

Understanding the Dynamics of Innovation in the Government Space Sector

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Biography
Zoe Szajnfarber is currently working towards her Ph.D. in ESD at MIT. Zoe has worked as a systems engineer at MDRobotics and Dynacon Inc; and at the European Space Agency as a researcher studying technology development in space science missions. Zoe received a B.A.Sc. in Engineering Science from the University of Toronto (2005) and S.M. degrees in Aeronautics and Astronautics and Technology and Policy from MIT (2009).
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Related Publications
Szajnfarber, Z. and Weigel, A. L., "Towards an Empirical Measure of Spacecraft Innovation: The Case of Communication Satellites," *Acta Astronautica*, 2009. (Accepted for Publication)
Szajnfarber, Z., Richards, M. G. and Weigel, A. L., "Implications of DoD Acquisition Policy for Innovation: The Case of Operationally Responsive Space," AIAA Space 2008, AIAA, San Diego California, September 2008. (Submitted to JIDAM, 2009)
Szajnfarber, Z., Grindle, A. T., and Weigel, A. L., "Instantiations of Government Space Innovation Systems: A Comparative Analysis" *International Astronautical Congress, IAF*, Daejeon S. Korea, October 2009.

Motivation (1): Space Market Creates Strategic Innovation Tradeoffs

C1 Monopsony markets enforce a top-down acquisition process. Need to balance funding for within-project and exploratory technology development

C2 When representing the needs of a disaggregated buyer, the extent to which to prioritize knowledge types

C3 When integrating fragmented sell-side knowledge from the top-down, need to maintain certain amount of in-house technical expertise.

C4 The extent to which to isolation of exploratory technology development from project application

C5 Given the politicization and public visibility of space activities, how to balance accountability and the need for experimentation

Space Sector Attributes

Market Structure: Monopsony-Oligopoly → Transactions only occur when buyer wants to buy (discrete and specific)

Product Complexity: Each subsystem is itself a complex system
Many disciplines, many organizations involved
Multiple different levels of maturity simultaneously

Nature of Space Acquisition: Harsh remote environment (Survivability, serviceability)
Expensive public good (Accountability, failures public)
Strategic asset (security, sensitive (e.g., ITAR), Reduced communication across boundaries)
Risk Aversion

Models for Understanding Innovation

Characteristics of the Space Sector

Market Structure: Complexity, Space
Process: Complexity, Space
Nature of Space Acquisition: Complexity, Space

Unique market structure of space industry lacks natural dynamic of "creative destruction." If radical change is to happen, requires government patronage.
(Peck and Scherer, 1962; Sherwin and Inenson, 1967; Adams and Adams, 1972)

Motivation (2): Evolution of NASA Tech Dev. Strategy

(1986-1992) R&T in Office of Aeronautics and Space Technology (OAST) = Basic, cross-cutting research (~250M)

(1992-1994) Aeronautics to Office of Aeronautics

(1992-1994) Space to Office of Advanced Concepts (OSAT, ~200M)

(1996-1999) Cross-Enterprise Technology Development (under Code S)

(1996-1998) Office of Space Science (~100M)

(1998-2007) NIAC

(2001-2004) "Pioneering Revolutionary Technology" ~\$100M Advanced ~\$180M IT/Comm

(1999-2001) Office of Aerospace Technology (OAT) ~\$40M NRA ~\$100M cross-cutting

(2004+) Exploration Technology Development program ~75% cut in 2005

Strategic Guidance: Focus "basic" R&T on ISS, Separate R&T base from focused, Focus on Commercialization (Clinton), 80% push -20% pull, Reduce Center R&T funding, 100% push -0% pull, Cut Technology Development, Restore R&T Funding

While there is general recognition of a need for both "basic cross-cutting" R&T and "applied" R&D efforts, there is little consensus on what the "right" balance is. Despite extensive experimentation, fundamental lack of understanding of innovation process in the space context. Without understanding, tradeoff cannot be resolved.

Conceptualization: Government Space as Innovation System

World events → Political Climate → Program Prioritization & Planning (Budget & Policy, User Needs, Technology state-of-the-art)

Desired Effects → Gap → Existing Capabilities → New Concepts → Directed R&T → Basic R&T → Advanced Tech Dev.

Data Use → Data → Mission Operations → System Acquisition → Advanced Tech Dev.

Updated Needs → Data Use, Future Needs → Approval Projects → Medical Coverage

Def'n: Innovation is the process through which the technological state-of-the-art (as defined by the user) changes over time. This can equivalently involve: a) generating a wholly new capability; b) improving an existing capability; or c) reducing the resources required to achieve an existing capability (e.g., making the system cheaper or lighter)

Insights from representation: 1) Three "development" loops – technology, system, science – which have mismatched time constants and interact through complex feedback, perturbed by the political climate. 2) Guidance/Planning is necessarily based on estimates and projections

Problem Refinement: Exploratory Case Study

Rising Environmental Awareness

30 years of LANDSAT data

Initial Observations: This innovation pathway (from scientific result to being baselined for a flight project) took 30+ years. Eventual mission had not yet been conceived at time of initial QWIPS proposals. Yet, The technologist was able to recognize the generic applicability to Earth Observation 20 years in advance of the specific need.

Concept of basic vs. directed dipole needs finer gradation.

The NASA innovation system provides funding buckets to support various types of R&D, but the pathways between them are informal and variable.

Need to understand why particular paths are taken at different times (DDF to ESTO should be similar to SBIR Phase II to III, this case did both with diff. effects)

Role of the Champion critical in this instance.

Timeline: 1985 (Basic S&T AT&T), 1990 (Basic S&T at JPL), 1995 (DDF@Goddard, ESTO@GFSC/JPL), 2000 (QWIPS as IR Camera?, Applied Instrument Dev.), 2005 (SBIR Phase I/II & IRAD, Chance encounter at conference, Funding Challenges resolved by Champion)

Understanding the nature and implications of the basic vs. directed S&T tradeoff requires a systems perspective, integrating both a representation of the formal institutional mechanisms and the informal "innovation pathways," studied over decades.

Research Design

Concept Development → Goal: Explanation and Theory Refinement

Empirical Theory Development: Cases selected based on variability in terms of key parameters. Formal Structure (notional) vs. Process tracing: Within-case and cross-case comparison.

Data Sources: Agency records, Procedural documents, Participant Interviews, Published reports, papers, contracts.

Selection of key parameters, Abstraction of Formal Structure.

Disturbances (e.g., policy change, mission need)

Research Status

- Currently:
 - Finalizing case selection
 - Beginning data collection
- Expect to complete process tracing by summer 2010

Potential Contributions

- New Understanding:
 - Conceptualization of space agencies as innovation systems
 - Representation of formal institutional structure
 - Causal explanation of a selection of innovation pathways
- Practical:
 - Basis for institutionalizing the pathways (that work).
 - Insights in the tradeoff between basic and applied R&D in government monopsonies.

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