

Seven Steps of Systems Engineering (horizontal axis of Activity Matrix)

- Problem Definition – What is the problem, really?
- Value System Design – How will we know when we've found a good solution?
- System Synthesis – What are some alternatives which *could* satisfy objectives?
- System Analysis – How do each of these alternatives perform relative to objectives?
- Optimization – How good can we make each alternative perform?
- Decision-Making – Which alternatives are deserving of further study?
- Planning for Action – Plan for the next *phase*.

Prior to System Analysis

- **Problem Definition** – you have established the “landscape” of the problem. You understand what the system needs are, what elements you can alter to solve the problem, and what elements you cannot alter.
- **Value System Design** – you have established the objectives that should be met in solving the problem. For each objective, there is some measure that can be used to determine how well a potential solution satisfies the objective.
- **System Synthesis** – you have identified some alternative solutions to the problem. These alternatives should pass the feasibility test, and should have some obvious relevance to satisfying system needs and objectives.

So What is System Analysis?

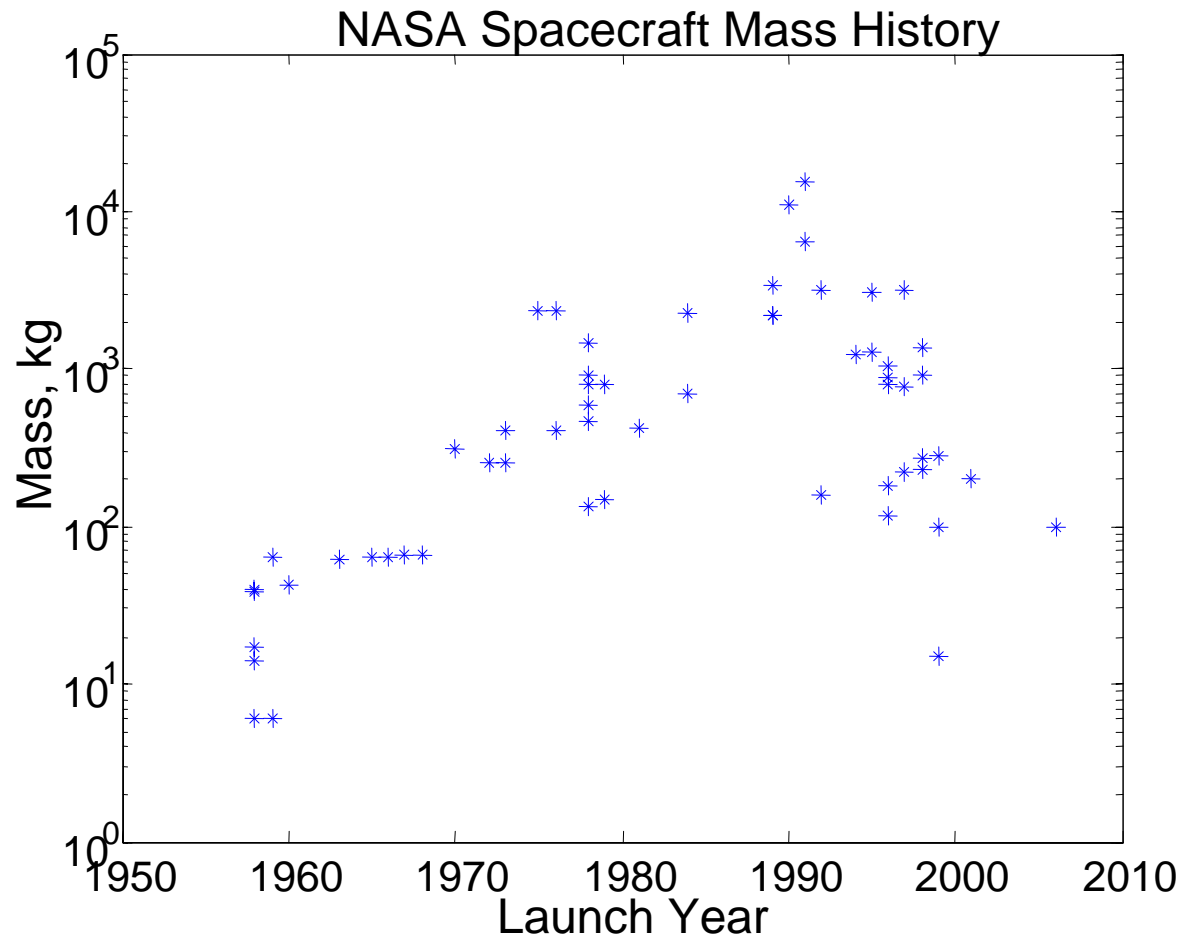
- System Analysis is the development of **models** of the alternative solutions (SA) with sufficient resolution to determine values for the measures of effectiveness (VSD)
- Optimization
 - Make each alternative “as good as possible,” using the models to generate MOEs to compute “goodness”
- Decision-making
 - Rank the alternatives and decide which deserve(s) further study, using weights obtained from the Chief Decision-Maker, generated using AHP, or obtained by interviewing experts
- Planning for action
 - Plot a course of action for the next iteration through the 7-step process

Models

- A model is an idealization of part of the real world that helps in the analysis of a problem
 - Free-body diagram
 - Circuit diagram
 - Control volume
- Descriptive vs Predictive
- Static vs Dynamic
- Deterministic vs Probabilistic
- Iconic vs Analog vs Symbolic
- Simulation subjects models to inputs to observe response

Descriptive vs Predictive Models

- Descriptive = observed or recorded (laboratory data)
- Predictive = predicts behavior of “new” system
- Descriptive model becomes predictive when you use it to predict behavior of a new system
- Scatter plot of Spacecraft Mass vs Launch Year
- A Curve Fit could be used to develop a predictive model

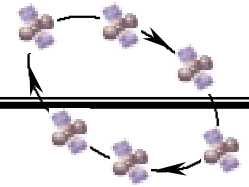


Static vs Dynamic Models

- Static models describe a system in a steady-state condition
 - Hooke's Law is a static model of structure performance
 - A Hohmann transfer is a static model for orbit transfer
- Dynamic models describe a system in a time-dependent condition
 - Vibration analysis of a space structure requires a dynamic model
 - The trajectory of a spacecraft in an orbit transfer using continuous thrust requires a dynamic model

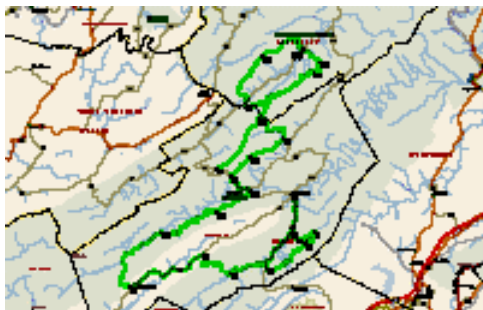
Deterministic vs Probabilistic Models

- Deterministic models have predictable and repeatable input-output relationship
 - Integration of differential equations of motion with the same initial conditions will give the same trajectory
- Probabilistic models account for system uncertainties
 - Randomly varying the initial conditions, the thruster performance, or the environmental effects will lead to a family of trajectories

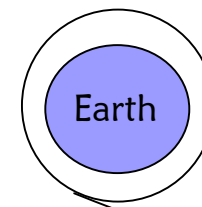


Iconic vs Analog vs Symbolic

- **Iconic models:** flow chart, blueprint, block diagram, free-body diagram, bond-graph diagram
- **Analog models:** electric circuits to represent mechanical systems, colors on a map, contour lines on a map, physical model
- **Symbolic models:** traffic signs (curve, intersection), equations of motion



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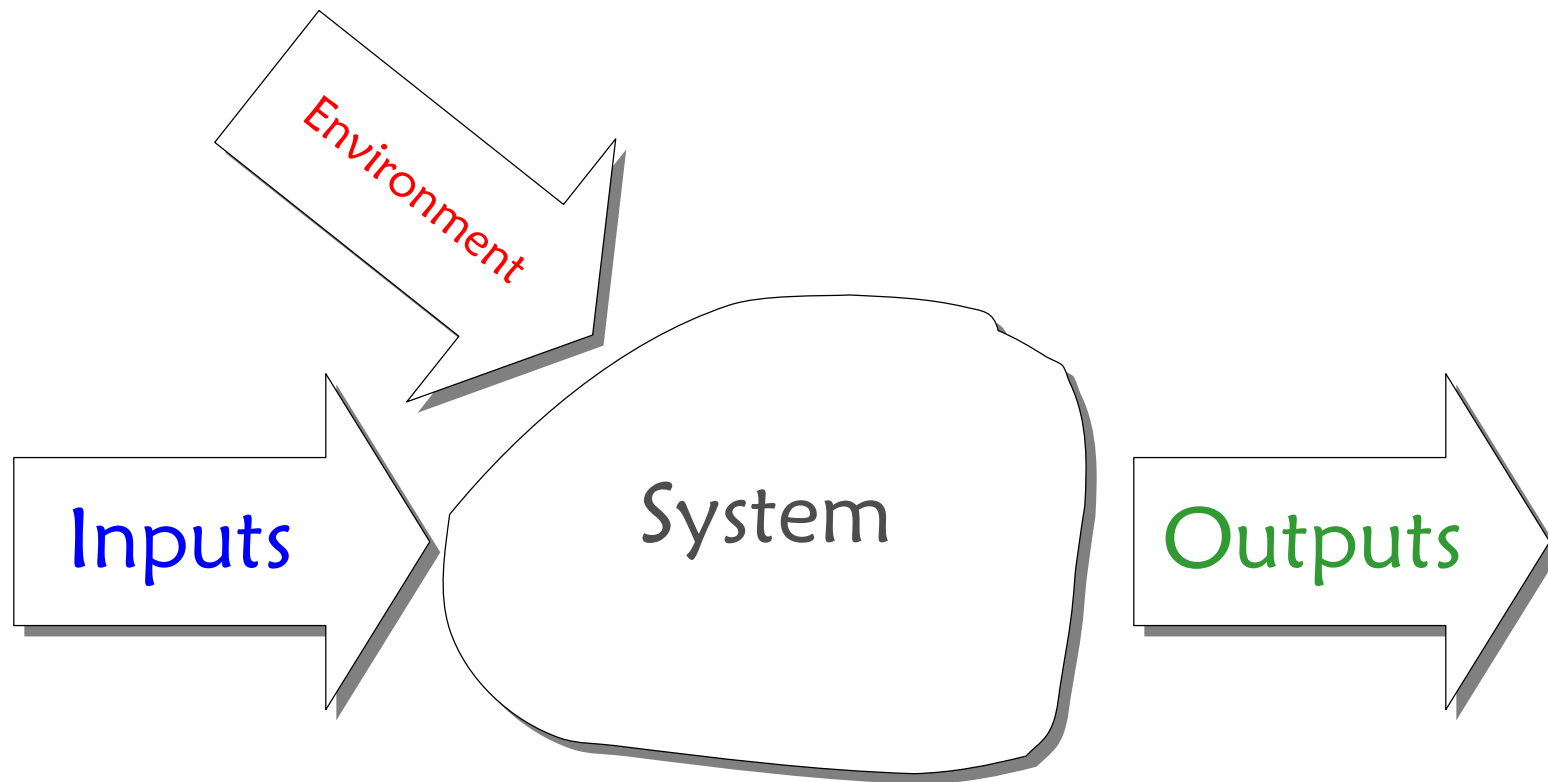
Moon

Mars

Models

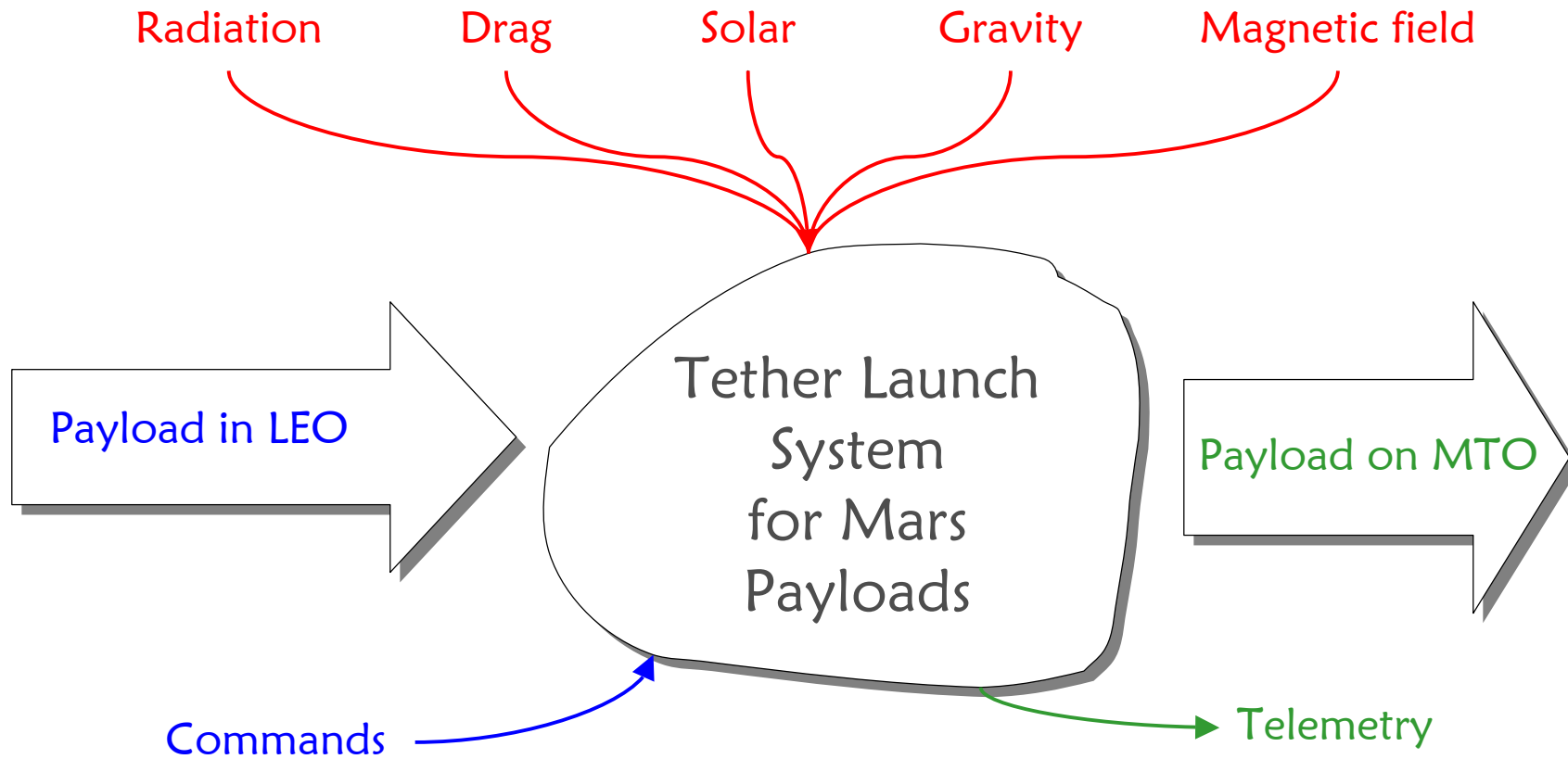
- A model only needs to focus on the aspects that are relevant to the problem
 - determine those elements of problem definition, value system, and synthesis that are relevant
 - determine the relationships between these elements
- Should be
 - valid
 - manageable
 - able to differentiate alternatives
 - complete with respect to the value system design
- Resolution
 - binary: yes/no; on/off; to be or not to be
 - finite number of classes: color; type; model #
 - real numbers: thrust; mass; height; price

Generic System Block Diagram

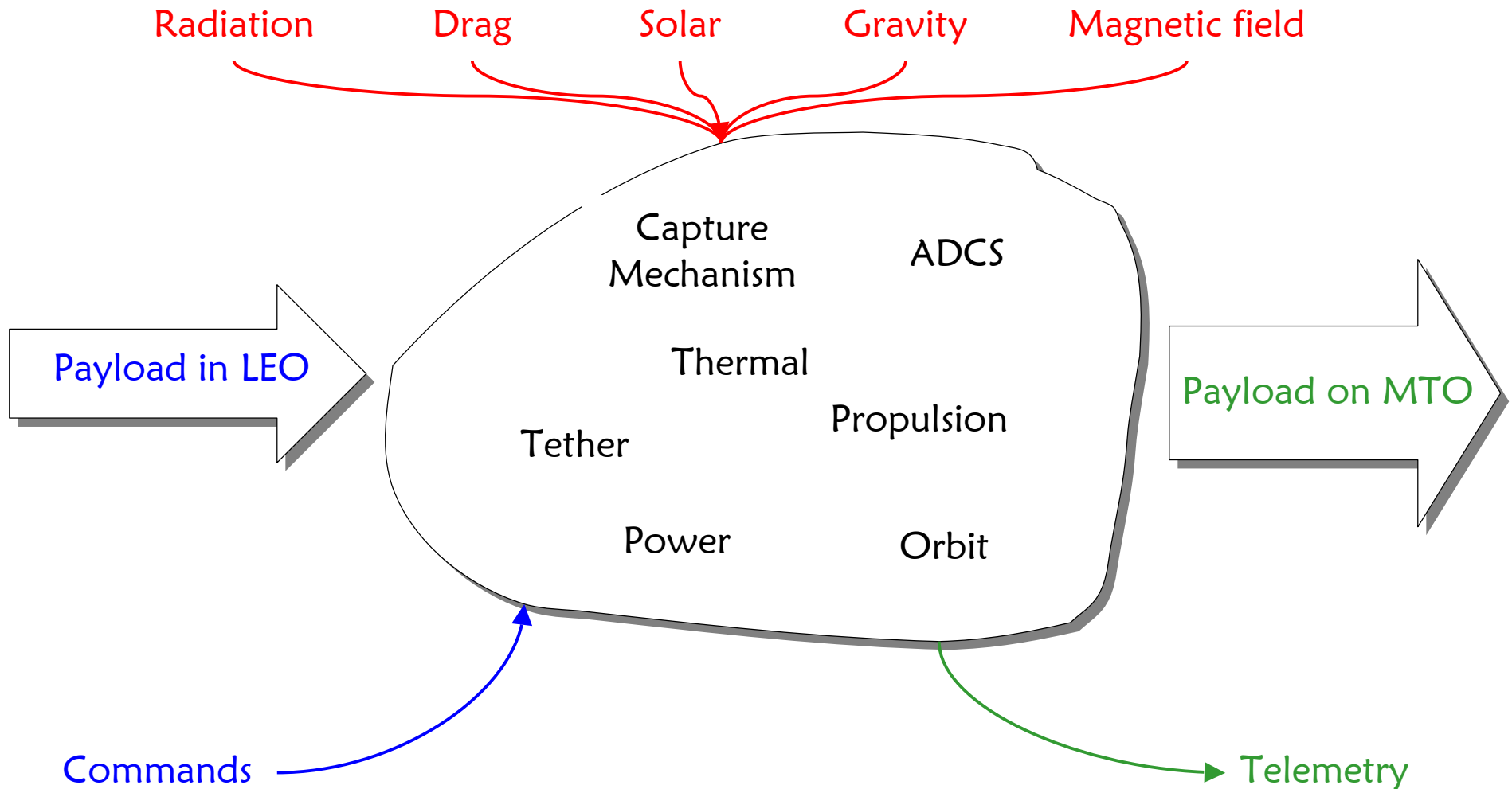


- The system has inputs which are related to constraints, is subject to environmental inputs which are related to constraints, and has outputs which are related to needs and objectives

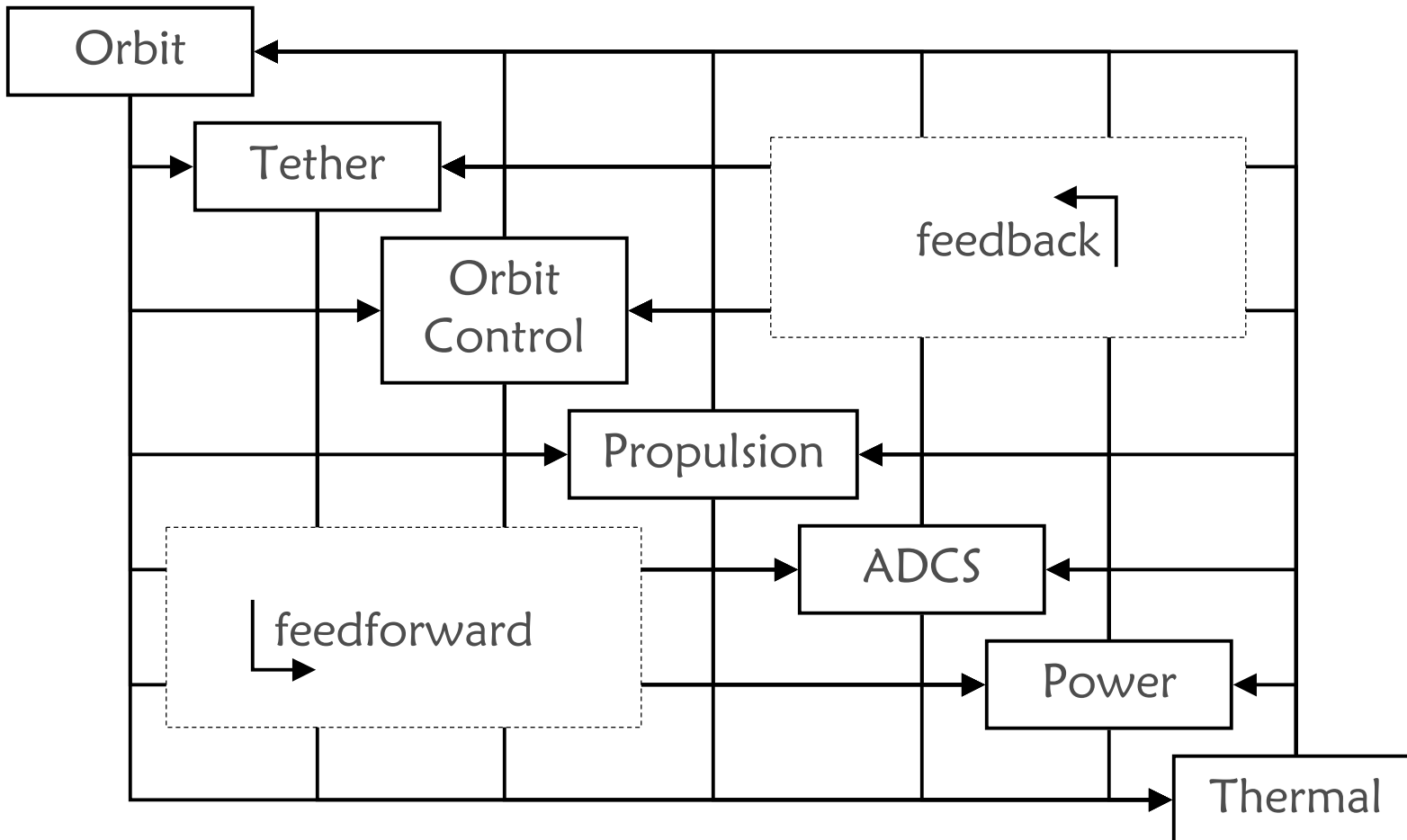
Example System Block Diagram



More Detailed TLS System Block Diagram



Possible Design Flow Matrix



Example Variation on Iterative Design Process

(from SMARTS Presentation, April 2002)

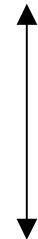
Get payload to Mars:



Survive lifetime:



Satisfy mission functions:



Subsystem & Discipline Interfaces

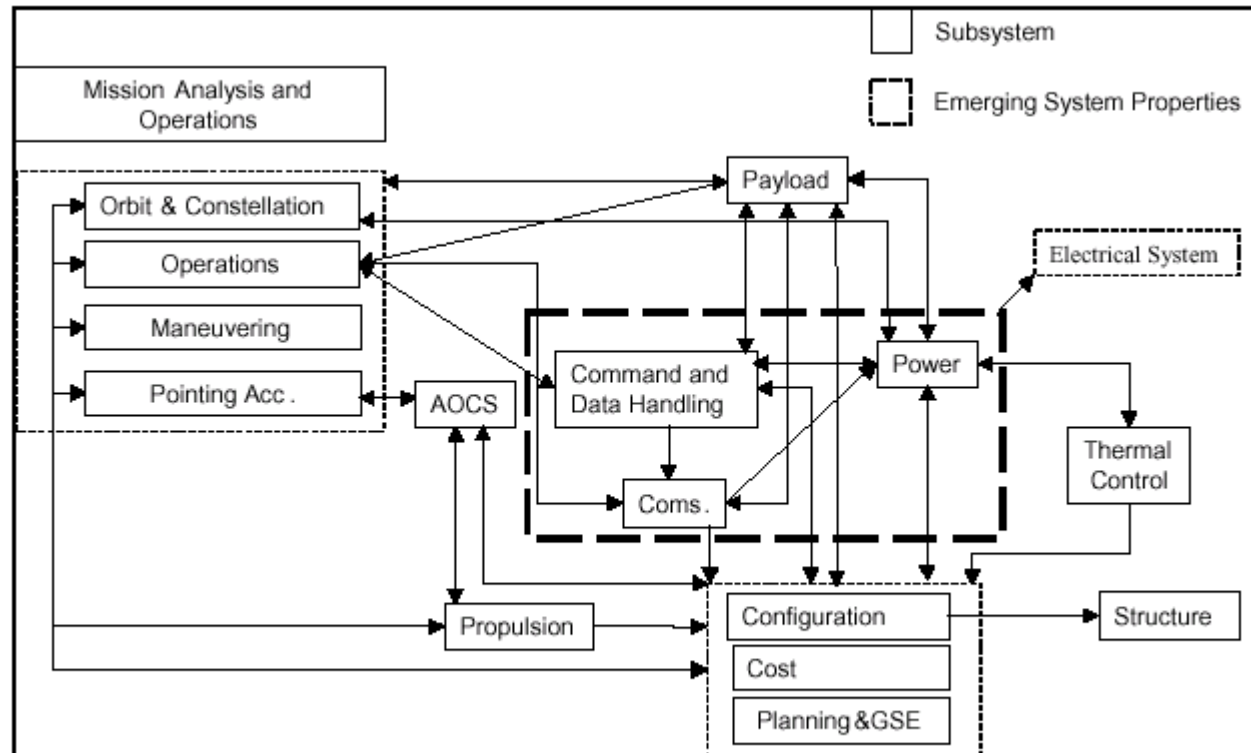


Figure 1: Major Discipline Interdependencies

- Source: “An Advanced Methodology for the Design Process of a Satellite,” by Heinz Stoewer, Ralf Hartmann, and L.A.J. Baron von Richter

System Analysis and Onward

- Develop models of appropriate resolution for each alternative
- Use models to calculate measures of effectiveness
- Establish weights for the Value System Design
- Optimize each alternative
- Pick the best alternative
- Carry the best alternative into the detailed design process