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System F6

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Tactical Technology Office

Proposers' Day Briefing

04 October 2010

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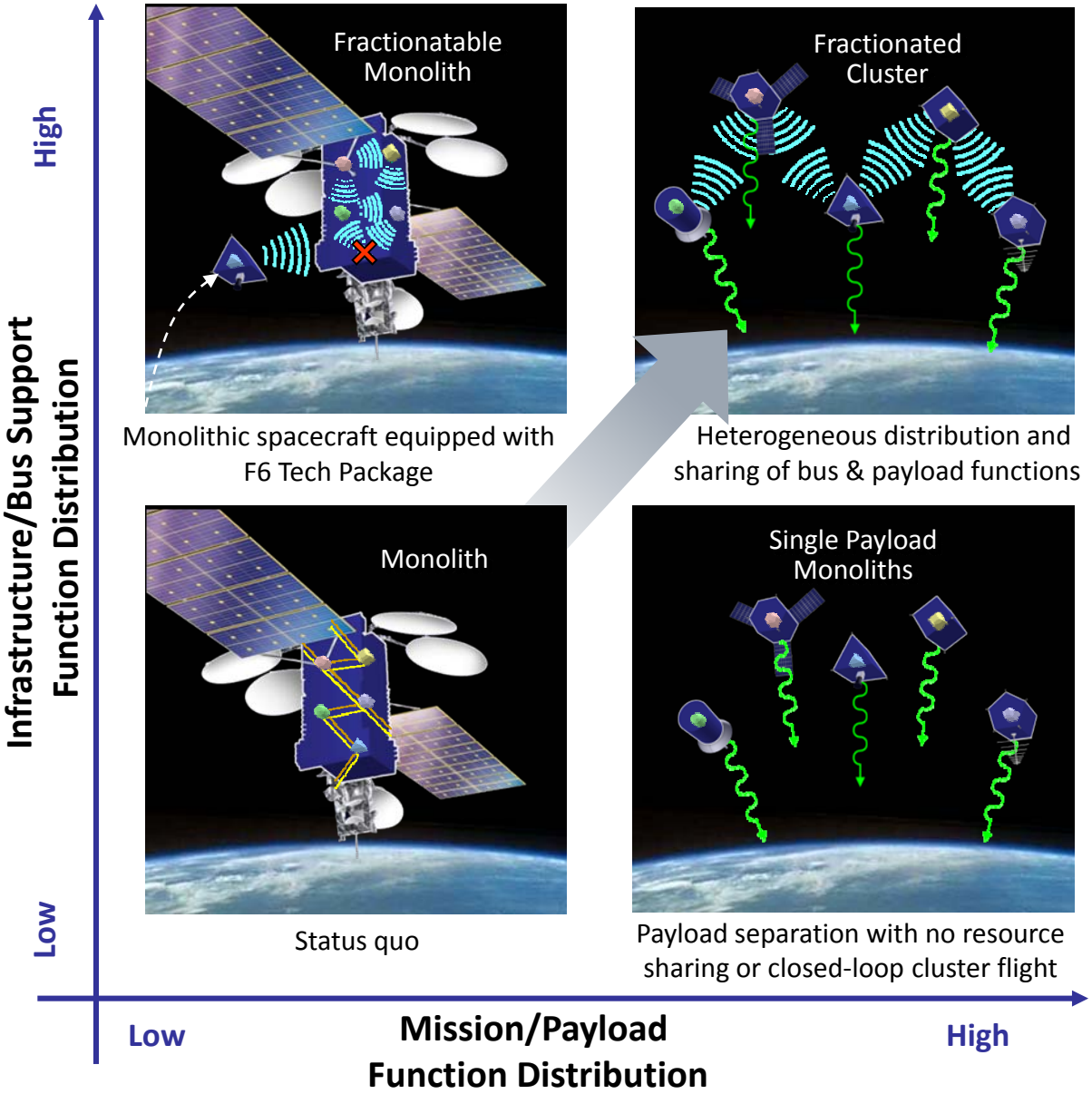
Fractionated Space Architectures



Enablers of Fractionated Space Architectures

- Cluster maintenance
- Rapid cluster maneuvering
- Relative navigation
- Wireless networking
- Real-time resource sharing
- Multi-level security

- 24/7 LEO-ground connectivity

- Open F6 Developer's Kit
- Modular F6 Tech Package

- Adaptability Metrics
- Design-for-Adaptability Tools

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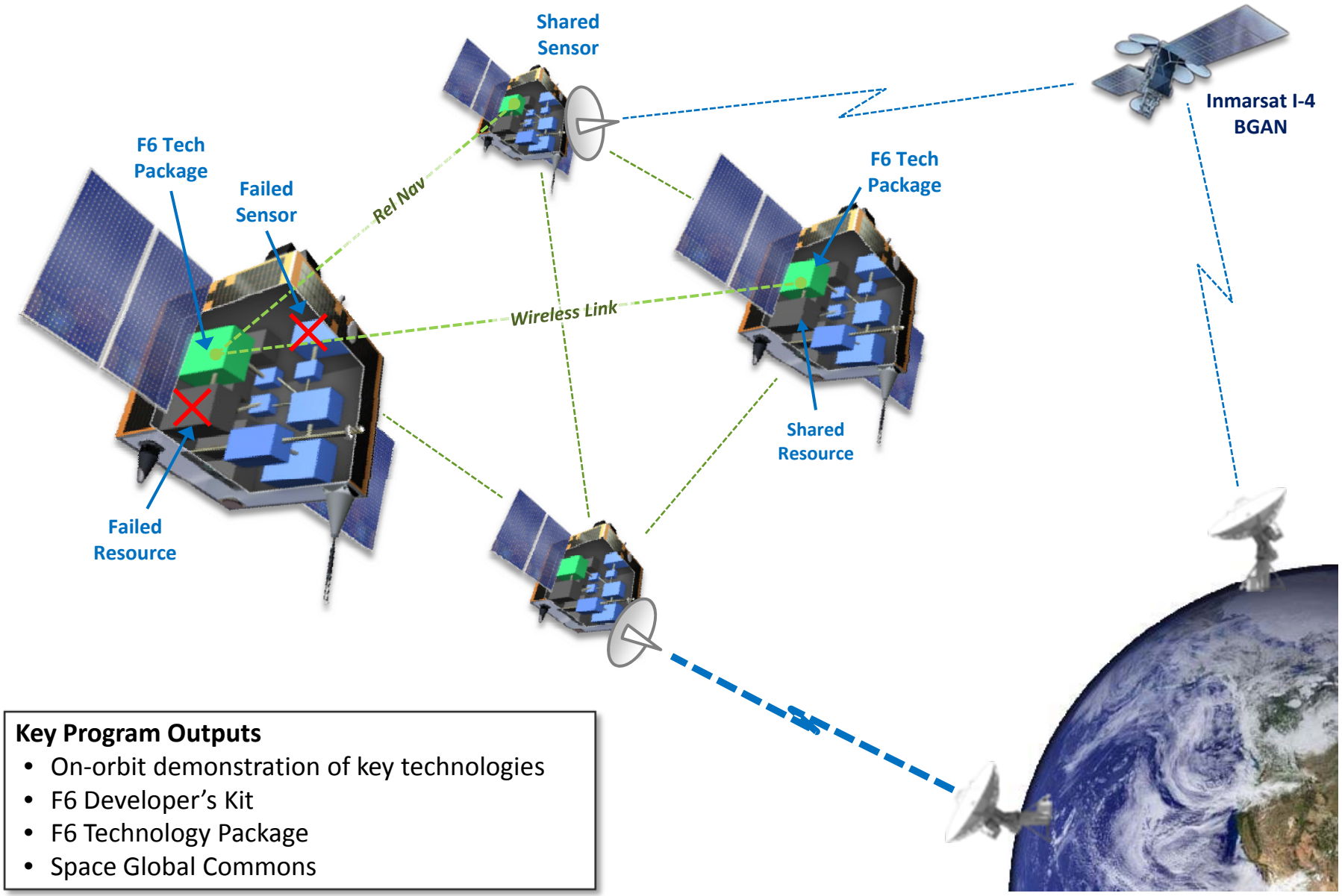
System F6 Demonstration Concept



Key Program Outputs

- On-orbit demonstration of key technologies
- F6 Developer's Kit
- F6 Technology Package
- Space Global Commons

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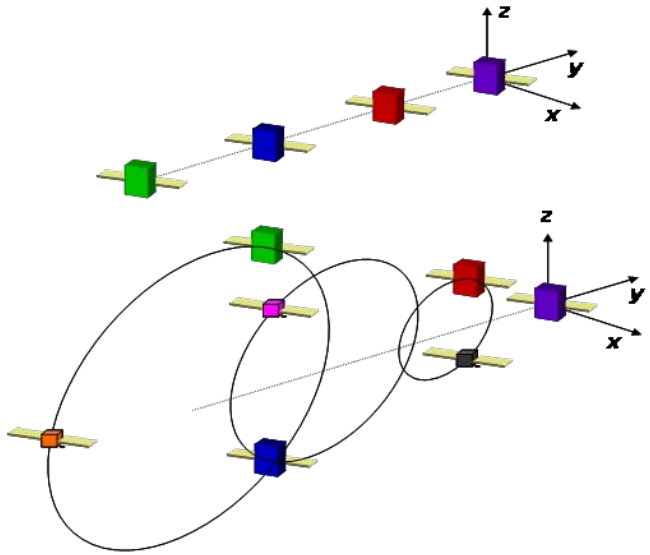
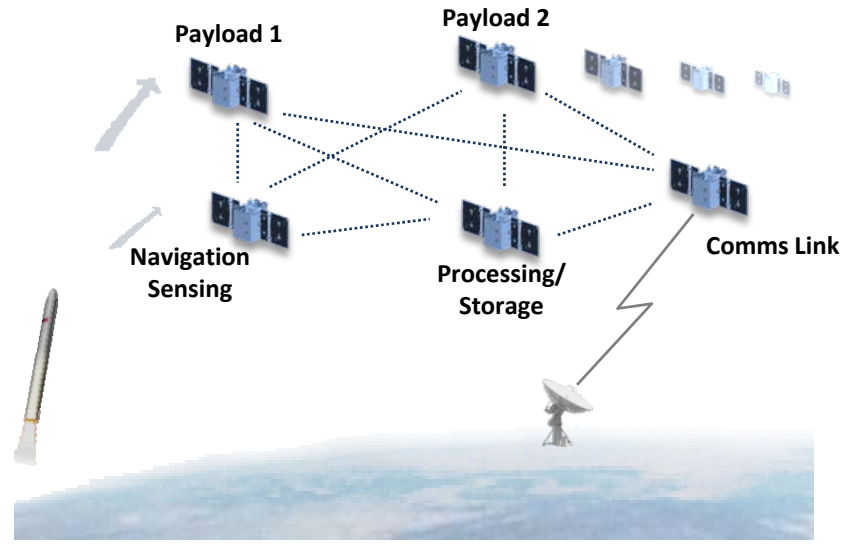
Key Capabilities for 2014-15 On-Orbit Demonstration

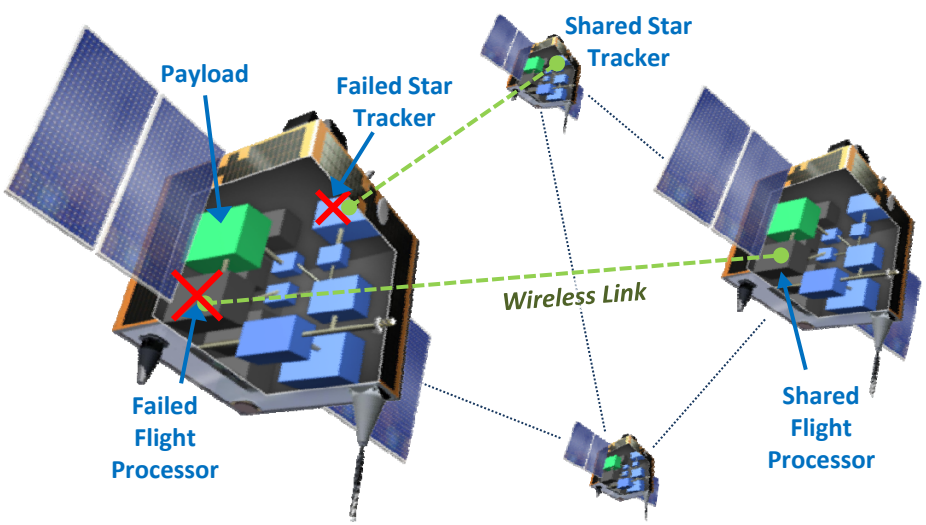
Demo 1: Long-Duration Cluster/Network Maintenance



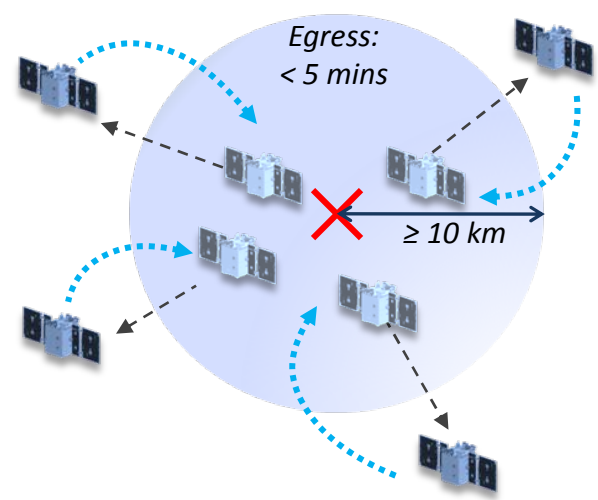
Demo 2: Resource Sharing at Multiple Security Levels



Demo 3: Cluster-Level Fault Tolerance



Demo 4: Defensive Scatter and Re-Gather



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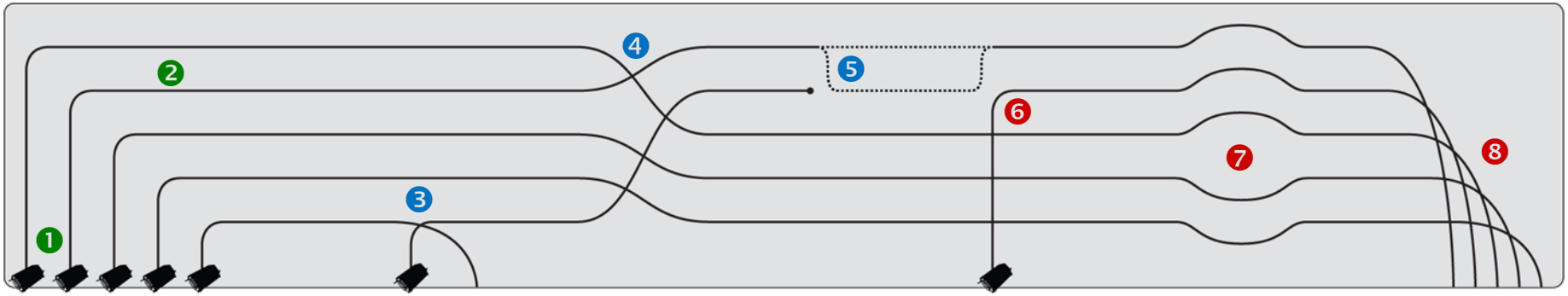
Military Utility of Fractionated Architectures

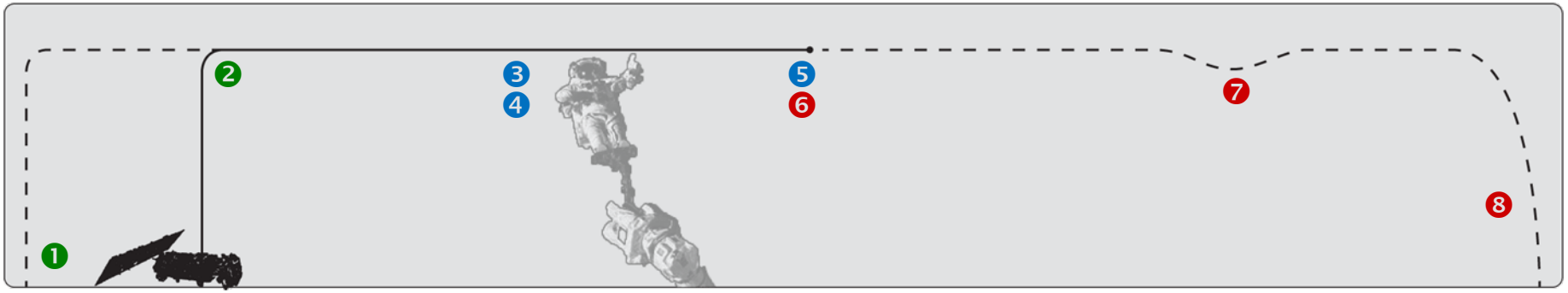
Fractionated System

F6 combines the strategies of distribution, modularization, and servicing into a single architecture, creating *virtual spacecraft* made up of free-flying, wirelessly networked elements. In addition to diversifying cost, schedule, and performance **risk**, this approach provides a more **responsive**, **adaptable** and **survivable** system than traditional, monolithic satellites.



1. Incremental deployment
2. Utility accrues before all pieces on orbit
3. Component upgrade/replacement possible
4. Reconfigure for different missions
5. Cluster-level redundancy
6. Replace failed components
7. Scatter to avoid attack or debris
8. Graceful degradation

Monolithic System



1. Single component can delay launch
2. No utility until entire system is launched
3. Upgrades rarely feasible
4. Capabilities strictly set
5. No system-level redundancy
6. Failure of any part may prove catastrophic
7. Larger target is more vulnerable
8. Capability ends abruptly

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Program Philosophy

- Focus on architecture development, standards, and protocols
- Make information assurance a center-piece of the architecture
- Write the software first, including new design tools, and plan for V&V
- Target best-of-class performers, including non-traditional and international
- Everything is open-source and maximally ITAR-free
- Build a community around the technology; use it to build the standard

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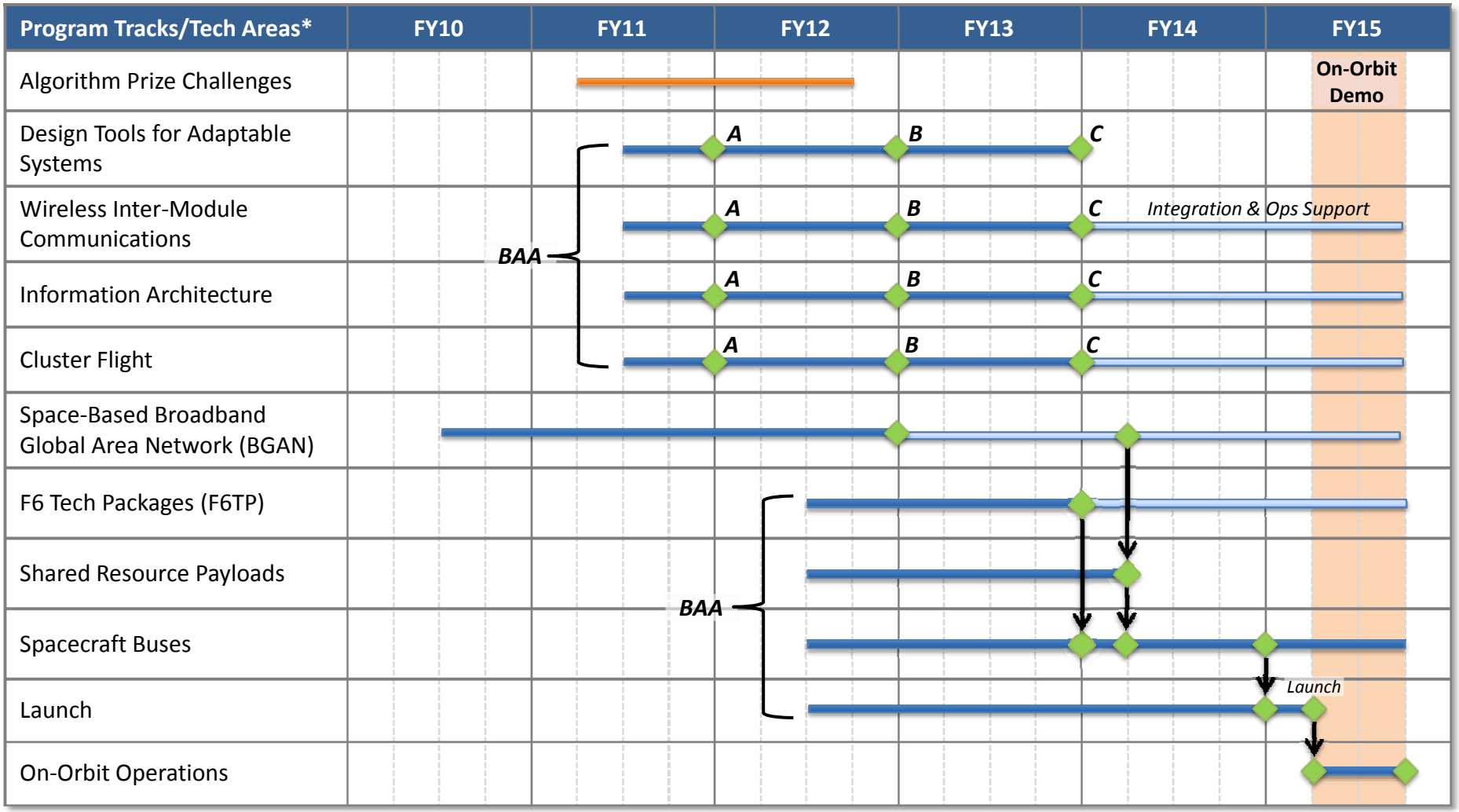
Key Program Artifacts

- **F6 Developer's Kit (FDK)**—everything neeeded for an independent third party to develop a module that can fully participate in a fractionated cluster
  - Interface standards, protocols, software, behaviors/rules
  - Reference implementation
  - Freely distributed under an open source license
- **F6 Technology Package (F6TP)**—modular physical instantiation of the FDK that enables a spacecraft bus to become a fractionated cluster module
  - Cross-link, protocol stack, middleware, cluster flight software
  - Multiple sources, capable of supporting multiple bus types
  - Goal is for a fully productized commercial off-the-shelf item
- **Prize awards**—lower the barrier to participation for solving fundamental technical challenges underlying fractionated architectures
  - Heuristics for bin packing problem with real time convergence guarantees
  - Optimal filtering for state estimation for large, multi-state systems with delays
  - Winning solutions will be made available to the F6 performer community for incorporation into designs

Program Structure



** Multiple awards in most tracks/tech areas are anticipated*

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BAA Scope & Structure (1)

- Four technical areas
  - Design Tools for Adaptable Systems
  - Wireless Inter-Module Communications
  - Information Architecture
  - Cluster Flight
- Base period (6 months)—culminates in Milestone A
  - Focused on preliminary design
  - Parametrization of design trade space
  - Draft FDK
- First option period (12 months)—culminates in Milestone B
  - Focused on detailed design
  - Software written, hardware built
  - Final FDK
- Second options period (12 months)—culminates in Milestone C
  - Focused on verification and validation (V&V)
  - Software and hardware flight-qualified

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BAA Scope & Structure (2)

- Program-wide PI meetings
  - Held bi-monthly in a major metropolitan area with easy access by air
  - Principal forum for delivery of performer results
  - May be made open to industry/public
- IP rights
  - Unlimited Rights to the Government, except on Commercial Items
  - Will require substantiation of commercial availability of Commercial Items
  - Inclusion of heritage intellectual property must be done with care!
  - DARPA will promulgate all deliverables under an open source license
- International participation
  - Affirmatively welcomed—level playing field
  - DARPA working to ameliorate ITAR issues with development and FDK
  - Fall-back option is a program-wide export license (TAA) for development effort
- Pre-publication restrictions
  - Program is funded with “6.3” dollars—requiring pre-publication review
  - Exceptions (via “6.2” funding swaps) *may* be possible on a case-by-case basis

BAA Technical Areas

<table>
<tr><th>OSI Model</th><td colspan="5"></td></tr>
<tr><td>Layer 7
(Application)</td><td rowspan="5"></td><td>Cluster Flight
(BAA Technical Area 4)</td><td>Payload Application
in Security Domain A</td><td>Payload Application
in Security Domain B</td><td>---</td></tr>
<tr><td>Layer 6
(Presentation)</td><td colspan="4" rowspan="4">Information Architecture
(BAA Technical Area 3)</td></tr>
<tr><td>Layer 5
(Session)</td></tr>
<tr><td>Layer 4
(Transport)</td></tr>
<tr><td>Layer 3
(Network)</td></tr>
<tr><td>Layer 2
(Data Link)</td><td colspan="5" rowspan="2">Wireless Inter-Module Communications
(BAA Technical Area 2)</td></tr>
<tr><td>Layer 1
(Physical)</td></tr>
</table>

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BAA Technical Area One

Design Tools for Adaptable Systems

- Scope
  - When does the business case for fractionated architectures close?
  - When it does close, how should a system be optimally fractionated?
  - Quantitative measure of adaptability
  - Quantitative trade-offs between adaptability and traditional system attributes (size, weight, power, cost, performance, etc.)
- Deliverables
  - Milestone A: Algorithm development complete, prototype implementation
  - Milestone B: Fully-functional, polished, well-documented, user-friendly tool
  - Milestone C: Tool validated against real data sets
- Special proposal contents
  - Theoretical substantiation of technical approach
  - Software development plan
  - Tool validation plan

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BAA Technical Area Two

Wireless Inter-Module Communications

- Scope
  - Layers 1 and 2* inter-spacecraft wireless communications for up to 20 modules
  - Looking for interesting point solutions—no specific performance requirements
  - Ranges and data rates of interest: 100 m to 100 km, 100 kbps to 10 Gbps
  - Interested in throughput, availability, scalability, size, weight, power, pointing requirements, intereference resistance, detection range
- Deliverables
  - Milestone A: Preliminary design, parametric model, draft FDK
  - Milestone B: Detailed design, full terrestrial prototype test, final FDK
  - Milestone C: Four complete flight-ready units
- Proposal contents
  - Conceptual design
  - Estimates of various technical parameters
  - Draft of Form DD1494, “Application for Equipment Frequency Allocation”

** Layer numbers refer to the OSI Reference Model*

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BAA Technical Area Three

Information Architecture

- Scope
  - Layers 3 through 7 information architecture for space and terrestrial network
  - Expose spacecraft and terrestrial devices as network-addressable nodes
  - Provide real-time distributed resource sharing across multiple security domains
  - Real-time fault tolerance, i.e., network and resource reconfiguration to maintain safety-critical functions and gracefully degrade mission capability
  - Additional considerations:
    - Throughput of available space-capable hardware
    - Principal security controls corresponding to DCID 6/3 PL5
    - Link encryption requirements—details TBD
    - V&V approach for distributed dynamic systems
- Deliverables
  - Milestone A: Preliminary design, draft FDK
  - Milestone B: Detailed design, complete implementation, final FDK
  - Milestone C: V&V for flight
- Proposal contents
  - Software development and V&V plans
  - Information assurance plan

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BAA Technical Area Four

Cluster Flight

- Scope
  - Long-duration semi-autonomous cluster ops for up to 20 modules
  - Autonomous rapid maneuvering capability—defensive scatter (20 km, 5 mins)
  - Holistic approach to collision avoidance—safe to most probable failure modes
  - Looking for interesting point solutions—no specific performance requirements
  - Cluster size range of interest: 100 m to 100 km
- Deliverables
  - Milestone A: Preliminary design, parametric model, draft FDK
  - Milestone B: Detailed design, complete implementation, final FDK
  - Milestone C: V&V for flight
- Proposal contents
  - Theoretical substantiation of technical approach
  - Estimate of various technical parameters
  - Software development and V&V plans

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Proposal Info

- Proposals intended to be simple, flexible, but technically specific
  - Single integrated technical and cost volume
  - Tight page limits, except on SOW
  - Details on regulatory compliance required for Tech Areas Two and Three
  - FAR (CPNF, CPFF, FFP-Milestone Payable) and OTA contract vehicles acceptable
  - Contracted through DARPA/CMO or NASA Ames (TBD)
- Proposal evaluation criteria
  - Overall scientific and technical merit
  - Potential contribution and relevance to the DARPA mission
  - Intellectual property
  - Cost realism
- Opportunity for written Q&A during proposal preparation period
  - Questions directed to the BAA mailbox: DARPA-BAA-11-01@darpa.mil
  - Questions of general interest will be answered via a FedBizOpps posting
  - No one-on-one discussions will be held with the Program Office
- Experimental online proposers' forum—more details later

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Proposal Timeline

- Draft BAA released—03 October 2010
- BAA comments due—08 October 2010
- Final BAA released—18 October 2010 (est.)
- BAA questions due—08 November 2010 (est.)
- BAA question responses posted—12 November 2010 (est.)
- Initial round of proposals due—17 December 2010 (est.)
- Selection Notification—07 January 2011 (est.)
- Contract Award—mid-March 2011 (est.)

System F6 Draft BAA:

http://go.usa.gov/xS5

Direct BAA Comments & Questions to:

DARPA-BAA-11-01@darpa.mil