The Engineering Design Process

MET 352

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The Engineering Design Process

- What is design?

Webster's Dictionary: To fashion after a plan

Establish and define solutions to, and pertinent structures for, problems not solved before, or new solutions to problems that have previously been solved in a different way

Research – Conceptualization –
Feasibility – Requirements –
Design – Produce

The Engineering Design Process

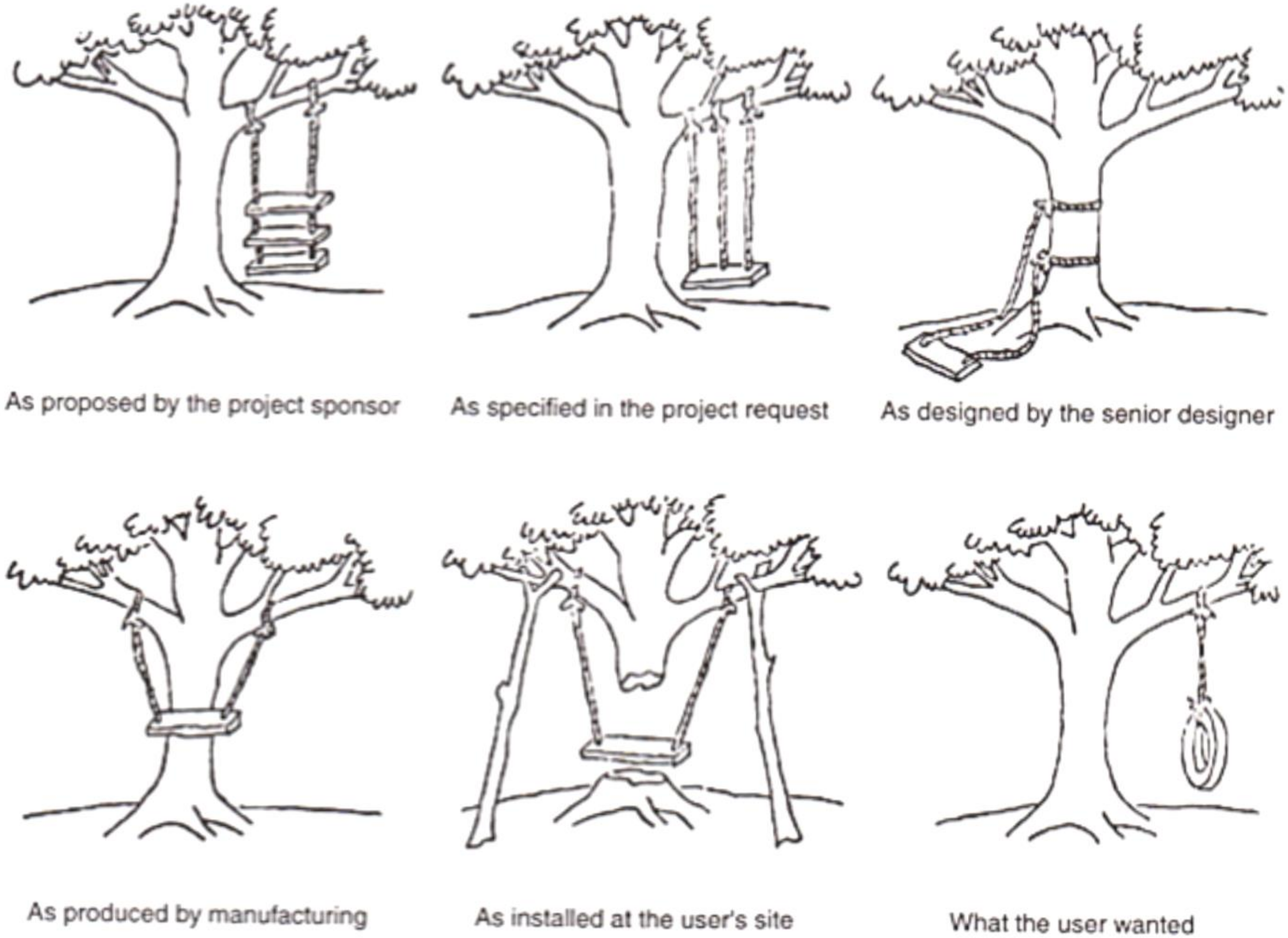


FIGURE 1.4
Note how the design depends on the viewpoint of the individual who defines the problem.

Basic Module For Design

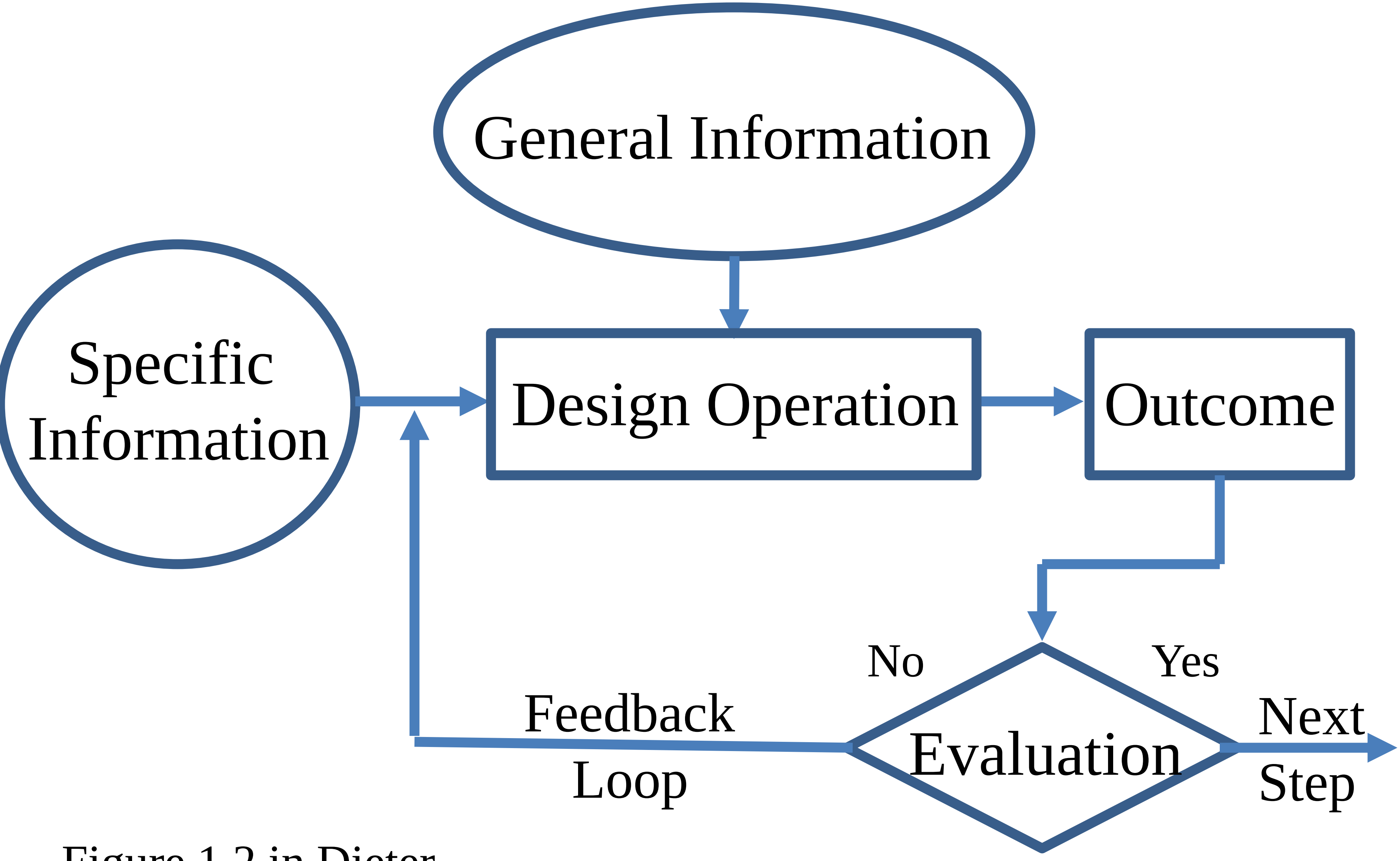


Figure 1.2 in Dieter

Scientific Method vs Design Method

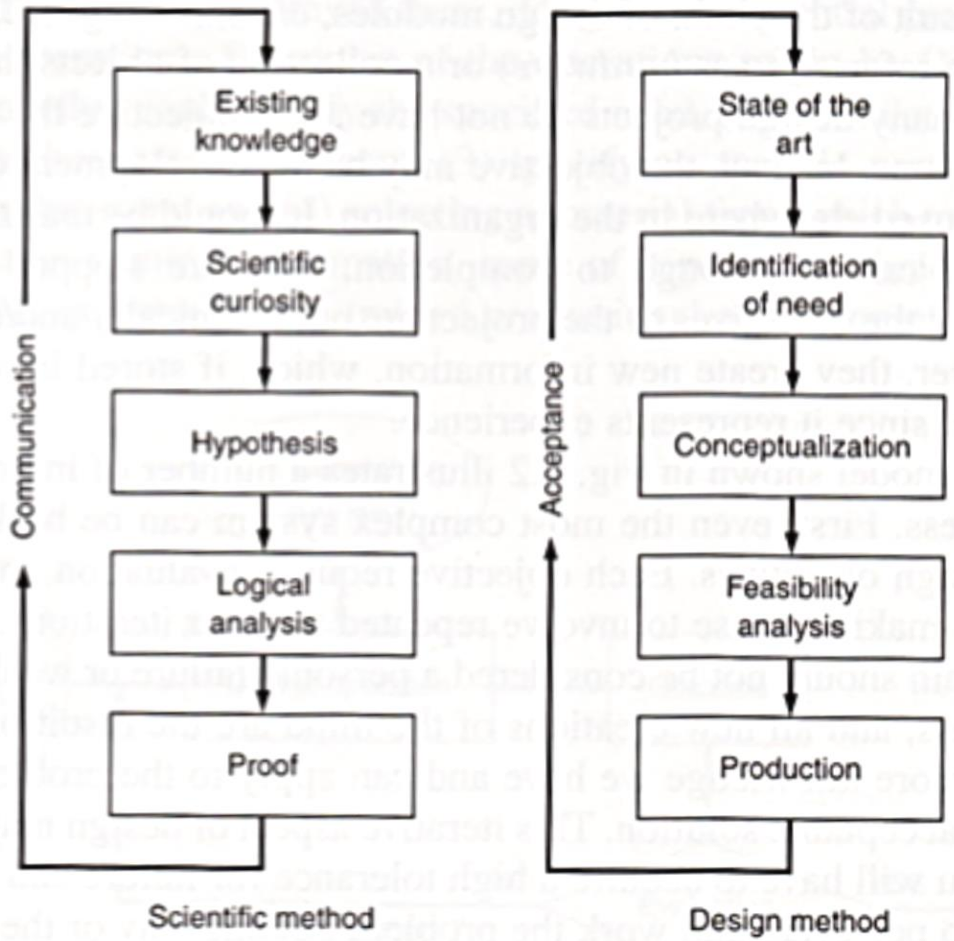


FIGURE 1.3
Comparison between the scientific method and the design method. (*After Percy Hill.*)

The Design Process

Three Major Phases

1. Conceptual Design
2. Embodiment Design
3. Detailed Design

Others

4. Planning for Manufacture
5. Planning for Distribution
6. Planning for Use
7. Planning for Retirement of Product

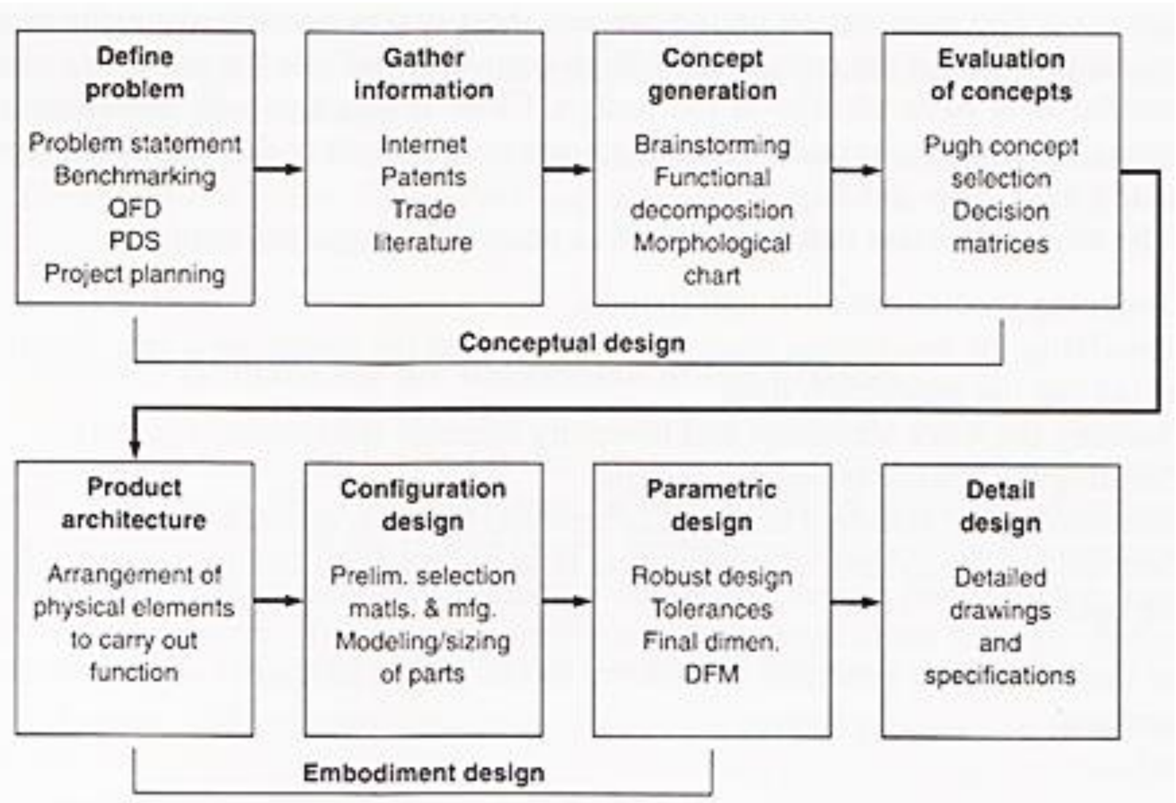


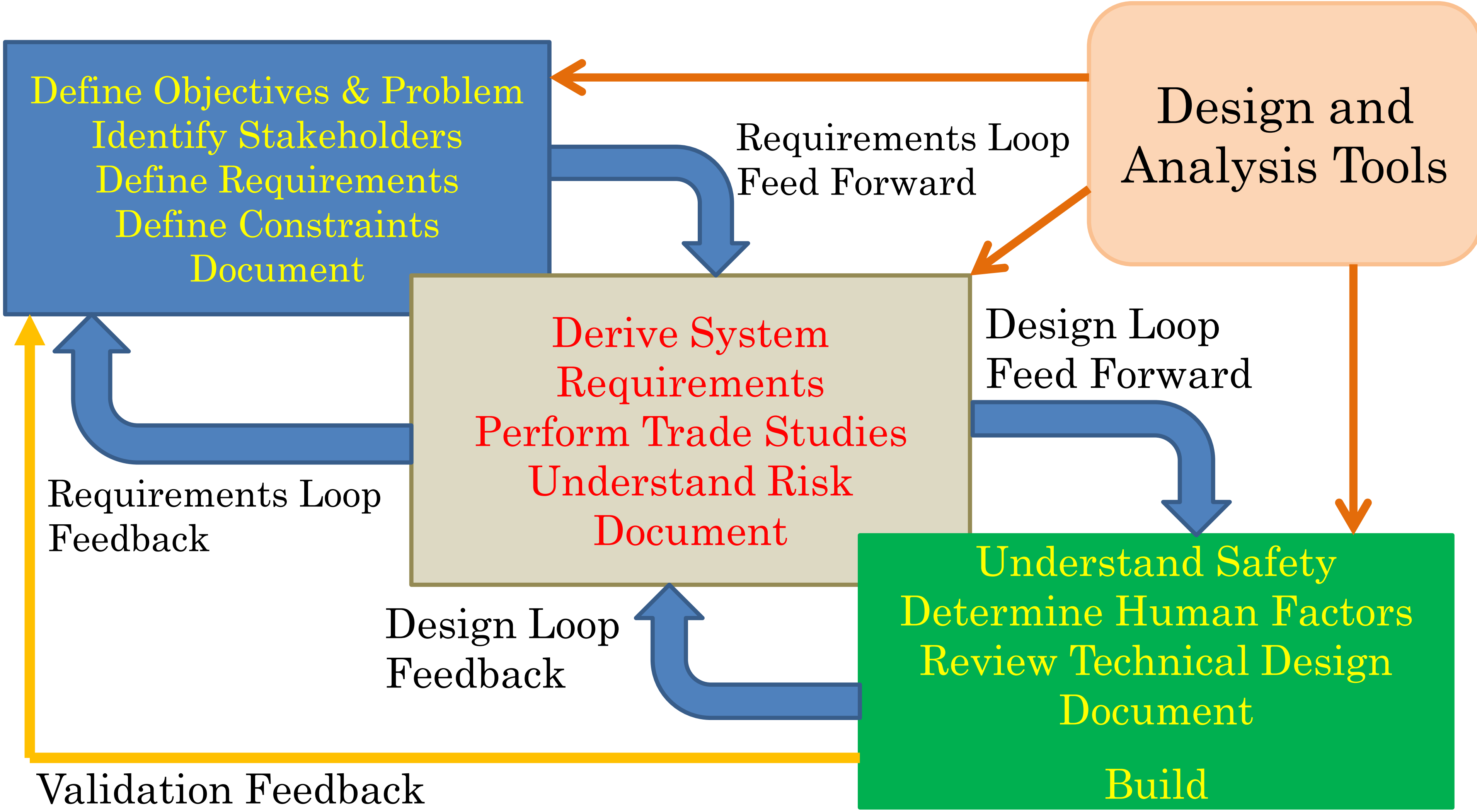
Figure 1.6 in Dieter

The Design Process

Conceptual Design

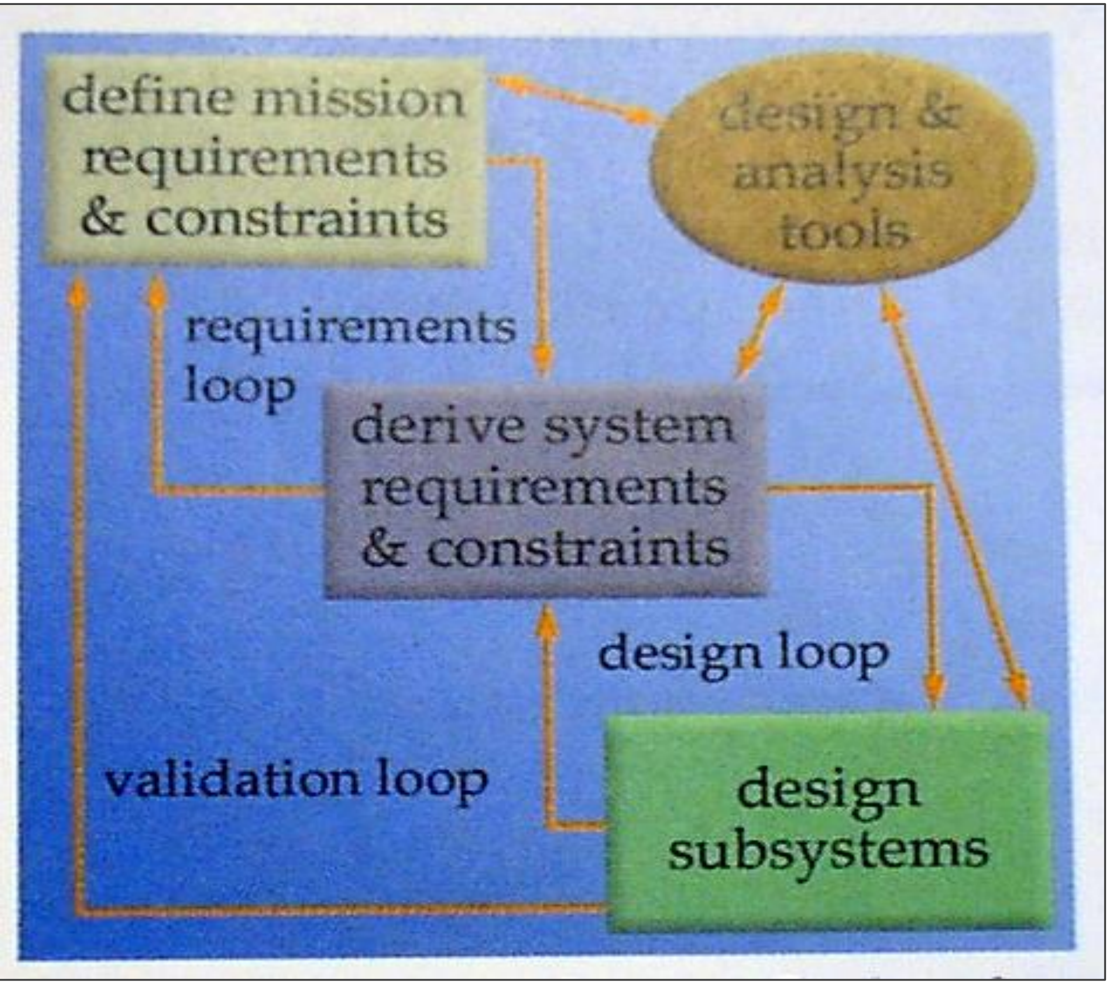
- Recognition of a need
- Definition of the problem
  - Includes defining the problem statement, design requirements, constraints, and risks.
- Gathering of information
- Developing alternative design concepts
- Evaluation of concepts and selection

NASA Systems Engineering Process



- **By following a well-defined process, engineers design systems that meet requirements, while staying within budget and conforming to constraints**

NASA Systems Engineering Process



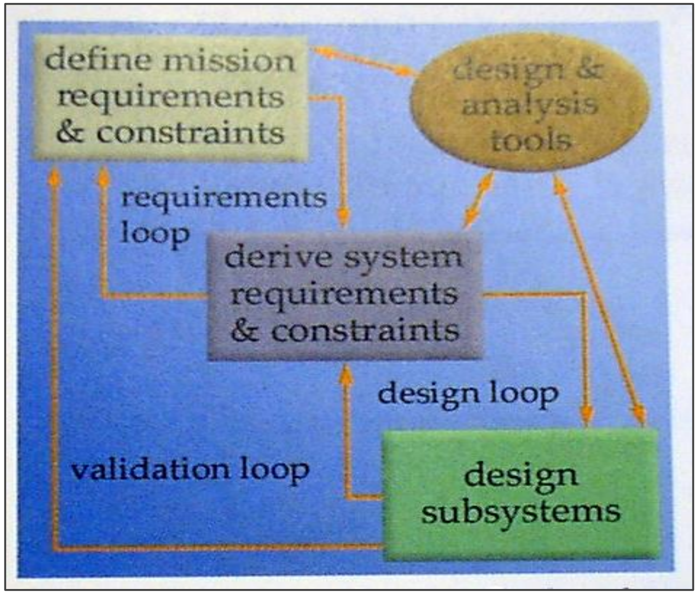
- Systems Engineering is a fundamental process that can be used to design anything from a backyard grill to a crewed-space platform.

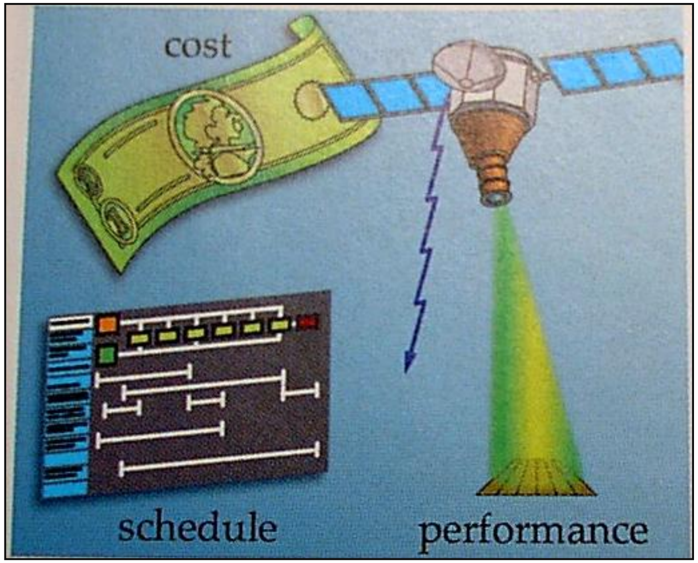
- Each step utilizes established design and analysis tools.

- The process is iterative.

- Between process steps there are “feedback loops” to review decisions made in previous steps.

NASA Systems Engineering Process



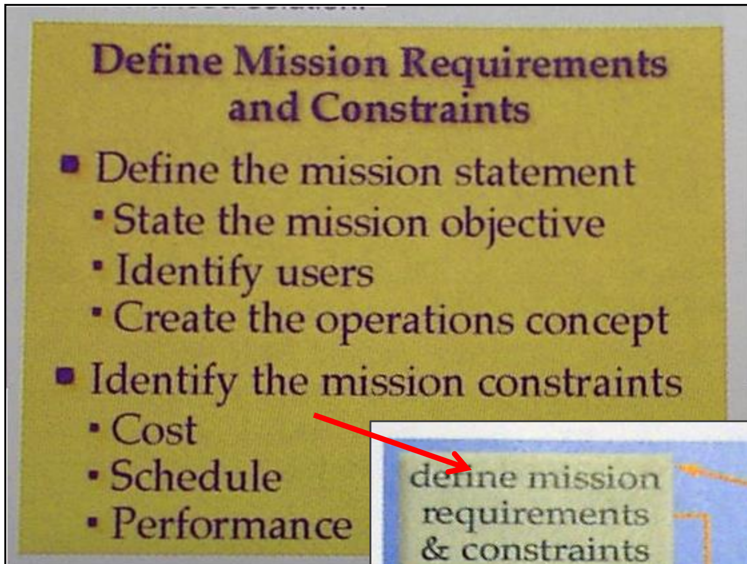


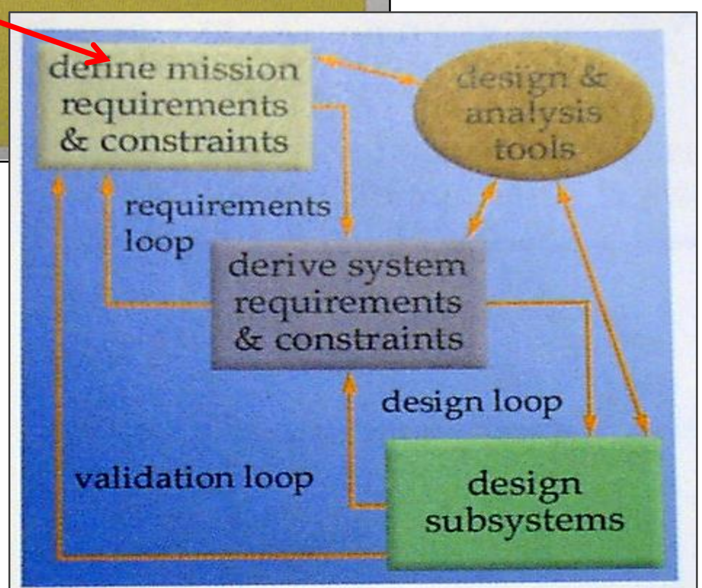
Cost, Schedule, Performance

- **3-D trade space that mission must operate within.**

- **Systems engineers continually trade competing objectives to achieve well-balanced solution -- "optimal" solution often not-achievable**

NASA Systems Engineering Process





- **First phase in design process is to define the mission requirements, objectives, and constraints.**

- **Often documented and detailed in the mission "Objectives and Requirements Document."** ***(ORD)***

Problem Statement

- A problem statement is a clear description of the issue(s), it includes a vision, issue statement, and method used to solve the problem.
- The 5 'W's (who, what, when, where, why) can be used to spark the discussion about the problem.
- A problem statement expresses the words that will be used to keep the effort focused and it should represent a **solveable** problem.

Problem Statement

- ***Who*** - Who does the problem affect? Specific groups, organizations, customers, etc.
- ***What*** - What are the boundaries of the problem, e.g. organizational, work flow, geographic, customer, segments, etc. - What is the issue? - What is the impact of the issue? - What impact is the issue causing? - What will happen when it is fixed? - What would happen if we didn't solve the problem?
- ***When*** - When does the issue occur? - When does it need to be fixed?
- ***Where*** - Where is the issue occurring? Only in certain locations, processes, products, etc.
- ***Why*** - Why is it important that we fix the problem? - What impact does it have on the business or customer? - What impact does it have on all stakeholders, e.g. employees, suppliers, customers, shareholders, etc. Each of the answers will help to zero in on the specific issue(s) and frame the Issue Statement. Your problem statement should be solveable. That is, it should take a reasonable amount of time to formulate, try and deploy a potential solution.

Initial Problem Statement

Freeport McMoRan would like to see if the Concentrate Leach Plant (CLP) at their Morenci mine would be a feasible addition to another site. The design for the plant addition will be modeled after the Morenci CLP and use material from an existing copper concentrator and feed into the existing copper solvent extraction electrowinning circuit. A Scoping Study Report will be used to determine if the design has some merit before performing full feasibility studies and detailed engineering.

Take a few minutes and revise this Problem Statement with your group.

Is the statement clear?

What is the vision?

What issue is to be solved?

What method will be used to solve the problem?

Are all questions answered?

Does the problem appear to be solvable?

Design Requirements

Design Requirements

- A good requirement states something that is **necessary**, **verifiable**, and **attainable**. Even if it is verifiable and attainable, and eloquently written, if it is not necessary, it is not a good requirement. To be verifiable, the requirement must state something that can be verified by examination, analysis, test, or demonstration.

- Statements that are subjective, or that contain subjective words, such as "easy", are not verifiable. If a requirement is not attainable, there is little point in writing it. A good requirement should be clearly stated.

Design Requirements

- A requirement is "something that governs what, how well, and under what conditions a product will achieve a given purpose."

- Requirements define the functions, performance, and environment of the system under development to a level that can be built [EIA 632] :

- WHAT is the system supposed to do? – These are Functional Requirements

- How well does the system do its functions? – These are Performance Requirements

Design Requirements

Functional Requirements

- A task (sometimes called an action or activity) that must be accomplished to provide an operational capability (or satisfy an operational requirement).
- Eight primary systems functions that most systems must complete over their life cycle: development, manufacturing, verification, deployment, training, operations, support, and disposal. These are known as the eight primary system functions.

Performance Requirements

- The extent to which a function must be executed, generally measured in terms such as quantity, accuracy, coverage, timeliness, or readiness
- Often correlate well with the statement of the needed operational capability

Requirements Analysis

Need. If there is a doubt about the necessity of a requirement, then ask: *What is the worst thing that could happen if this requirement were not included?* If you do not find an answer of any consequence, then you probably do not need the requirement.

Verification. As you write a requirement, determine how you will verify it. Determine the criteria for acceptance. This step will help insure that the requirement is verifiable.

Attainable. To be attainable, the requirement must be technically feasible and fit within budget, schedule, and other constraints. If you are uncertain about whether a requirement is technically feasible, then you will need to conduct the research or studies to determine its feasibility. If still uncertain, then you may need to state what you want as a goal, not as a requirement. Even is a requirement is technically feasible, it may not be attainable due to budget, schedule, or other, e.g., weight, constraints. There is no point in writing a requirement for something you cannot afford -- be reasonable.

Clarity. Each requirement should express a single thought, be concise, and simple. It is important that the requirement not be misunderstood -- it must be unambiguous. Simple sentences will most often suffice for a good requirement.

Requirements Analysis

- Requirements use *shall*.
- Statements of fact use *will*.
- Goals use *should*.

Avoid terms such as:

- Support
- But not limited to
- Etc.
- And/Or

- ***WRONG:*** *The system shall support the training coordinator in defining training scenarios.*

- ***RIGHT:*** *The system shall provide input screens for defining training scenarios. The system shall provide automated training scenario processes.*

Requirements Analysis

Specifications

- Detailed, exact statement of particulars, especially a statement prescribing materials, dimensions, and quality of work for something to be built, installed, or manufactured.
- Provide a basis for obtaining a product or service that will satisfy a particular need at an economical cost and to invite maximum reasonable competition.
- Set limits and thereby eliminates, or potentially eliminates, items that are outside the boundaries drawn. A good specification should do four (4) things:
  - Identify minimum requirements
  - List reproducible test methods to be used in testing for compliance with specifications
  - Allow for a competitive bid
  - Provide for an equitable award at the lowest possible cost.

Requirements Analysis

Common Problems

- Making bad assumptions
- Writing implementation (HOW) instead of requirements (WHAT)
- Describing operations instead of writing requirements
- Using incorrect terms
- Using incorrect sentence structure or bad grammar
- Missing requirements
- Over-specifying

Design Requirements

- Freeport-McMoRan requires the design to be modelled similar to an existing CLP used at their Morenci Location. The Morenci CLP is designed to process 400 ton/day from the crusher. This process will alleviate production from the concentrator and allow minerals to be sent through the CLP process line. Ms. Green requires a feasibility analysis and report to be conducted on this idea for a specific high-sulfur grade of ore found at a certain mine location.

Take a few minutes and discuss these requirements with your group.

Are they

- Achievable?
- Verifiable?
- Unambiguous?
- Complete?
- Consistent?
- Needs?
- Documented?

Design Constraints

- Often confused with requirements
- Types of constraints
  - **Functional**
  - **Safety**
  - Quality
  - **Manufacturing**
  - **Schedule**
  - **Economic**
  - Ergonomic
  - Ecological
  - Aesthetic
  - Life-Cycle
  - Legal/Ethical

Design Constraints

As of now there are no necessary expenses for this project, but if costs are incurred later, Freeport has a small amount of funding available. If any concentrate is needed for testwork, Freeport will transport the material to us at their cost.

All design work must be completed within the current school year, ideally before the Design Fair in April. The final report and video documentary must be done by the end of spring semester.

For the design to be considered by Freeport, it must have a payback period of three to five years based only on copper extraction. It must also have a copper recovery rate of at least 98.5% and an 85% uptime. If operational costs prove this to be unfeasible, then the project will not go ahead.

Assignment #2

- **State the problem:** Write a clear, concise statement summarizing your view of the problem for which you are designing a solution.

- **Identify your customers/stakeholders:** Provide a brief statement specifying your customer/stakeholders for this project.

- **Determine customer requirements, both needs and expectations:** Write a paragraph indicating the requirements, needs and expectations you have identified at this time. Keep in mind, good requirements should be achievable, verifiable, unambiguous, complete and consistent.

- **Identify cost, schedule and performance constraints:** Provide a brief statement specifying your cost schedule and performance constraints.