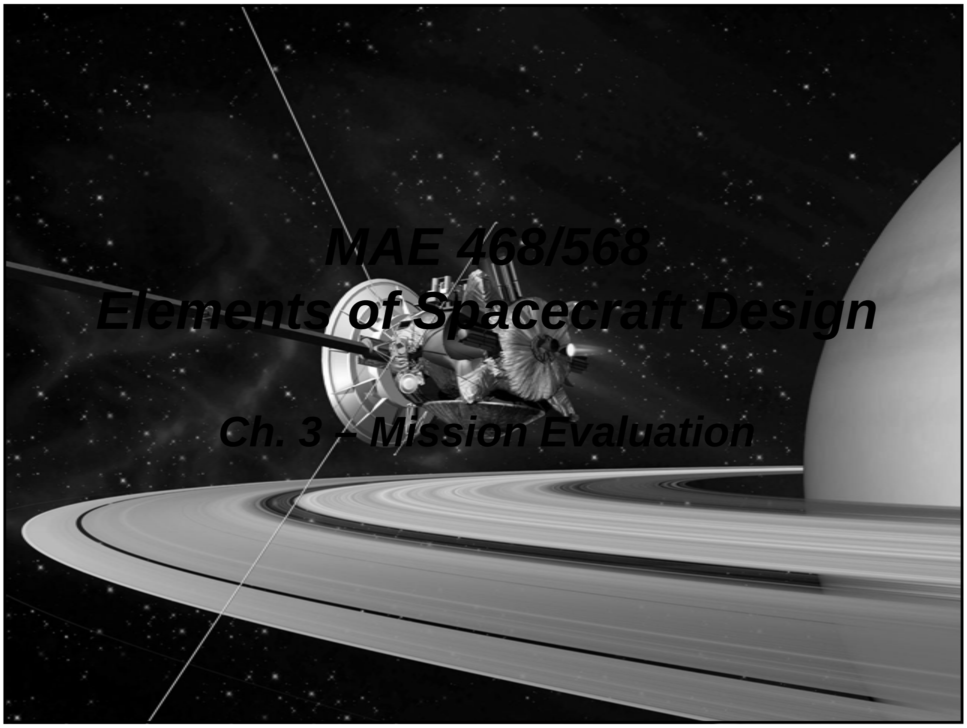

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Class Agenda

- Identification of critical requirements
- Mission analysis
  - Mission analysis hierarchy
  - Studies with limited scope
  - Trade studies
  - Performance assessments
- Mission utility
  - Performance parameters and measures of effectiveness
  - Mission utility simulation
  - Mission utility tools
- Mission concept selection

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ID of Critical Requirements

- Critical requirements – dominate space mission's overall design – most strongly affect performance and cost
  - Need to id key requirements early as possible to achieve best performance at minimal cost
- No single mechanism to find critical requirements for any particular mission
  - Could be function of mission concept selected

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Most Common Critical Requirements

Requirement	What it Affects
Coverage or Response Time	Number of satellites, altitude, inclination, communications architecture, payload field of view, scheduling, staffing requirements
Resolution	Instrument size, altitude, attitude control
Sensitivity	Payload size, complexity, processing, and thermal control, altitude
Mapping Accuracy	Attitude control, orbit and attitude knowledge, mechanical alignments, payload precision, processing
Transmit Power	Payload size and power, altitude
On-orbit Lifetime	Redundancy, weight, power, and propulsion budgets, component selection
Survivability	Altitude, weight, power, component selection, design of space and ground system, number of satellites, number of ground stations, communications architecture

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ID of Critical Requirements

- Approach
  - Look at principal performance requirements – will be key critical requirement
  - Examine most common critical requirements table – look to see which ones drive system design, performance, or cost
  - Look at top-level requirements – determine how you will meet them – ask whether or not meeting that requirement fundamentally limits the system's design, cost, or performance
  - Look for hidden requirements – hidden requirements may dominate the mission design and cost

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Mission Analysis

- Mission analysis – process of quantifying the system parameters and the resulting performance
- Mission utility analysis – process of quantifying how well the system meets its overall mission objectives
- Mission objectives – not quantitative
- Mission requirements – numerical expressions of how well the objectives must be met
  - Represent balance between what we want and what is feasible within the constraints on the system
- Mission analysis should be process which defines and refines mission requirements in order to meet broad objectives at minimum cost and risk

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Mission Analysis

- Key mission analysis component – documentation
  - Provides organizational memory of both the results and reasons
- For successful analysis must document real reasons so others can reevaluate them later when situation may be different

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Mission Analysis Hierarchy

- Analyze as many reasonable alternatives as possible so we may understand how the system behaves as a function of the principal design features (design drivers)
  - Limited in both cost and schedule
- If cost/schedule are limited – need to intelligently limit scope of individual analyses
- Two methods to limit depth of analysis
  - Clearly ID each area's system drivers – concentrate on drivers
  - Clearly ID goal of system study to provide level of detail appropriate to goal

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Mission Analysis Hierarchy

Analysis Type	Goal	
Feasibility Assessment	To establish whether an objective is achievable and its appropriate degree of complexity	
Sizing Estimate	To estimate basic parameters such as size, weight, power, or cost	Quick, limited detail
Point Design	To demonstrate feasibility and establish a baseline for comparison of alternatives	
Trade Study	To establish the relative advantages of alternative approaches or options	
Performance Assessment	To quantify performance parameters for a particular approach	More detailed, complex trades
Utility Assessment	To quantify how well the system can meet overall mission objectives	

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Studies with Limited Scope

- First three types provide methods for undertaking quick-look assessments
  - Provide limited detail, done quickly at low cost
- Biggest difficulty – tendency to believe that they are more accurate than they really are
  - Not uncommon to use a feasibility assessment or point design to establish requirements for a mission
- Feasibility assessment – used to establish whether a particular objective is achievable and to place broad bounds on its level of complexity
  - Can do a comparison to existing systems
  - Can determine goal feasibility by extrapolating past experience

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Studies with Limited Scope

  - Provide a very broad design of how such a mission might be accomplished
- Sizing estimate – provide an estimate of basic mission parameters such as size, weight, power, or cost
  - By analogy of existing systems
  - Could provide quantitative estimate of key mission parameters by scaling parameters from existing missions or payloads
  - As design proceeds, more and more accurate sizing estimates come from scaling process
  - Break down spacecraft into its relative components – estimate size, weight, and power

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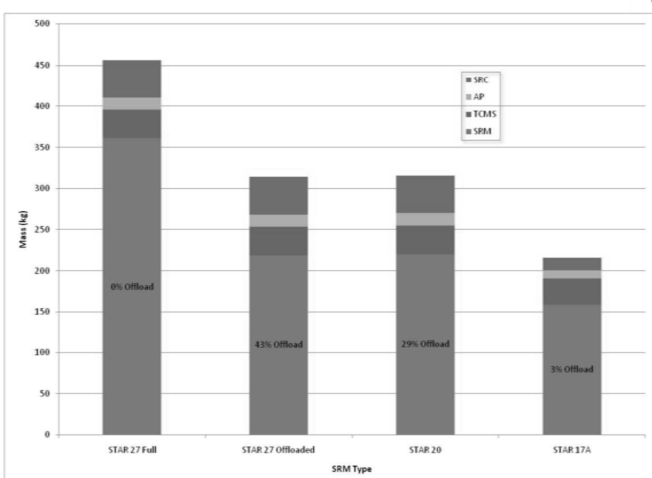
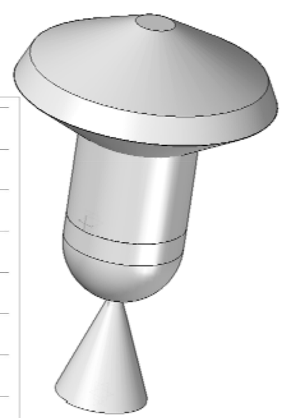
Sizing Example





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Studies with Limited Scope

- Point design – design, possibly at top level, for entire system which is capable of meeting the broad mission objectives
  - Referred to as point if no attempt made to optimize design to either maximize performance or minimize weight, cost, or risk
- Two purposes
  - Demonstrates that the mission is feasible
  - Can be used as a baseline for comparison of alternatives
- If we continue to optimize design so that the cost and risk decrease, we will let the baseline evolve to take into account new design approaches

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Studies with Limited Scope

- Point design – valuable – can be done quickly and easily
- No need to optimize any of the parameters associated with design unless necessary to meet mission objectives
  - Gives sense of difficulty in meeting mission objectives
- Problem – taking it too seriously at later stage
  - Need to recognize their limitations

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Trade Studies

- Deciding to proceed with a mission
  - Develop a strawman system concept or point design that shows mission objectives are attainable
- Need to consider alternatives
  - System trade process evaluates different broad concepts to establish their viability and impact on performance and cost
- System trades – consist of analyzing and selecting key parameters (system drivers) which determine mission performance
  - Use parameters to define mission concept and mission architecture

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Trade Studies

- Key system trades – define how system works and determine its size, cost, and risk
- Typical trades
  - Critical requirements
  - Mission concept
  - Subject
  - Type and complexity of payloads
  - Orbit

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Trade Studies

- Simplest option – a list of options and reasons for retaining or eliminating them
- Should go back to key system trades on regular basis and determine whether assumptions and conclusions are still valid
- Alternative – system trade in which we made a quantitative comparison of multiple effects
  - Effective in providing insight into impact of system drivers – 2 categories – more is better & multiple effects

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Trade Studies

- System drivers and critical requirements which cause multiple effects demand more complex trade studies
- Need to select the correct independent parameter to trade
- System trade process for parameters with multiple effects
  - Select trade parameter (typically system driver)
  - Identify factors which affect parameter or are affected by it
  - Assess impact of each factor
  - Document and summarize results
  - Select parameter value and possible range

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Performance Assessments

- Quantifying performance demands an appropriate level of detail
- Three techniques to compute system performance
  - System algorithms
  - Analogy with existing systems
  - Simulation
- System algorithms – basic physical or geometric formulas associated with particular system or process
  - Provide best method for computing performance
  - Provide clear traceability and establish relationship between design parameters and performance characteristics

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Performance Assessments

- Powerful – show directly how performance varies with key parameters
- Limited – presume rest of system is designed with fundamental physic or geometry as limiting characteristic
- Assumption – have correctly ID what limits system performance

- Comparing design with existing systems
  - Use established characteristics of existing components and adjust expected performance according to basic physics or continuing evolution of technology

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Performance Assessments

- Simulation
  - Time consuming – typically used only for key performance parameters
  - Allow much more complex modeling and can incorporate limits on performance from multiple factors
  - Provide much less insight – review results carefully

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Mission Utility

- Mission utility analysis quantifies mission performance as a function of design, cost, risk, and schedule
- Uses
  - Provide quantitative information for decision making
    - Based on overall performance, cost, and risk
    - Other factors as well
  - Provide feedback on system design
    - Assessing how well alternative configurations meet mission objectives

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Performance Parameters

- Mission analysis purpose is to quantify system's performance and its ability to meet the ultimate mission objectives
- Requires
  - Performance parameters – quantify how well the system works, without explicitly measuring how well it meets mission objectives
  - Measures of effectiveness – quantify directly how well the system meets the mission objectives
- Can usually determine performance parameters unambiguously
- Good measures of effectiveness are critical to successful mission analysis and design

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Performance Assessments

- Good measures of success
  - Clearly related to mission objectives
  - Understandable by decision makers
  - Quantifiable
  - Sensitive to system design
- MoEs are useless if decision makers cannot understand them
- No single MoE can be used to quantify how the overall system meets mission objectives

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Performance Assessments

- MoEs generally fall into one of three categories
  - Discrete events
  - Coverage of a continuous activity
  - Timeliness of information or other indicators of quality

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Mission Utility Simulation

- Try to evaluate MoEs numerically as a function of cost and risk – hard to do!
  - Typically other principal system parameters are used
- Remember mission utility analysis has two distinct but equally important goals
  - Aid design
    - Design mission by examining relative benefits of alternatives
    - Can show how utility depends on design choices – intelligently select among design options
  - Provide information for decision making
    - Informing higher officials by providing summary performance data
- Mission simulator – assumes level of performance for payload and assesses its ability to meet mission objectives

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Mission Utility Simulation

- Mission simulators are straightforward
  - Expensive and time consuming to create
  - To achieve excessive fidelity tend to dramatically increase cost and reduce effectiveness
- Goal of mission simulation is to estimate MoEs as a function of key system parameters
  - Must restrict simulator as much as possible to achieve this goal
  - Overly detailed simulations require more time and money to create

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Mission Concept Selection

- Decisions
  - Go/no-go decision on proceeding with mission
  - Selection of mission concept
  - Detailed engineering decision
- Go/no-go factors
  - Does proposed system meet overall mission objectives?
  - Is it technically feasible?
  - Is level of risk acceptable?
  - Are schedule and budget within established constraints?
  - Do preliminary results show this option to be better than nonspace solutions?

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Mission Concept Selection

- Other go/no-go factors
  - Does mission meet political objectives?
  - Are organizational responsibilities acceptable to all of organizations involved in decision?
  - Does mission support infrastructure in place or contemplated?
- Top level trades in concept selection are usually not fully quantitative
- Purpose of trade studies and utility analysis is to make decisions as informed as possible

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