Systems Architecture and Engineering Applied to Technology Development

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Increasing Complexity

• Systems of systems
  – Appliances, Home Entertainment Systems, Vehicles, Spacecraft

• Technology Development
  – Not just simple components
    • Microchips
    • Displays
    • Drive Systems
    • Electric Propulsion
  – All must be developed for the target application
    • Usage
    • Environment
Finding the Benefits

Array Mass

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Trade Space Example

Dust Mitigating Array Design

Extreme Temp. and Rad Tolerant Cells

Increased Cell Efficiency

Lightweight Arrays

Technology

Decreased Deterioration

Increased Low/High Temp Performance

Increased Rad Tolerance

Increased Available Power

Decreased Stowage Volume

Decreased Array Surface Area

Decreased Array Mass

Power System Impact

Increased Performance in harsh env

Decreased Propellant Mass (better trajectory)

Increased Delivered Mass (lower C3)

Increased Fuel Capacity

Lowered Launch Mass

Increased Mobility

Increased Science Payload

Increased Telecom Capacity

S/C Systems Impact

Opened Mission Design Space

Decreased Trip Time

Increased Mission Life

Decreased Mission Risk

Decreased Costs

Increased Science Return

Increased Data Return

Mission Benefit

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Finding the "knee"

SEP VGA to Neptune
High Eff Silicon Cells, 30 kW Solar Array
NEXT ion engine, 4 operating max.

Flight Time (yrs)

Net Delivered Mass (kg)

- 60 W/kg
- 80 W/kg
- 100 W/kg
- 120 W/kg
- 140 W/kg

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JPL’s Need:
- Unbiased, apples-to-apples comparisons of the benefits of various technologies for sets of future deep space missions

Approach
- Establish a capability to rapidly determine system-level mass savings from infusion of any of a list of specified technologies
  - Includes “ripple effects” of technology mass savings on other subsystems (e.g. propulsion, structures, etc.)
- Contracted with Caltech’s Laboratory for Space Mission Design to develop a tool, document the design and operation (user’s manual), and train JPL engineers to use it

Mathematical Models:
- Simplified semi-analytical models for mass and power of all major spacecraft systems
- Based on well established rules of thumb, historical analysis, and engineering judgment (Sercel and JPL advisors)
- Major Simplification: Models calculate deltas from Team X reports, not absolute values of mass and power
Some results

RPS Mass Savings (kg)

Specific Energy (w/kg)

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More Results

Mass Savings

Solar Array Specific Power (W/kg)

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Some Final Thoughts

- Increasing complexity of advanced technologies requires application of system engineering techniques to ensure technology is architected/designed to fit the application

- More and better tools
  - More complete and cost-effective systems engineering analyses of technology benefits

- Getting over the "knee"
  - Does not mean the technology has no future
  - An indicator that the “application” (mission architecture) may need re-architecting to regain benefits from additional development
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