Assessing the Value Proposition for Operationally Responsive Space

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Outline

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  - Distinguishing ORS from “Big Space”
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- Model of Electro-Optical Spacecraft
  - Multi-Attribute Tradespace Exploration (MATE)
  - Results
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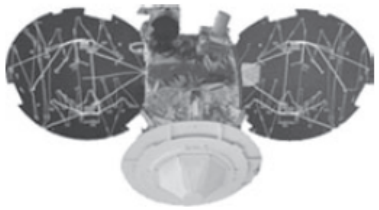
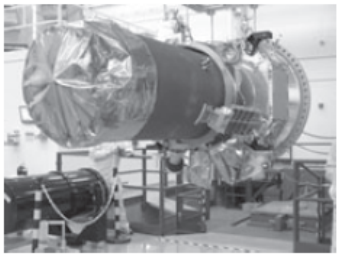
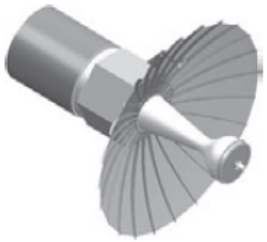
Motivation

*ORS is "...**assured** space power focused on **timely** satisfaction of **Joint Force Commanders**' needs…while also maintaining the ability to address other users' needs for improving the responsiveness of space capabilities to meet national security requirements"*
(*The Plan for Operationally Responsive Space, DoD, 2007)*

TacSat 1	TacSat 2	TacSat 3	TacSat 4
			

(GAO 2006)

- Goal: reduce time constants associated with space system acquisition, design, and operation *(DoD 2007)*
- Fundamental idea: trade off reliability and performance of "big space" for speed, responsiveness, and customization potentially offered by small tactical spacecraft (TacSats)
- *Tomme* Problem: uncertain value proposition *(2006; Fram 2007)*

"ORS deserves, yet has not received, our analytic due diligence."
(Mr. Gil Klinger, Former Director of Space Policy, U.S. National Security Council, 22 August 2007)

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Distinguishing ORS from "Big Space"

Characteristic	"Big Space"	ORS
Historical Context	Cold War	acquisitions crisis; fragilities inherent in integral, long-life designs
Original Beneficiary	National Command Authority	theater combatant commander
Programmatic Drivers	performance	cost, schedule
Innovation Dynamic	capability-pull	technology-push
Payloads	customized, satisfy multiple missions	off-the-shelf; single-mission focus
Design Life	10+ years	1+ year(s)
Risk Tolerance	risk averse	risk tolerant

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Paradigms: Values vs. Alternatives

	"Big Space"	ORS
Values	Big Space Values – Performance	ORS Values – Timeliness
Alternatives	Big Space Alternatives – Unique – Multi-payload missions	ORS Alternatives – Plug n Play – Fractionated Space – TacSat

Values: what we care about; Alternatives: what we do

Can trade alternatives only when values are understood

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Research Questions

- Mission: Electro-Optical imagery
- Divergent priorities across communities
  - "Big Space": technical performance (e.g., resolution)
  - ORS: timeliness
- ORS may have trouble finding sustainable niche in traditional acquisition environment

Research Questions

In examining trades within a single system concept, do design alternatives exist that are acceptable to both stakeholder communities?

…or are their respective value propositions too different?

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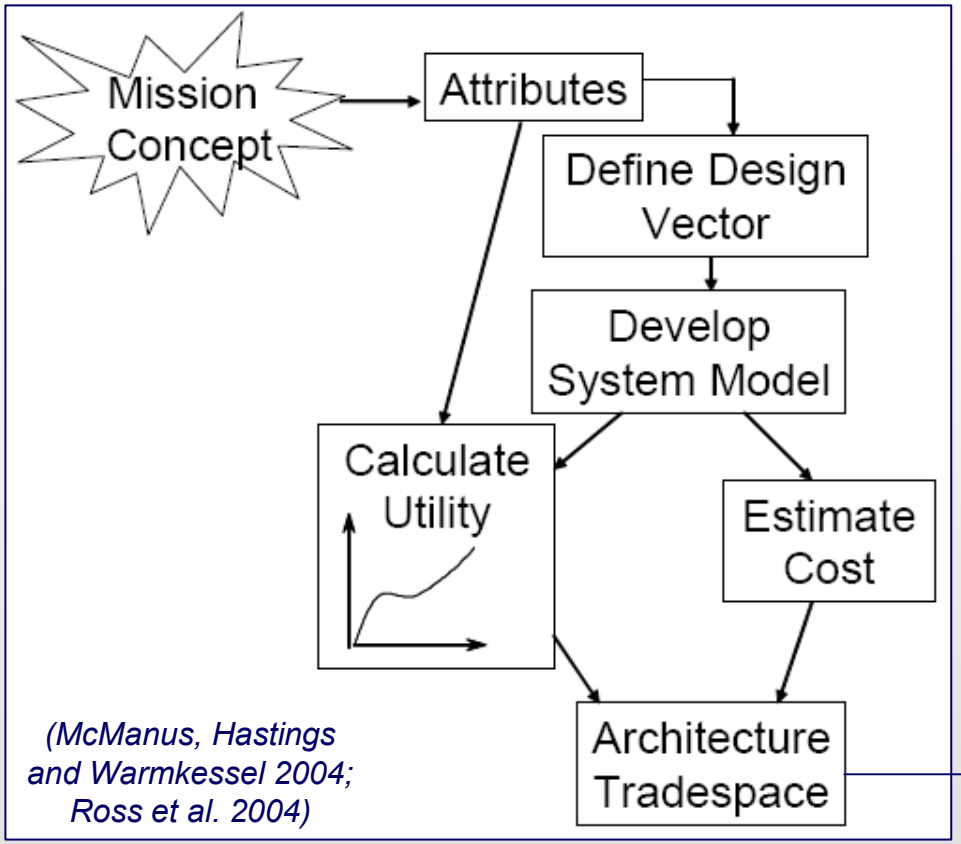
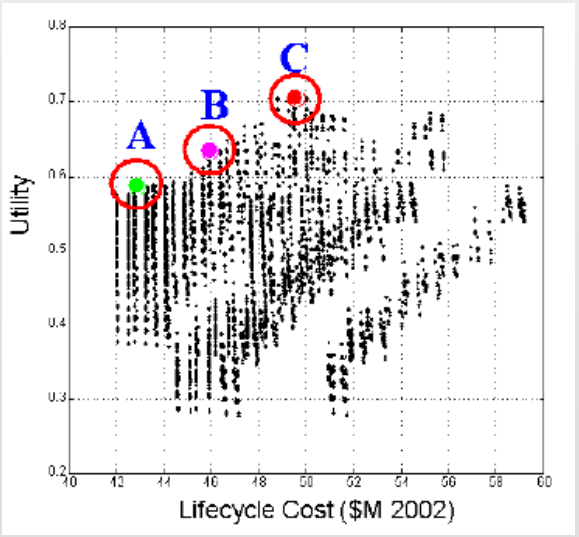
Multi-Attribute Tradespace Exploration



(McManus, Hastings and Warmkessel 2004; Ross et al. 2004)

1. Specify value proposition
   - Interview decision-maker(s)
   - Create a list of attributes
   - Elicit utility curves
2. Enumerate design vector
3. Develop system model
4. Evaluate candidate architectures in tradespace



Application of decision analysis and utility theory to model and simulation-based design

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Attributes and Design Variables

Attribute	Units	Acceptable Range
Signal Coverage	km^2	1,000-10,000
Global Coverage	%	66-100
Resolution	m	0.1-1
Revisit Rate	days	0.2-2
Sensitivity	Sensor type	Day-Night
Availability	%	95-99
Timeliness	Years	1-10

Attributes
- Those aspects of a design that the stakeholder articulates and will use to distinguish good designs from bad designs
- Need to be measurable in some way
- Attributes should be perceived independent

Design Variables
- Those aspects of a design that the engineer can control
- Typically technical details
- Adding schedule as a design variable
- Tradespace can be populated with a full-factorial of design variables

Design Variable	Units	Range
Orbit Altitude	km	200-500
Orbit Inclination	degrees	20-90
Focal Length	m	0.5-2
Optic Sensitivity	day and/or night	0-2
Desired Schedule	years	1-10

Attributes elicited from a proxy stakeholder. MAUT evaluates attributes that are bounded, such that the user derives no utility below the bound and no added utility above the bound.

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Develop System Model: Modeling ORS with MATE

N-squared Diagram

Coded Modules	1	2	3	4	5	6	7
(1)Design Variable							
(2)Optics/ Bus	x						
(3)Orbits	x	x					
(4)Launch		x	x				
(5)Schedule	x	x		x			
(6)Utility	x	x	x		x		
(7)Tradespace	x	x	x	x	x	x	

- A tradespace for decision making requires model of system or systems trades
- ORS trades performance and time
  - Standard exercise for most engineers
  - Level of fidelity determined by available time, information and computing power
  - Process and Schedule Model
    - Not yet attempted in any MATE studies
    - Will draw from the Process Development literature

Model takes in design variables and calculates attributes.
To capture "timeliness," need to include a schedule module.

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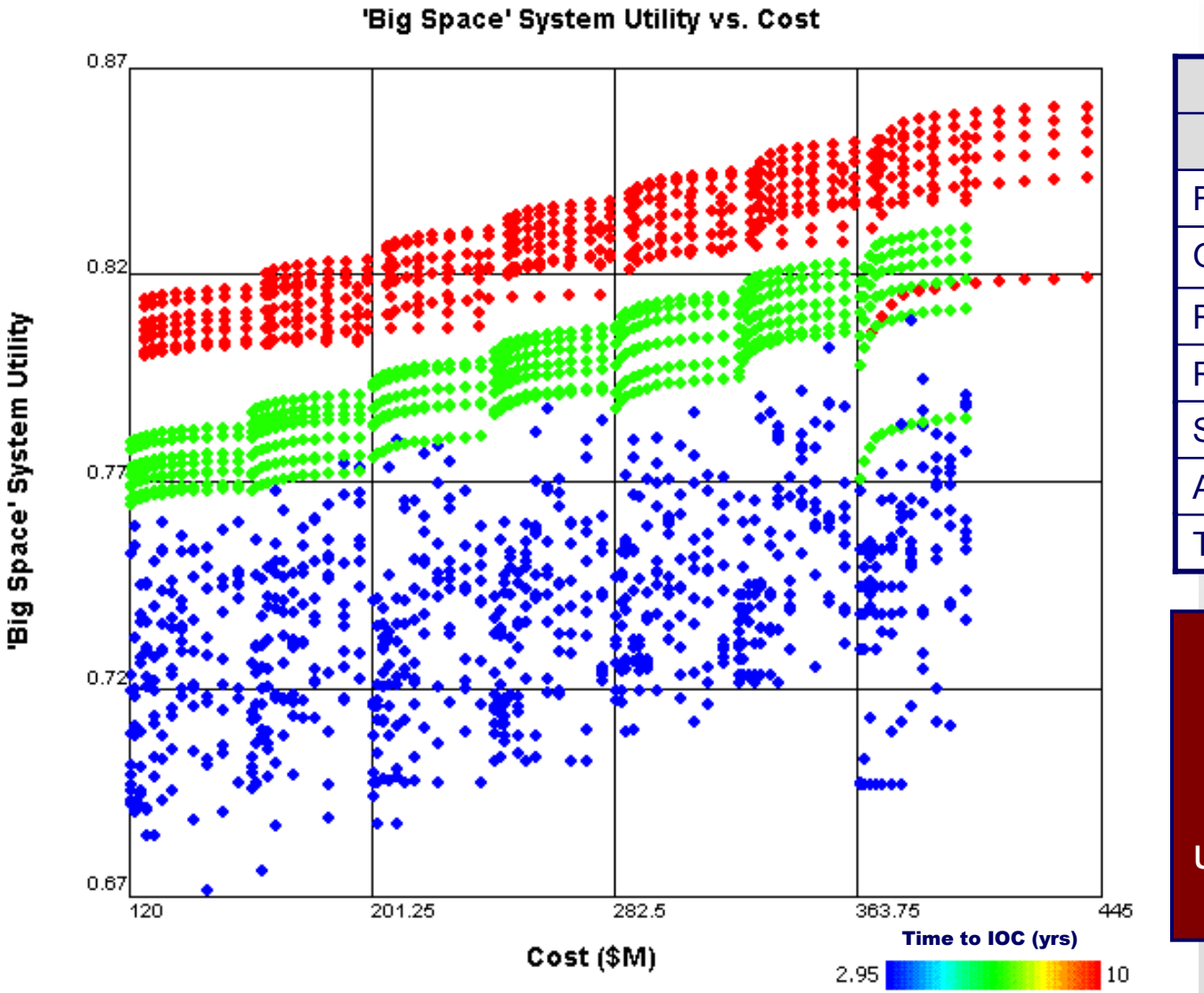
Big Space View



'Big Space'	
Attribute	**Weight**
Field of Regard	0.7
Global Coverage	0.4
Resolution	0.45
Revisit Rate	0.8
Sensitivity	0.4
Availability	0.98
Timeliness	0.7

Pareto Efficient, or "best", designs are high performance with minimal uncertainty, and long development times.

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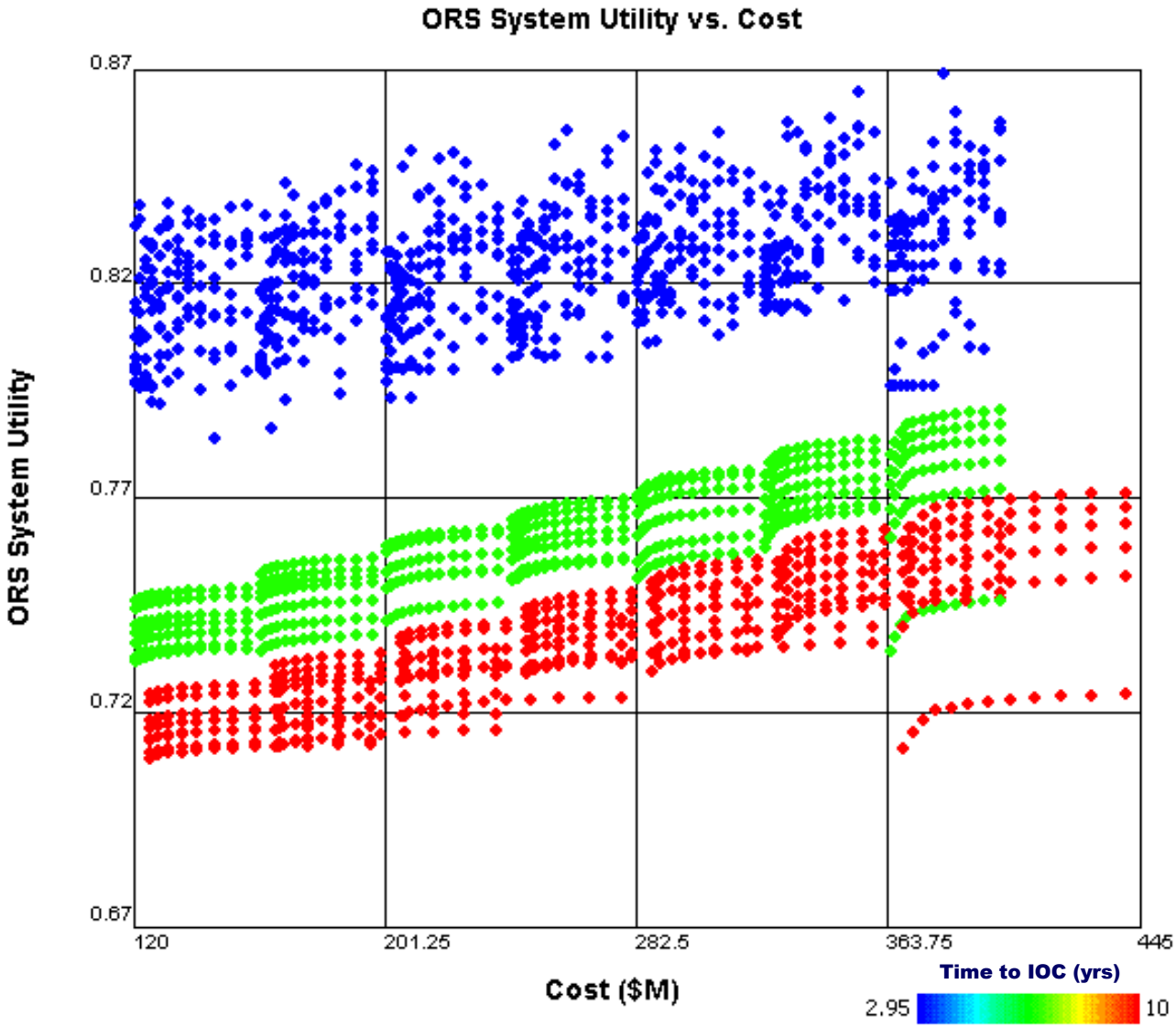
ORS view



ORS	
Attribute	**Weight**
Field of Regard	0.35
Global Coverage	0.2
Resolution	0.25
Revisit Rate	0.4
Sensitivity	0.2
Availability	0.5
Timeliness	0.8

Increased uncertainty in design performance creates "cloud" of designs, suggesting a risk-seeking attitude.

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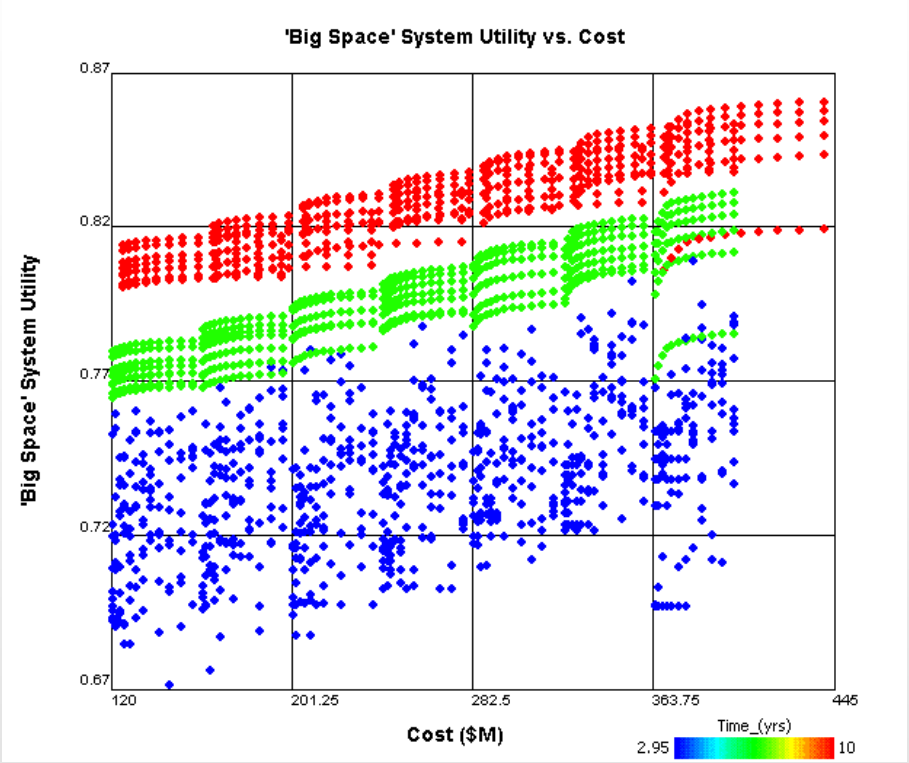
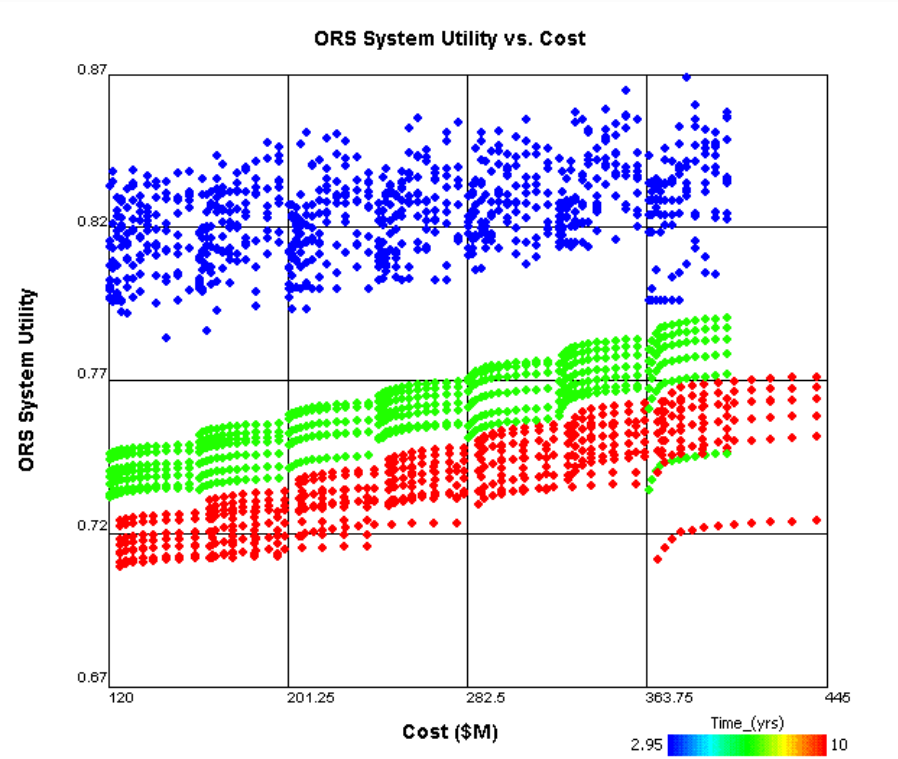
Side by Side





Inversion of tradespace due to attribute priority shift. The Pareto Efficient designs for each stakeholder excludes all but a few designs.

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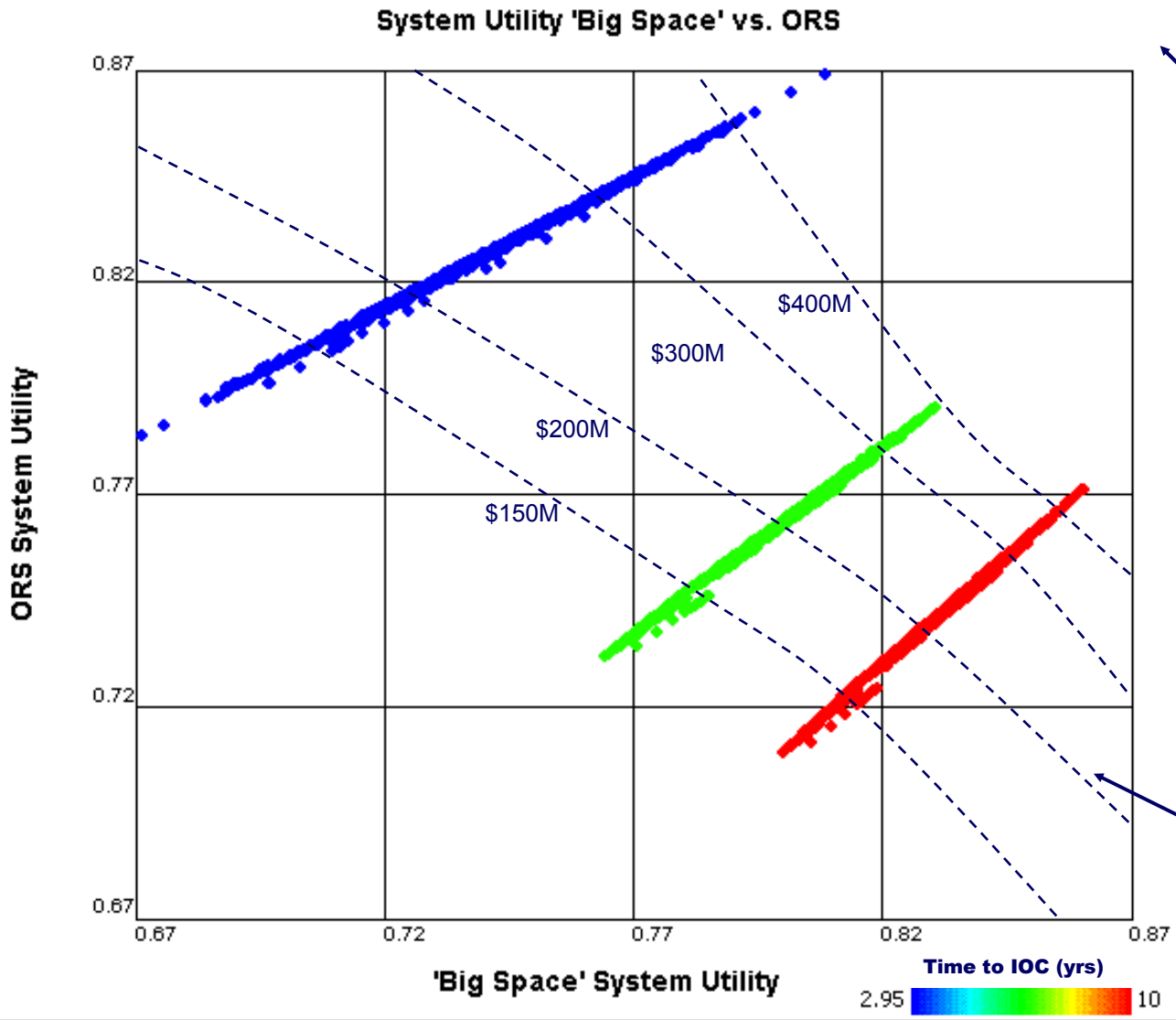
Stakeholder's Views



Utopia Point

Approximate Iso-cost lines

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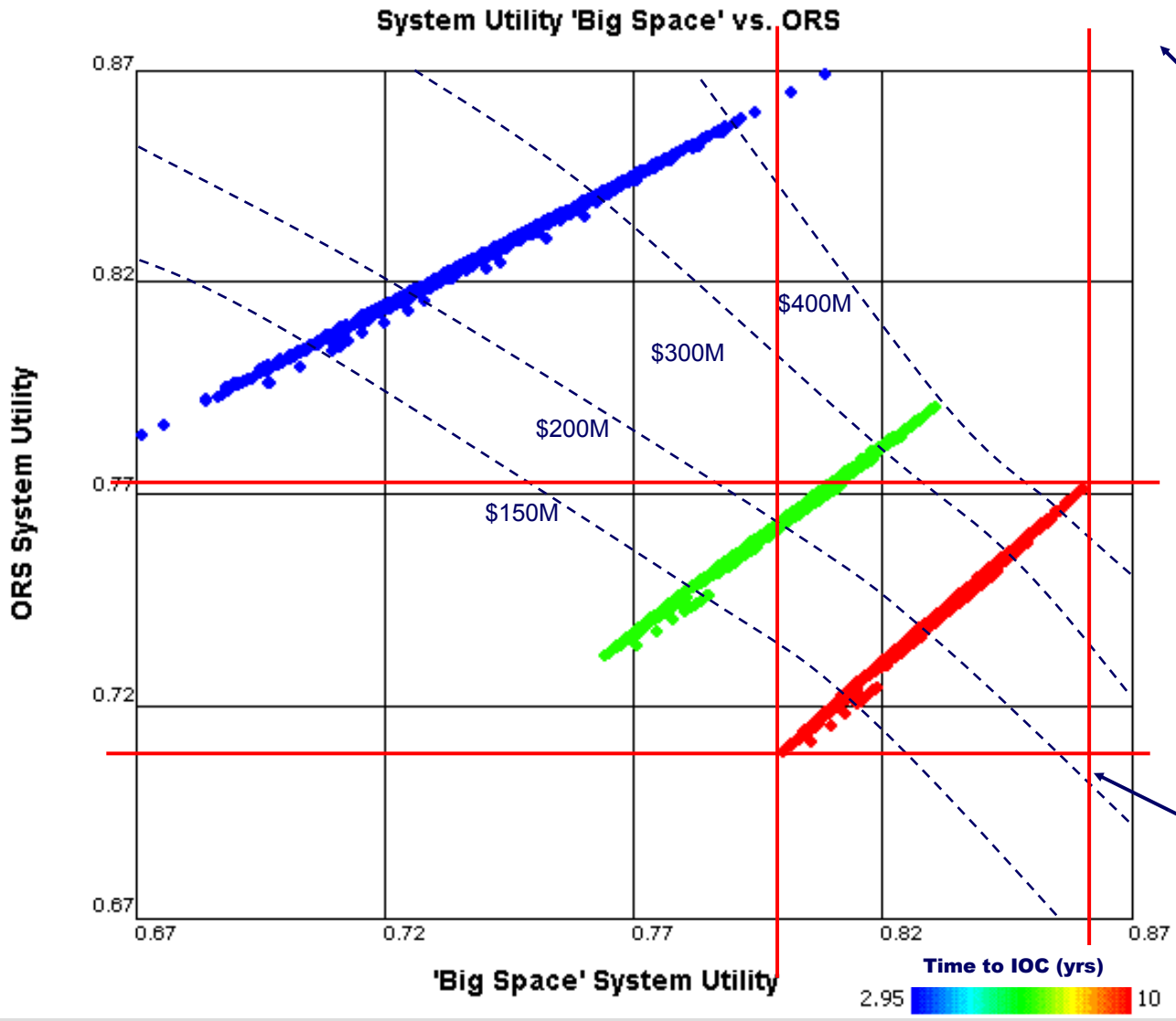
Stakeholder's Views



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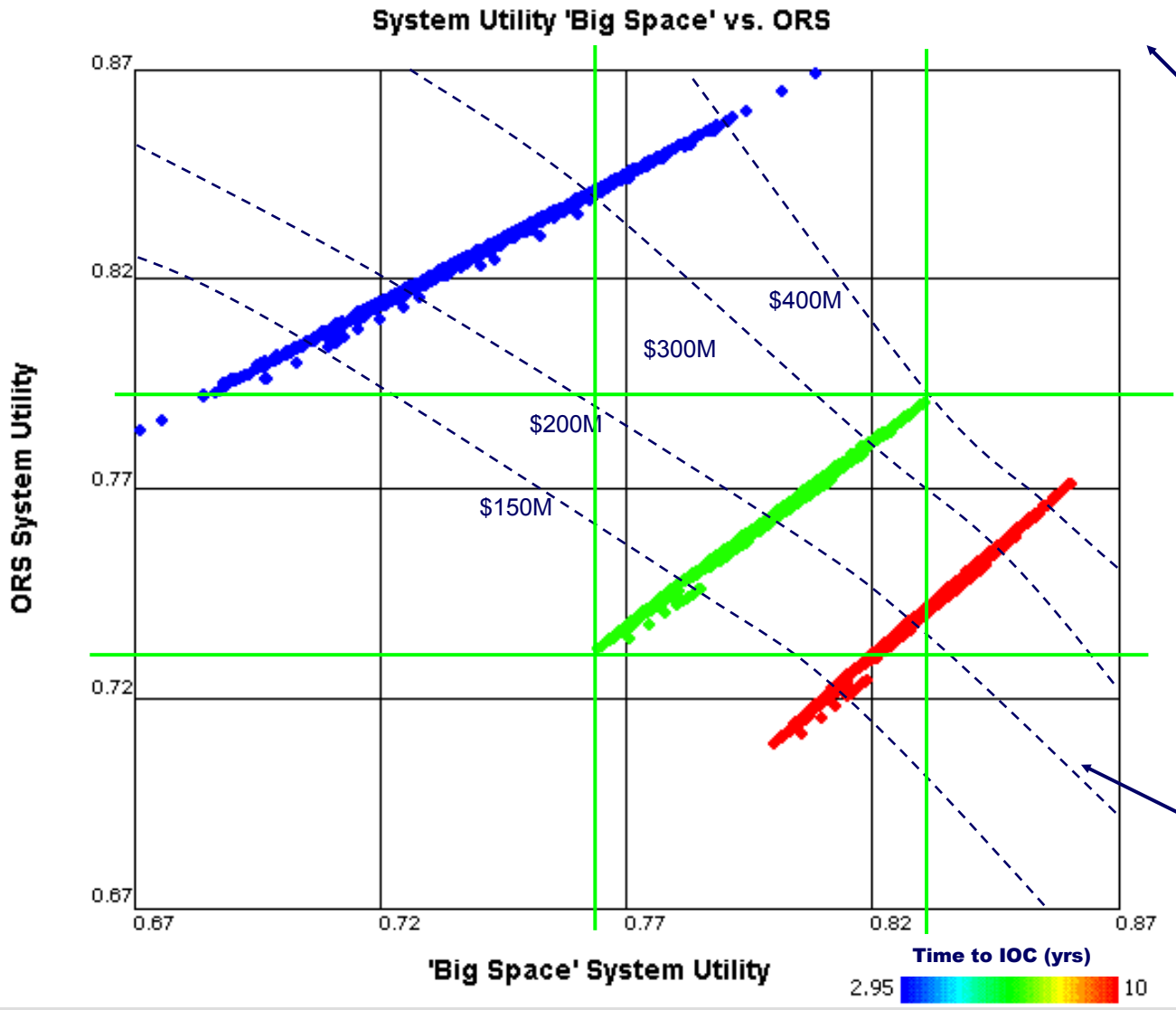

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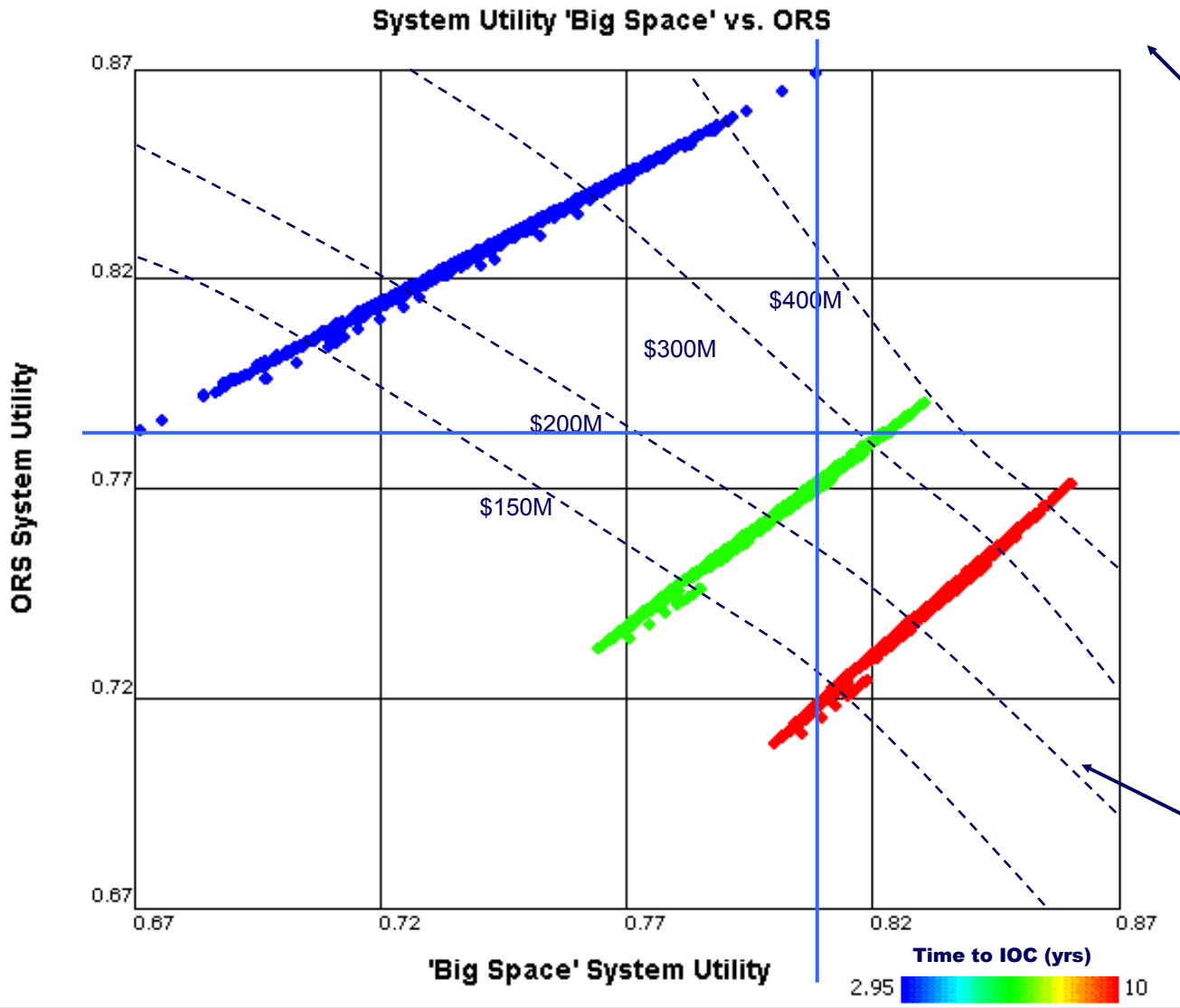

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Conclusions

- Explicitly defining value proposition enables objective assessment of ORS *vis-à-vis* "Big Space"
  - ORS suitability may vary across space mission areas
  - Methodological approach: multi-attribute utility theory
- Value Propositions similar- technical constraints and risk attitude limit designs to satisfy both stakeholder groups.
  - "Big Space" averse to performance risks, losing spacecraft due to shortened testing regimes
  - ORS averse to schedule slippage
- Computer model suggests this concept could satisfy both groups of stakeholders
  - Possible to inform negotiations, search for better middle ground.
  - Tradespace exploration makes clear where value propositions diverge
    - Some designs with short design schedules can meet minimal 'Big Space' utility while delivering high ORS utility

Value-focused approach allows for explicit and objective comparison of different paradigms

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Future Work

- Identify mission areas and operational contexts where “Big Space” or ORS alternatives (technology and architecture) are most valuable
- Analysis of hybrid systems, with some Big Space and ORS designs
- Model is improved through “spiral development,”
  - Starting with small number of design variables
  - Adding fidelity to model
  - Increase confidence in preference sets, more stakeholder interviews required

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Systems Engineering Advancement Research Initiative

Thank you.

Questions?

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