Systems Engineering Advancement Research Initiative

MIT Lincoln Laboratory

DRAPER LABORATORY

Innovation Pathways in National Security Space

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Biography (Erik Stockham)

Erik's research interests include the management of systems acquisition in technology-intensive government bureaucracies and the improvement of capability delivery to the end user. Before returning to MIT in 2010, Erik served as a USAF intelligence officer in analysis, operations, and leadership positions in the US and overseas. He graduated from MIT in 2003 with a S.B. in Aeronautics and Astronautics with Information Technology.

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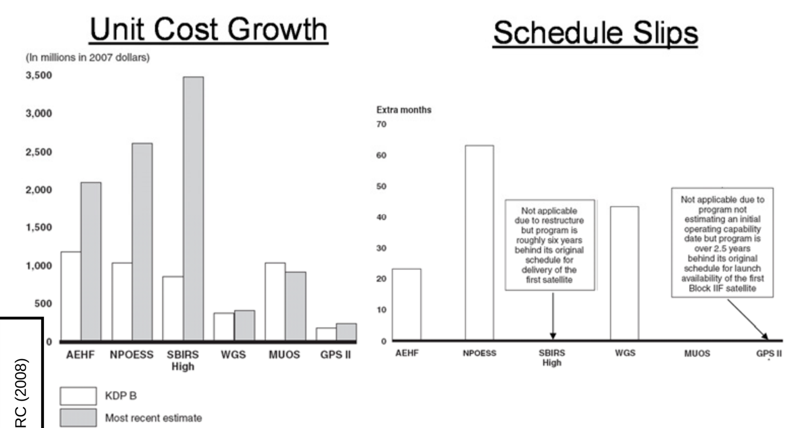
Biography (Amanda Rohrbach)

Amanda is a master's student in MIT's Technology and Policy Program. Her research will focus on Space Policy and Policy issues within the Government Acquisition Process. She received her B.S. in Aerospace Engineering from the Florida Institute of Technology in 2008. Outside of academia, she has worked as a researcher in space engineering research, as a space structural analyst in the Aerospace Corporation, and most recently as the Chief Engineer for the Global Broadcast Service Joint Program Office, USAF.

Motivation

Despite a rich legacy of delivering *impressive* technological solutions, government space acquisitions are increasingly underperforming (fig 1).



Szajnfarber, Z., Richards. M. G. and Weigel, A. L. (2008) Implications of DoD Acquisition Policy for Innovation: The Case of Operationally Responsive Space . AIAA Space 2008, September 9th – 11th San Diego, California.

		Rumsfeld (2001)	NDIA (2003)	Young (2003)	GAO (2006)	DAPA (2006)	NRC (2008)
technology	Restore funding for testing space technologies	X			X		
	Maintain U.S. technological lead in space	X					
	Keep R&D separate from systems acquisition				X		X
	Identify technology for rapid exploitation and control					X	
management	Establish Presidential and NSC space advisory groups	X					
	Integrate defense and intelligence space activities	X					
	Improve front-end systems engineering (req's=resources)		X	X	X	X	X
	Improve collaboration on requirements		X		X	X	X
	Budget space programs to most probable (80/20) cost			X			
	Evaluate contractor cost credibility in source selections			X			
	Conduct independent program assessments at MDA's			X			
	Do not allow requirements creep			X	X	X	X
	Match PM tenure with delivery of a product			X	X	X	X
	Pursue incremental increases in capability				X		
	Withold contractor award fees when goals not met				X		
	Establish a stable program funding account					X	
	Structure development to achieve IOC within 3-7 years						X
policy	Recognize space as top national security priority	X					
	Deter and defend against hostile acts in space	X					
	End practice of appointing only flight-rated CINCSPACE	X					
	Incentivize government career paths in acquisitions	X	X	X		X	X
	Improve workforce technical competence	X		X	X	X	X
	Research systems architecting design tools		X				
	Establish mission success as guiding principle			X			
	Compete acquisitions only when in best interest of gov't			X			
	Develop integrated strategy for R&D and acquisitions				X		X
	Encourage LSI to compete major subsystems					X	
	Evaluate gov't internal training programs for acquisition						X

Multiple *blue ribbon* panels have been convened (fig 2.) and many recommendations made

- **Leverage members' vast experience, leading to similar proposed solutions (i.e., "back to basics")**
- **Need for external theory and insight to identify/address fundamental issues limiting innovative performance**

Problem Framing

Problem: Technology infusion into government acquisition programs is viewed as a cost, schedule and operability risk by program managers. A key challenge in aligning stakeholders is *the identification of the optimal architectural level for integration.*

Complication: Current stage-gate conceptualization of technology readiness fails to capture this interaction between technology development and applicable technology insertion opportunities into acquisition programs. TRL alone does not predict the likelihood of an operational application.

The **technology innovation pathway** is an analytical construct to capture the linkage between a technology and its insertion opportunity.

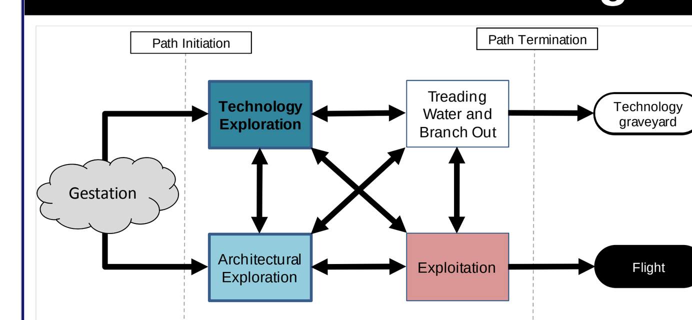
Research Questions for Innovation Pathways:

1. What is the structure of the National Security Space *innovation system*?
2. How do new capabilities traverse the innovation system as they are matured, and infused into flight projects?
3. Are there patterns of *innovation mechanisms*, important across multiple *innovation pathways*?

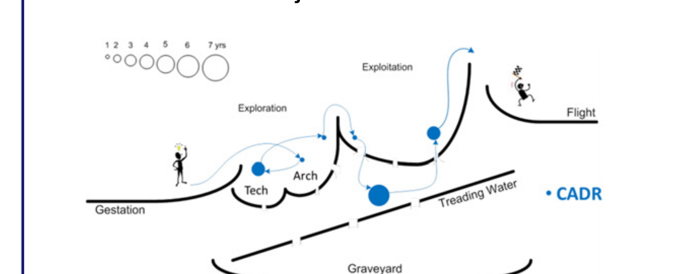
Research Questions for Modularity and Flexibility:

1. How can organizations effectively plan for technology insertion at the appropriate architectural level in an uncertain acquisition environment?
2. How can modularity be implemented within a system's architecture to mitigate programmatic impacts of changes such as technology insertion?

Background - Szajnfarber



Szajnfarber 2011



- Stage-Gate conceptualization does not capture all important dynamics in innovation at NASA
- Epoch-Shock model captures state transitions where the technology innovation is the unit of analysis

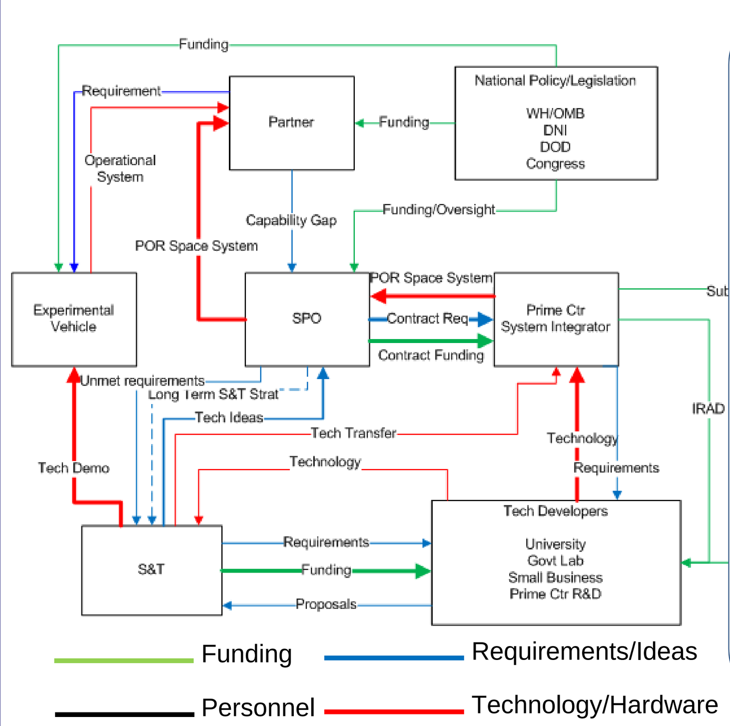
Gestation: Pre-path initiation; sets initial conditions for path (incl. relationships, technical & application knowledge, access to resources). Typically, Multiple disjointed small groups are separately engaged in other, tangentially related projects

Epoch	Description	People	Technology	Funding
Tech Exploration	Simultaneous pursuit of multiple new technological approaches. Goal: fund the effort long enough to find some strategy that works and proves the concept	Small core team of internal experts, augmented by ad hoc external collaborations.	Proliferation of ideas, parallel experimentation, inexpensive mock-ups	Slack resources at branch-level; different institutional sources applied for indiscriminately, without differentiating among target maturity levels
Arch Exploration	Focused form of exploration, guided by articulated performance-oriented goal. Goal: demonstrating flight feasibility (breadboarding/ detailed simulations)	Similar to Tech Ex, with addition of end-user (i.e., scientists)	Reconfiguration of existing components to solve a new problem	Similar strategy as Tech Ex, with higher funding burden (i.e., more NRA vs. IRAD)
Exploitation	Structured actions taken to mature the selected systems architecture towards flight readiness.	Major expansion of team size; bring on engineers and PMs (internal additions).	Focus on testing and implementation issues.	Typically project-specific or large NRA (cost of activities is proportionally much higher than other epochs)
Treading Water & Branching out	This is survival mode: keep key team members funded, so they won't be permanently reassigned to other unrelated projects .	Reduction to original core; external collaborations motivated by branching out	Proliferation of applications, leveraging same core innovation	Drought. Applying to every possible source and creating new ones.

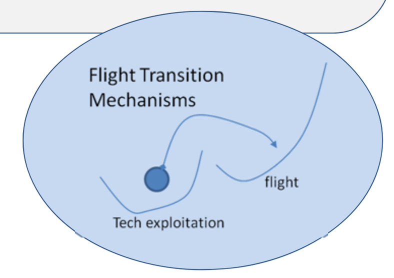
Termination 1: innovation infused into approved flight project (phase B).
Termination 2: Drought persists to point where key team members are forced to join other funded projects. While constituent ideas may resurface in later projects, this will only occur based on significant efforts from an individual champion.

Shock	Description	Direction of Impact
Solutions	A. Tech A: Laboratory demonstration that a new concept can yield the desired effect (often with poorer performance than incumbent). B. Tech B: Demonstration of practical utility. **Timing:** unpredictable/unpredictable	A. Can open up new search space; shift in current trajectory. Raises or lowers level of exploration (from tech to arch or visa versa) B. Weaker than Tech A (legitimate rather than initiate). Necessary precursor to exploitation, but rarely forces transition.
Problems	C. DevOpFlag: Revolutionary, focused aspirations prompts search for radically new approach in target areas. D. DevOpEx: Explicitly non-specific, relatively small opportunity. Still serve as important focus. E. DevOpNeed: Identification of key technical roadblock in the context of existing architectural concept. **Timing:** cyclical/semi-cyclical/unpredictable	C. Typically initiates architectural exploration (explicitly corresponds to resource availability) D. Enables transition from exploration to exploitation (assuming recent Tech B). E. Can initiate new innovation pathway (per Tech A) or lower the level of exploration from arch to tech.
Context	F. Drought: Sudden and/or sustained inability to secure resources (including yearly center- and directorate-level). Often related to change in administration. G. Context: captures key events and activities exogenous to innovation pathway, not covered by other label (e.g., failures of Astro E/EII change risk assessment on H). **Timing:** semi-cyclical/unpredictable	F. Initiates transition to treading water & branching out epoch, regardless of current epoch. G. Impact is highly dependent on nature of context change (e.g., in Astro case, it precipitated DevOpEx).
Collabora-tion	H. Join: In the context of a small team, each member brings unique and important skills/equipment, that often shaped the pathway. **Timing:** semi-cyclical (external)	H. Join (+), particularly when the addition was external, precipitated several Tech As and Bs, but didn't tend to induce transitions. Internal additions tended to correspond to/follow otherwise induced transitions.

Context Extension to NSS



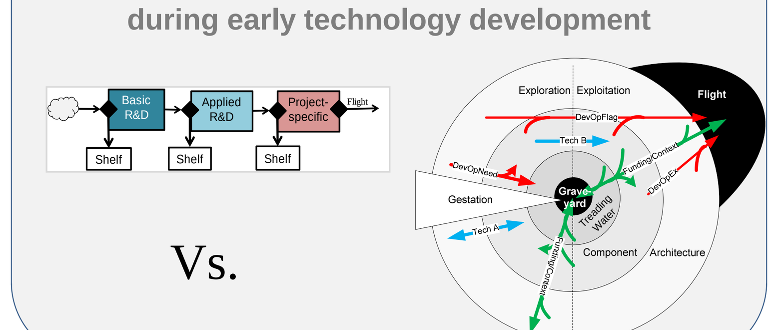
- Test generality of Epoch-Shock Model outside NASA with similar technology
  - National Security Space is first context extension
- The independent variable is the organizational context
- Organizational context difference
  - System Integrator role for contractor
  - National Security context changes due to US strategy
  - End user advocacy for a capability must be cultivated
- Observed NSS transitions that move from tech exploitation to flight
  - Low-risk auxiliary payload
  - Mandated auxiliary payload
  - Prime Contractor tech push



- Organizational view combines policy documentation with interviews and program documentation
  - Enables analysis of differences between NASA and other technology intensive gov't organizations

Toward Generality and Prescriptive Research

Recognize that transitions are commonly observed as the result of a shock unforeseen during early technology development



Additional research planned outside the space vehicle context

Preserve flexibility and adaptability in technology development to enable more effective and less costly transitions

How can an organization architect for evolvability in path-dependent technology intensive systems?

Observations captured in Epoch-Shock Model	Predictions for context-extension studies
1. New technologies and the systems in which they are integrated embody multiple levels of maturity simultaneously, challenging the concept of monotonically increasing "maturity.	1. Technology efforts use multiple funding vehicles during development.
2. Process is not usually controllable through funding allocation and gate decisions because transition shocks between epochs are not known in advance.	2. Transitions result from efforts that were able to capitalize on an unforeseen transition opportunity.
3. The valley of death cannot be overcome solely with targeted transition funding; a transition shock mechanism is also required, and the specific shock may be unknown to the technology developers.	3. Transition shocks are not under the control of technology developers
4. Shelf life" is as much a matter of keeping the team intact as a question of obsolescence.	4. Successful transitions will involve high-longevity government or contractor employees who continue to pursue the technology development.

Future Directions

Currently have:

1. Interview and document data from example technology infusion cases
2. Context-specific descriptive process model

FY2011

Future Work:

3. Detailed innovation pathway analytical chronologies
4. Cross-case comparison between NSS cases and with other cases in government acquisition

FY2012

Descriptive in NASA Context

Compare observed transition pathways across key dimensions

Descriptive

Compare the influence of different organizational structures on innovations in similar technology

Prescriptive

Manage development of technology such that its insertion pathway is adaptable to unpredictable transition shocks

For more information, please visit: http://seari.mit.edu