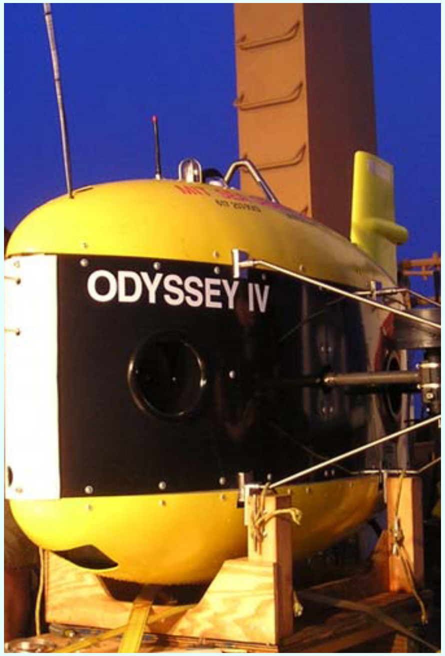
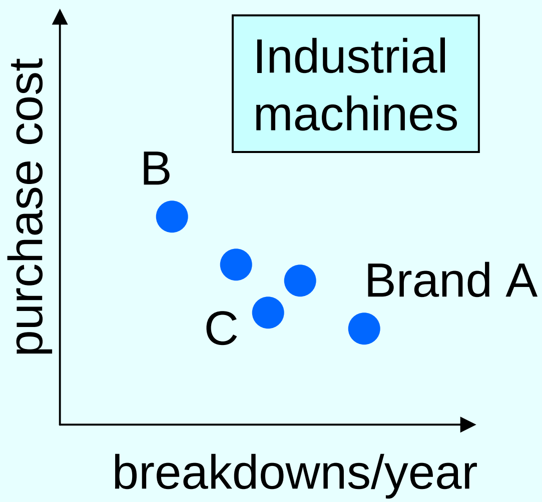
CONCEPTS OF DESIGN

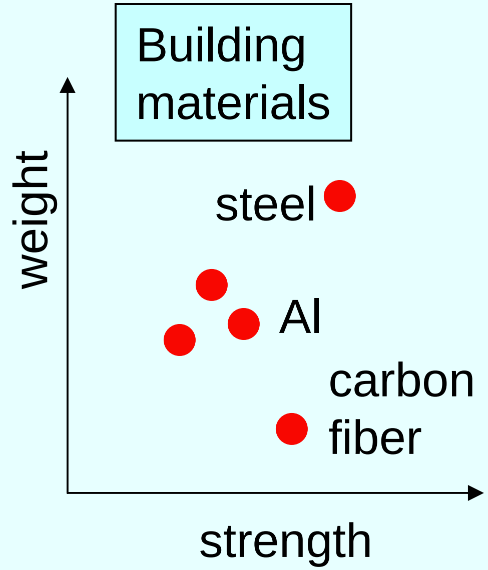


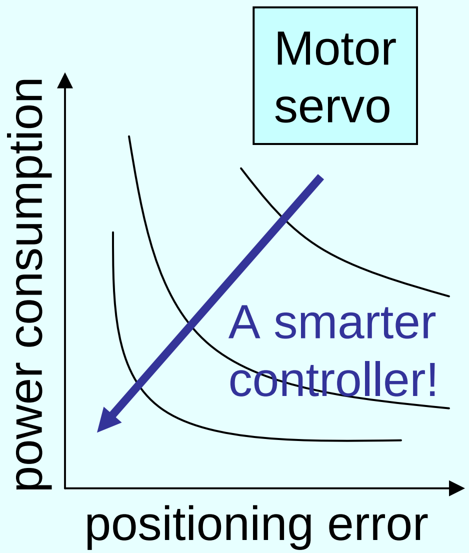

Yours truly, as a high-school senior!

Tradeoffs

- Everything interesting that you do in LIFE and in DESIGN is a tradeoff – *getting what you want at the expense of something else*.





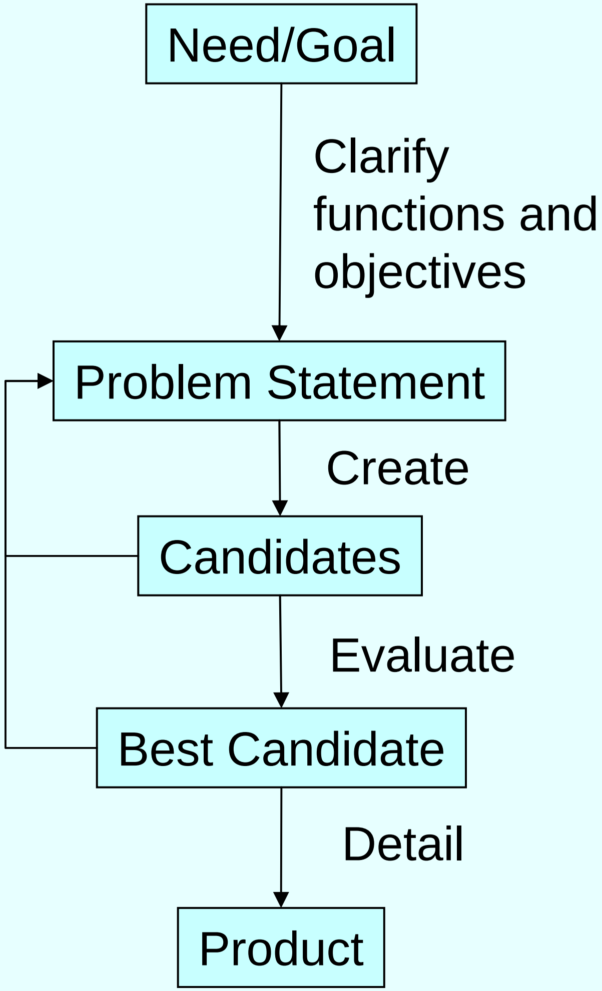


Old vs. used?
Maintenance?

Cost? Fatigue?
Heterogeneous?
Finish? Corrosion?

Complexity?
Robustness? Cost?

- Design is a process of
  - Understanding the problem
  - Creating solutions
  - Evaluating solutions
    - *Crucial role of modeling and testing*
  - Refining and revising
  - Detailing the design



DOCUMENTATION THROUGHOUT !

Other Views of Design …

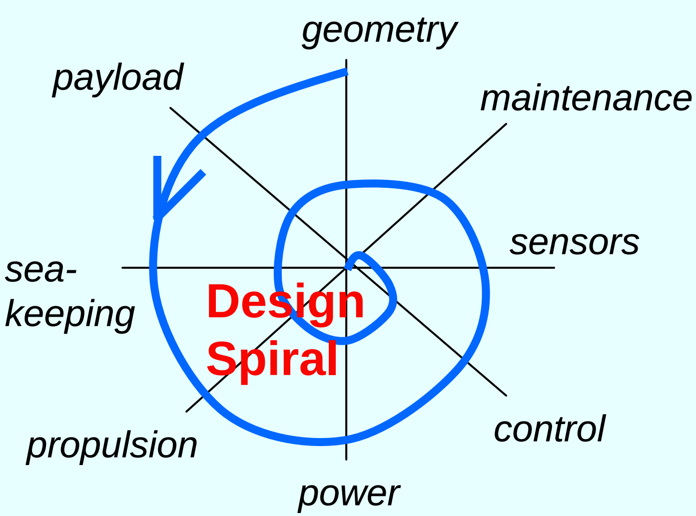
“classwork” **Math, Science, Engineering Fundamentals**

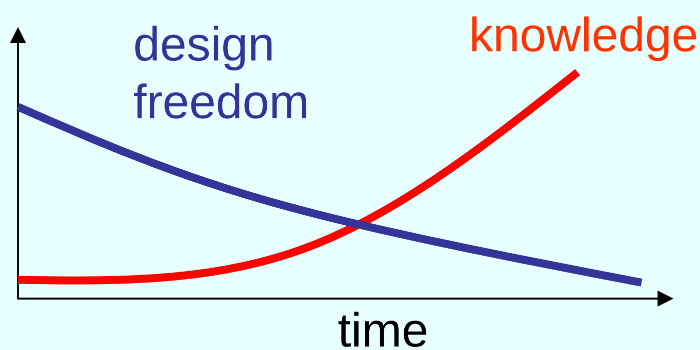
Practical Knowledge “hands-on” “what works”

“formal” “modeling” **Quantitative Design Analysis, Optimization**

Pragmatic Design Analysis “organization” “planning”

Product





The Objectives Tree

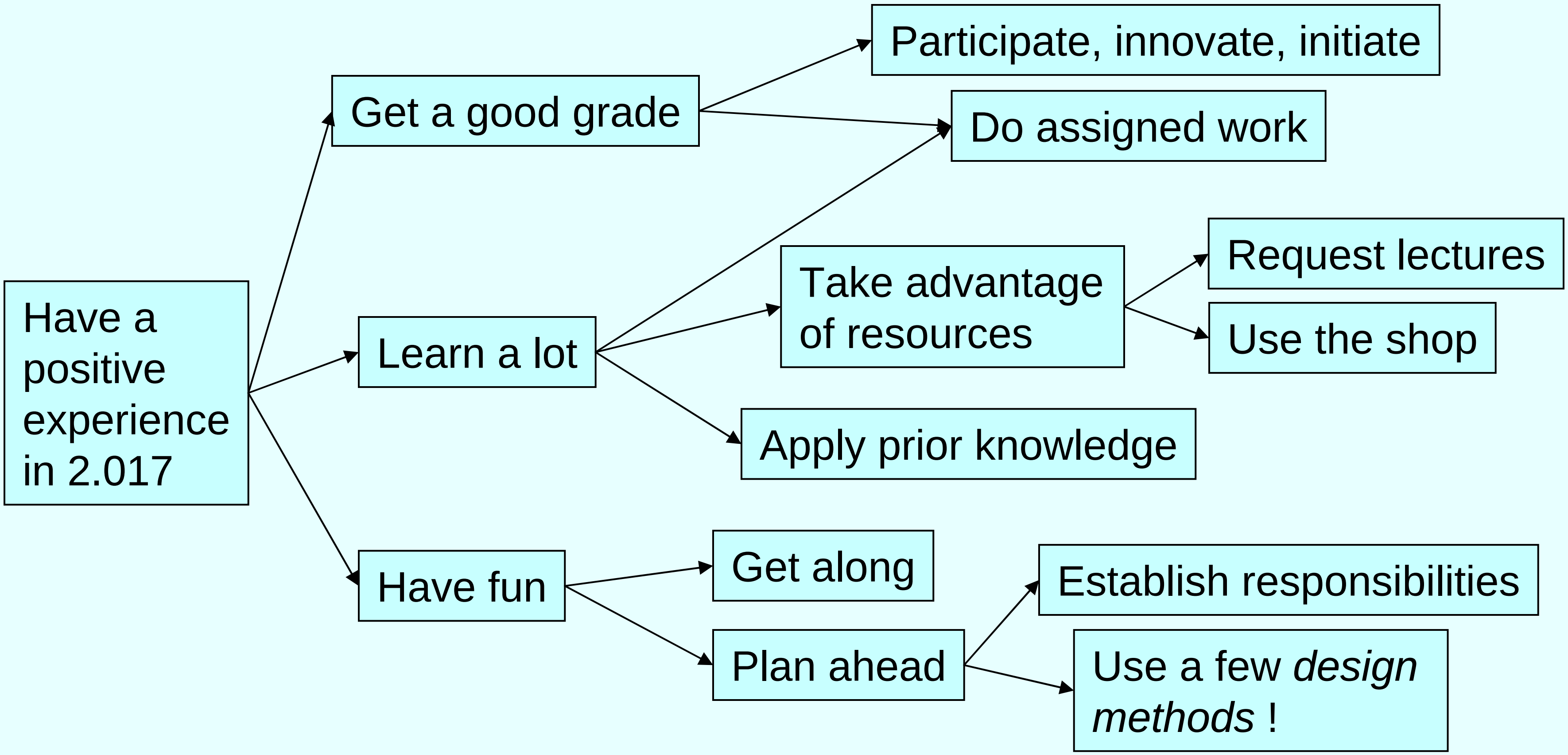
The FSH Objectives Tree

Broad objectives…

→ *HOW ?* →

← *WHY ?* ←

… Specific objectives



A Decision Matrix: Flettner Rotorship

What is the impact of these ENGINEERING ATTRIBUTES, relative to REQUIREMENTS?

A: High rotary speed B: Large rotor diameter C: Stiff inner structure

D: Number of rotors E: Height of rotor

REQUIREMENTS	Weighting	A	B	C	D	E
Propels the boat	40	2	2	0	2	2
Robust to damage	10	-1	0	2	-1	-1
Easy to fabricate	30	-1	0	-1	-1	-1
High boat stability	20	0	-1	-1	0	-2
Weighted sums:		**40**	**60**	**-30**	**40**	**-40**

- Attribute B (a large rotor diameter) is **most important** to meeting the requirements.
- Attributes C and E (stiff inner structure, tall rotors) have **negative** impact on meeting the requirements.
- The calculation helps identify and document priorities and the direction of the design.
- It suggests areas where further clarification of requirements or attributes is needed.
- Related to “House of Quality” and “Quality Function Deployment”

Knowledge vs. Confidence

Photo removed due to copyright restrictions.

Knowledgeable but probably not confident at the moment – his vehicle just went into the ocean for the first time!

- Knowledge about an idea and confidence in it are <u>not</u> the same thing!
- *Target*: a specification, criterion, requirement
- *Idea*: one possible solution
- A measure of <u>knowledge</u>: what is the probability of you getting a true/false question right about the idea?

  Clueless: K = 0.5 *Expert: K = 1.0*

- A measure of <u>confidence</u>: what is your certainty that the idea will meet the target?

  Impossible → Doubtful → Likely → Perfect

  C = 0.0 C = 0.3 C = 0.7 C = 1.0

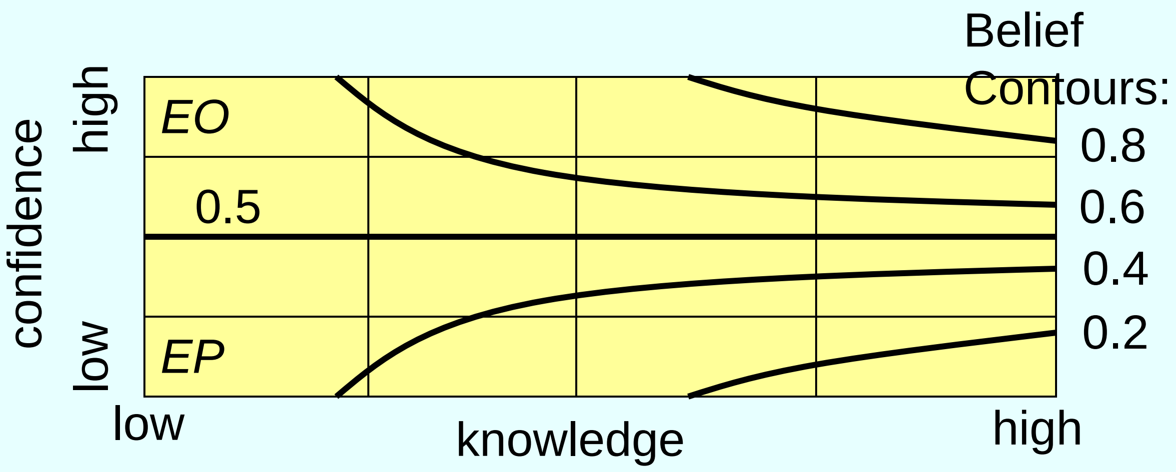
  Confidence is subjective!

Combine Knowledge and Confidence: Belief

- A measure of belief: confidence that an idea meets the target, based on current knowledge.
- *Using the above numerical values and Bayesian analysis, Ullman (2001) computes*

$$\textbf{\textit{Belief = 2KC - K - C + 1,}}$$

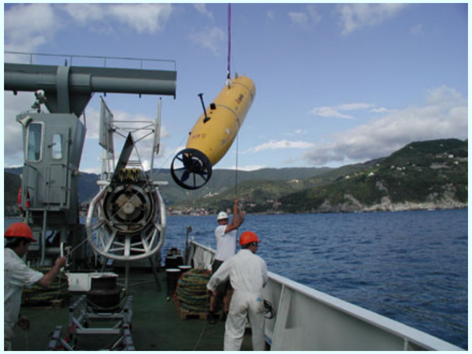
leading to a "belief map" →



Decisions should be based on a high level of belief – you have to have knowledge of the idea AND confidence that it meets the target

Function Analysis

Robot and docking mechanism



<u>Flow-Chart</u>: Algorithm design, Processes

Drive robot toward target

Range rate?

–

+

Go in a straight line for one minute

Turn around

0

Captured!

Autonomous underwater vehicle homing to an acoustic beacon

<u>Layered Functions</u>: A complex system having multiple functions

Allows a person to write and edit words or images on paper

Similarity to objectives tree

Makes mark on paper

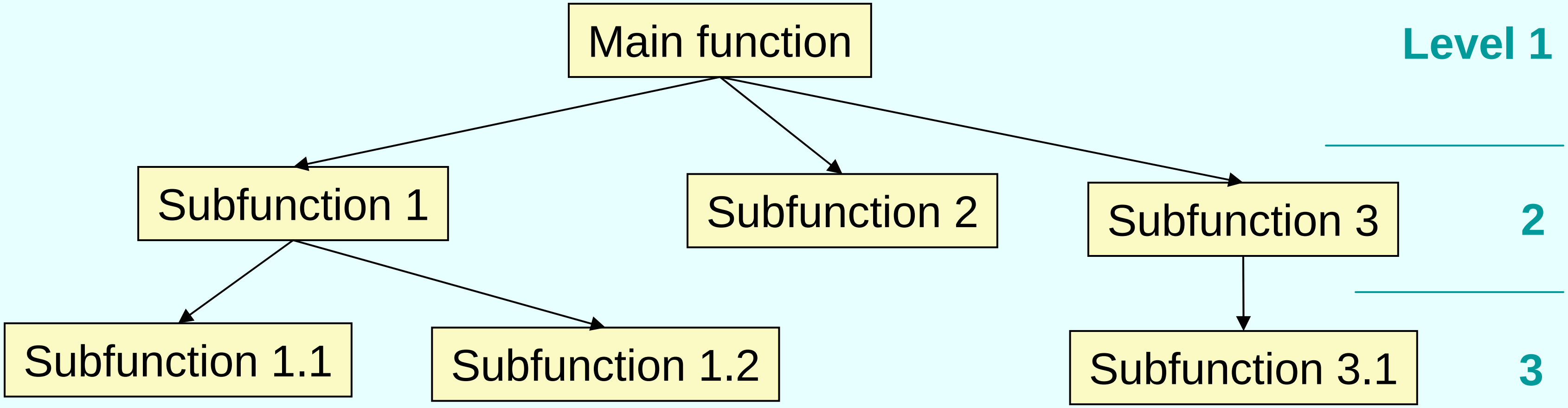
Fits in hand comfortably

Erases own marks

Fluid mechanics rig at the
MIT Testing Tank

Understanding Complexity

- Complexity is often what causes the hardest problems – and solutions that are time-consuming and expensive.
- High costs of errors once a product is out the door.
- Piecemeal vs. Holistic design.
- Fundamental rules of design – e.g. grounding & isolation, stainless steel, well-known vendors, etc.
- Basic rule: Layered Sub-functions ➔ Complexity.



How many functions does a <u>car door</u> serve?

Why does it take so long!?

Autonomous kayak in Singapore Harbor – lots of functions but not <u>too</u> many subfunctions

Person-hours design effort can be estimated as

H = A * B * C where

A = a constant depending on communication and size of engineering group: values typically in the range 30-150 in commercial world – it may be lower or higher for students!

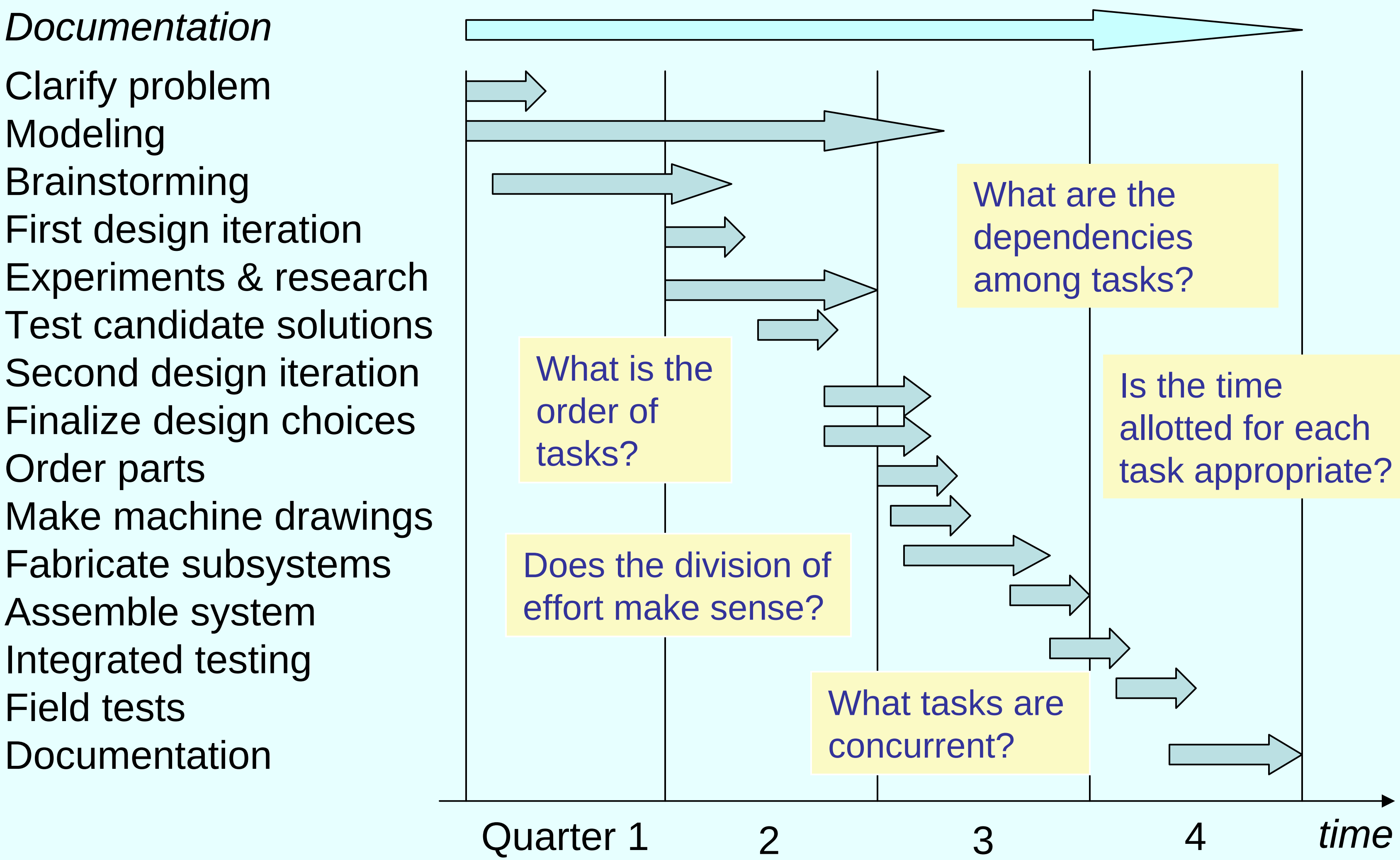
B = sum of products of level number and number of subfunctions at that level (1+6+9 = 16 in figure above).

C = difficulty (1 is easy – known technologies, 3 is hard – many unknown technologies)

→ *Even a seemingly simple project easily runs into thousands of hours @#$%^&**

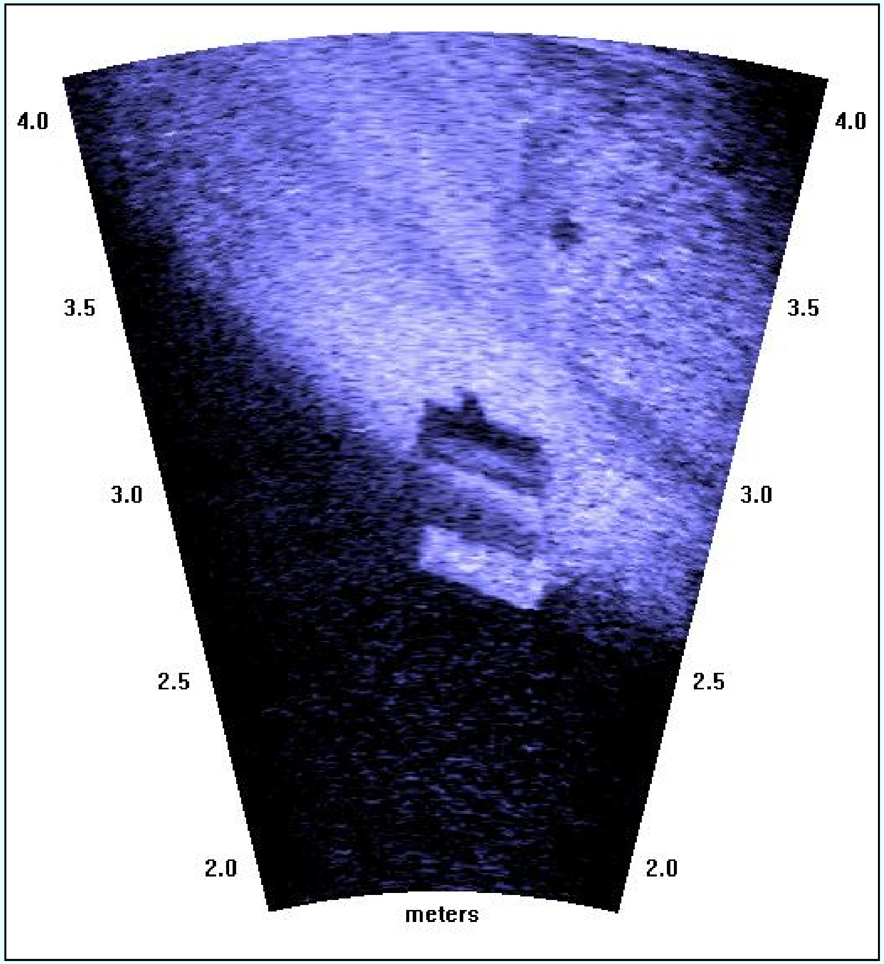
→ *Role of complexity should be kept in mind when milestones are defined and set*

Gantt Charts: a Graphical Schedule



A Few References…

- D.G. Ullman. The mechanical design process (Third edition). New York: McGraw-Hill. 2003.
- N. Cross. Engineering Design Methods: Strategies for product design (Third edition). New York: Wiley. 2000.



Acoustic image of a metal box on the bottom of a barge, taken from an autonomous underwater vehicle, June 2007.

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