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In-Space Developmental Test Persistent Platform for the United States Space Force (USSF)

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Overview

- Provide a flexible framework to meet both long-term evolutionary development and rapid revolutionary development
- Focus on science and technology (S&T) innovation and facilitate transition to existing and new programs of record
- Fill the technology transition “valley of death” with corporate dollars and program initiatives
- Integrate and manage S&T and research and development policies and processes
- Ensure earlier technology planning is complete to structure programs for success before they begin
- Communicate the S&T strategy to the field command and assist with aligning future investments (6.1–6.7) to the guidance
- Coordinate Pre-Milestone B efforts for greatest effect to cross the valley of death

In-Space Developmental Test (iSDT) Introduction

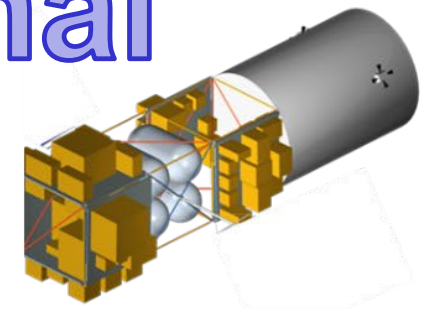
- Purpose for iSDT Advanced Space-Based Testbed (XST)
  - Seed technologies for the emerging space economy and “space superhighway”
  - Accelerate technology development
  - Overcome the technical readiness levels 4–7 valley of death
  - Reduce acquisition cost
- What Is an XST?
  - Unmanned and highly autonomous
  - Capable of in-space assembly (iSA) morphing in shape
  - Accommodating to as many test payloads as possible using in-space servicing (iSS)
- Government Conceptual Developments Related to XST
  - Space maneuver and logistics for space superhighway at the United States Space Force (USSF)
  - In-Space Servicing, Assembly, and Manufacturing (ISAM) National Initiative
  - Robotics at the Defense Advanced Research Projects Agency and U.S. Naval Research Laboratory

iSDT Benefits to Mission Areas

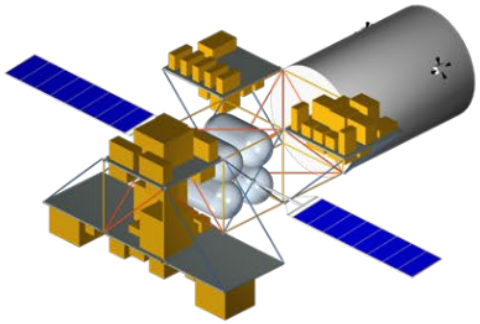
- Satellite Communications and Position, Navigation, and Timing
  - Provide a host to test payloads prior to undertaking production
    - iSDT could host protected tactical satellite prototypes
    - iSDT could have hosted Navigation Technology Satellite 3 payload
- Missile Warning; Tactical Intelligence, Surveillance, and Reconnaissance; and Environmental Monitoring
  - All such missions require extensive time and effort to calibrate their payloads
    - This needs large space-to-ground bandwidth
  - iSDT could be the payload host to enable calibration
- Space Domain Awareness and Combat Power
  - Host find, fix, and track payloads for testing
  - Develop or train operators for combat power missions
- Interface Standards for Servicing, Assembly, Rendezvous Proximity Operations (RPO), Docking, etc.
  - Consortium for Space Mobility and ISAM Capabilities (known as COSMIC) administering and linking ISAM across government, academia, and industry
  - Linkage to servicing mobility and logistics—check out, validate, and verify interface standards for iSA, iSS, RPO, docking (electrical power and data, fiducials and RPO, and refueling)
  - Rapid maneuverability, repositioning, refueling, and “maneuver without regret”

Tentative Mission Timeline

Notional



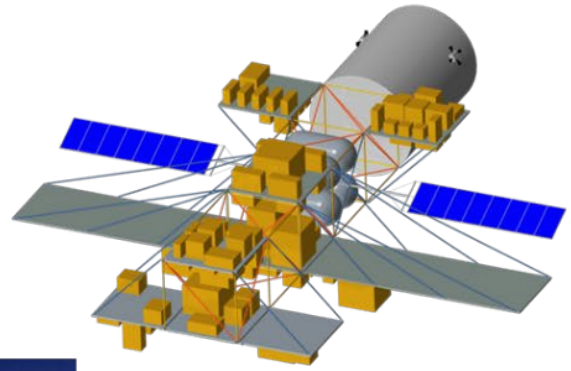
- System assessment:
  - 80% candidate accommodation
  - Requirement definition
  - Interface definition/maturation



- System development:
  - 1st XST contract funded
  - Detailed design activities

- 1st XST launch

- In-space operation:
  - Deployed
  - IOT
  - Use iSM, iSA, & iSS (i.e. Restore-L) to:
    - Add Instrumentation/Communication
    - Add ADCS
    - Add UDA points for test candidates/eqt/etc.

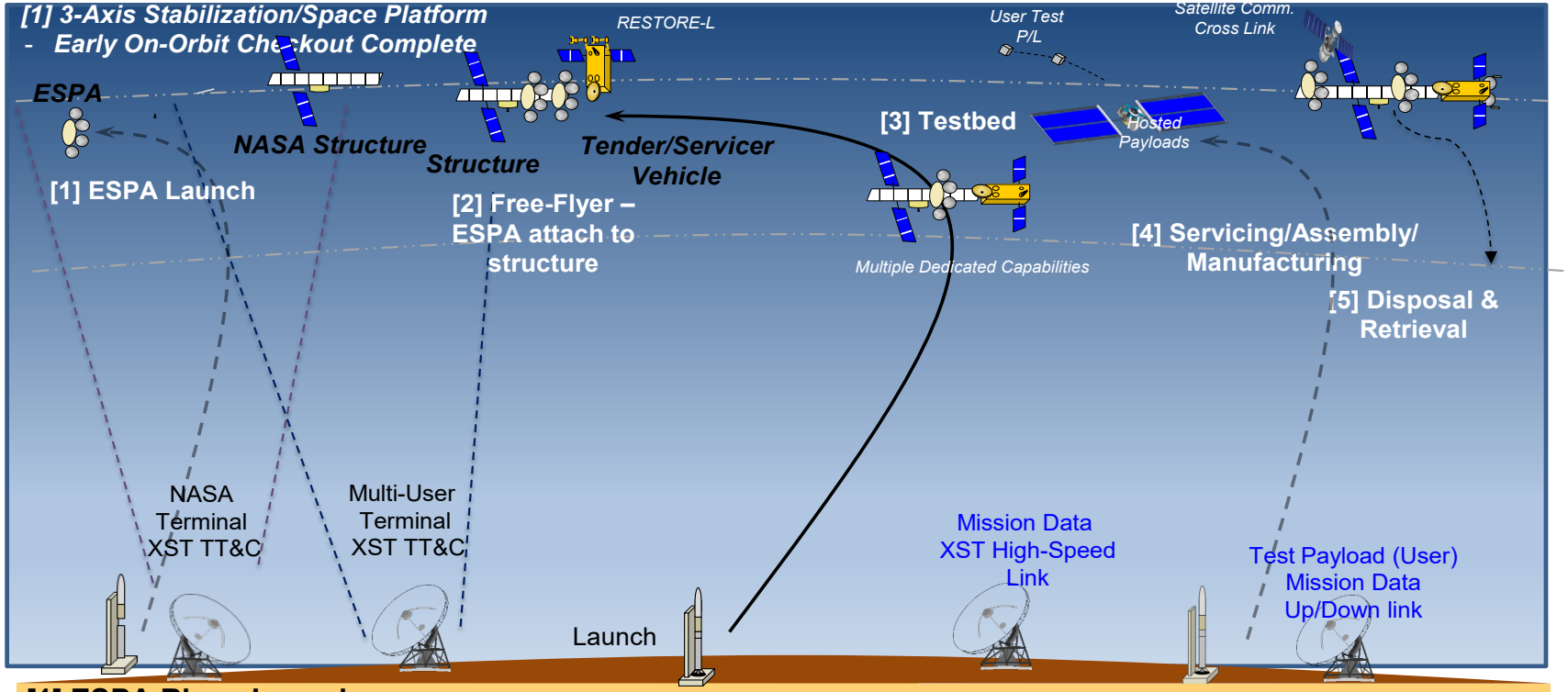


- In-space test:
  - Conduct tests
  - Expand payloads/structure

Source: Courtesy of SSC/Enterprise Future Systems Architect (BZY)

Note: IOT = initial operational test, ADCS = altitude determination and control system, UDA = user-defined adapter

Operational Concept

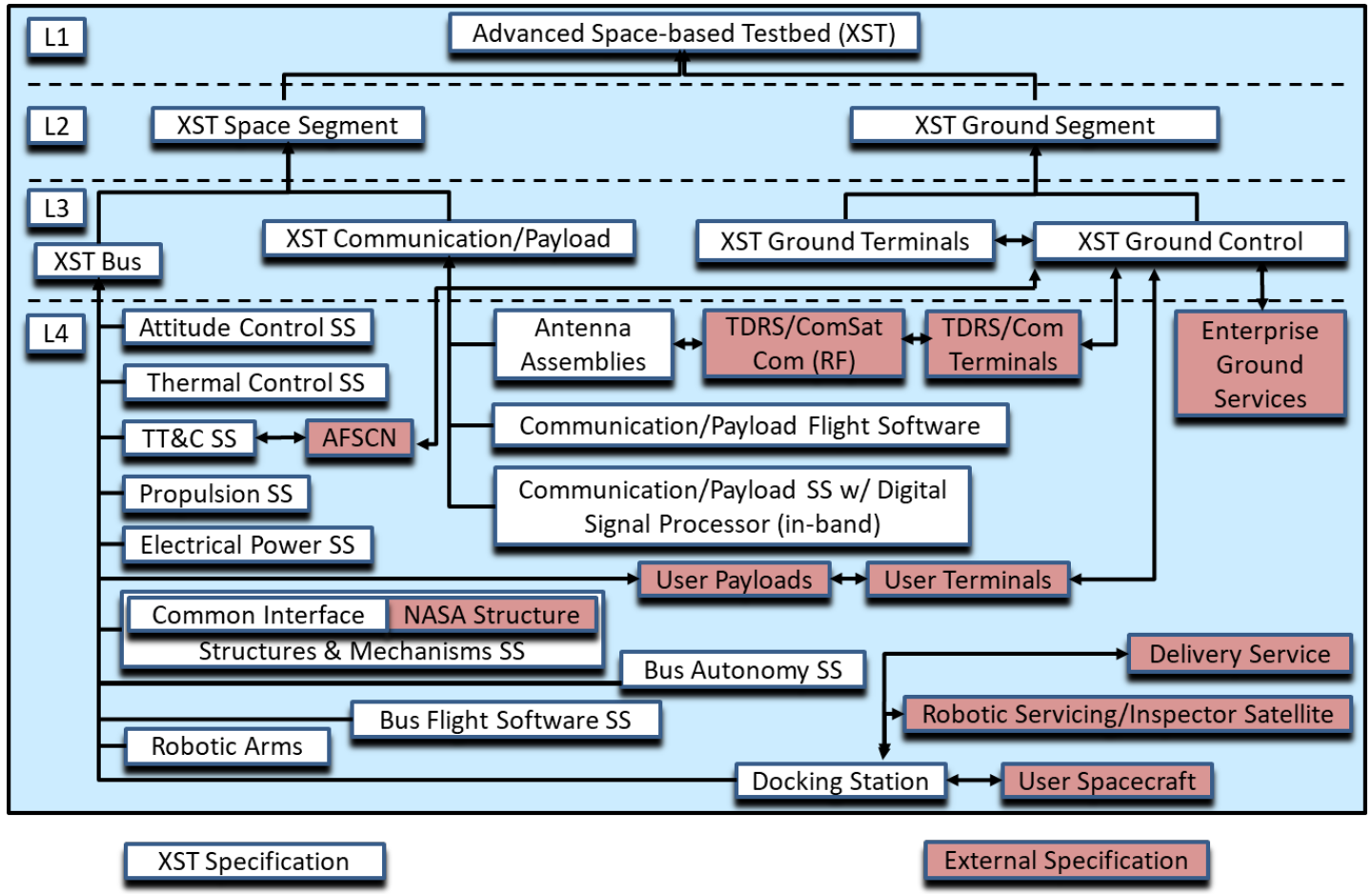


Source: Courtesy of SSC/BZY

Note: ESPA = evolved expendable launch vehicle (EELV) secondary payload adapter, NASA = National Aeronautics and Space Administration.

Requirements

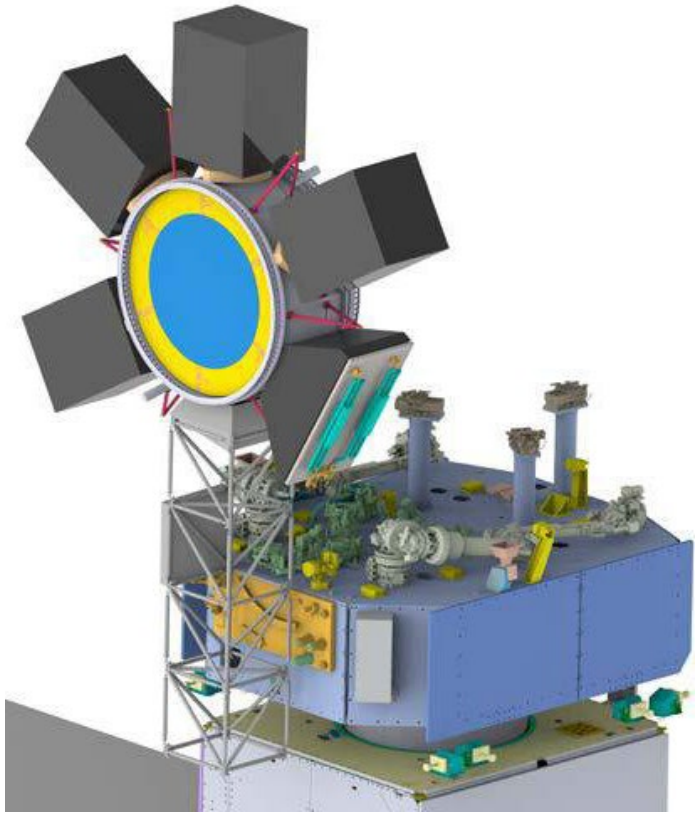
- **Specifications Tree**
  - **L1: System Level**
  - **L2: Space and Ground**
  - **L3: XST Bus, Test Payloads, Ground Systems, etc.**
  - **L4: Subsystems**
- **Key Requirements and Interface Control Documents**
  - **Automation**
  - **Communication**
  - **Reconfigurability**
  - **Serviceability/Modularity**
  - **Survivability**



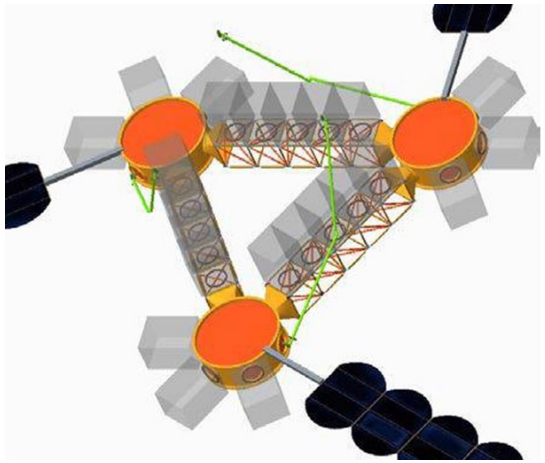
Note: SS = subsystem; TDRS = tracking and data relay satellite; RF = radio frequency; TT&C = telemetry, tracking, and command; AFCN = attention-guided, feature-fusion ConvNeXt network

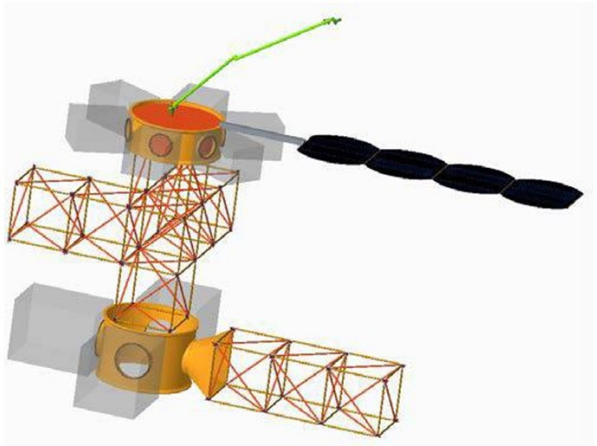
Source: Courtesy of SSC/BZY

XST Design Options

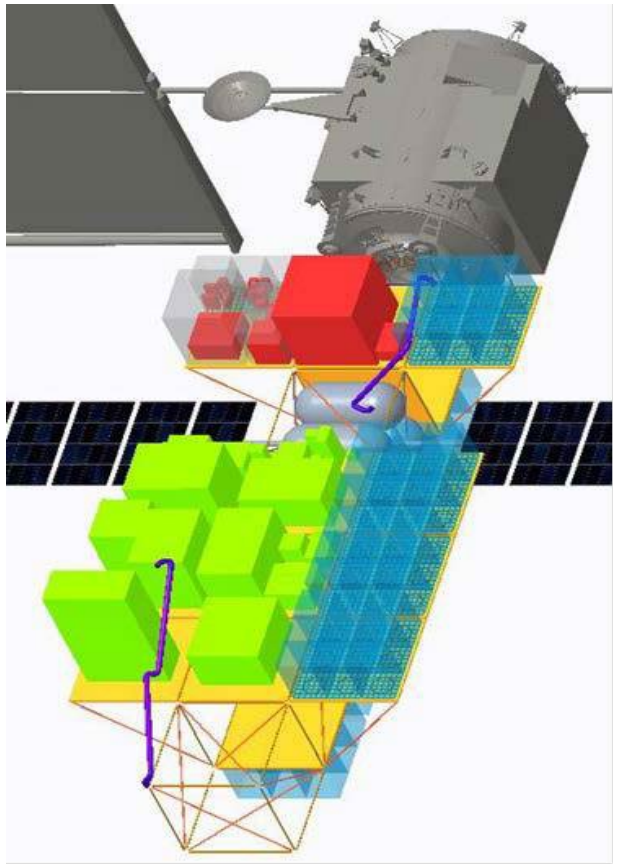


Servicer-Based Test Platform





ESPA-Based Test Platform

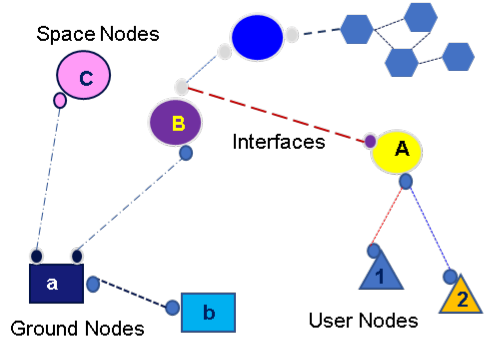


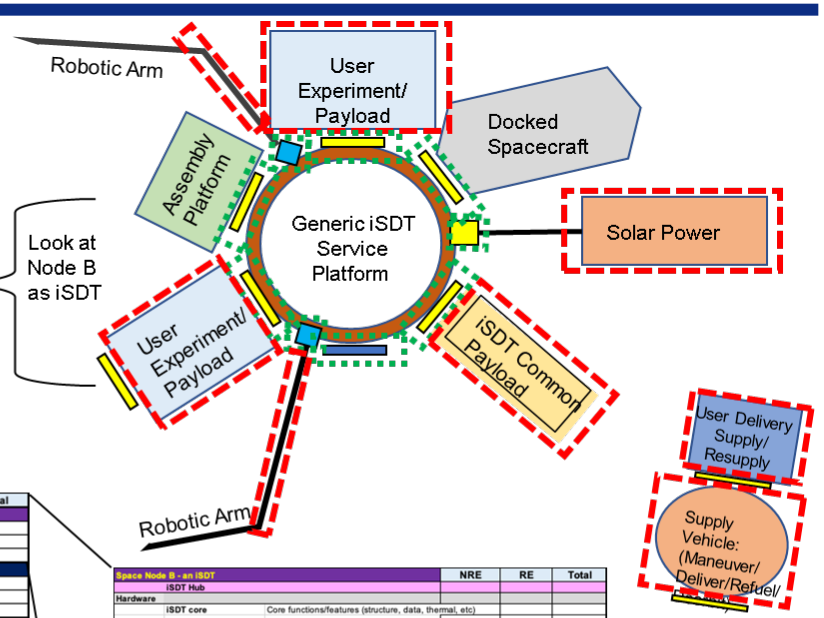
Bus-Based Test Platform

Source: ***https://ntrs.nasa.gov/citations/20205007927***

Cost Estimation

- **Represent by Nodes and Interfaces**
- **Components to Cost Estimate**
  - **Nodes**
  - **System interfaces (communication)**
  - **Hardware interfaces (refueling, power, data, thermal, and structure)**
  - **Software for payloads and other external entities to interoperate with XST**





System WBS Example		NRE	RE	Total
Space Node B				
Hardware	Spacecraft; payloads; interfaces			
Software	Operating System, Payload I/F, Mission			
I&T	Local interface testing; Vehicle level			
Operation Ground Node(s)				
Hardware	New hardware; leased services			
Software	Operations software; interfaces			
I&T	Local interfaces testing; ground node end-to-end			
User Node(s)				
Hardware	Can be direct to user; or user data centers			
Software	Data processing; interfaces			
I&T	Local interface testing			
System Node Check				
	S/C A to S/C B			
	S/C A to User 1			
	S/C A to User 2			
	Ground a to S/C B			
	Ground a to Ground b			
	Ground a to S/C C			
	S/C B to "other"			
System checkout and test				
	end to end testing			
Launch(es)				
	Initial flight			
	Resupply/delivery flights			
Operations				
	Operation of iSDT; changes over time			

Space Node B - an iSDT			NRE	RE	Total
	iSDT Hub				
Hardware					
	iSDT core	Core functions/features (structure, data, thermal, etc)			
	iSDT Interfaces	Physical interfaces (5x) - all connections			
		Physical interface (2x) - structure only			
	Service Payloads	Solar Array (1x shown)			
		Radios/Antennas			
		Thrusters			
		Robotic Arms			
		High power processors			
	User Payload Interface*	Experiment 1 physical interface			
		Experiment 2 physical interface			
	User Payloads*	User Experiment 1			
		User Experiment 2			
Software					
	isDT OS	Operating System			
	Mission	Mission management; service fulfillment			
	iSDT Payload Interfaces	Solar Array to iSDT			
		Radio to iSDT			
		Thruster to iSDT			
		Robotic Arm to iSDT			
	User Payload Interface	User Experiment 1			
		User Experiment 2			
Integration & Test					
	iSDT Interfaces	Solar Array to iSDT			
		Radio to iSDT			
		Thruster to iSDT			
		Robotic Arm to iSDT			
	Mission	Service availability, configurations			
	User Payload Interface	Experiment 1			
		Experiment 2			
Assembly & Test					
		iSDT Assembly			
		Vehicle Ground Testing			

Software Applique: connects Experiment/ Payload to an Interface and exposes Payload functions

Software: connects iSDT to an Interface; enables operation with iSDT

Physical Interface options (power, data, thermal, structure, fluid)

Source: Courtesy of SSC/BZY

Way Ahead

- Generate Detailed Roadmap and Schedule for a Fiscal Year 2026 Program Objective Memorandum Initiative
  - Request Assistant Secretary of the Air Force (Space Acquisition and Integration) for Technology be the sponsoring organization
  - Allocate resources to the Space Systems Integration Office Enterprise Future Systems Architect and SSC Innovation and Prototyping (SZI) to conduct a joint (SSC, NASA, Space Development Agency, etc.) design exercise
    - Link to the Space Training and Readiness Command and future developmental test (currently only operational test)
    - Link to the SZI ring management efforts
    - Define how an XST in-space developmental test persistent platform will benefit the enterprise across the USSF and integration into the larger enterprise

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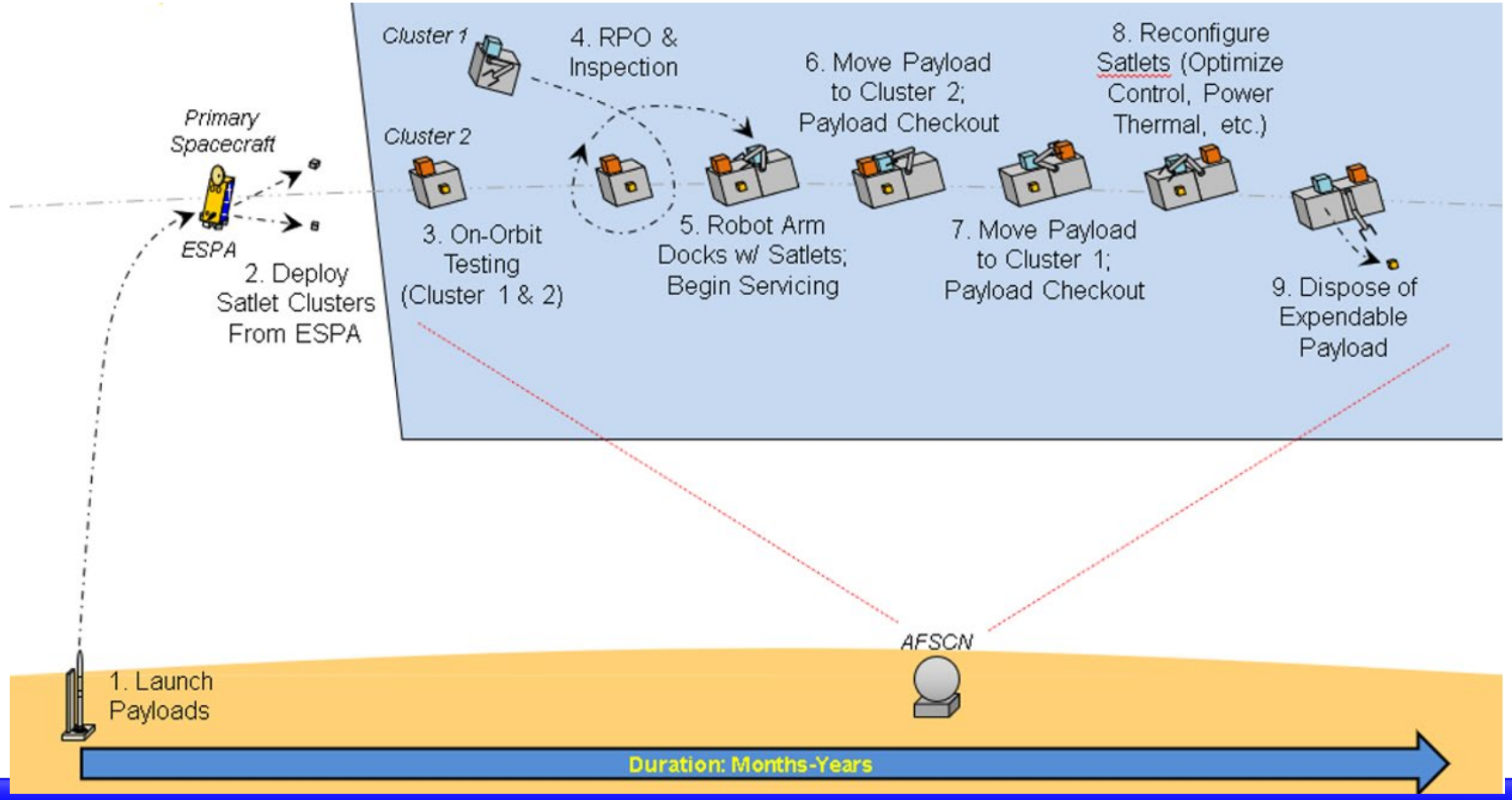
BACKUP

Demonstrate Capabilities and Operations

- Cooperatively, autonomously, and safely fly space vehicles to perform inspection, RPO, capture, and docking
- Perform iSA using onboard robotic arms to attach and detach modular payloads
- Optimize space vehicle power, thermal, and attitude control authority by reconfiguring space vehicle
- Demonstrate integrated vehicle health management
- Check out, validate, and verify interface standards for iSA, iSS, RPO, docking (electrical power and data; fiducials and RPO; and refueling)
- Demonstrate disposal of expendable payloads

Mini-XST Will Demonstrate iSS and iSA Functions

Mini-XST Demonstration of Concept of Operations



Day in the Life of a Mini-XST

Source: Courtesy of SSC/BZY

Tentative Schedule (Fulfillment Plan Component)

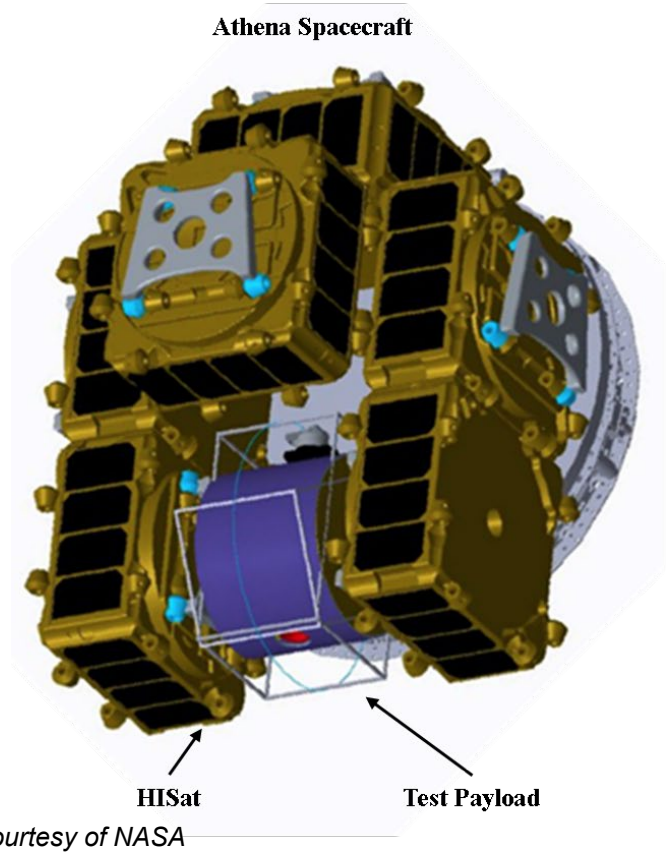
Event	Milestone Year
Milestone A (MSA) – System Assessment & Spacecraft Development	ATP + 3 yrs
Initial Operational Capability (IOC) – Launch & Transfer Orbit	ATP + 3.5 yrs
Full Operational Capability (FOC) – In-Space Test	ATP + 4 yrs
End-of-Life (EOL)	ATP + 7 yrs ATP + 10 yrs if refueled

Notional Schedule Tied to the Government Authority to Proceed (ATP)

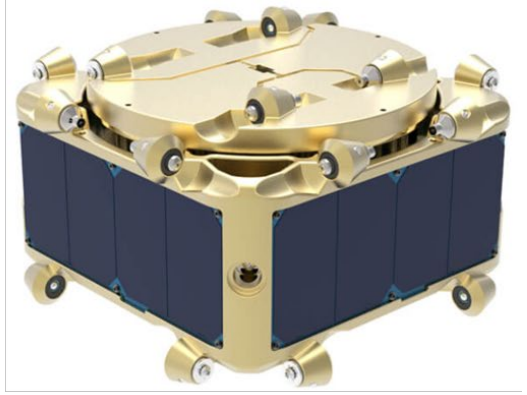
Key Technology Development Candidates

- Acceleration of Key Technologies
  - Space power generation and storage
  - Long-duration stress testing and radiation exposure
  - Structures and materials
  - Integrated vehicle health management
  - Propellant transfer
  - RF and optical transceivers design and calibration
  - Spacecraft servicing depot and docking stations for experimentation and user payloads

Athena Spacecraft Built From Multiple Hyper-Integrated Satellite (HISat) via UDA

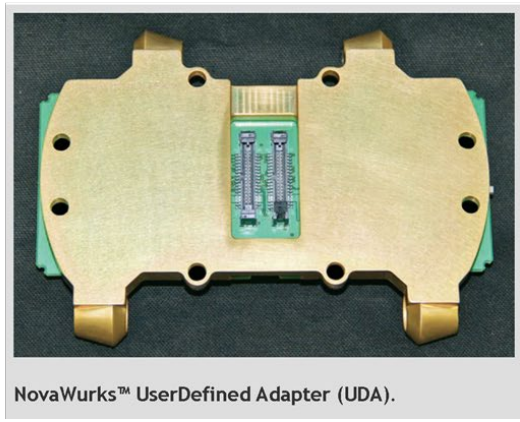


Source: Courtesy of NASA



NovaWurks ™ HISat

Source: http://www.satmagazine.com/story.php?number=1724933603



NovaWurks™ UserDefined Adapter (UDA).

Source: http://www.satmagazine.com/story.php?number=1724933603

Example of Small Spacecraft (Known as SmallSat) Form Factor With a Standard Interface for Payloads