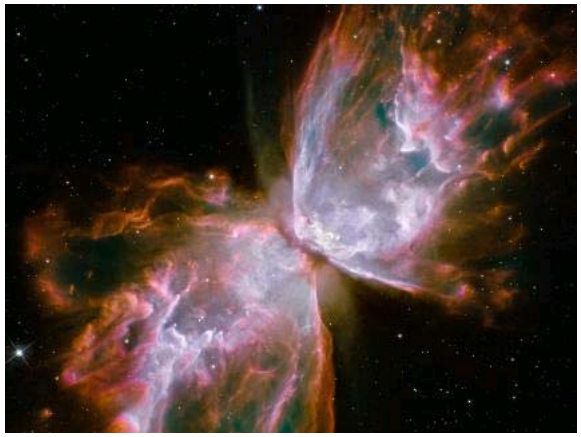

2011 SEAri Annual Research Summit

Research Report from the Field

Managing Innovation in Technology-Intensive Organizations:
The need to move beyond Stages and Gates

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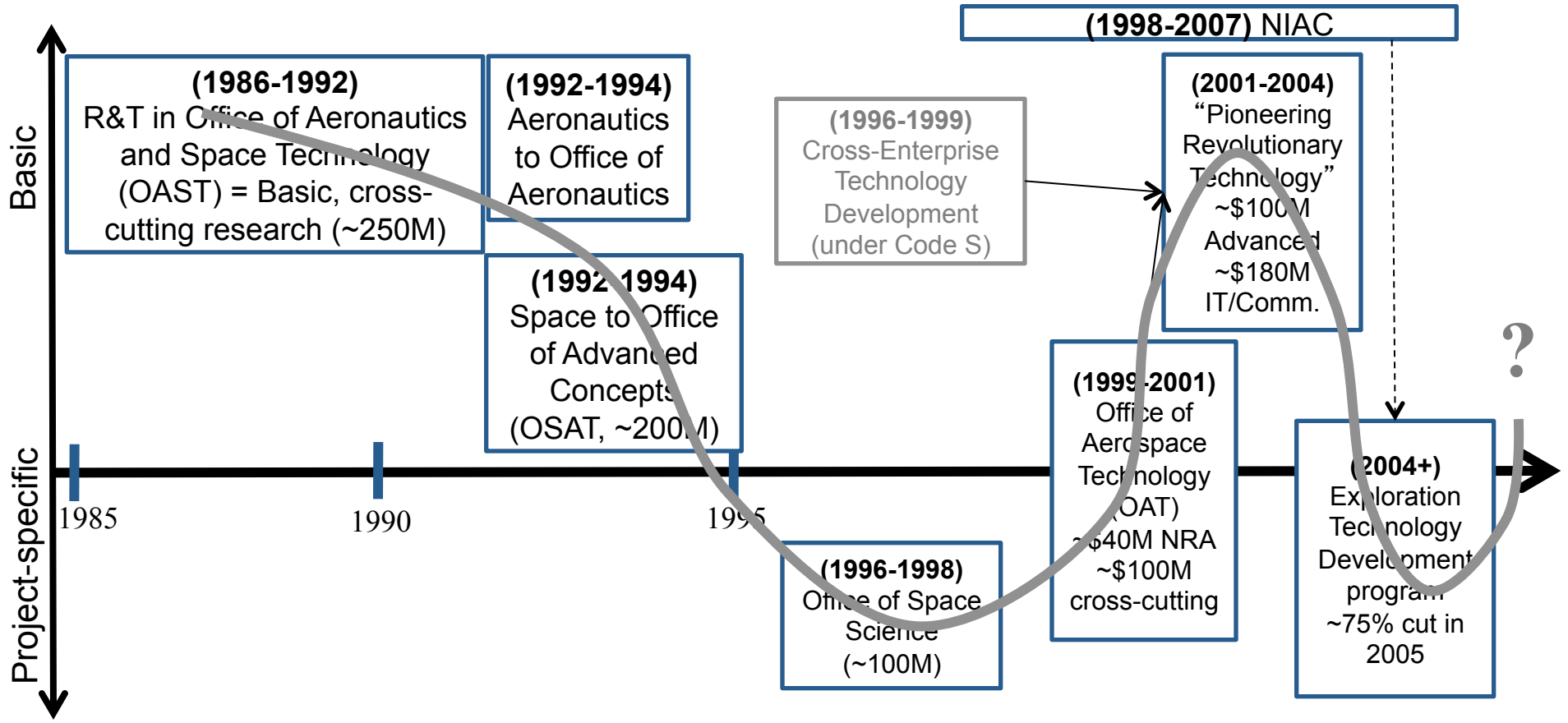
Assistant Professor

Engineering Management and Systems Engineering

The George Washington University

Presented October 21st 2011, Cambridge MA

History of Shifts in R&D Strategy



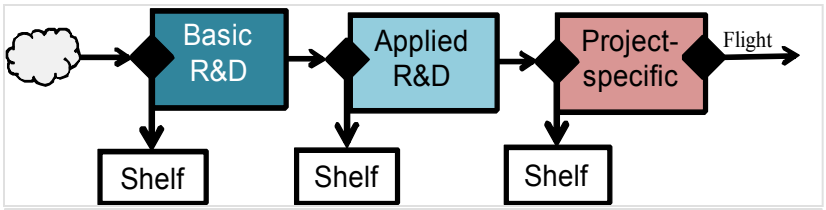
(Based on data collected for NASA R&T Study and NRC study of NIAC)

NEED: Improved understanding as a precursor to change

Overview

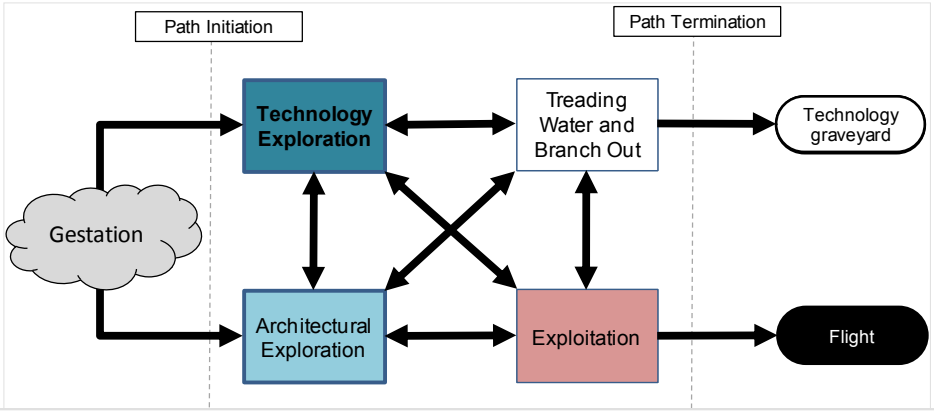
Research Questions:

1. How do new capabilities traverse the innovation system as they are matured and infused into flight projects?
2. To what extent can the observed *innovation pathways* be improved through feasible management interventions?



Stage-Gate conceptualization is not just coarse; it's wrong.

vs.

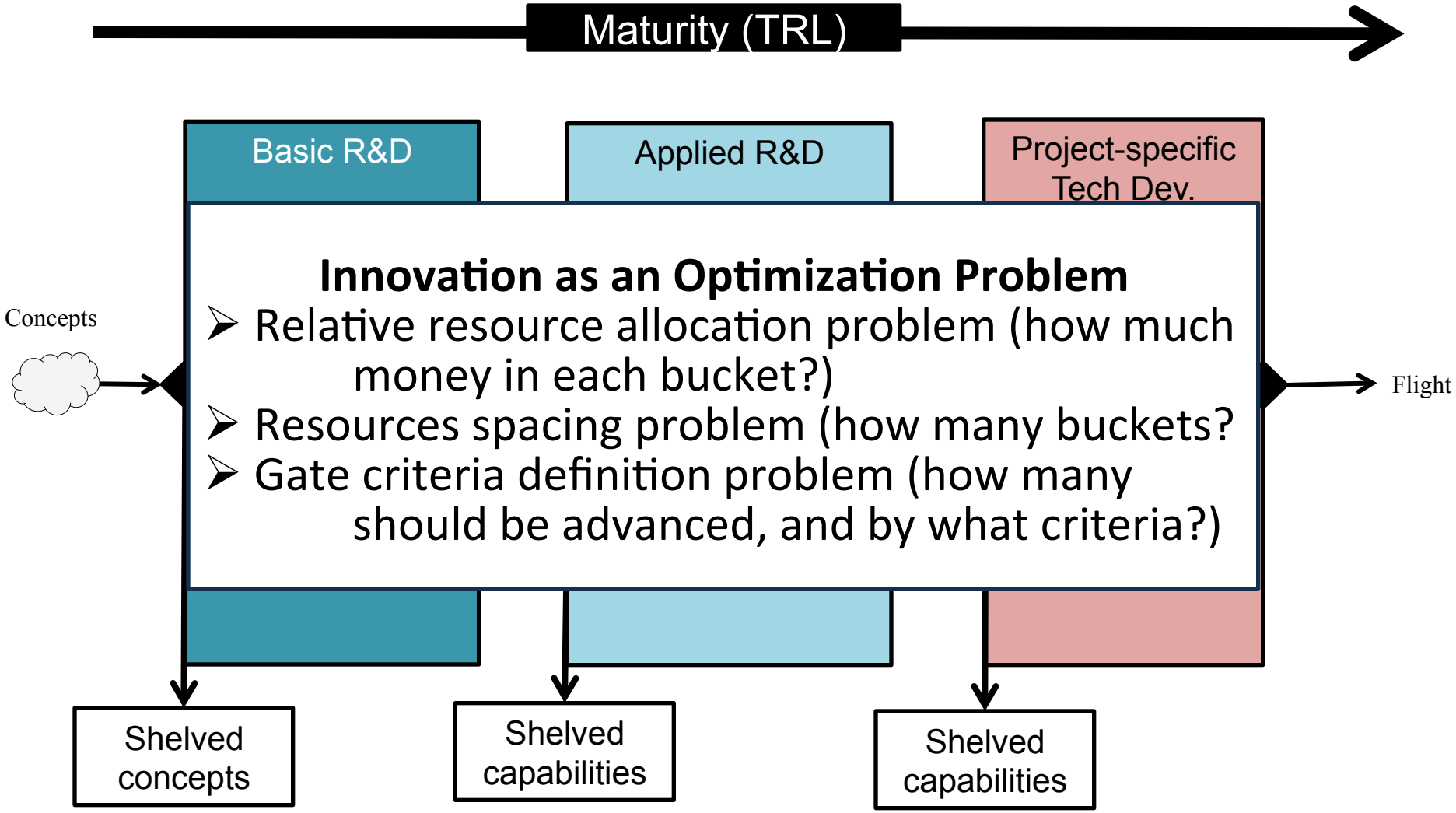


Introduce empirically grounded model; explains conflicting observations

Implications for technology management for the long run

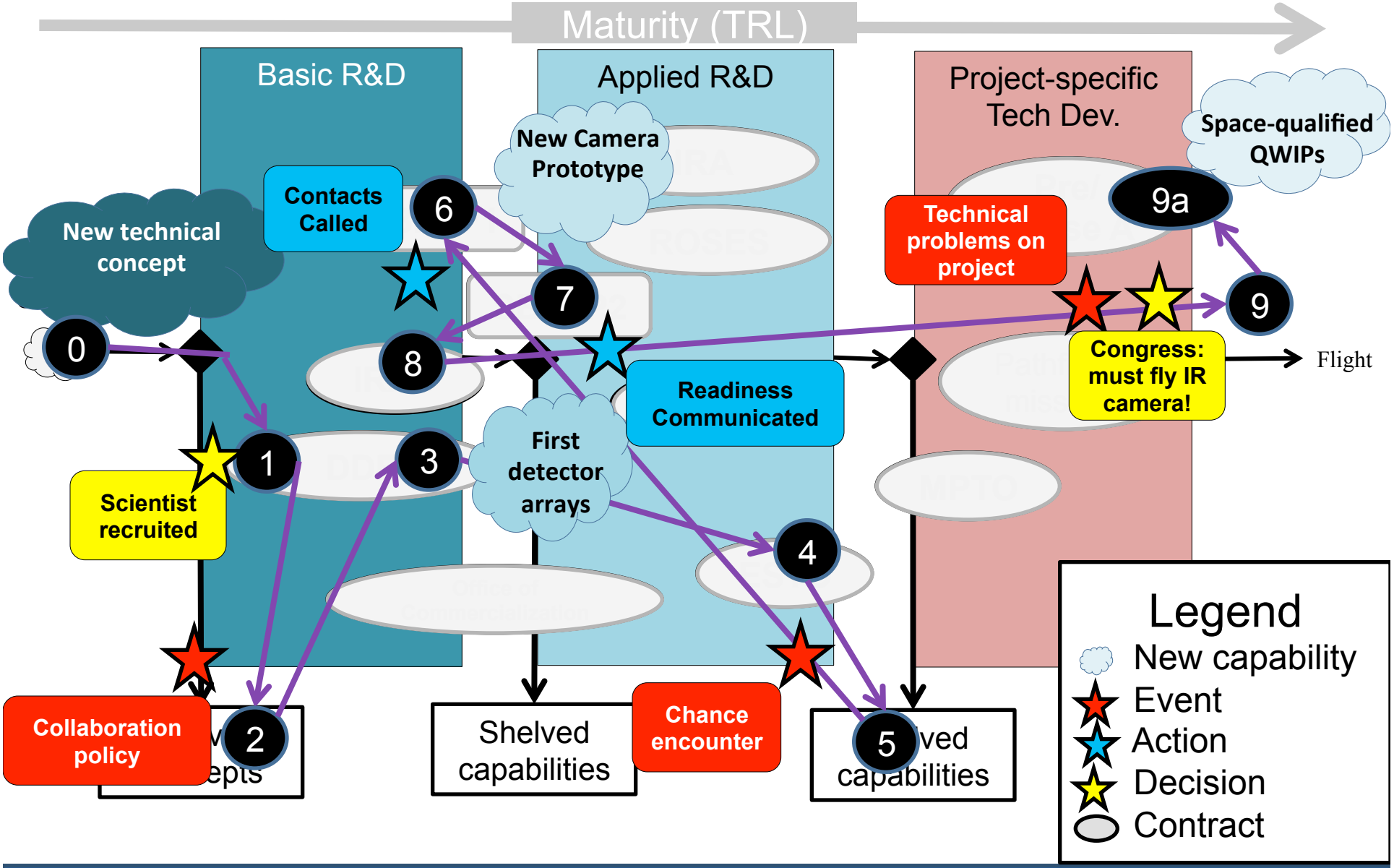
Problem Formulation

Current Conceptualization: Stage-Gates

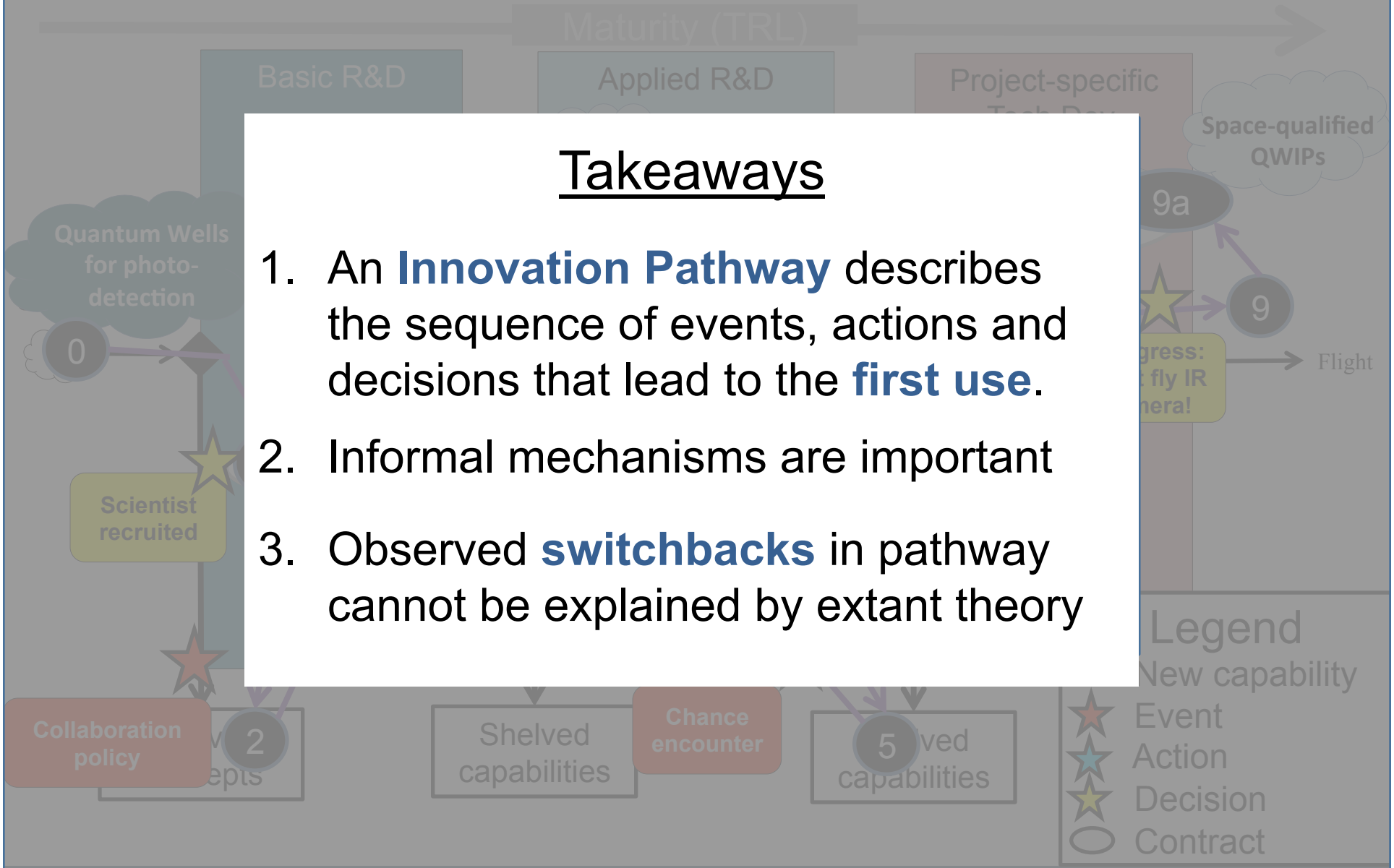


*Synthesized from NASA strategic planning documents 1990-2006

Actual Complexity of The Process



Actual Complexity of Process



Takeaways

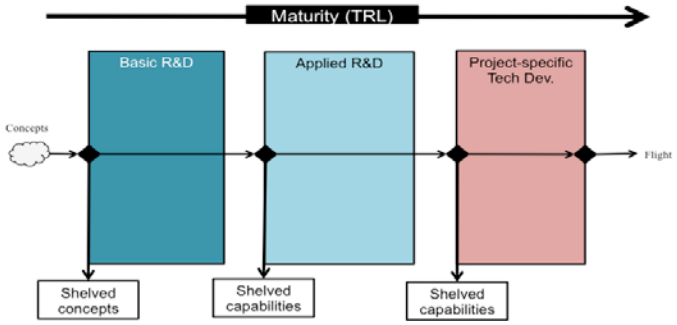
1. An **Innovation Pathway** describes the sequence of events, actions and decisions that lead to the **first use**.
2. Informal mechanisms are important
3. Observed **switchbacks** in pathway cannot be explained by extant theory

Limitations of the Stage-Gate View:
Is the model coarse or meaningfully inaccurate?

Stage-Gate Assumptions

Innovation as an Optimization Problem

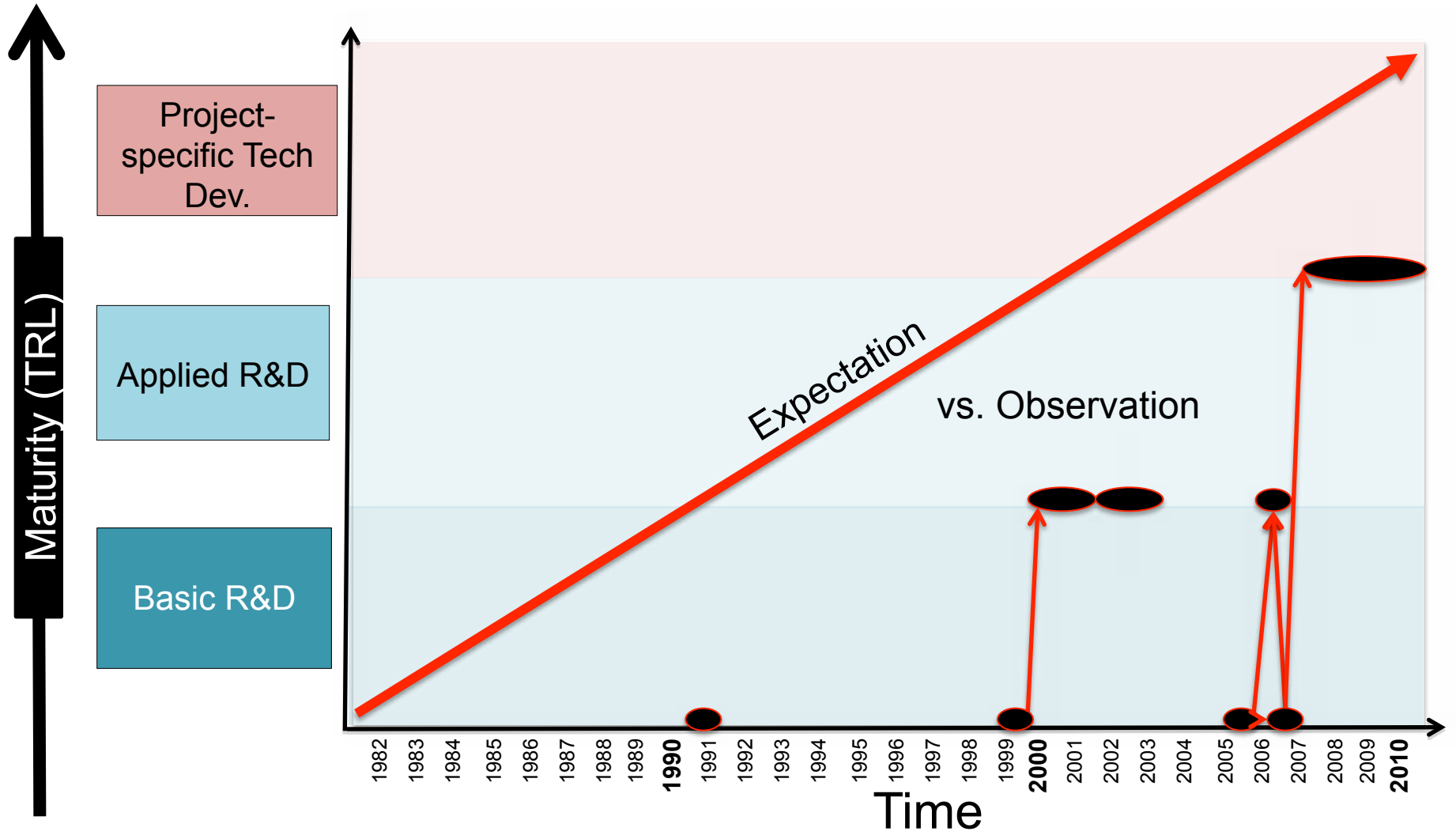
- Relative resource allocation problem (how much money in each bucket?)
- Resources spacing problem (how many buckets?
- Gate criteria definition problem (how many should be advanced, and by what criteria?)



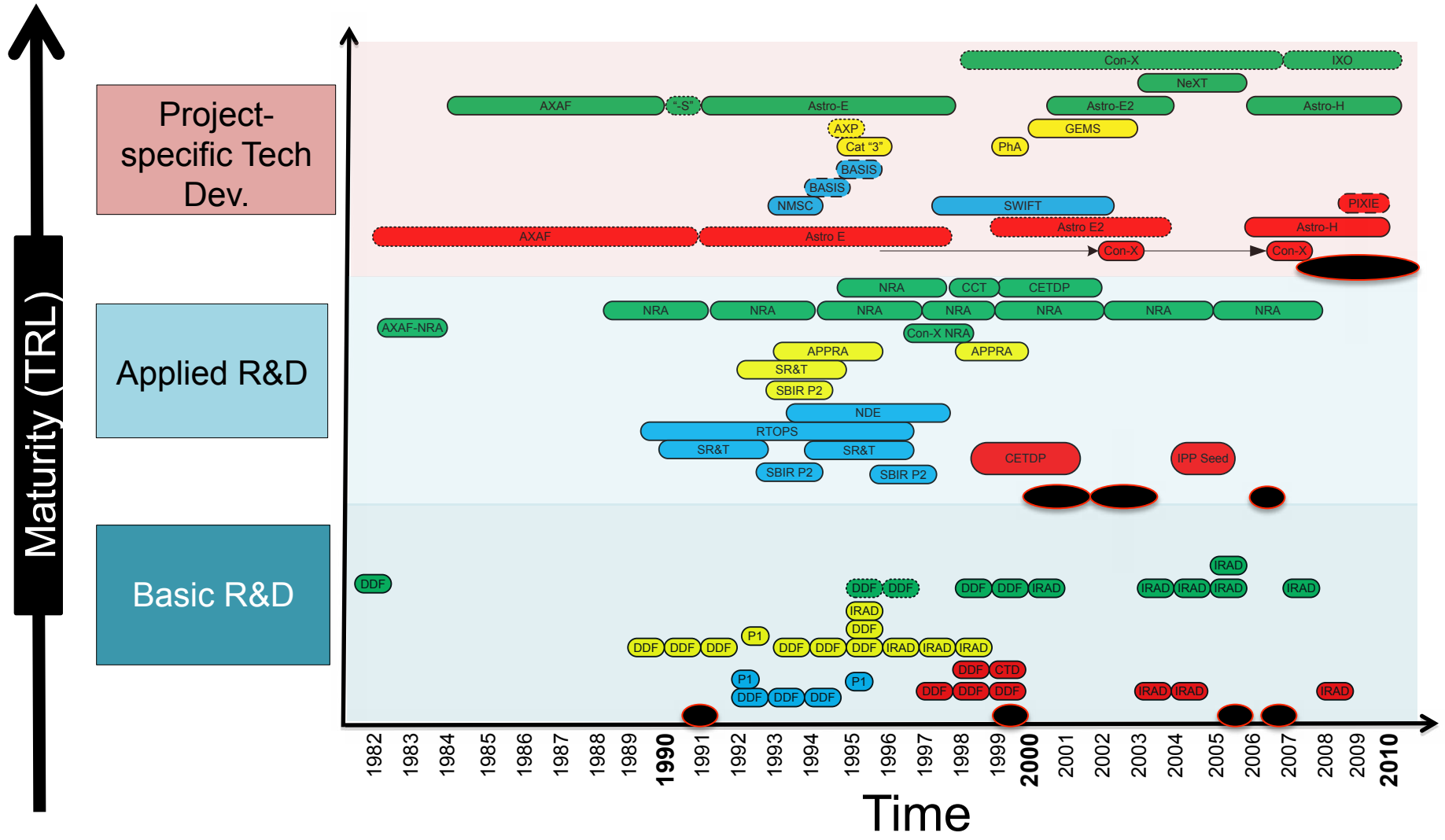
Underlying assumptions:

(1) Technologies **mature** from left to right over time;
(2) **Stages** are mutually exclusive (at a given time);
(3) **Shelving** is an active process, controlled by decision- makers;
(4) **Shelf life** is passive and a function of technical obsolescence.

Observed Switchbacks in Maturity



Assumptions #1 and 2, not respected



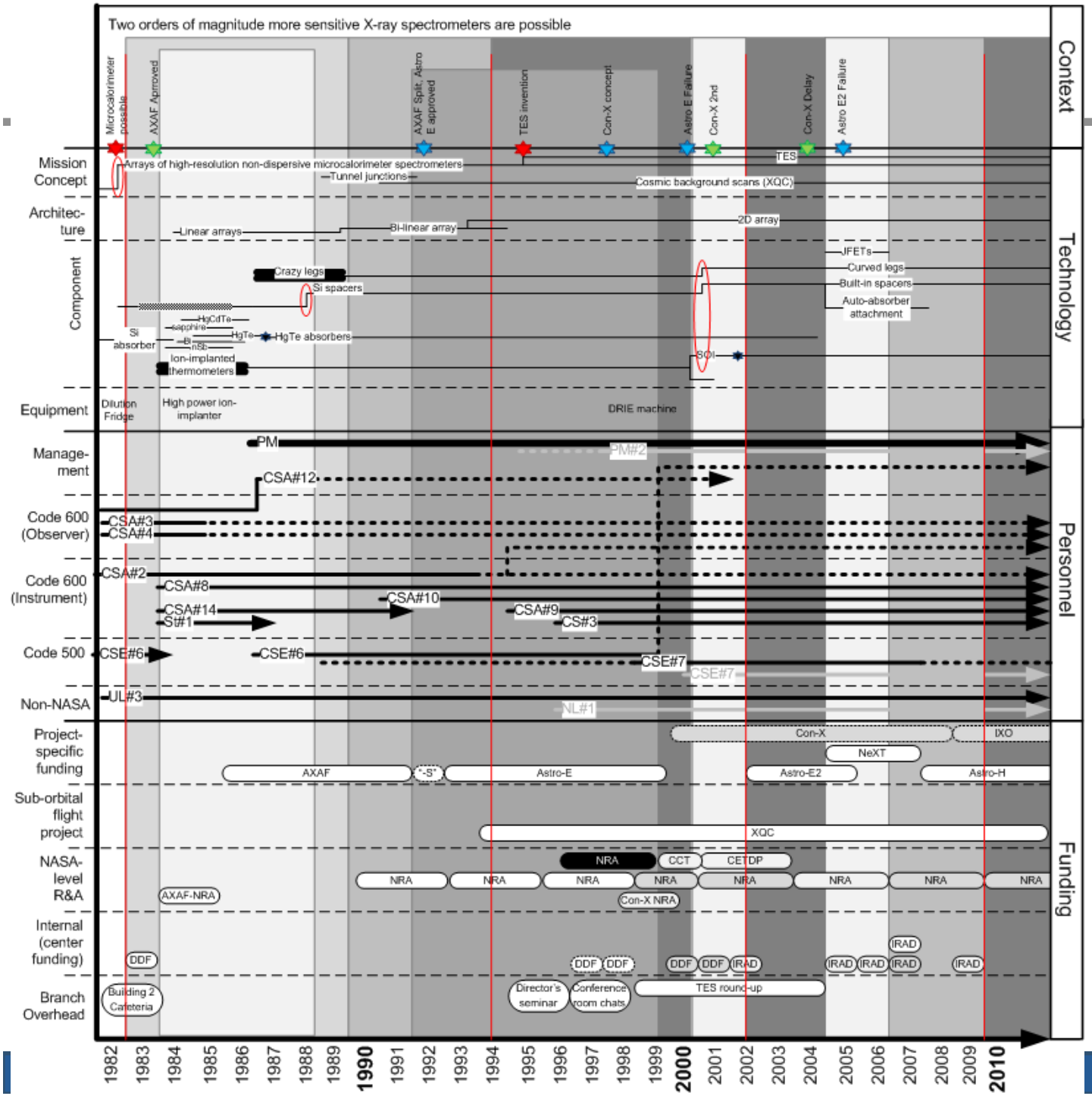
Passive Gates, Active Shelves

- Expectation:
  - Rejection at Gate => Shelving
  - Similar shelf lives for similar technologies
- Observation:

Case	Rejected + Shelf	Rejected + !Shelf	!Rejected + Shelf	Duration on Shelf
Tech A	1	1	1	8 /1yrs
Tech B	0	2	1	5 yrs
Tech C	0	3	0	N/A
Tech D	0	2	1	2 yrs
Tech E	1	Multiple	1	2 / 5 yrs
Tech F	0	multiple	0	N/A

Need: More nuanced understanding of underlying processes

Empirically Grounded Process Model



New technical insights at the component, architectural and ConOps levels

Team composition, tracking role on project and duration of participation

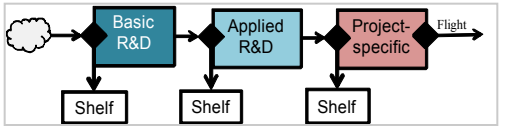
Funding sources, categorized by institutional level (e.g., center vs. HQ vs. program)

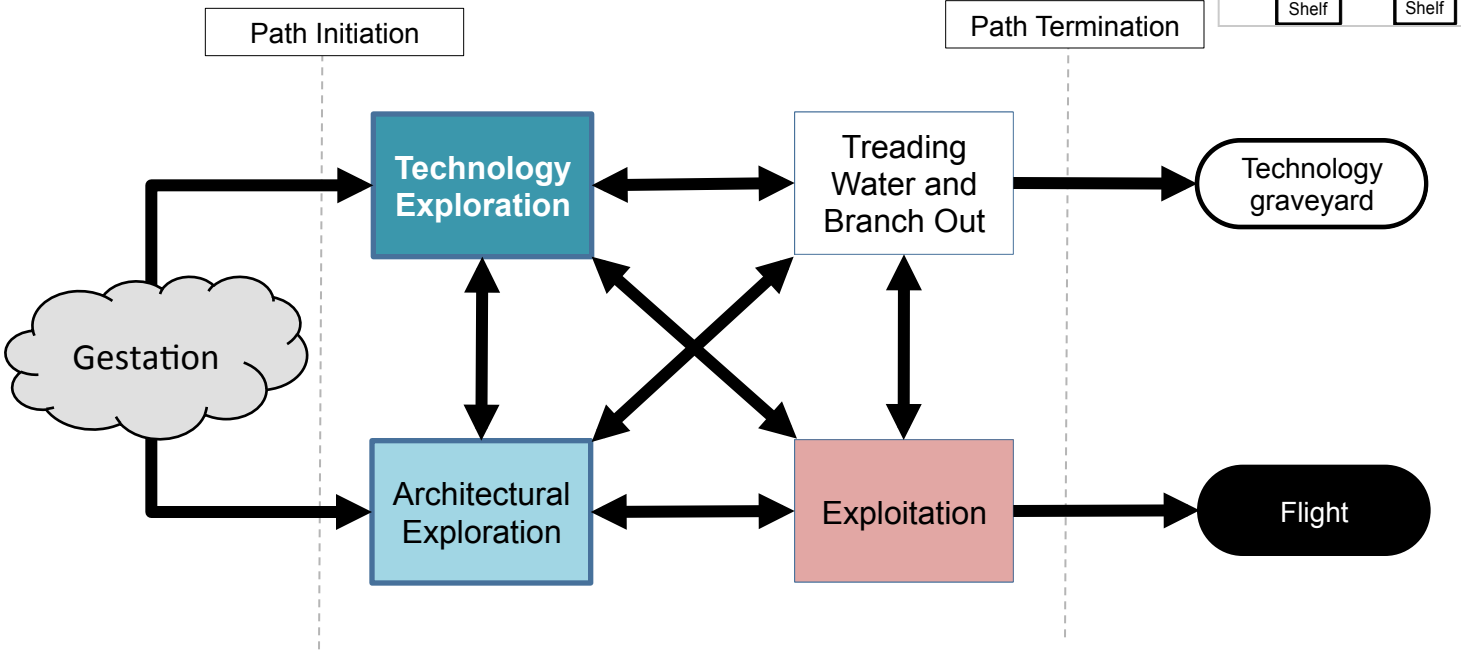
Epoch-Shock Model: Track View

- System exhibits **epochs** of persistent stable (and identifiable) behaviors punctuated by transition inducing **shocks**

Epoch-Shock Model: Track View

- System exhibits **epochs** of persistent stable (and identifiable) behaviors punctuated by transition inducing **shocks**

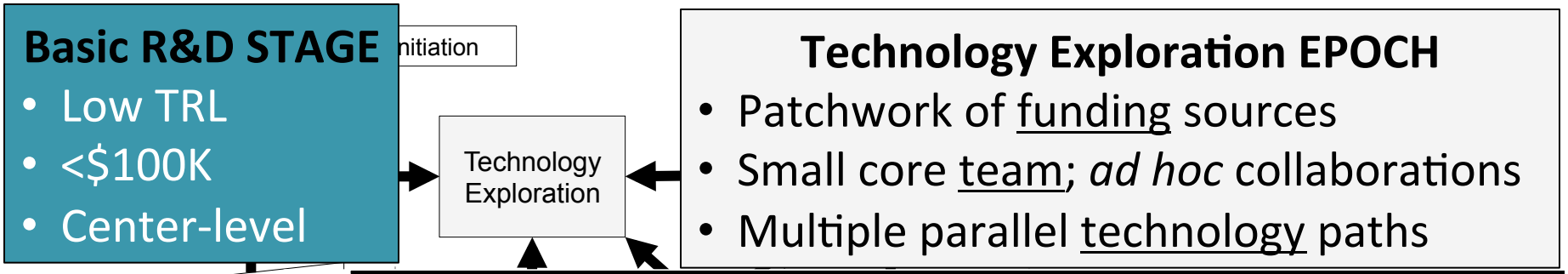




  - **Epochs** are illustrated as boxes, and roughly map to stages
  - **Shocks** induce transitions following arrows from one box to another

Epoch-Shock Model: Track View

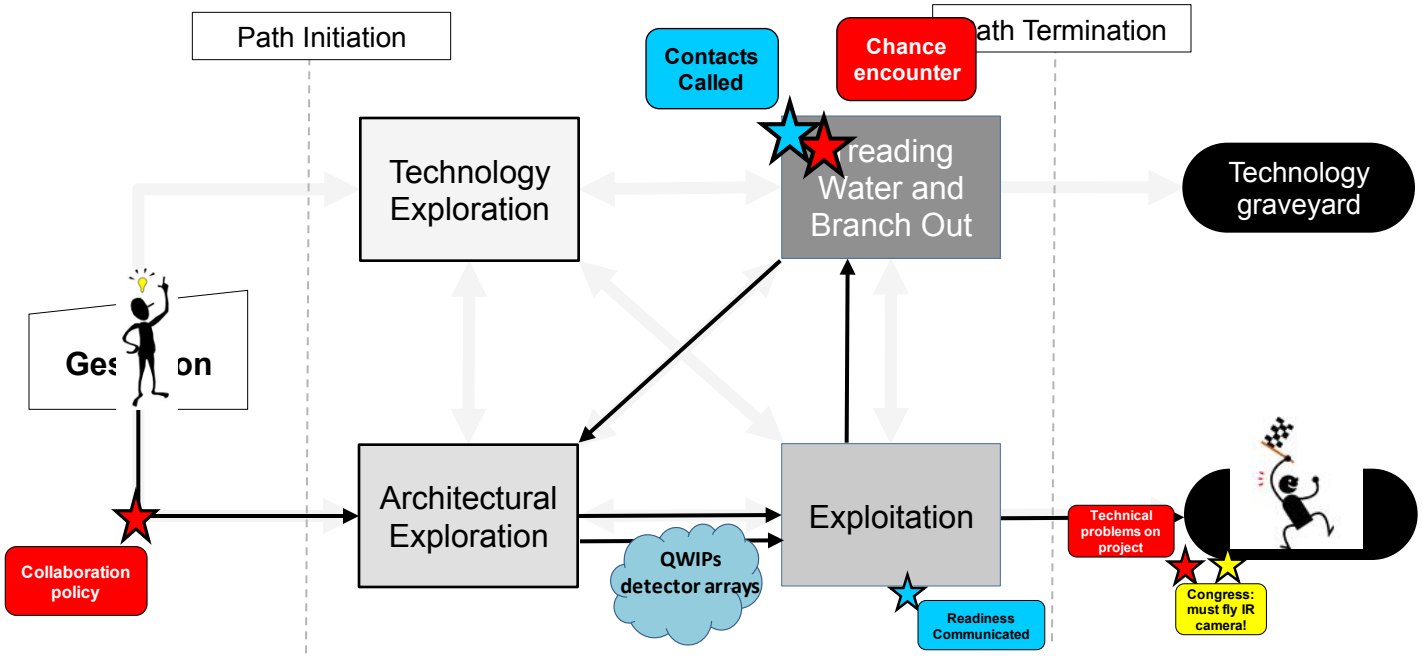
- System exhibits **epochs** of persistent stable (and identifiable) behaviors punctuated by transition inducing **shocks**



	Case	Funding	Personnel	Technology
Technology Exploration	CADR#1	4xCenter	team + Inst - Tech	parallel component paths
	CZT#2	3xCenter + 3xNASA + Balloon	team +4xTech +Inst	multiple technique strategies
	Pol#3	Brainstorm + 2xCenter + 3xNASA	team + Tech	multiple readout strategies
	Si#4	NASA + Project	team + 3xInst + Tech - 3xObs	multiple materials and techniques tried
	Si#5	2xCenter + 2xNASA + Sounding Rocket + Project	team + Tech	multiple materials and techniques tried
	Si#6	2xCenter + NASA + SR +2xProject	no change	multiple readout strategies and techniques tried
	TES#7	Branch +3xCenter + 2xNASA + SR + Project	team + Tech	Exploration of new materials and techniques

Epoch-Shock Model: Sample Traversal

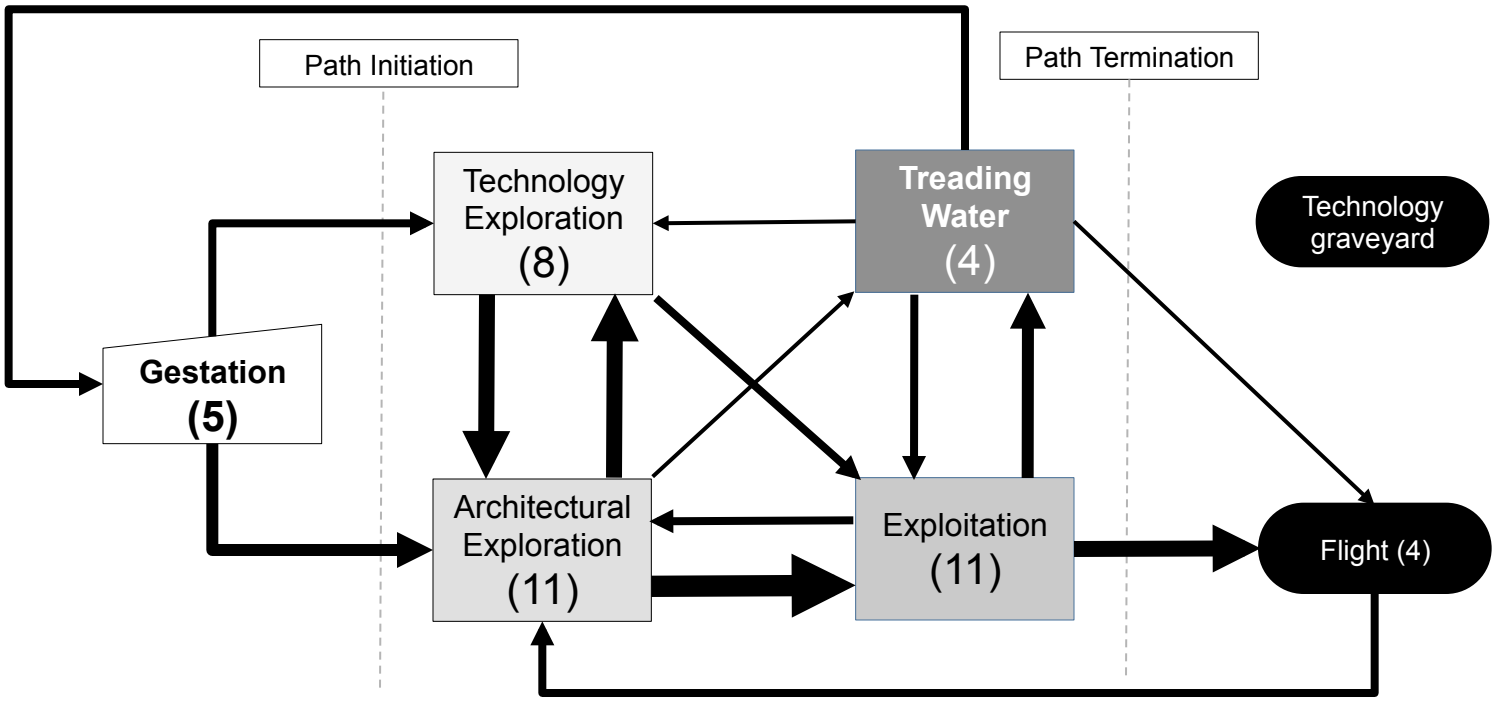
- System exhibits **epochs** of persistent stable (and identifiable) behaviors punctuated by transition inducing **shocks**



- **Epochs** are illustrated as boxes, and roughly map to stages
- **Shocks** induce transitions following arrows from one box to another
- **Innovation pathways** start in gestation and move through the system.

Epoch-Shock Model: Paths Traveled

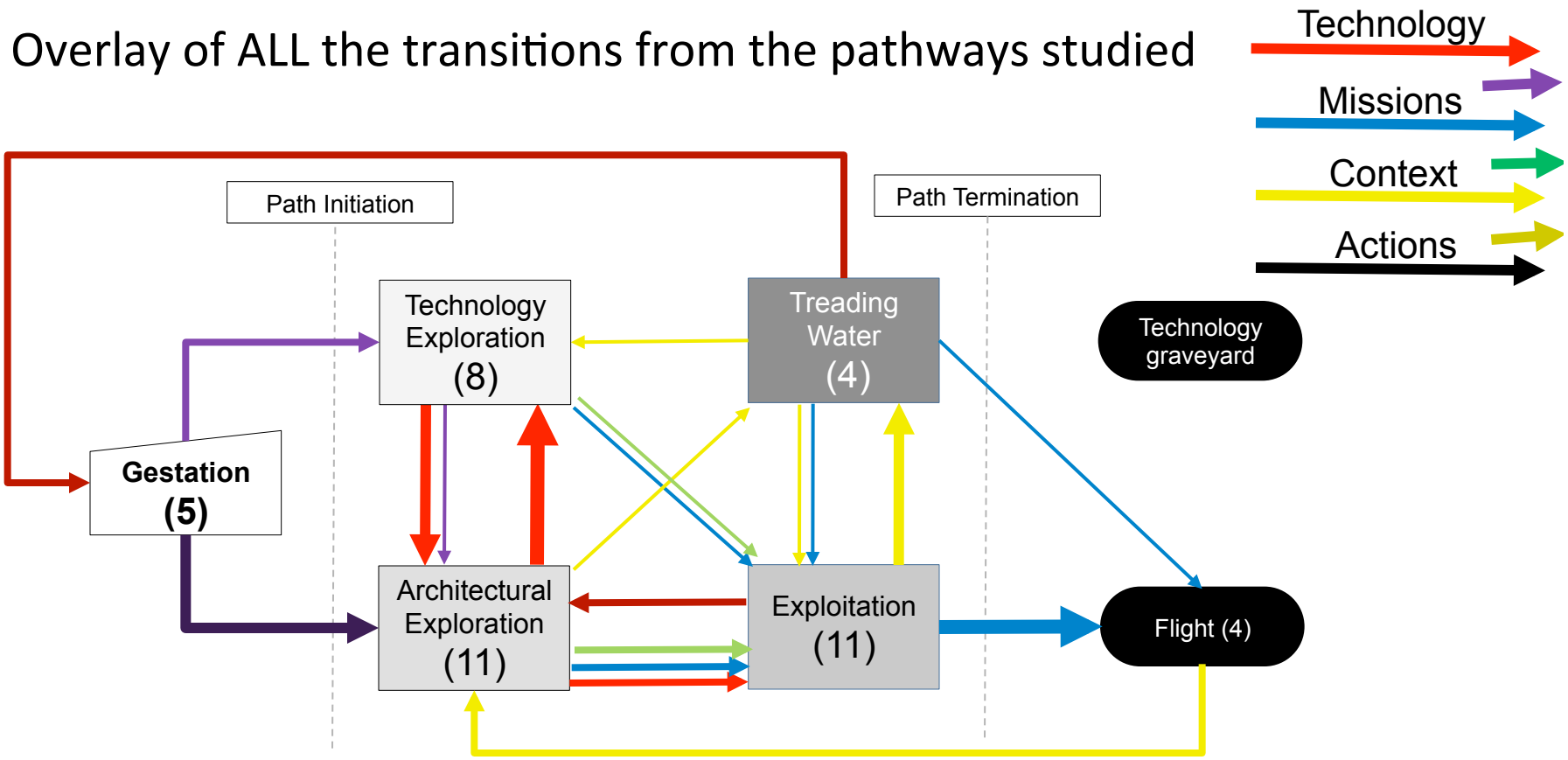
- Overlay of ALL the transitions from the pathways studied



  - Bi-directional and heavy flow between Technology and Architectural exploration.
  - Flow through Exploitation forks between Treading Water and Flight

Epoch-Shock Model: Paths Traveled

- Overlay of ALL the transitions from the pathways studied



  - Colors differentiate different types of shocks, some of which are more controllable by management interventions
  - Combined shocks are possible (e.g., red + blue = purple)

Using the detailed understanding captured in the model to explain the observed behaviors

Explaining the Observed Behaviors

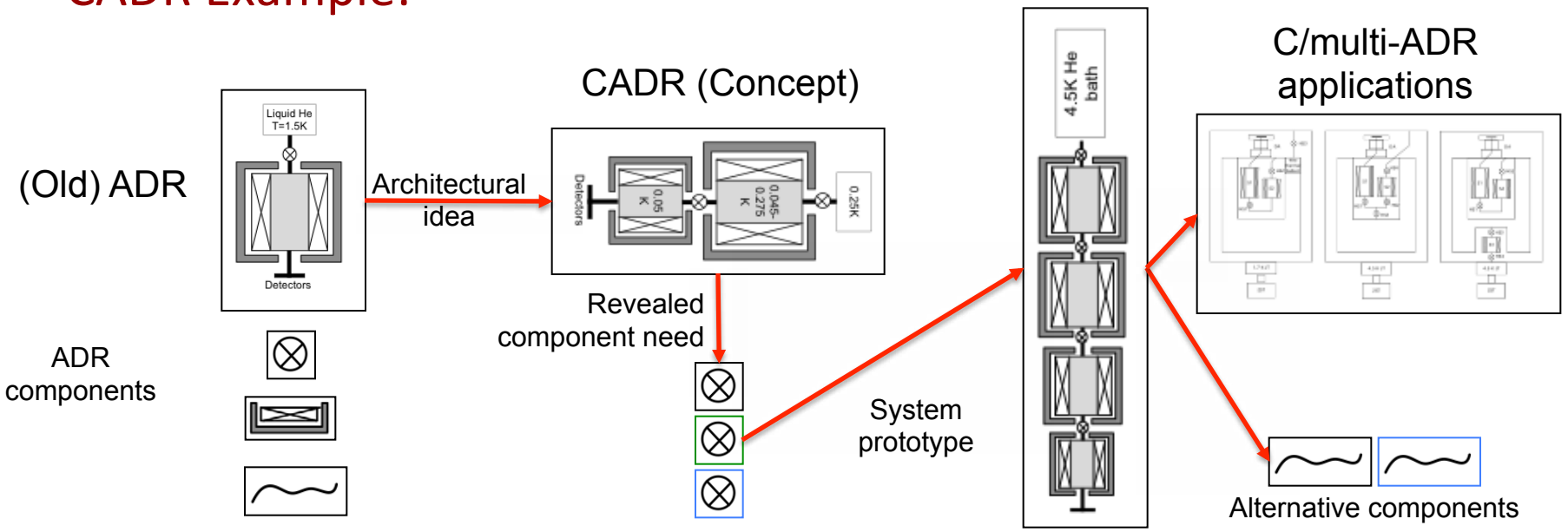
- Recall Conflicting Observations:
  - Innovation doesn't progress monotonically from left to right.
    - Resources are being drawn simultaneously from different stages
    - AND switchbacks to earlier stages were observed.
  - Shelving isn't an active administrative decision.
    - Some pathways persist despite being rejected at nominal gates,
    - while others wane due to external context changes
- Explanation in two parts:
  - Architectural complexity creates "option" for switchbacks.
  - This "option" can be strategically exercised to survive droughts.

Explanation 1: Architectural Complexity

- Explanation 1:

  In a complex integrated product, innovation can happen at different rates, in different sequences at different levels of the architecture. Thus, switchbacks are a natural corollary to complexity.

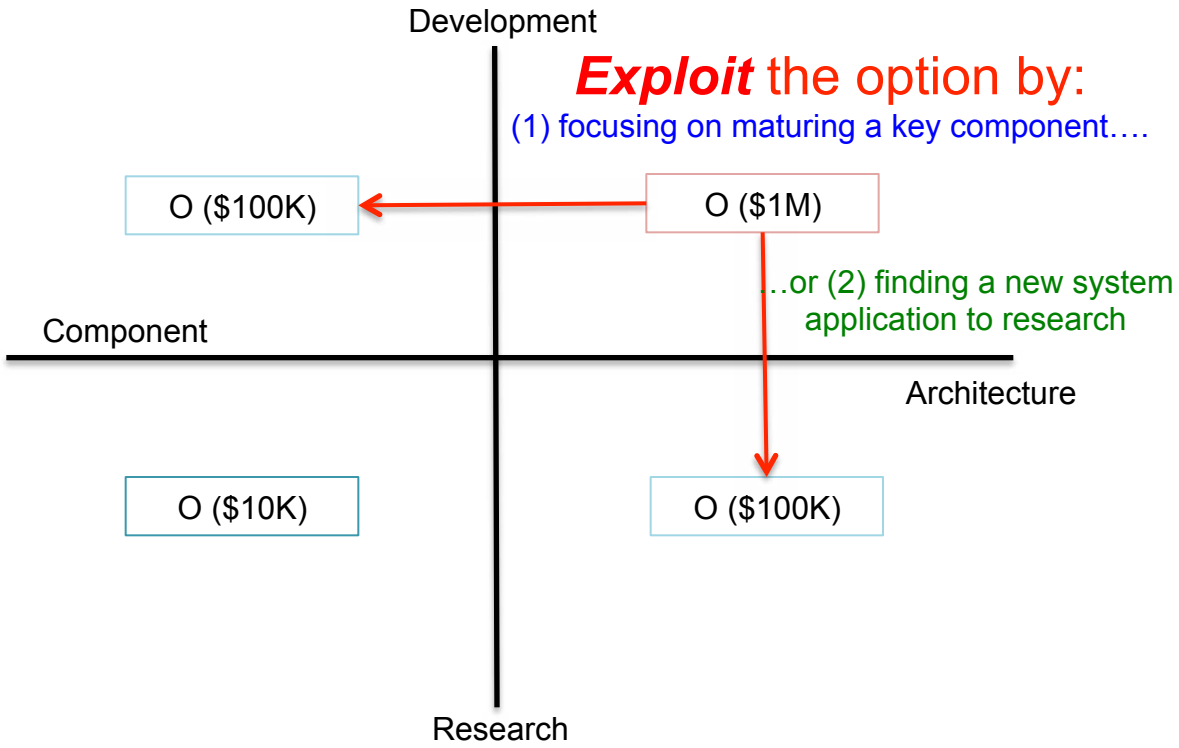
- CADR Example:

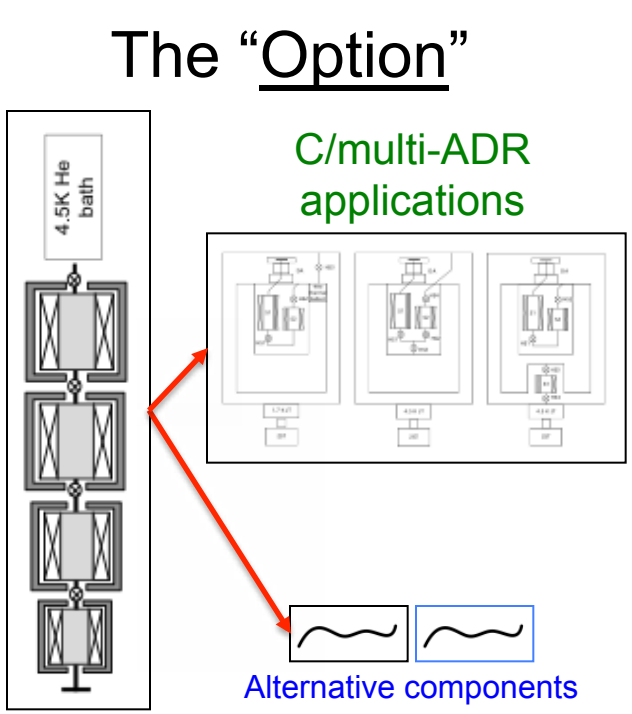


Explanation 2: Survival Strategy

- Explanation 2:
  - Technologists can ***exploit*** the switchback "option" to *survive* funding droughts.

… were never concerned that the technical capability would become obsolete…worried about losing one key technician… who was the kind of guy who would rather retire and work on his motorcycle than transition to another project while waiting for funding to be restored. And rebuilding that kind of expertise would have taken a very long time…



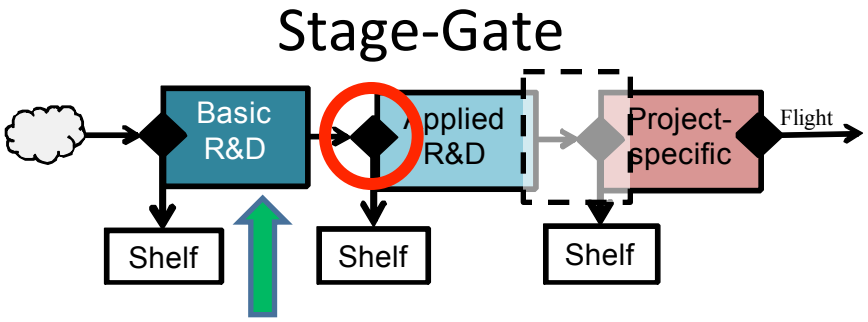


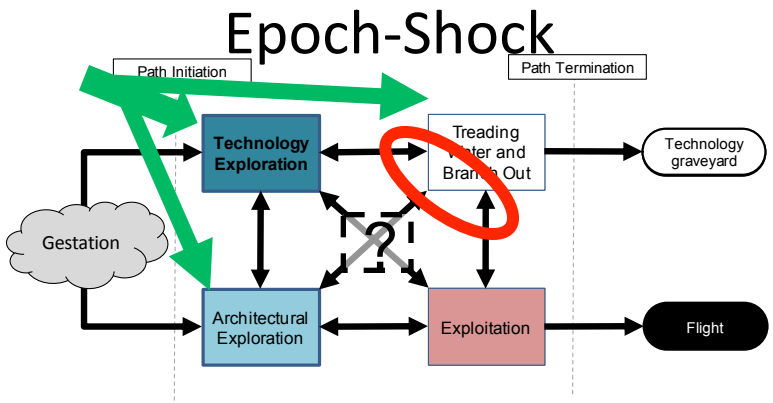
Explanation

(1) Switchbacks are a natural byproduct of complexity
AND
(2) Architectural complexity creates an “option” that can be exploited to tread water

Implications for Technology Mangement

Stage-Gates vs. Epoch-Shocks





Current control mechanisms

1. Proportionally more funding for basic R&D to increase pool of early-stage concepts.
2. Used gate decisions to control % progression to next stage.
3. Adding more stages to facilitate transitions

Assessment based on Epoch-Shock model

1. Resources can't be earmarked for "early stage/ basic." In practice that funding stream is split between basic concepts and others that are treading water and branching out.
2. Actively controllable gates don't exist. As long as teams can draw resources from multiple levels simultaneously, no gate can control the flow.
3. The lack of linear progression invalidates the concept of bridging transitions. There is an important human component of the transition dynamics.

New control mechanisms are needed

Natural Extensions

Explains why the NASA science innovation system works the way that it does and shows that administrative-level interventions cannot work as intended.

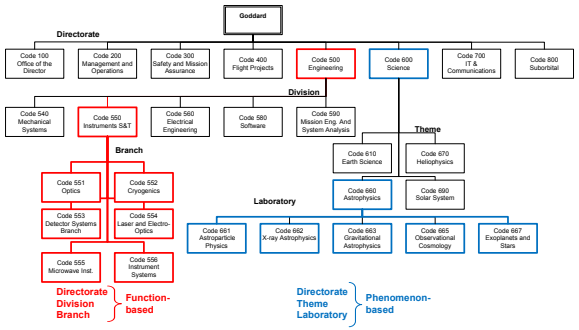
1

Replicate study in comparable context

>> Do the observed dynamics hold?

2

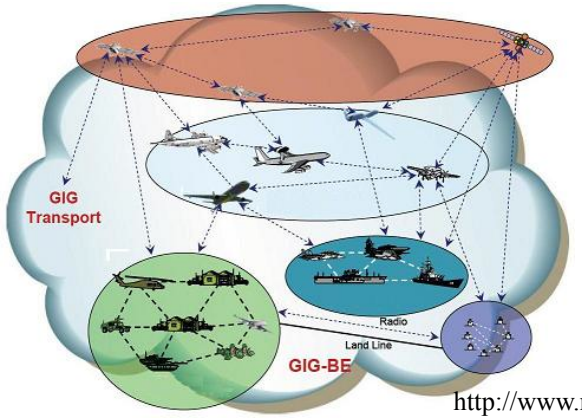
Identify feasible interventions at lower institutional levels



>> Can changes in org structure and/ or funding strategies serve as levers

3

Extend the insights beyond one-off missions to technology transition in path-dependent infrastructures.



http://www.markjessing.com/

>> How can mismatches in technology cycles and context shocks be mitigated by architecture

Questions, Comments?

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