SEAri Short Course Series

Course: PI.27s Value-driven Tradespace Exploration for System Design

Lecture: Lecture 0: Introductions and Course Overview

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[PI.27s] Value-Driven Tradespace Exploration for System Design

Lecture 0
Introductions and Course Overview

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Massachusetts Institute of Technology

Welcome and Introductions

- MIT Instructor Team
- Course Schedule/Logistics
- Learning Objectives
- Class Introductions

Systems Engineering Advancement Research Initiative (SEAri)

SEAri is positioned within the Engineering Systems Division at MIT

Mission

Advance the <u>theories, methods, and effective practice</u> of systems engineering applied to complex <u>socio-technical systems</u> through <u>collaborative research</u>

<u>Current Sponsors:</u>

US Air Force, Singapore DSTA, MIT Portugal Program, Lean Advancement Initiative, selected US Government Agencies

292 Main Street

E38-575

Instructor Team

Dr. Donna H. Rhodes	Dr. Adam M. Ross
MIT	**MIT**
SEAri Director	SEAri Co-Director
Principal Research Scientist	Lead Research Scientist

Our research is motivated by having impact on practice, not just academic thought

Logistics & Information

- We are in MIT Building E38, 5th floor, located at 292 Main Street
  - Classroom opens at **8:45** each morning

- Nearby:
  - MIT Press Bookstore (below us)
  - MIT COOP Bookstore (across from us)
  - Food Court (across/behind MIT COOP)
  - Rooftop garden (top of parking structure by Marriott)
  - Starbucks – one in Marriott, one nearby
  - Many restaurants along Main Street

Daily Schedule

Class runs 9:00AM – 5:00PM

- Mid-morning break
- Lunch break (on your own)
- Mid-afternoon break

About the Course

Value-Driven Tradespace Exploration for System Design

- One of the key contemporary challenges in developing successful systems is to be able to **make effective architectural design choices in the face of complexity and a changing world.**
- The course presents a **new method for tradespace exploration** based on a value driven perspective, allowing designers to better understand and meet both present and future stakeholder needs and expectations.
- The Multi-Attribute Tradespace Exploration (MATE) methodology was developed at MIT for ***exploring* tradespaces of possible architectures** rather than settling quickly on an optimum.

Learning Objectives: Fundamentals, Application, Strategic

Learning Objectives
Fundamentals

1. Understand the **motivation for and increasing importance of tradespace exploration** in the context of the contemporary engineering environment and associated challenges.
2. Grasp **how the value driven perspective can help designers** better understand both present and future stakeholder needs and expectations.
3. Identify **where in the system lifecycle** the tradespace exploration and system design activities should be performed.
4. Describe **fundamental concepts** including stakeholder preferences, decisional vs. experienced value, latent value, attributes, design vectors, and multi-attribute utility theory.

Learning Objectives
Application

5. Understand Multi-Attribute Tradespace Exploration (MATE) **method**, and how it has been **applied** to real-world systems.

6. **Choose and use appropriate tools** for analysis of the tradespace (e.g., Multi-attribute Utility Theory, N-squared or Design Structure Matrix analysis, etc.)

7. **Set up and justify a tradespace analysis** using system attributes, stakeholder utilities, and a scoped and quantified design vector.

8. **Analyze a simple tradespace** using the Multi-Attribute Tradespace Exploration (MATE) framework, and identify and assess the effects of risk, uncertainty, and/or policy effects using appropriate techniques.

Learning Objectives
Strategic

9. Identify the **metrics for quantifying changeability** of a design, and active vs. passive strategies and methods for **increasing the perceived changeability** of a system.
10. Gain insight into the **latest thinking** on advanced topics including valuation of selected “ilities”, uncertainty management, change taxonomy, tradespace networks, and real options.
11. Have knowledge of strategic issues such as **temporal considerations** in tradespace exploration, and exploring complex tradespaces for families of designs and systems of systems.
12. Have pointers to latest published **literature** in the field and **research topics**.

Class Introductions

Please share:

- Your name
- Your organization and position
- Your motivation for attending the class

Your Course Materials

- Lecture Materials
- Exercises
- Survey and Assessment
  - Daily Feedback Survey
- Reading List
- Supplemental Materials

Day 1: Introduction

Value Driven Tradespace Exploration for System Design

Participants will be introduced to the value driven perspective as a paradigm for system architecting and design. The motivations for and challenges of tradespace exploration will be discussed with regard to the contemporary engineering environment, and methods in use. Practical approaches to setting up the tradespace will be described and experienced.

Topics will include:

- Why Use Trade Studies?
  - Motivations, Drivers, Challenges
  - Benefits of the Value Driven Perspective
- Overview of Classical Methods for Architecting and Design
  - Tradespace Exploration and Design in Context of System Lifecycle
  - Basics of Architecting and Design Methods
- Introduction to Multi-Attribute Decision Making
- Exercise 1: Setting up a Simple Decision Space
- Introduction to Tradespace Exploration
- Exercise 2: Setting up a Simple Tradespace
- Basics of Utility Theory
  - Benefits, Limitations, and Considerations
  - Comparison with Other Methods

Background Knowledge for Understanding Simple Space System Examples Used in Class

Space Systems: Military "Capital Asset" Missions

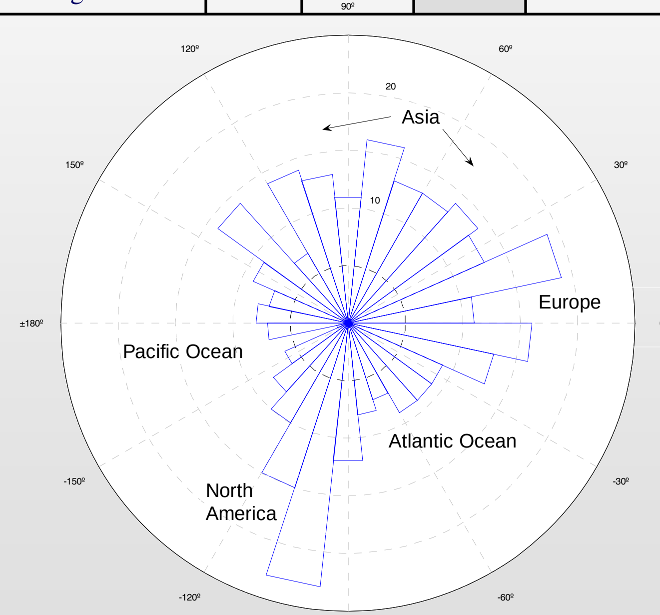
- Enduring space services provided by capital asset constellations (1,000-10,000 Kg class)
  - Planning, development, launch (~10 yrs), operates for long time (~10yrs)
  - Design in anticipated needs for redundancy, protection, and capacity
    - Navigation, Communication, Weather, Intelligence missions

Slow cycle time, well understood missions, dominated by need for and achievement of technical capability and reliability

Commercial "Capital Asset" Missions

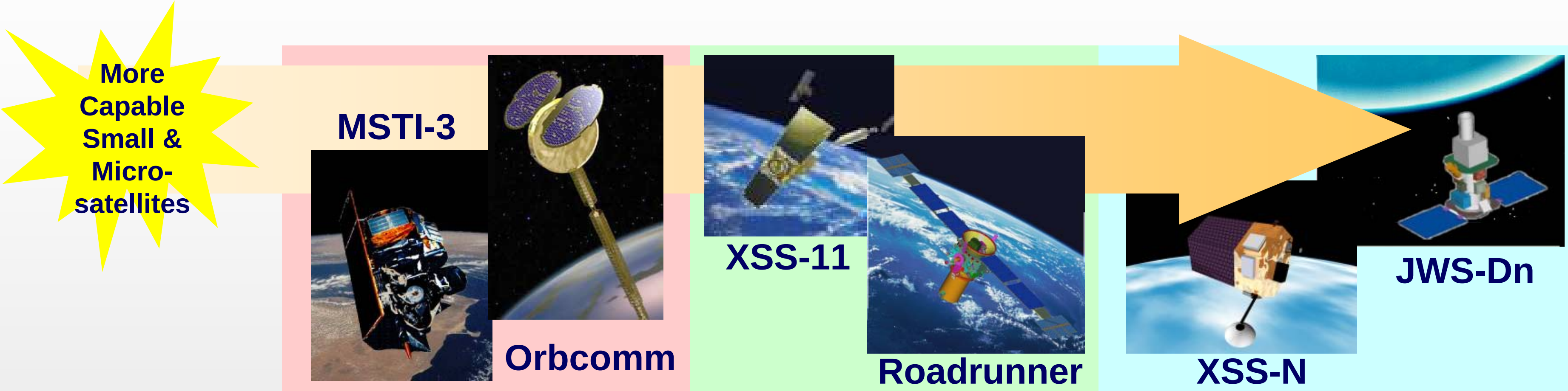
- Dominated by Geosynchronous Communication
  - "Dominant Design" - few other commercial products
  - Operates for long time (10+yrs)
  - Planning, detail design, some tech insertion on shorter (18 month) cycle - enabled by product family architecture
  - Design in anticipated needs for redundancy, protection, and capacity
    - Navigation, Communication, Weather, Intelligence missions

	LEO	MEO	**GEO**	Elliptical	Total
Astronomy	53	0	1	17	71
Communications	203	2	**318**	11	534
Earth Observation	87	0	23	2	112
Navigation	9	44	3	0	56



Very well understood missions, dominated by need for market responsiveness,technical capability and reliability

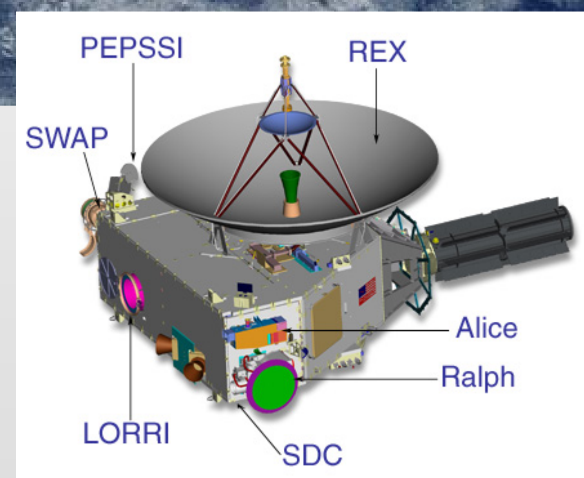
Smaller Satellites enabled by Technology advancements



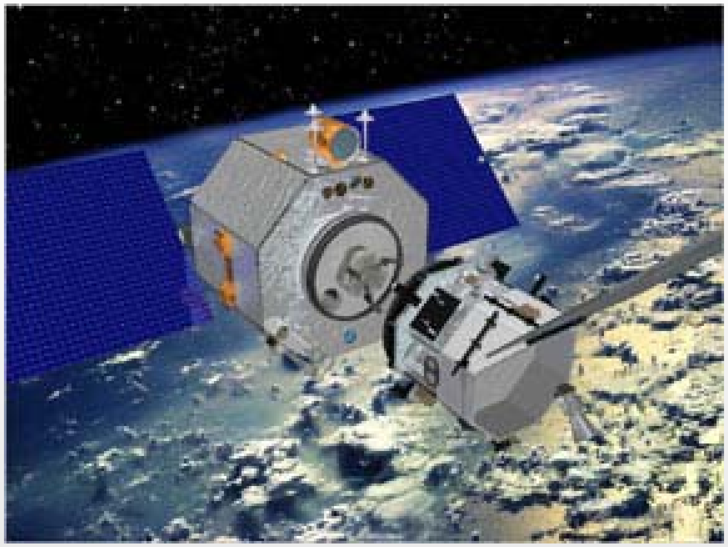
Technology	1998	2004	2010
Power System	Baseline	x4 Power, x1.4 Power Density	x10 Power, x3 Power Density
Avionics	Baseline	/4 Weight, x6 Speed	/8 Weight, x100 Speed
Propulsion	Baseline	x5 Delta-V	x20 Delta-V
Comm	Baseline, S band	x14, X band	x500, Ku band
Payload	Very small	Small	Medium
Payload Mass Fraction (dry)	20%	50%	75%

Science Space in Both Worlds

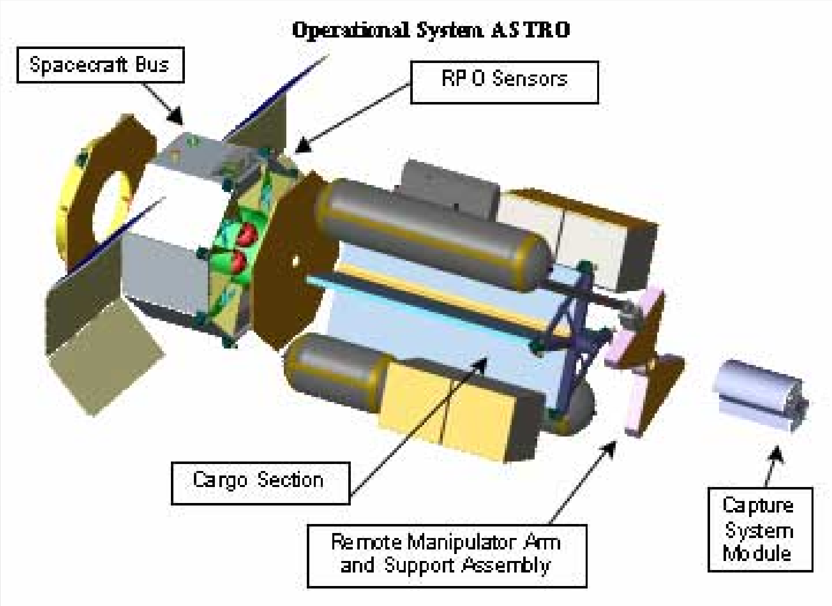
- Big Science - Capital Asset Missions
  - Hubble
  - Cassini/Huygens
  - Webb
- "Faster Better Cheaper" Science
  - New Horizons (Pluto mission)
  - Pioneer Mars Rover
  - *Failed Mars Missions*
- Trend is towards smaller missions
  - Setbacks and political realities make movement in this direction uneven.



Running Example: Space Tug



General purpose vehicle to intercept, interact with, and accelerate other vehicles: General question - what would be a useful design for such a vehicle?



Recently flown Astro/NextSat mission:

Robotic, autonomous on-orbit refueling and reconfiguration test program

Proof of concept!