work?
- Meets all technical specifications?
- Assess performance in different conditions and scenarios.
- Repeat the design cycle if problems are discovered.

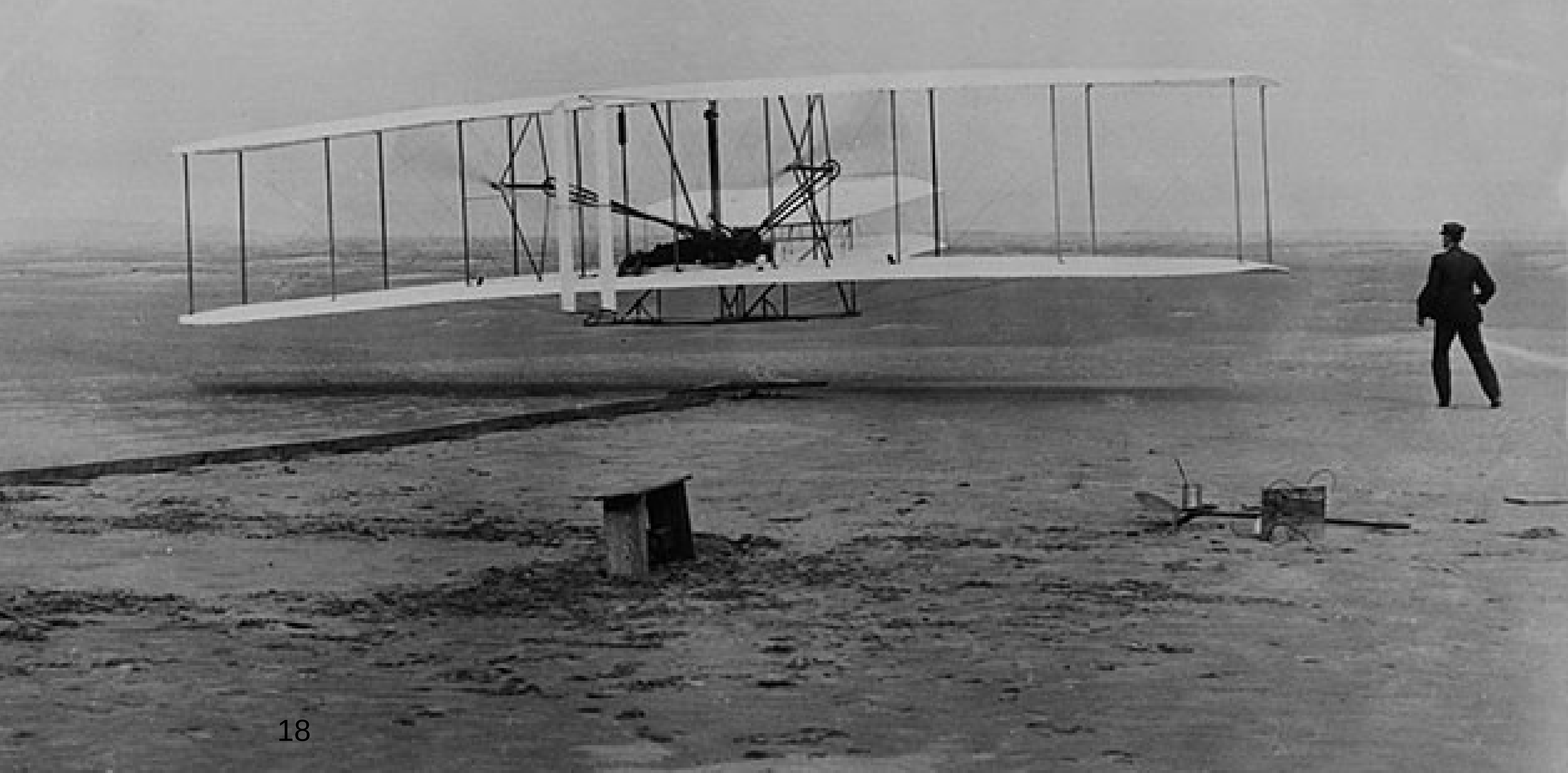
The Design Cycle

- Design is an iterative process!
- Final product may be completely different than what was initially envisioned.
  - Prepare for failure –
    - Don’t be discouraged! Failure is a normal part of the design process, and it is how we learn the most!

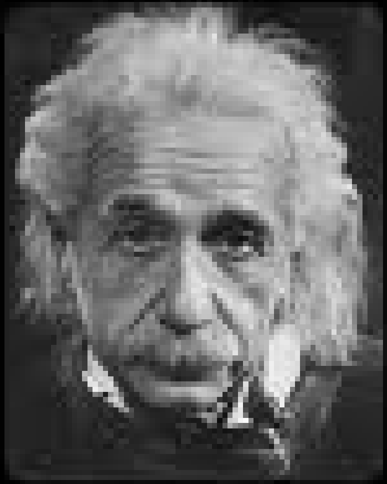


If you are looking for perfect safety you will do well to sit on a fence and watch the birds; but if you really wish to learn you must mount a machine and become acquainted with its tricks by actual trial.

Wilbur Wright



“No problem can be solved from the same level of consciousness that created it.”



- Albert Einstein