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OFFICE OF THE DIRECTOR OF NATIONAL INTELLIGENCE

ANALYSES OF ALTERNATIVES FOR SPACE SYSTEMS

ODNI/SRA/CA

LEADING INTELLIGENCE INTEGRATION

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Audience: ICEAA

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Why are satellite architecture trades important?

- **Many customers value satellite trades**
  - Congress
  - Program Offices
  - Agency Leadership
- **Successful AoAs require a repeatable and accurate way to estimate satellite trades and measure relative differences**
- **AoAs are different from ICEs:**
  - Typically ICEs consider an established baseline with an Intelligence Capability Baseline Document (ICBD) and datasheets
  - ICEs usually performed at or after Authority To Proceed (ATP)
  - AoAs are notional and are generally done years before an eventual ATP
- **Costs cannot be modeled without understanding technical baseline**
  - Need definition/capabilities of payloads and key bus elements
  - Predicting size and performance helps define scope
  - Facilitates discussions of key technical parameters and relevance of analogies

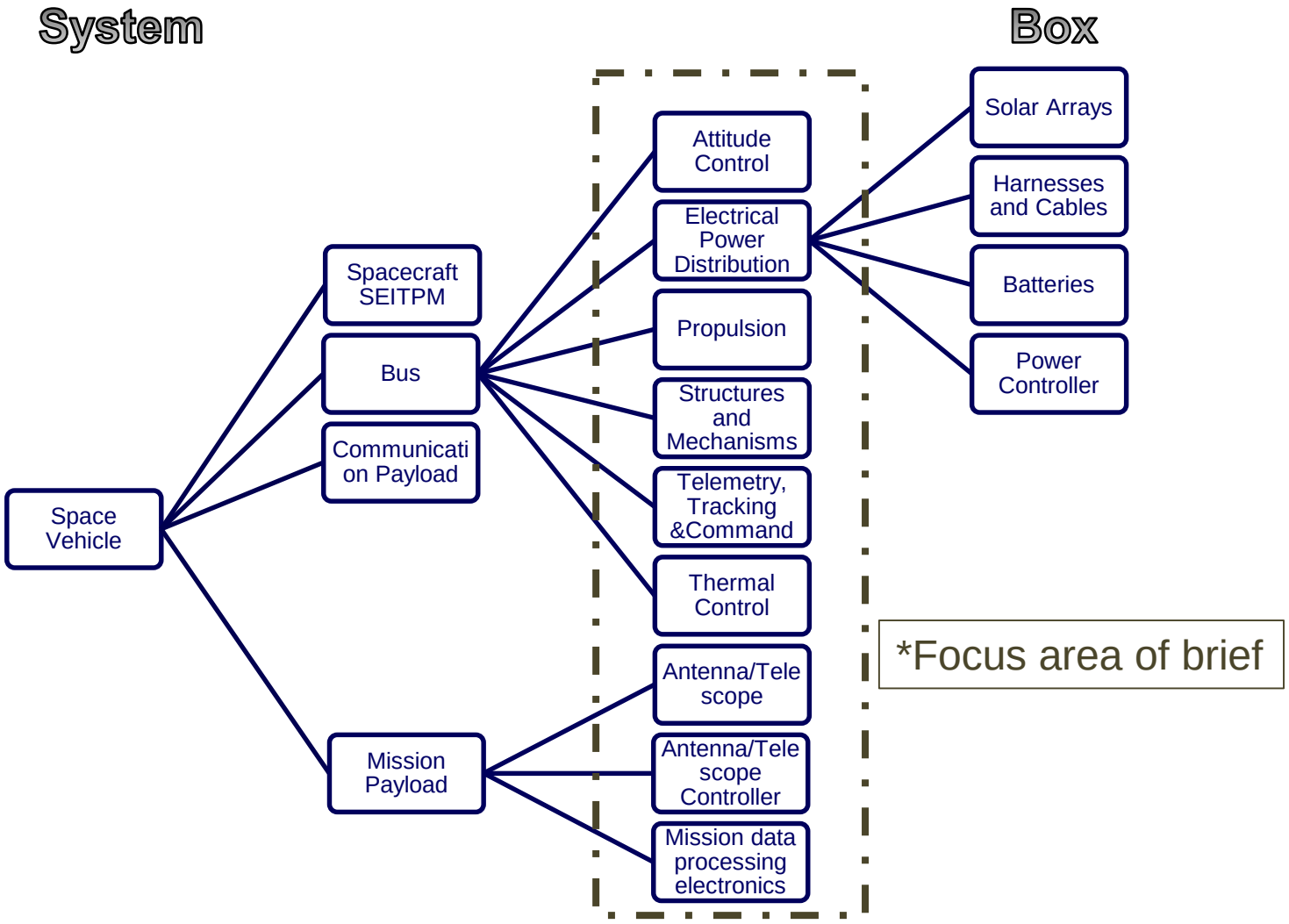
Space System Concepts

- **Attitude: Space vehicle orientation about Center of Mass**
- **Constellation: Set of satellites performing a common mission**

Spacecraft

- **SEITPM: Systems Engineering, Integration & Test, Program Management**
- **Payloads: Include communications equipment and mission sensors**
- **Bus: subsystems needed to support the spacecraft and providing,**
  - Power Generation & Distribution
  - Thermal Control
  - Structural Support
  - Propulsion
  - Vehicle Telemetry and Ephemeris
  - Commanding
  - Attitude Determination
  - Maneuvering and Pointing

Concepts: Space Vehicle Hierarchy

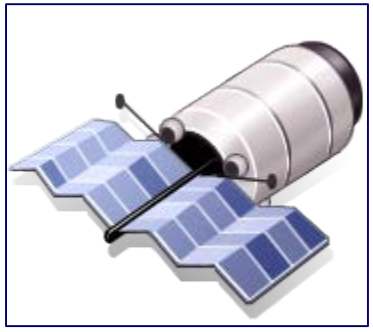


Sparse definition results in limitless trade space

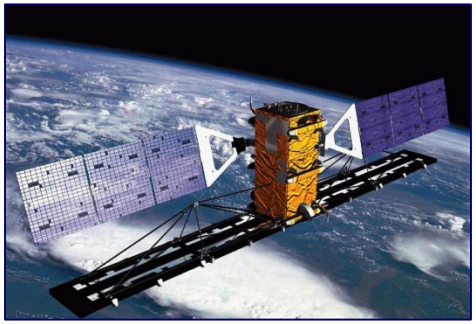
Problem: Perform current sensing mission at a reduced budget

Solution Trade Space: Without historical context, trades can be vague, contradictory or impossible

Airborne paper design



Vague new sensors

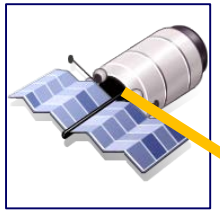


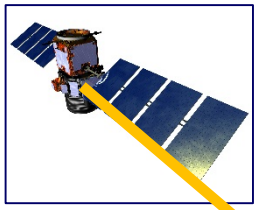
CSA – Radarsat-1

Legacy operating satellite

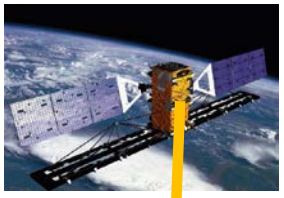
Refine trades by examining historical programs

Trade space as defined:

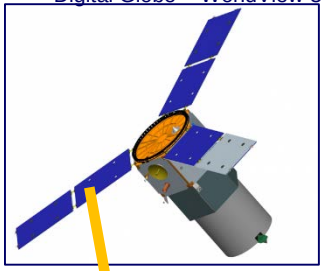




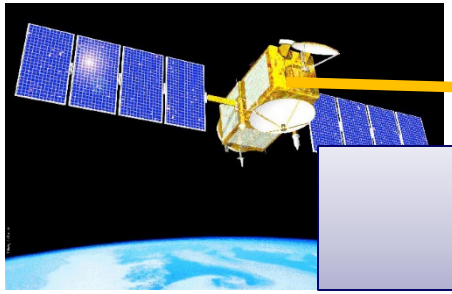
CSA – Radarsat-1



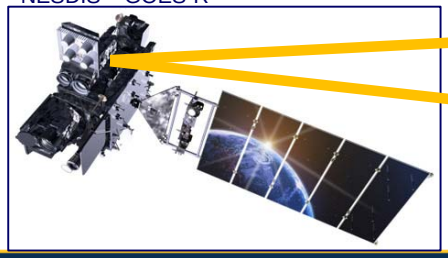
Digital Globe – WorldView-3



NASA – JASON-1



NESDIS – GOES-R

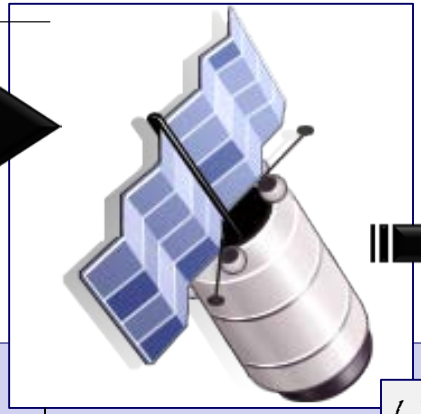


AoA Sat 1

Technical parameters and weight are used to estimate cost

Estimate Weight & Technical Parameters

Options	1
Orbit	LEO
Payload 1	Sensor 1
Payload 2	Sensor 2
Agility	High
Comm	Gimbaled
Design Life	36
Launch Vehicle	MLV



Estimate SV Cost

Identify Mission & Sensors

Build subsystem-level weight estimate

Use historical analogy data

Use Subsystem parametrics based on historical data

Add discrete payloads & sensors (payloads not estimated by weight)

ASSESS % NEW DESIGN & USE HISTORICAL NR/T1 RATIOS

Add historical program loaders

Slide Terms
T1: Theoretical first unit
NR/T1: Non-Recurring to T1 Ratio
LEO: Low Earth Orbit
MLV: Medium Launch Vehicle
SV: Space Vehicle

Few inputs can create many alternatives

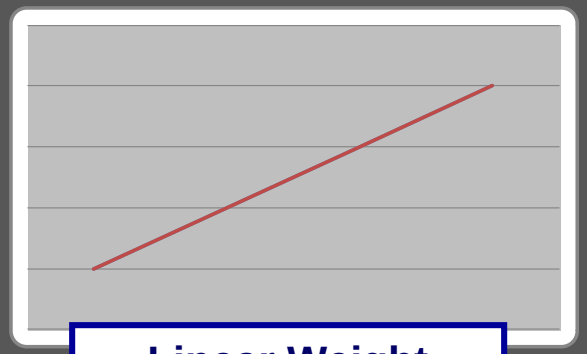
- **A wide range of performance parameters are often addressed, but each study generally focuses on a few key trades**
- **Often paper designs are compared to currently-flying satellites**
- **However, can scale paper designs effectively based on historical vehicles**

Options	1	2	3	4	**... n**
Orbit	LEO	MEO	LEO	LEO	... n
Payload 1	Sensor 1	Sensor 1	Sensor 2	Sensor 3	... n
Payload 2	Sensor 2	Sensor 3	Sensor 3	None	... n
Agility	High	Low	High	Low	... n
Comm	Gimbaled	Gimbaled	Body	Body	... n
Design Life	36	36	60	60	... n
Launch Vehicle	MLV	MLV	MLV	MLV	... n

- A recent study provided only 7 inputs to drive cost and weight
- These 7 inputs were varied to create 34 unique architectures

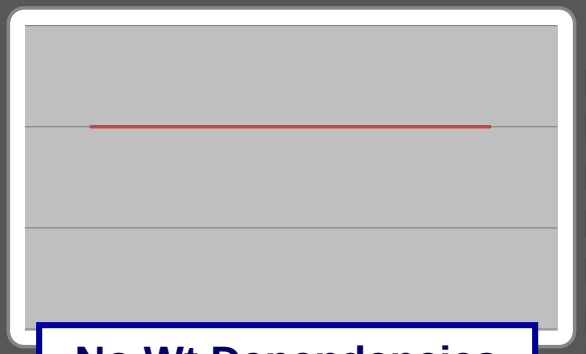
Most AoA trades examine space vehicles not yet designed

Subsystem weight scaled with physical dependency



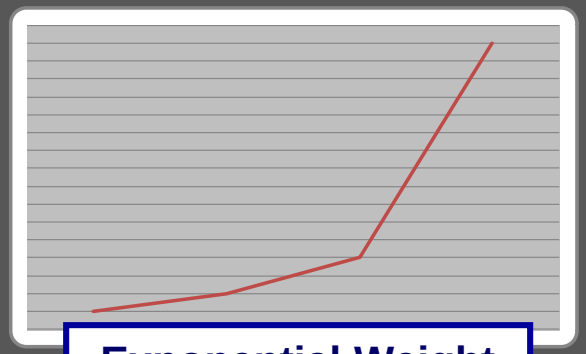
Linear Weight

- Structures and Mechanisms
  (Satellite / payload weight)
- Battery
  (Solar array weight)
- Solar Arrays
  (Good: All major power-drawing subsystems weight)
  (Better: BOL power)



No Wt Dependencies

- All control electronics
- Attitude Control Sensors
- Communication Payload



Exponential Weight

Telescopes
- Fore and Aft Optics
  (Aperture^2)

- Structures & Outer Barrel Assembly
  (Aperture^2)

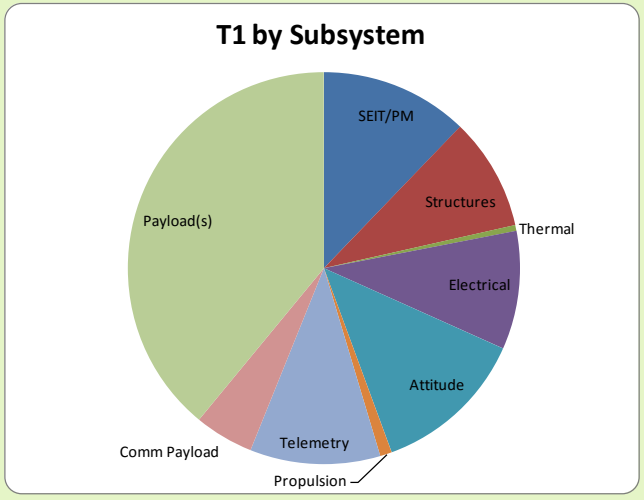
Signals
- Antenna
  (Diameter^2)

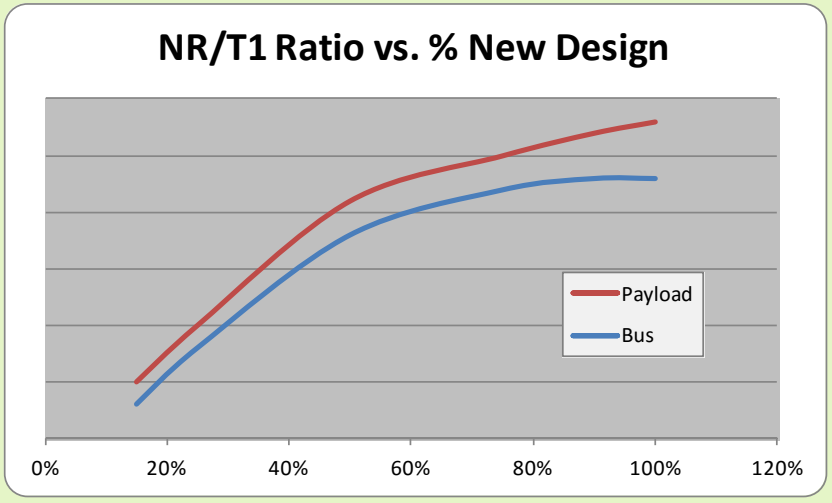
Slide Terms
Aperture: diameter of primary mirror
BOL: Beginning of Life

Dependencies drive weight buildup

Once weight is predicted, cost can be estimated

- **Recurring costs:**
  - Bus subsystem $/lb relationship based on analogy data and weight buildup
  - Payload costs estimated discretely using historical data scaled to technical capabilities
  - Can use average $/lb of many data points or subsystem CERs
- **Non-recurring costs:**
  - % new assessment, validated independently by SME
  - NR/T1 relationship based on historical agency data

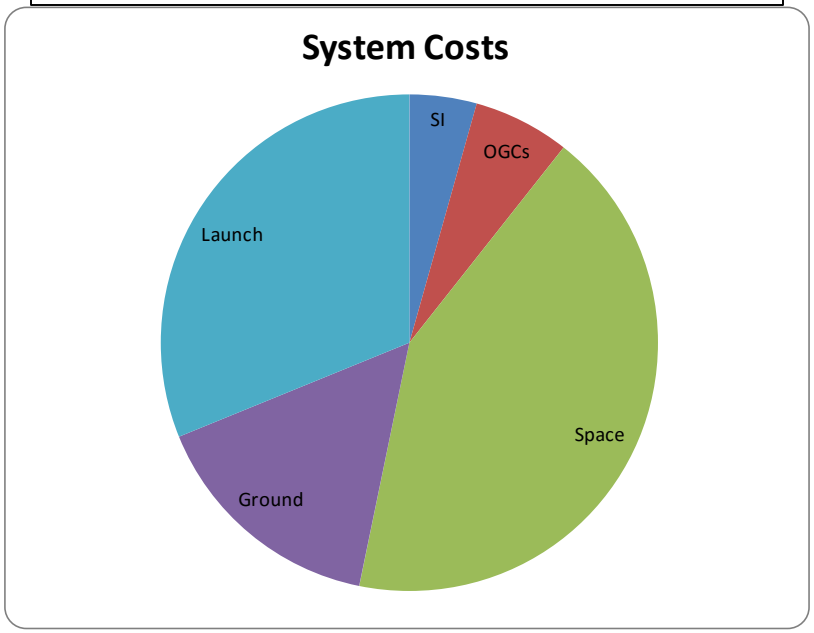




System of Systems (SoS) costs are included

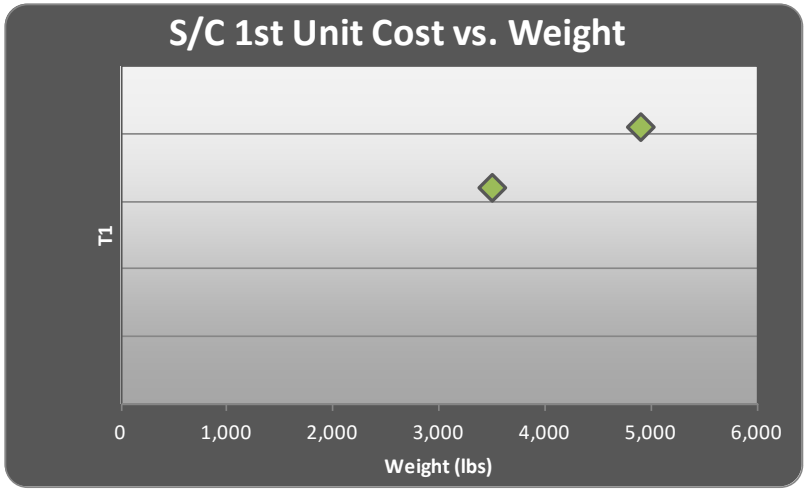
- **Non-spacecraft costs are expensive**
- **Additional costs:**
  - System Integration (Space + Ground)
  - Other Government Costs
    - Program office
    - Studies
    - Government Funded Equipment (GFE)
  - Ground
    - Command and Control
    - Mission Planning
    - Mission Data Processing
    - Ground Terminals
  - Launch (function of sat size and orbit)

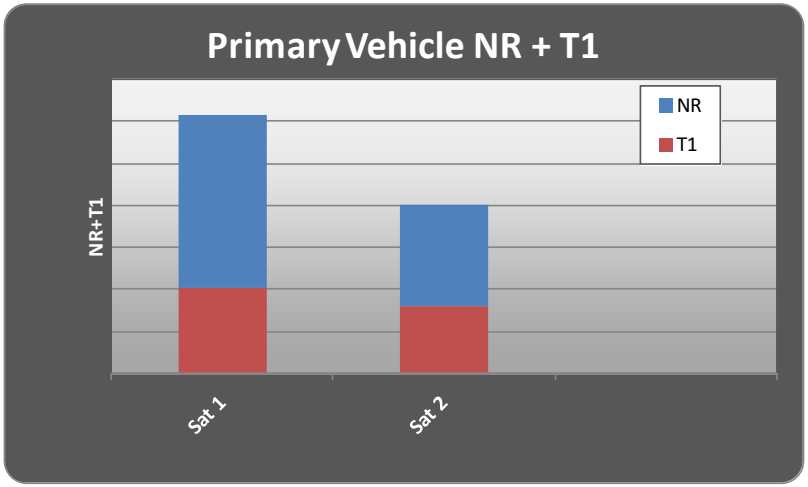
On any given program, hierarchy of system elements can change drastically



When applying SoS costs, need to treat all architectures consistently

Comparisons can be drawn from results





- **Method also provides good crosscheck to ICEs**
- **Rapid and consistent mechanism to perform AoA**
- **Focuses technical discussion on new design and payload technology**
  - NR and payloads are the key drivers in any estimate, AoA or ICE

Sizing and cost modeling techniques are effective and repeatable

Slide Terms
S/C: Spacecraft

Continuing to evolve AoA modeling capability

- **Recent additions:**
  - Schedule estimating relationships
  - Schedule visualization
  - Phasing component; includes ability to constrain
  - Phasing visualization
  - Architecture modeling and replenishment
    - Combination of design life, launch centers, budget constraints
  - Configuration management mechanisms

- **Future planned enhancements:**
  - Cost and technical risk assessment capability

Questions?