

Pathways to Changeability: Examining Form, Operational, & Cyber Change Mechanisms

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Introduction & Motivation




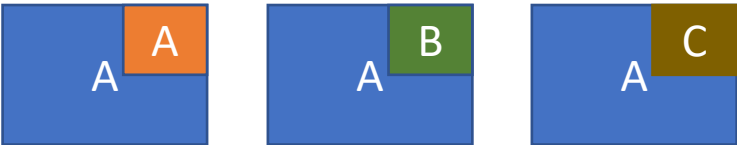
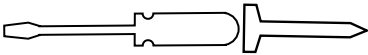
Protracted design phases and long lifecycles introduce uncertainty in operating environments

Research Question



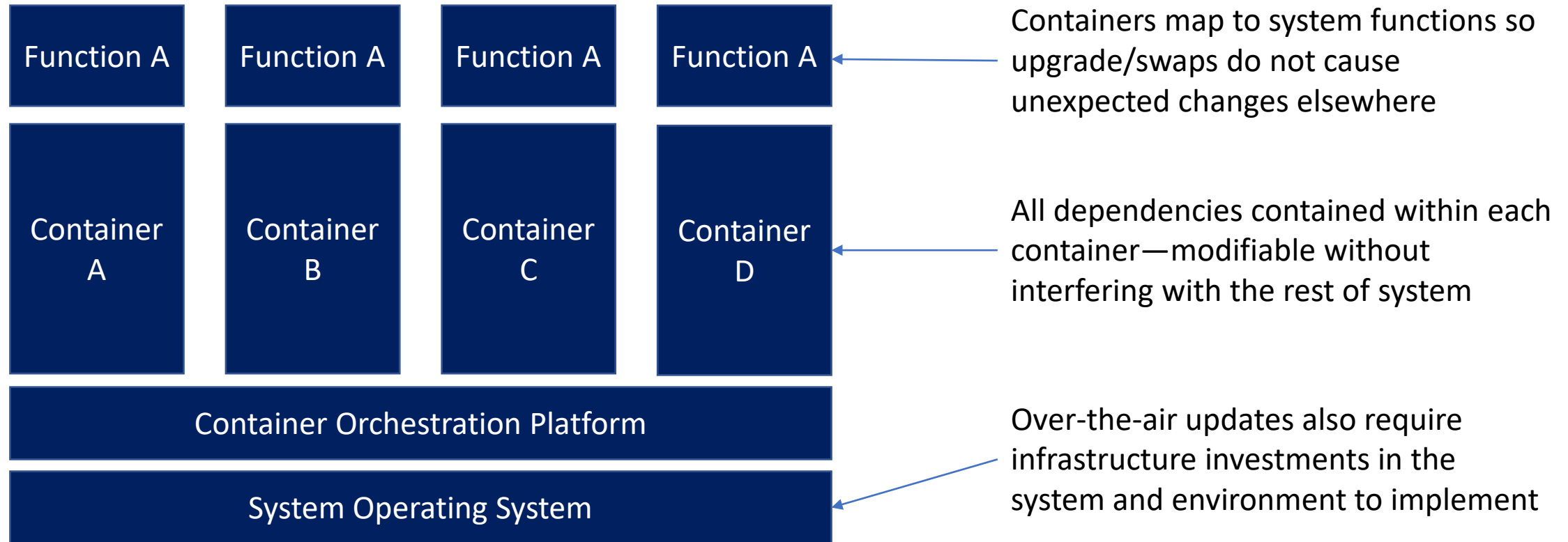
Research has not properly examined how capabilities are gained during operation

Lessons from Previous Work

Margin	Modularity	Operations
<p>Excess of a system parameter enables additions to the system</p>	<p>Loose coupling of modules, function to form mapping, and common interfaces enable module swapping</p>	<p>Change <i>how</i> the system is used without extensive change to the form of the system</p>
 <p>Requirement Margin</p>		 <p>No Change to Form of System</p>

Previous empirical work showed that margin, modularity, and operations have been used for capability gain

Software Changeability



Form Change: GPU-5/A

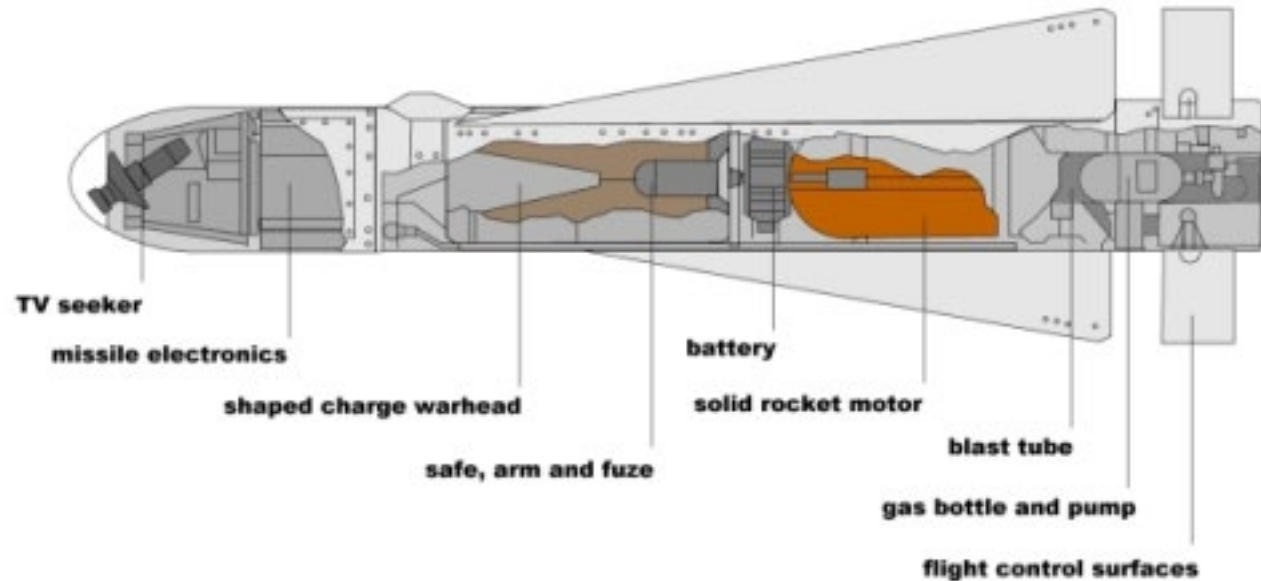


Modularity is important, but it is not a silver bullet

Form Change: Agile Pod

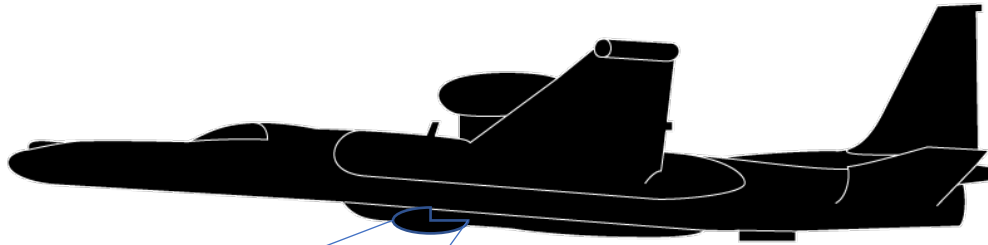


Operational Change: A-10 Nighttime Flight



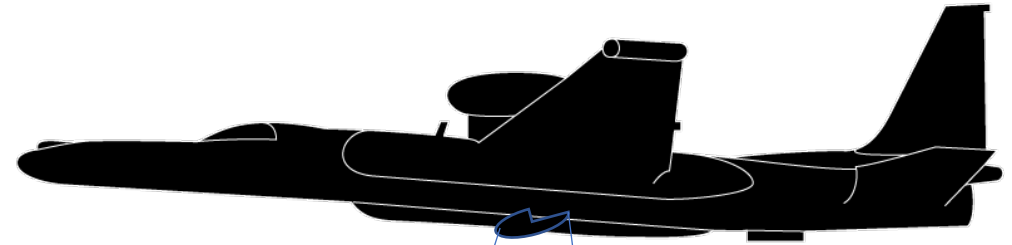
Changing *how* a system is used can enable new capabilities rapidly

Operational Change: Desert Storm H-Cam



**U-2 H-Cam
Normal
Position**

**Large Coverage Area,
Low Resolution**



**U-2 H-Cam
Modified
Position**

**Smaller Coverage Area,
Higher Resolution**

Cyber Change: Over-the-Air Updates

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:
%:.
H%:
U-2 FEDLAB
Hello Dr. Roper! What's next?
Hello Dr. Roper. Time now is 2020-10-16T17:26:48.084Z. What's next?
Hello Dr. Roper. Time now is 2020-10-16T17:27:03.084Z. What's next?
Hello Dr. Roper. Time now is 2020-10-16T17:27:18.084Z. What's next?
Hello Dr. Roper. Time now is 2020-10-16T17:27:33.084Z. What's next?
Hello Dr. Roper. Time now is 2020-10-16T17:27:48.084Z. What's next?
Hello Dr. Roper. Time now is 2020-10-16T17:28:03.084Z. What's next?

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Rapid software changes can bring enhance and add capabilities

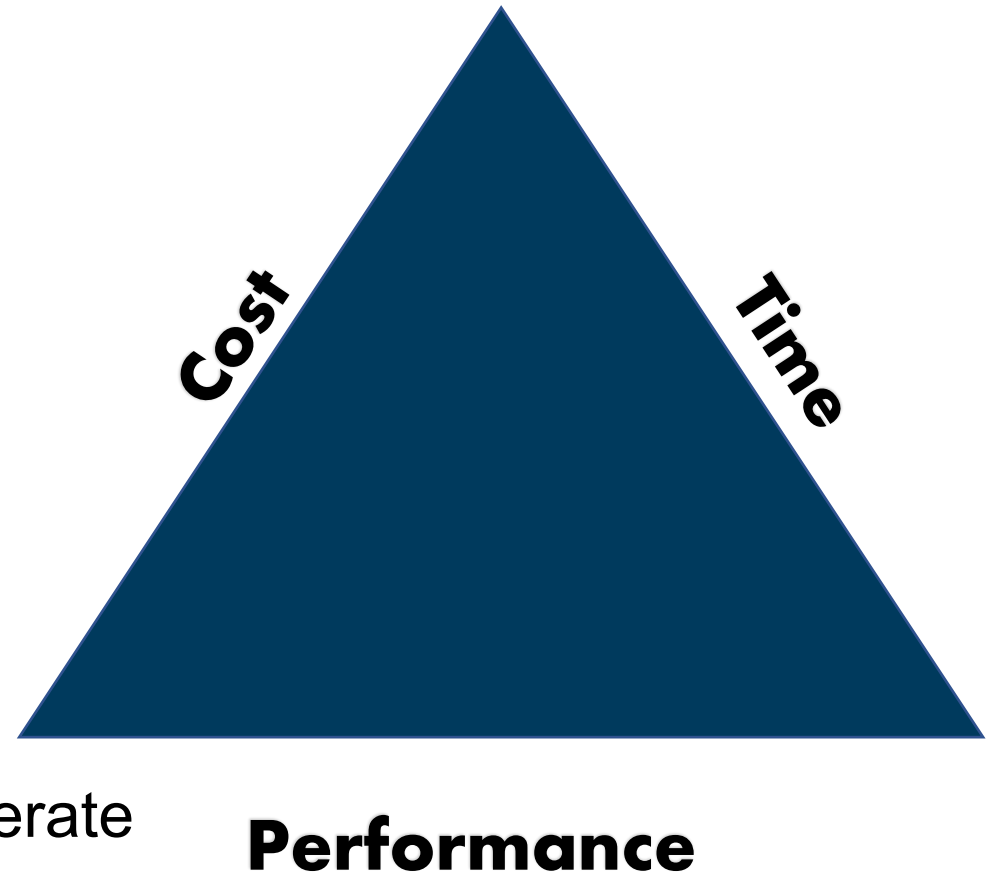
Cyber Change: F-16 & F-22



F-16 also got OTA updates and F-22 flew with 3rd party apps by leveraging open cyber architecture

Tradeoff Triangle

- Form Change
 - High Cost, Long Time to Implement, Potentially High Performance
- Operational Change
 - Low Cost, Rapid Implementation, Constrained Performance
- Cyber Change
 - Cost, Time, & Performance are Moderate



Enabling Change: Margin

- Form and cyber changes are limited by the constraints of the system as originally designed
- If changeability of systems is a priority, margin needs to be built into our systems
- While increasing upfront costs, addition of margin may lower lifecycle costs and increase *value* if systems

Conclusions & Recommendations

- Operational changes drive the most urgent needs
- Cyber changeability needs to be a greater emphasis
- Cyber changes require infrastructure, hardware investment
- For systems we anticipate will be in service for a long time, implementing margin is critical for changeability and system value

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