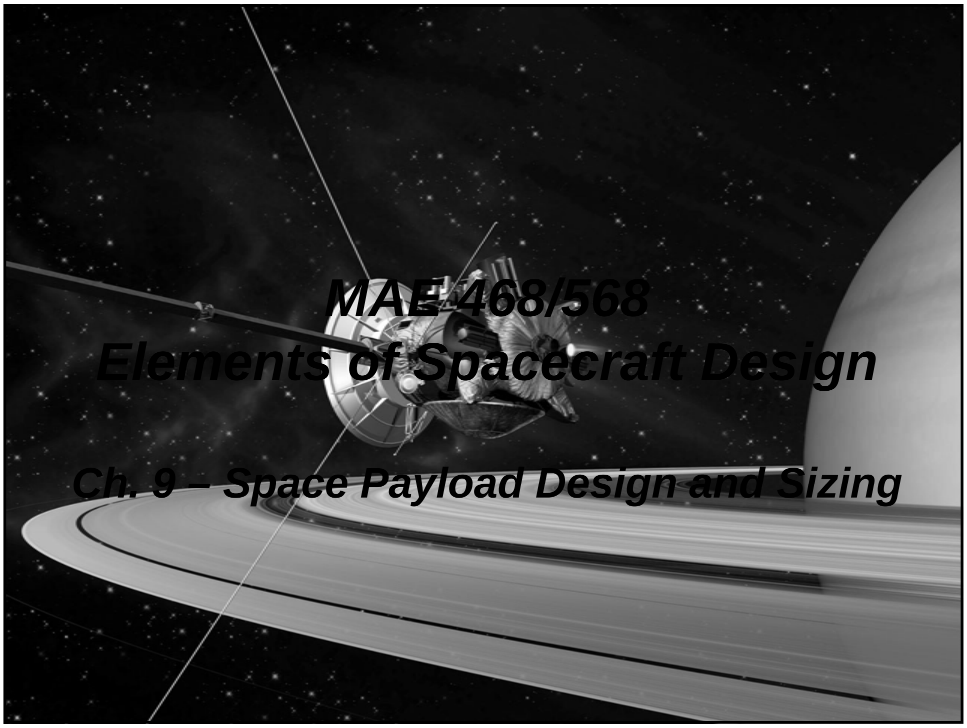


## Class Agenda

- Payload design and sizing process
- Mission requirements and subject trades
- Observation payload design
- Observation payload sizing

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## Spacecraft Payload Design and Sizing

- Payload – combination of hardware and software on spacecraft that interacts with subject
- Subject – portion of outside world that spacecraft is looking at or interacting with
- Purpose of rest of spacecraft is to keep payload healthy, happy, and pointed in right direction
  - Usually what drives mission size, cost, and risk
- Critical to understand what drives a particular set of payloads
- Most missions have unique requirements, thus requiring a unique payload/spacecraft

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## Spacecraft Payload Design and Sizing

- Classification into broad categories
  - Communications
  - Remote sensing
  - Navigation
  - Weapons
  - In situ science
  - Other

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## UAH Payload Design and Sizing Process

- Payload definition and sizing determines many of the capabilities and limitations of the mission
- Payload determines what mission can achieve
- Size of payload influences design of remainder of spacecraft support systems
- Must first understand mission requirements – have major effect on all aspects of design
- Begin with payload – critical mission element bounding spacecraft performance
- Need to determine level of detail required to satisfy different aspects of mission

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## UAH Payload Design and Sizing Process

1. Select payload objectives
   – Strongly related to mission objectives
   – Depend on overall mission concept, requirements, and constraints
   – More specific statements of what payload must do
2. Conduct subject trades
   – Key part of trade – what subject is or should be
   – Need to define performance thresholds to which system must operate

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## Payload Design and Sizing Process

3. Develop payload operations concept
   – Data or product produced by payload must get to user in an appropriate form or format
   – Payload ops have major impact on cost of both spacecraft and mission operations
4. Determine required payload capability
   – Throughput and performance required of payload equipment to meet performance thresholds
5. ID candidate payloads
   – ID possible payloads and their specifications
   – Simple missions – single payload instrument
   – Most missions have multiple instruments that work together to meet mission requirements

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## Payload Design and Sizing Process

6. Estimate candidate payload characteristics
   – Determine performance characteristics, cost, and impact on spacecraft bus and ground system to understand cost vs. performance for each viable candidate system
   – Payloads differ in performance and cost, but also in weight, power, pointing, data rate, thermal, structural support, orbit, commanding, and processing requirements

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## Example Lunar Payloads

| Lander Payload Element | Objective | Nominal Mass (kg) | Mass with 30% Margin (kg) | Nominal Power (W) | Power with 30% Margin (W) | Duty Cycle | Dimensions (cm) |
|---|---|---|---|---|---|---|---|
| Arm | Deploy instruments, conduct geotechnical experiments, collect regolith samples | 13.0 | 16.9 | 43.0 | 55.9 | multiple uses | 110 x 10 x 10 |
| Drill and drill deployment mechanism | Recover regolith samples from depths of up to 2 m | 20.0 | 26.0 | 30.0 | 39.0 | single or multiple use depending upon design. analysis of multiple samples required | 100 x 50 x 50 |
| Scoop | Recover surface regolith samples to a depth of TBD cm | 0.5 | 0.7 | 0.0 | 0.0 | single or multiple use depending upon design. analysis of multiple samples required | 15 x 15 x 10 |

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## Payload Design and Sizing Process

7. Evaluate candidates and select baseline
   - Examine alternatives and make preliminary selection of payload combination that will best meet cost and performance objectives
   - Must decide which elements of performance are worth how much money
   - Strongly related to mission baseline
   - Can not be defined in isolation to rest of parts of mission and what it will be able to do for the end user

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## UAH Payload Design and Sizing Process

8. Assess life-cycle cost and operability
   – Need to determine mission utility as a function of cost
   – Typically not simple cost vs. level of performance characterization
   – May need to prioritize some of the mission requirements in order to meet cost and schedule objectives
9. Define payload derived requirements
   – Detailed definition of impact of selected payloads on requirements for rest of system

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## UAH Payload Design and Sizing Process

10. Document and iterate
   – Need to document what has been decided and WHY!
   – Why is critical to allow system trades to proceed at future time
   – Must understand reasons in order to intelligently continue to do payload and system trades
   – Payload definition is iterative

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## UAH Payload Design and Sizing Process

- Key to deciding how to size payload is to look carefully at mission objectives, particularly how well we want to do
  – Do we need best performance regardless of cost?
  – Can mission proceed only on a minimum budget?

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## UAH Mission Requirements and Subject Trades

- Overall mission requirements dictate technical performance of payload
- Mission concepts and constraints determine operational implementation for mission
- Frequently technical specification and operations concept for payloads are interrelated
- Need to ensure mission requirements capture fundamental needs of users without constraining designer's ability to satisfy requirements through alternative means
- Must specify physically observable quantities that contribute to elements of information about problem in sufficient detail to ensure they can be detected by a spacecraft payload with sufficient resolution to provide meaningful insight into subject

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## UAH Mission Requirements and Subject Trades

- Establishing performance thresholds provides a framework for trading off performance across a number of different design features
- Payload performance evaluation categories include physical performance constraints (resolution) and operational constraints (duty cycles, tasking)
- With each category need to establish an absolute minimum threshold – does not meet is unacceptable
- Minimum threshold values generally will not satisfy mission objectives

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## UAH Mission Requirements and Subject Trades

- Need to also specify desired performance to establish performance that will fully satisfy requirement
- Can made intermediate value (acceptable) – to articulate a level of performance that will meet bulk of mission objectives
- Need to parameterize the mission in such a way that we can evaluate, size, and design candidate sensors
  - Involves requirements analysis that focuses on matching tasks involved in mission with categories of discipline capabilities

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## UAH Mission Requirements and Subject Trades

- There are many choices and types of sensors for a given mission
- Selection of a spacecraft payload represents the fundamental leap in determining how to satisfy mission requirements with a space sensor
- Payload design process begins with a task or mission requirement and ends with a spacecraft payload design

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## UAH Subject Trades

- Space mission objective – to detect, communicate, or interact
- Subject – specific thing that spacecraft will detect, communicate, or interact with
- Subject choice dramatically affects performance, cost, and mission concept
  - Need to do trade carefully and review it from time to time to ensure consistency with mission objectives and minimizing cost/risk

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## Subject Trade Process

1. Determine fundamental mission objectives
2. Determine what possible subjects could be used to meet these objectives
   – What could system detect or interact with to meet objectives
3. Determine broad class of ways that the spacecraft can detect or interact with possible subjects
4. Determine if subject is passive or controllable
   – Passive – characteristics may be known but cannot be altered

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## Subject Trade Process

5. For controllable subjects, do trade of putting functionality at the subject, in space system, or ground system
6. For passive subjects, determine general characteristics that can be detected
7. Determine whether multiple subjects and payload should be used
8. Define and document initial subject selection
9. Review selection frequently for alterative methods and possible use of ancillary subjects

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## Observation Payload Design

- Spacecraft remote sensing is concerned with processing measurements from four primary spectral types
  - Visible systems – operate only in daylight
  - Infrared systems – operate in night or day
  - Microwave systems – resolution 3 to 5 orders of magnitude worse than visible wavelength sensors with same aperture size
  - Radar systems – reflected signals can be processed to identify physical features in the scene

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## Observation Payload Design

- Radiometric performance of an optical instrument
  - Observation geometry
  - Effective aperture
  - Integration time
  - Detector sensitivity
  - Spectral bandwidth
  - Transmission through atmosphere

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## Observation Payload Design

- Three basic categories of observation
  - Optical instrument receives reflected radiation from surface when it is illuminated by Sun
  - Optical instrument receives emitted radiation from surface when reflected radiation of sun is negligible
  - Optical instrument receives contributions from direct and reflected sources

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## Observation Payload Sizing

- Must be able to estimate size and main characteristics of mission payload before completing a detailed design
- Need to be able to look at several options without necessarily designing each in depth
- Would like to estimate size, weight, and power
- Three methods
  - Analogy with existing systems
  - Scaling from existing systems
  - Budgeting by components

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## Observation Payload Sizing

- Most straightforward approach to use analogy with existing systems
- Look for existing payloads which have characteristics matching mission we have in mind
- Look for payloads whose performance and complexity match what we are trying to achieve and make a first estimate that our payload will have characteristics comparable to previously designed, existing payload
- Can help determine reasonableness of approach

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## Observation Payload Sizing

- 2nd approach – scaling payload estimate from existing systems
- Provides moderately accurate estimates of reasonable accuracy if scale of proposed payload does not differ too greatly from current payloads
- Provides excellent check
  - Existing payloads have been carefully designed ad optimized
  - If new payload is either too large or too small relative to prior ones, should be some reason for this change in characteristics

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## *Observation Payload Sizing*

- Most accurate process is budgeting by component
- Develop list of payload components
- Estimate weight, power, and number of each
- Best and most accurate approach – may be difficult to apply at early mission stages (not enough information)
- Ultimately we will size payload with budgeting by components

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## *Scaling From Existing Systems*

- Look at Table 9-13, pg. 275 for existing payload characteristics
- Will scale instruments based on aperture – main design parameter that can be determined from preliminary mission requirements
- To scale, compute aperture ratio

$$R = \frac{A_i}{A_o}$$

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## *Scaling From Existing Systems*

- With R calculated, estimate size, weight, power based on ratio with selected instrument from Table 9-13
- Linear dimensions

$$L_i \approx RL_o$$

- Surface area

$$S_i \approx L_i^{\,2}$$

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## *Scaling From Existing Systems*

- Volume

$$V_i \approx L_i^{\,3}$$

- Weight

$$W_i \approx KR^3 W_o$$

- Power

$$P_i \approx KR^3 P_o$$

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## Scaling From Existing Systems

- K should be 2 when R is less than 0.5 and 1 otherwise
- For instruments more than a factor of five smaller than those listed in Table 9-13, scaling become unreliable

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## Example

- What is the preliminary surface area, volume, weight, and power of a new solar optical telescope that has an aperture of 4 m?

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