SEAri Short Course Series

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

Lecture: Lecture 13: Policy and Other Non-Technical Influences on the Tradespace

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Systems Engineering Advancement Research Initiative

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

Lecture 13
Policy and Other Non-Technical Influences on the Tradespace

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Outline

- Motivation
- Policy impacts on architectures
- Examples for incorporating policy
  - Space systems
    - Influence diagrams
    - Tradespace effects
  - Chicago Airport Express
    - Feedback between technical and political goals

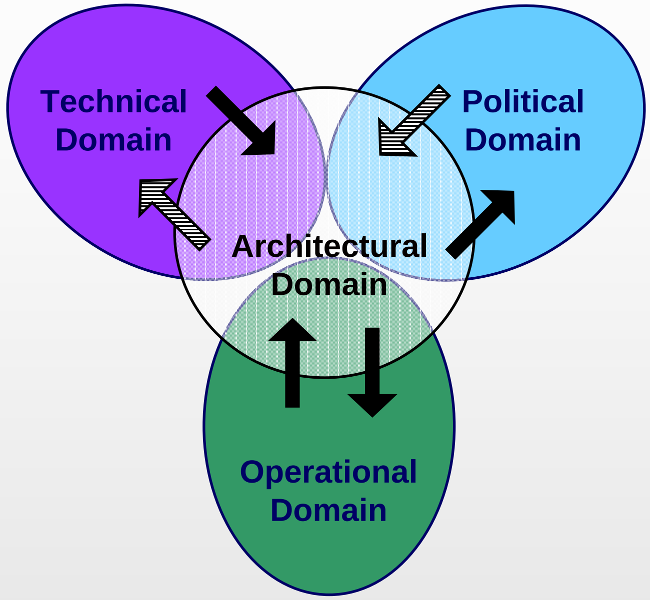
Motivations - Overall

- Policy and related factors can have significant implications for value delivery of a system throughout its lifespan

- Considering possible and anticipated future policy impacts as part of the concept analysis phase can lead to better decisions and understanding of risks

Motivation

- For a system architecture to be robust, it must weather changes over its entire lifecycle
- Instabilities may arise from large number of domains
- While poorly understood, actions taken in political domain have profound effects of space systems
  - Government restrictions on launch vehicles
  - Budget revisions



Weigel, A.L., *Bringing Policy into Space Systems Conceptual Design: Quantitative and Qualitative Methods*, Doctor of Philosophy Dissertation, Technology, Management and Policy Program, MIT, June 2002

Understanding the effects of political domain instabilities on systems is the focus of this presentation

Definition of Policy

Policy

"A definite course or method of action selected from among alternatives and in light of given conditions to guide and determine present and future directions." [Webster's Third Intl. Dictionary]

- Policy statements have several features associated with them:
  - definite course(s)
  - selected from alternatives
  - true in light of specific conditions
  - to move one in specific (desired) directions

Policy Formulation
(Weigel 2002)

- Policies arise from the political domain
  - Represents voice of customer (e.g., public)
  - Politics is the mechanism through which value judgments are expressed

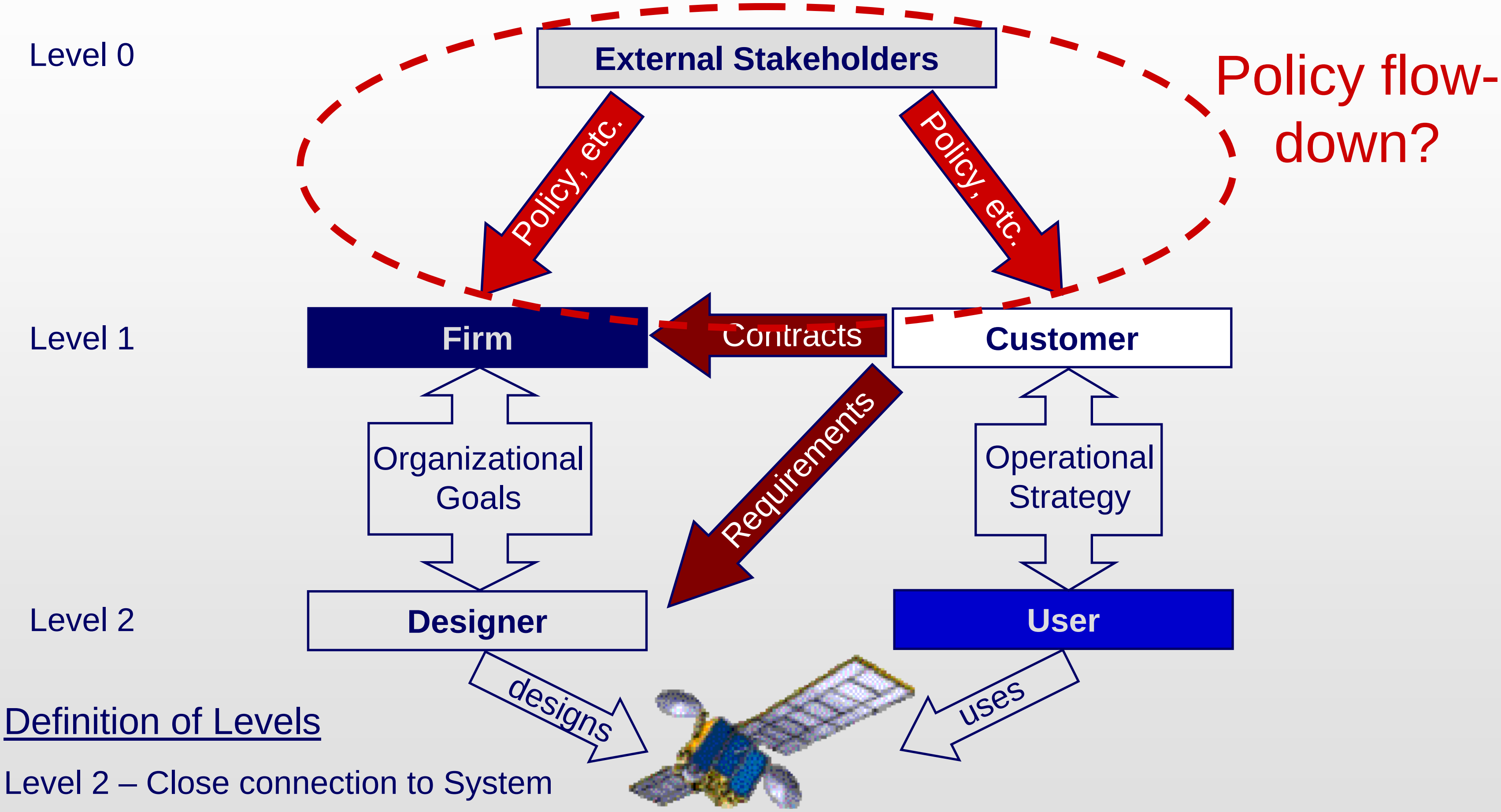
- Legislative institutions control budget for government systems

- Funding decisions driven by aggregate of local politics:

Security Benefits Jobs Revenue	Personal experiences Relationships Negotiations Compromise

But how to translate complex stakeholder interactions into policy goals?

Identifying Key Decision Makers



Definition of Levels

Level 2 – Close connection to System

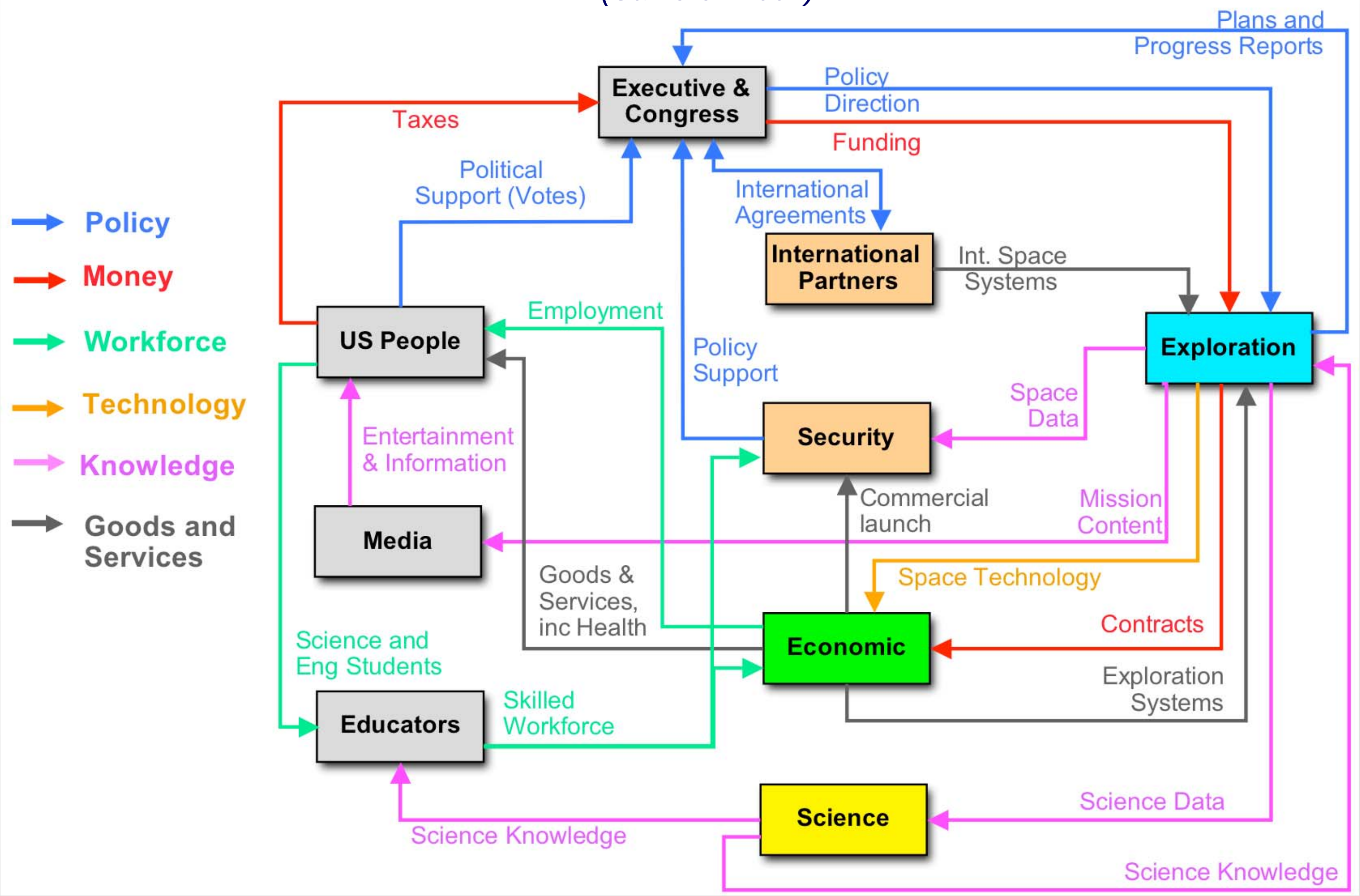
Level 1 – Distant connection to System

Level 0 – Little or no connection to System

From Ross 2003

Complex Stakeholder Interactions Influence Policy Goals

Sample decomposition and mapping for NASA exploration
(Cameron 2007)



Example Policy Constraints: US Space Policy Issues

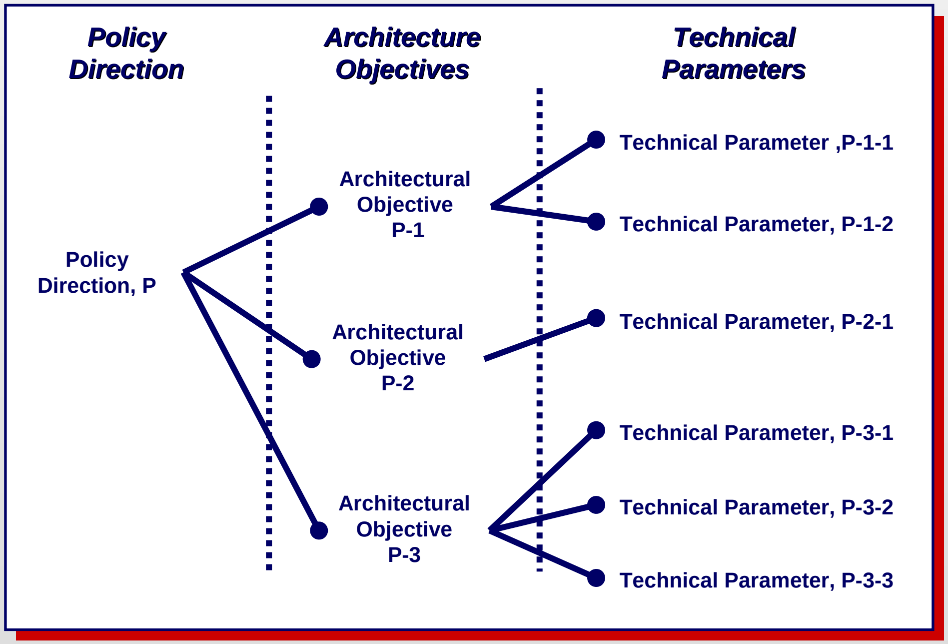
- Budget restrictions
- Space programs as cooperative foreign policy tools
- Export restrictions on space products
- Restrictions on foreign launches
- Space control
- Operational responsiveness
- Balancing national priorities

Written policies captured as constraints in MATE method

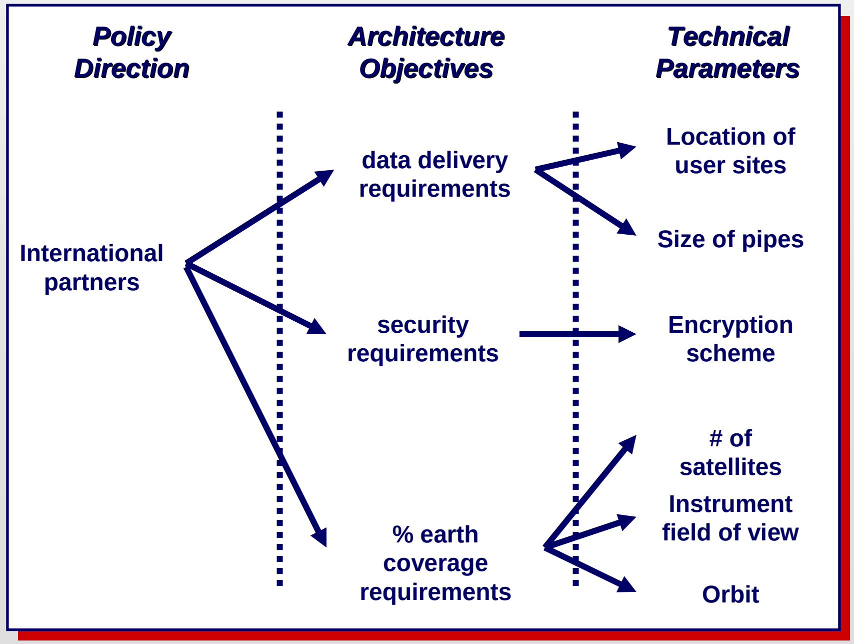
Policy Impact on System Architecture: Influence Diagrams

- Understand policy impacts at early (architecture) stages
- Framework shows flowdown to technical domain, (e.g., design variables)

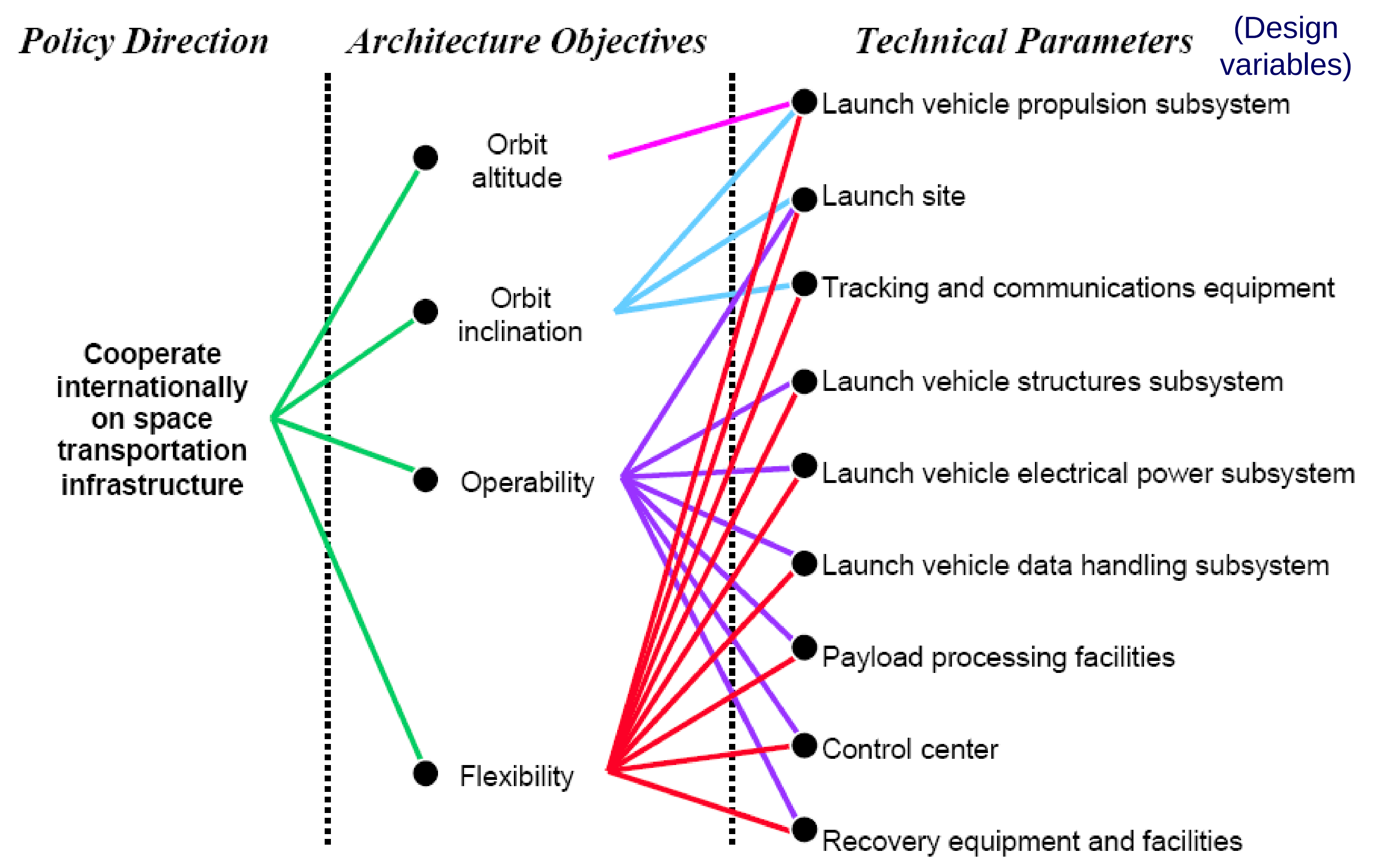
Generic Flow of Policy Impacts into Technical Domain



Discoverer II Example *(Weigel 2002)*
(Space-based GMTI mission)



Example Influence Diagram: International Launch Cooperation

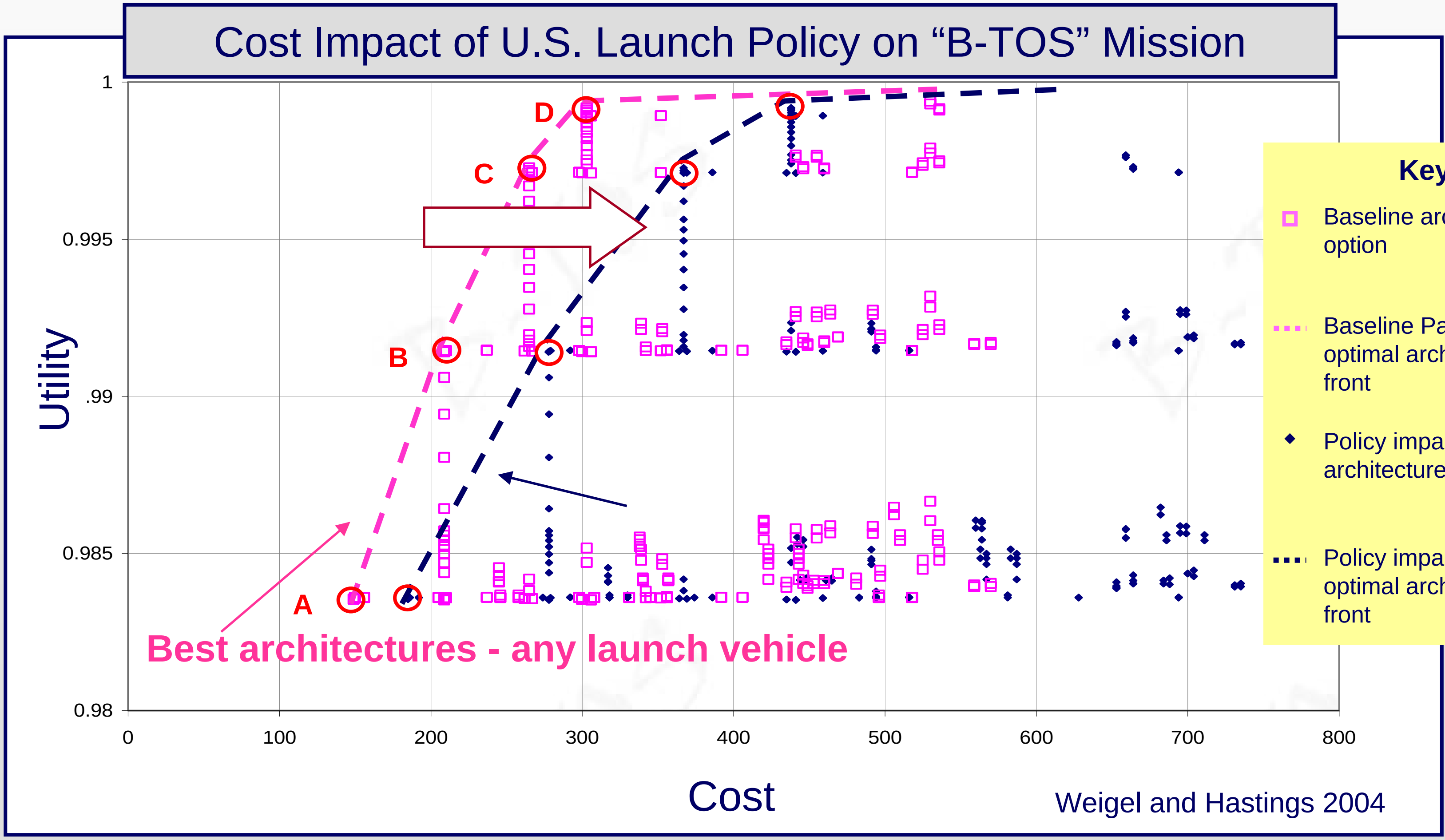


(Weigel 2002)

Policy influence can be traced to technical (design) parameters, often treated as constraints on allowable enumerations in a MATE study

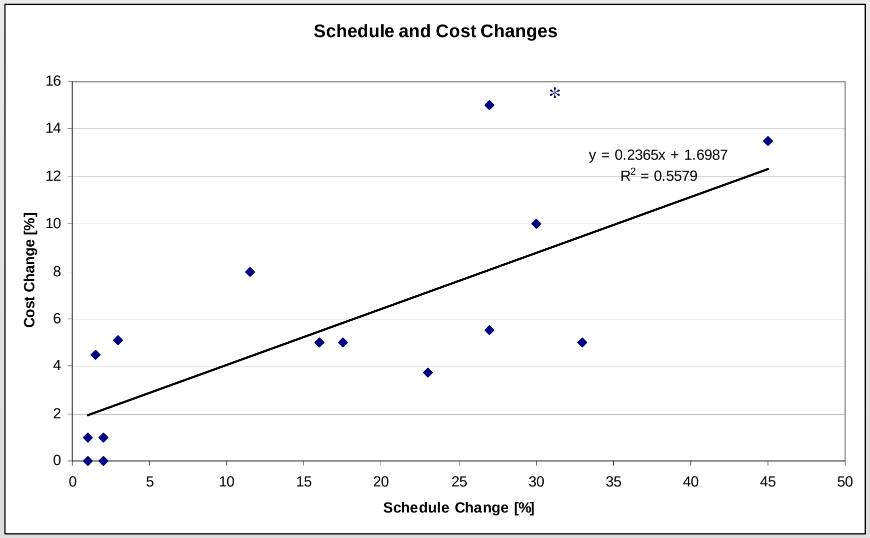
Policy Impact on System Architecture: MATE Tradespace

Policy Intervention: U.S. space transportation policy of 1994 requires U.S. government payloads to fly on U.S. launch vehicles



Cost-Capping Policy Intervention

- Cost-capping government program expenditures is most frequently reported government policy intervention
  - Annual program budget capped by Congress
  - Capping stretches out program duration and increases total program costs as a result
- Historical examples provide basis for relationship between schedule extension and cost growth *(Weigel 2004)*



Schedule extension and resulting cost change relationship

$c = 0.24s + 1.7$

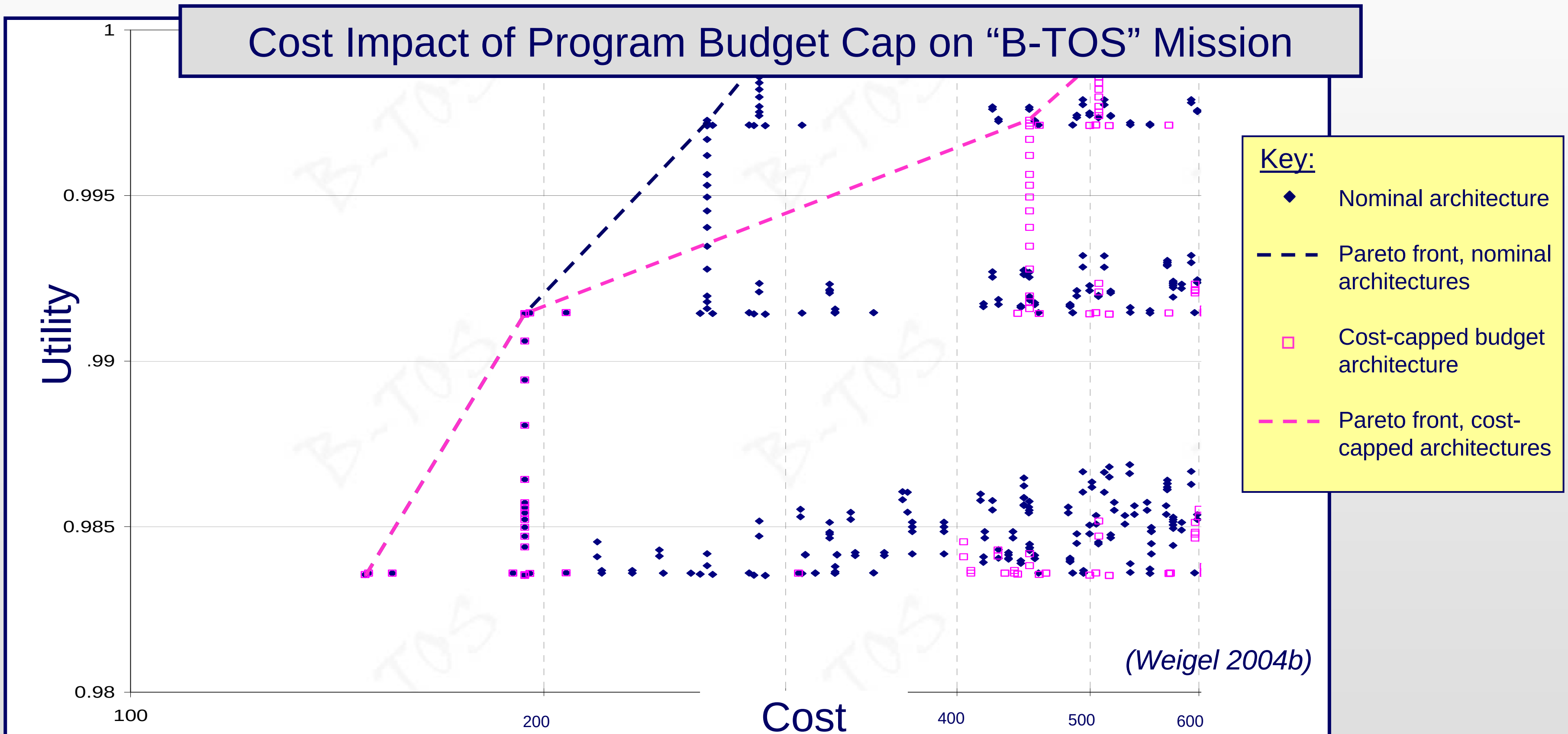
where c = % cost change,

and s = % schedule change

* Data adapted from Augustine, Norman R. *Augustine's Laws*, New York: Viking Penguin Inc., 1986

Cost-Capping: MATE Tradespace

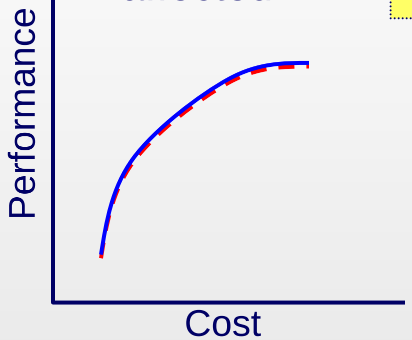
Policy Intervention: $35M annual program budget cap imposed by Congress



Cost-capping policy differentially pushes tradespace Pareto Front to the right

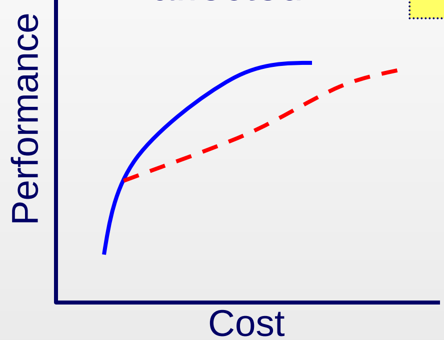
Application of Real Options: B-TOS Cost-Capping

Stage 0:
No Pareto architectures affected



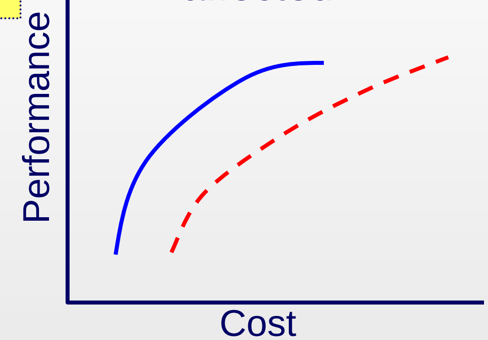
Transition at:
$c_{max}/d_{max} > b_i$

Stage I:
Some Pareto architectures affected



Transition at:
$c_{min}/d_{min} > b_i$

Stage II:
All Pareto architectures affected



Transition option has no value in Stage 0, because there is no need to transition.

Transition option has value in Stage I

When
$c_{\text{max}}/d_{\text{max}} > b_i$
and $c_{\text{min}}/d_{\text{min}} < b_i$

Transition option has no value in Stage II, because there is no architecture in the Pareto set to transition to.

Designing for Budget Policy

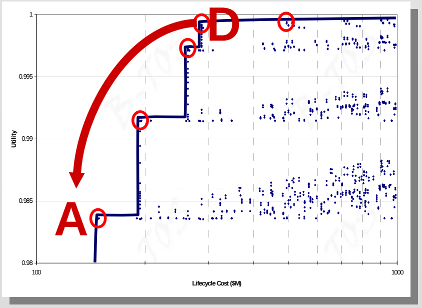
Goal of analysis: Use real options analysis to measure value of designing architecture to accommodate budget policy instability

- Scenario
  - Future budget levels are uncertain
  - Pursue initial architecture choice
  - When budget is cut, program manager may want to transition to a new, lower budget architecture
- What is the value of a transition architecture option, which provides insurance against budget policy instability and makes a program more policy robust?
- Real options useful for valuing projects under uncertainty

Owning an Architecture Transition Option (Weigel 2004b)

How might program managers acquire real options in practice?

- Risk mitigation strategy against uncertainties
  - Insurance policy (e.g., hedge against budget instability)
- "Purchasing" means funding the design of the unique elements of an alternative architecture
  - Assess commonalities and differences between baseline and candidate transition architectures
  - Co-develop unique elements such that alternative architecture is at similar level of maturity if transition is required
- B-TOS example
  - Assume architecture D is initially chosen and architecture A is held as a transition option
  - Unique technical challenge of A is reduction of swarm radius to .18 km
  - Option costs
    - Development of higher precision attitude control
    - Development of thruster plume impingement management strategy



Pathway to Policy-Robust System Architectures

1. Understand the system architecting domain framework, the specific players involved for your project, and their motivations

2. Identify the important current policy issues relevant to your system

3. Construct influence diagrams for each policy issue, at each stage of your architecture creation and system design, to assess which policy issues most greatly impact your system

4. Identify on influence diagrams which policy impact paths can be understood mathematically and which cannot

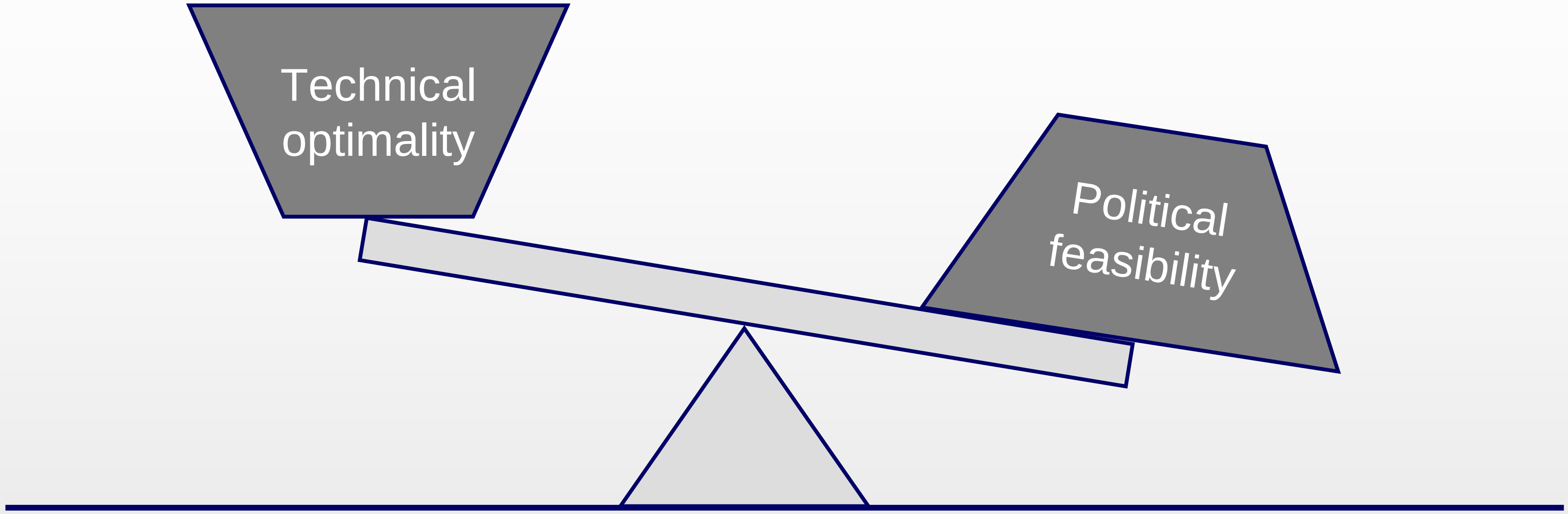
5. Seek expert opinion to evaluate those policy impact paths that cannot be understood mathematically

6. Quantify the effects of those impact paths that can be understood mathematically, assess the volatility of the policy issues they stem from, and assess the value of designing for changes in those policies

7. Take the necessary action indicated by preceding analyses to ensure a policy robust architecture

Weigel 2002

Balancing Technical and Political Goals

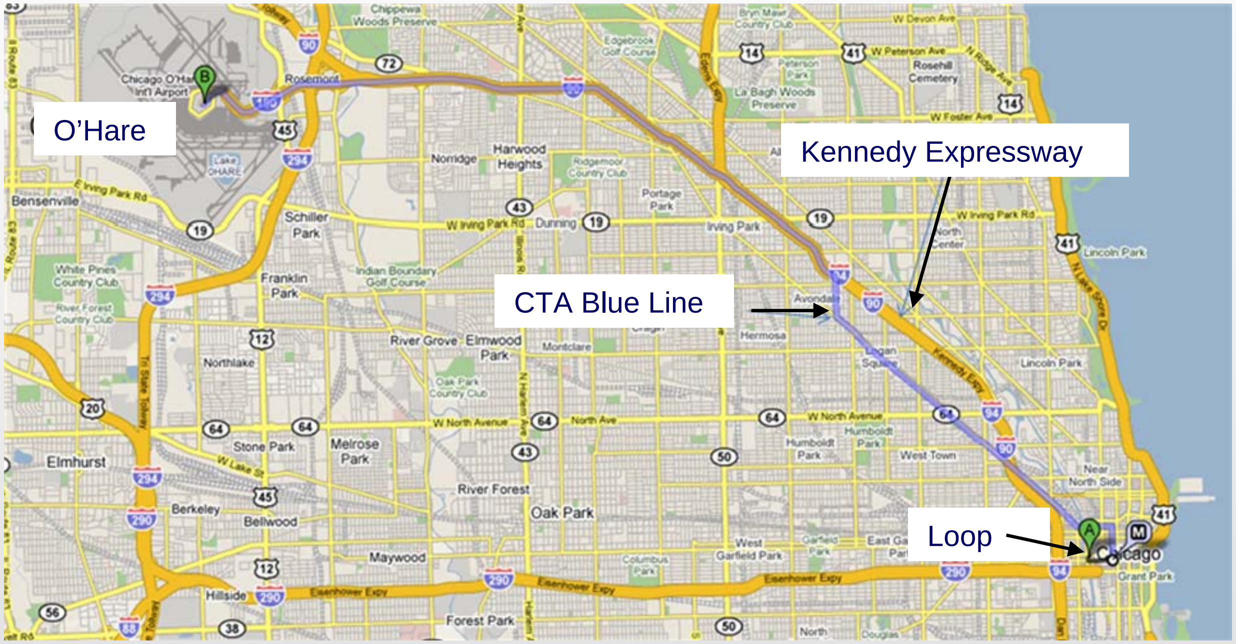


Technical optimality: Performance/cost of the physical system that is designed to meet a specified goal

Political feasibility: Implementation and acceptability concerns

In addition to "designing for policy robustness" one can also consider the matter a balancing of technical with political considerations

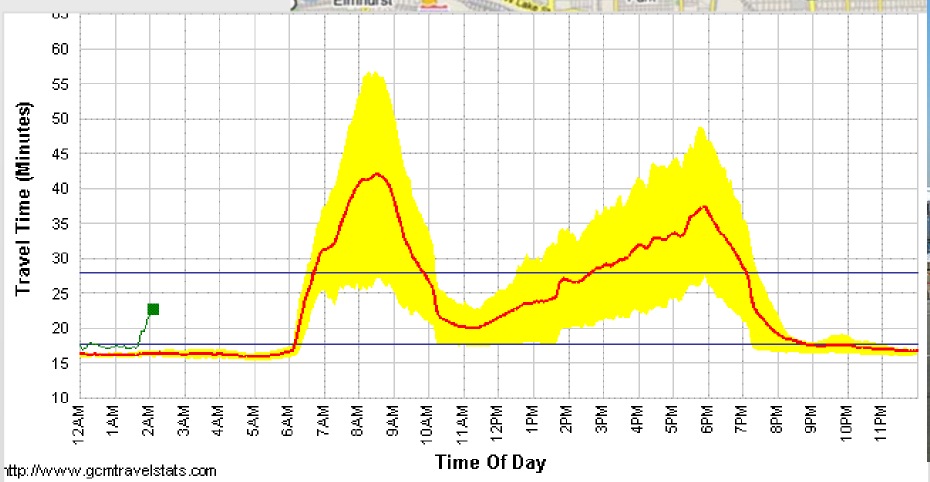
Example: Chicago Airport Express

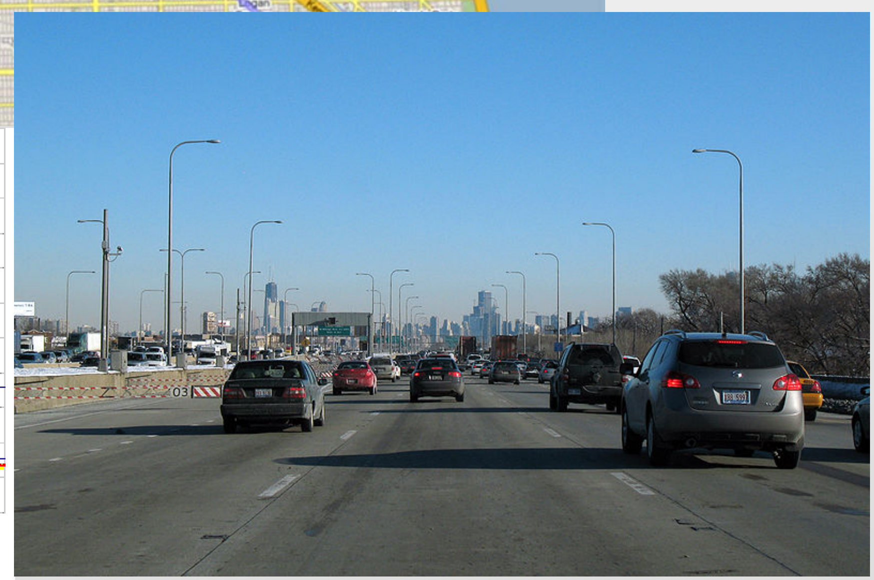


Case example from: Nickel, J., *Using Multi-Attribute Tradespace Exploration for the Architecting and Design of Transportation Systems*, Master of Science Thesis, Engineering Systems Division, MIT, February 2010.

Chicago Airport Express

Cab fare ~ $45





Chicago Airport Express

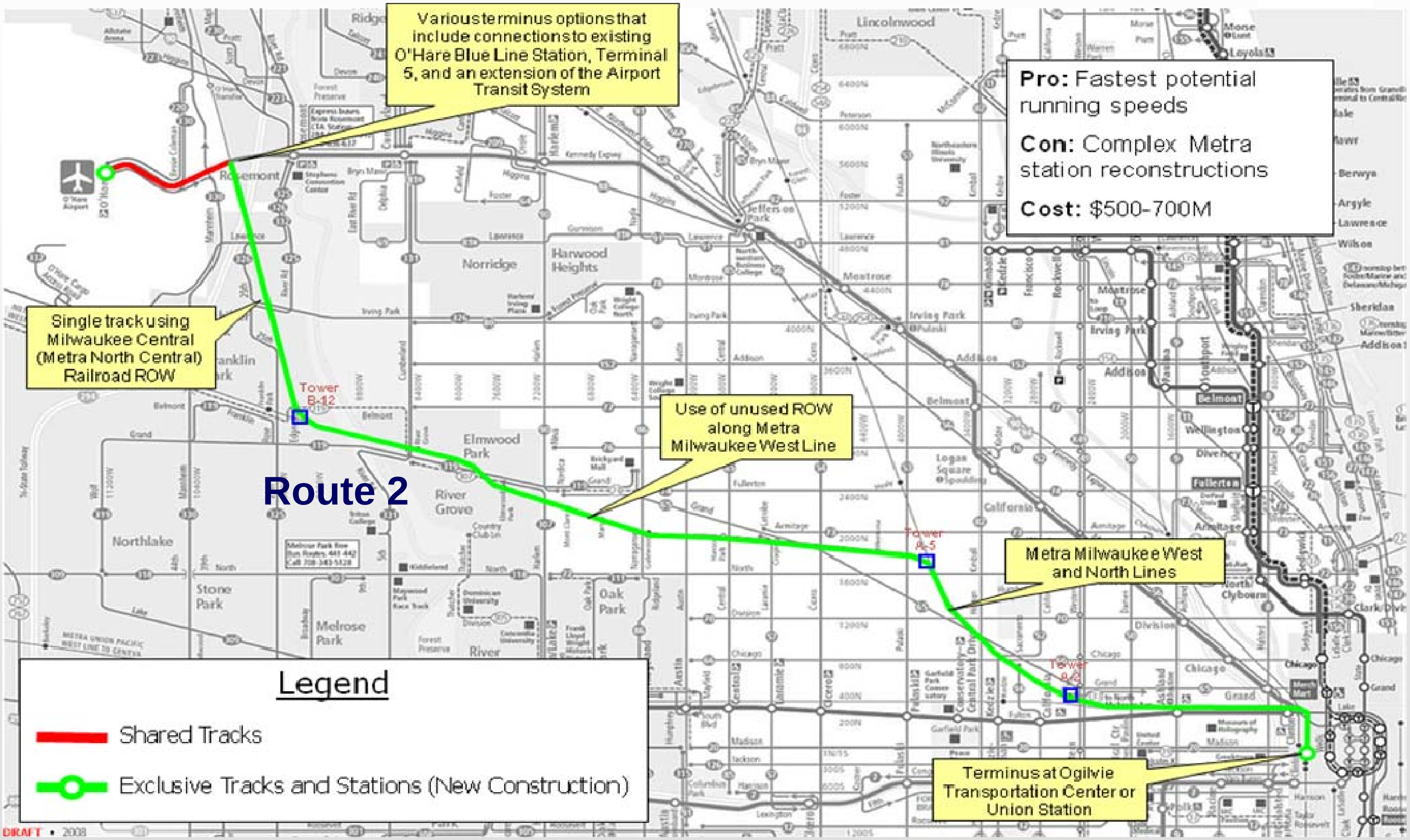
Architecture Concept Scoping

Nr.	Concepts	Abbreviation	Description	Rejected?	Reason
0	**Base case**	Base	Minimal improvement to status quo infrastructure	yes	Requirements specify minimal improvement from status quo
1	**Direct service**	Route 1a	Train solution, shared tracks with local train	yes	Violates reliability requirement of 80% on time
		Route 1b		yes	Cannot be financed based on willingness to pay information from stakeholder interviews
2	Express service	**Route 2**	Train solution, individual right-of-way	**no**	-
3	**Bus Rapid Transit**	BRT1	Rapid buses on Kennedy Expressway, no separate lane	yes	Violates reliability requirement of 80% on time
		BRT	Rapid buses on separate lane of Kennedy Expressway	**no**	-
4	Blue Line Switch	**BLS**	Rapid buses on separate lane on Kennedy Expressway replacing local train, Airport Express on freed-up tracks from base case	**no**	-

(Nickel 2010)

Three architecture concepts meet cost constraint and Minimum reliability requirements -> Further MATE analysis

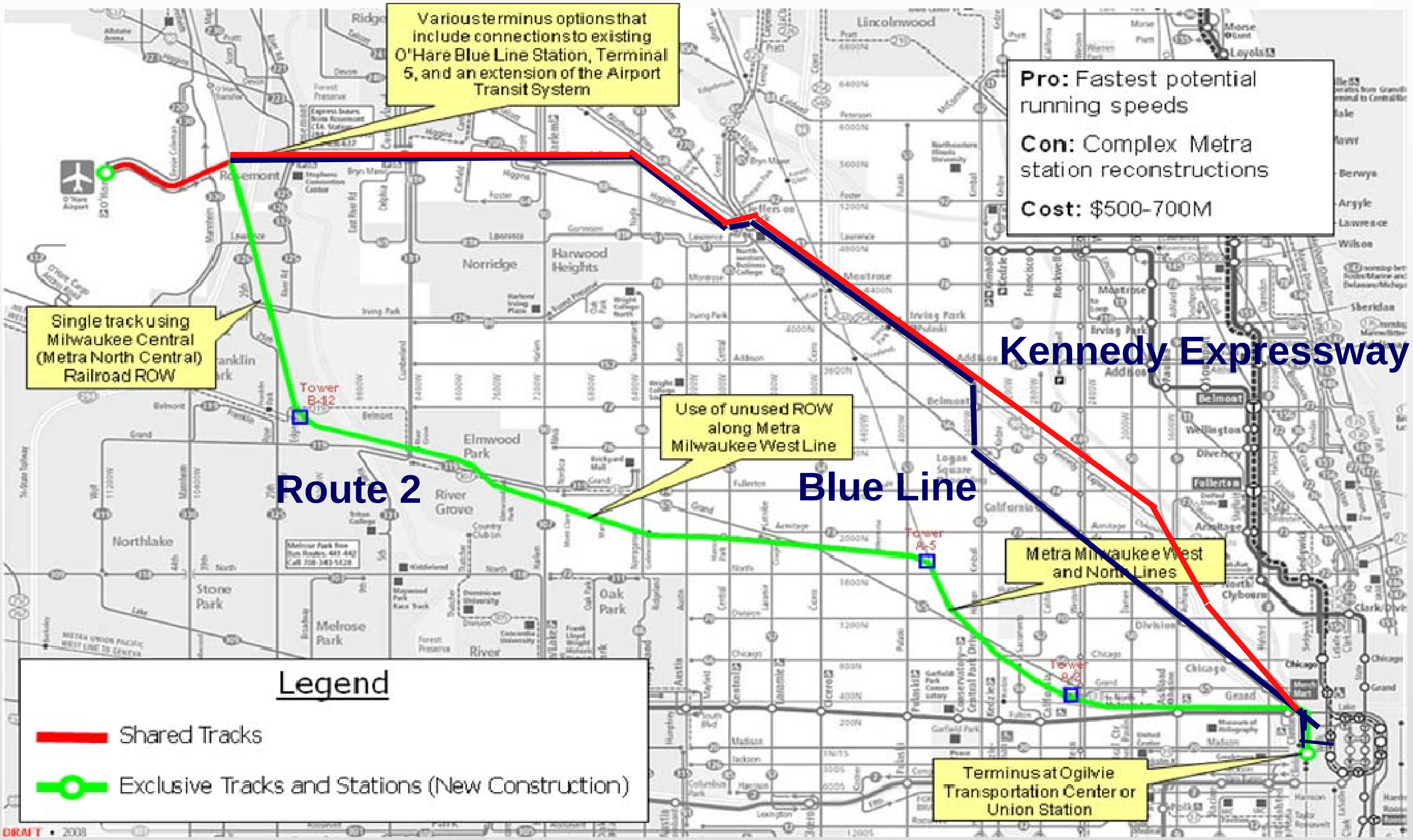
Rights-of-way of Architecture Concepts



"Right-of-way": The strip of land over which is built a public "road" or public utility

(Merriam-Webster online, www.m-w.com, cited 7/22/10)

Rights-of-way of Architecture Concepts



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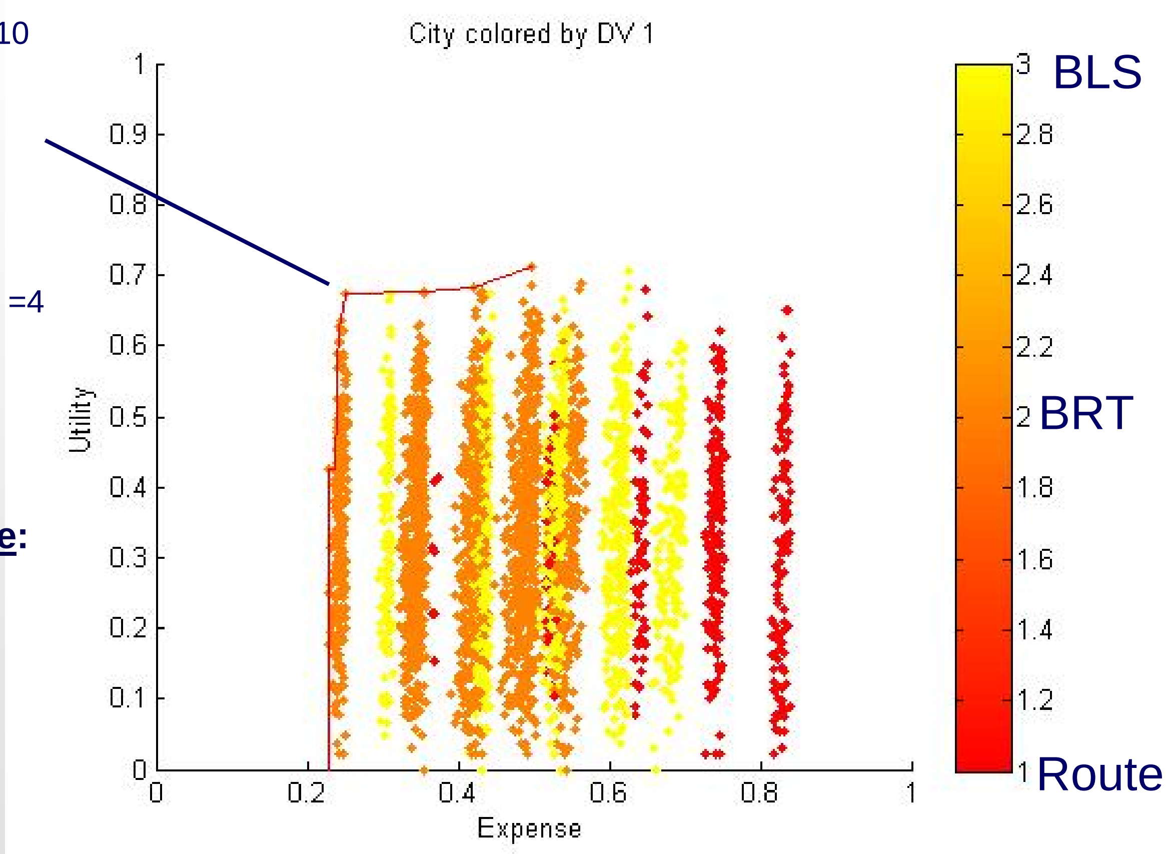
(Merriam-Webster online, www.m-w.com, cited 7/22/10)

City Tradespace (by concept)

Concept= BRT, Fare= $10
Frequency= 8 min
Travel time =27min
Amenities = 1
Span of service = 19 hrs
City Cost Share= 10%
Comp agreements= 5
Freed. to make changes =4
CTA paym.= 15



Quality of Service:
Fare level
Frequency
Travel time
Amenities
Span of service

n=20,000

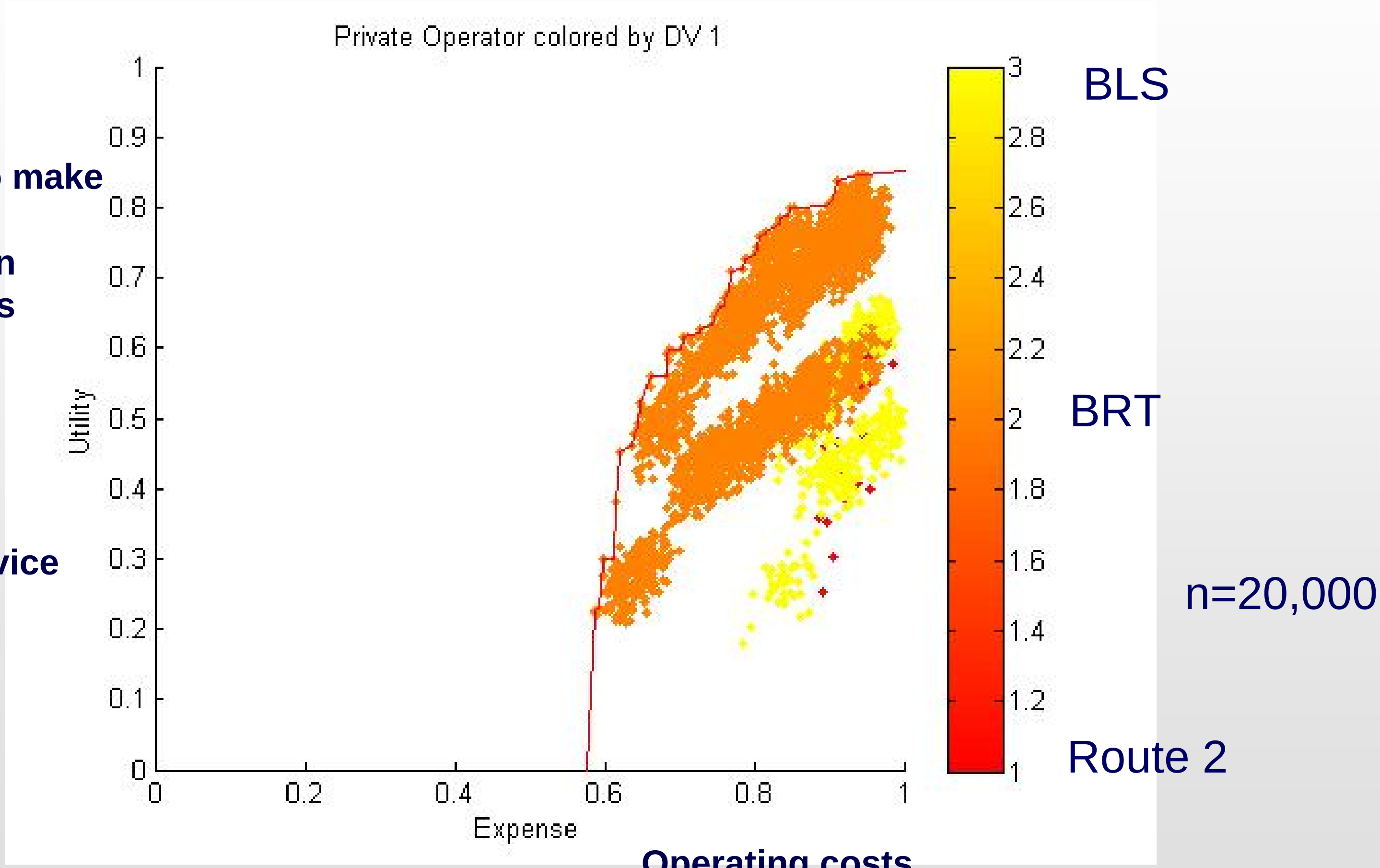
City cost share

City's initial cost

Red (Route 2) is the only concept planners had initially considered

Private Operator Tradespace (by concept)

- **Freedom to make changes**
- **Competition agreements**
- **<u>QOS_PO:</u>**
Fare level
Frequency
Travel time
Amenities
Span of service



Operating costs
Concession payment

Red (Route 2) is the only concept planners had initially considered

Political Feasibility Dimension

Concept	Implementation concern	New design variable
Route 2	Financing	-
BRT	• Image/ Prestige • Visibility of underused dedicated lane • Increased congestion on Kennedy Expressway	• Marketing of service • Lane use policy
Blue Line Switch Option	Workforce turnover	-

Fuzzy non-technical concerns
Make or break a project

Some implementation challenges can be mitigated -> new design variables

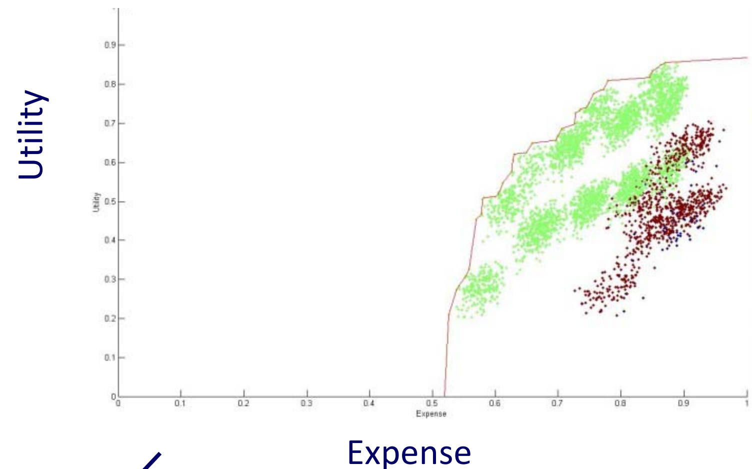
Adding Political Feasibility Dimension to MATE

Explore tradespace

Technical and cost models

Utility models, based on stakeholder interviews

$(DV_1, DV_2, \ldots DV_m)$ → $(X_1, X_2, \ldots X_n)$ → $U(X)$



Change model, reiterate

DV_{m+1}, DV_{m+2},

1. Present to policymakers/ planners
2. Evaluate implementation concerns
3. Generate new design variables

Case Study Insights

a) Designs **should not be ruled out early** on because of political feasibility concerns **since** those **concerns can** sometimes **be mitigated**.

b) **Alternating focus** on political feasibility and technical optimality **suggests and explores new design variables** that can mitigate implementation concerns, thereby broadening design space, and possibly helping to make more informed decisions.

Political feasibility can be addressed through tradespace exploration

Concluding Remarks

- Policy robustness is critical to sustaining large programs such as government space programs
  - Technical performance is only one of many requirements for a successful program
  - Need political mandate / business case and validated user needs
- System architecture navigates flow of policy to technical system
- Policy impacts may be assessed qualitatively and quantitatively
  - Influence diagrams
  - Cost impact estimating relationships
  - Real options analysis
- Methods may be used prescriptively by MATE analysts

Make policy an active consideration in systems architecting and design

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