Integrity ★ Service ★ Excellence

AFRL Space S&T Update

19 November 2015

Colonel David Goldstein
Air Force Research Laboratory
Space Vehicles Directorate

Overview

- Who We Are
- Strategic Context
- A Subset of our Investments
- Challenge To You

Vision and Mission

AFRL/Space Vehicles Directorate

Our Vision

Be indispensable to our nation in improving AF and DoD space capabilities

Our Mission

Stay One Step Ahead in Space

Our Goals

1. Be the first call
2. S&T that makes a difference
3. Operate with agile business processes
4. Hire, develop and retain a world-class workforce

What We Value

Our Core Values

- S&T Excellence
- Boundary Pushing
- Professional Competency & Contribution
- Mission Focus

External

- Innovation
- Resiliency
- Synergistic Partnerships
- Skin in the Game

Organization
AFRL/Space Vehicles Directorate

Chief Scientist
Space Capability Lead
Dr. Greg Spanjers

Director
Col David Goldstein

Deputy Director
Mr. Barry Bunn

Chief Engineer
Mr. Dale Hite

Senior Scientist
Dr. Michael Duggin

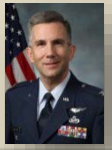
Mission Leads

Space Situational Awareness
Dr. Victor Gamiz

(Acting) Intelligence, Surveillance & Recon
Dr. Jonah Colman

Defensive Space Control
Ms. Monica Montoya

(Acting) Space Comm / Position Nav & Timing
Dr. David Chapman



Battlespace Environment
Col Glenn Vaughan
Division Chief

Spacecraft Technology
Mr. Mark Roverse
(Acting) Division Chief

Integrated Experiments
Dr. Joel Mozer
Division Chief

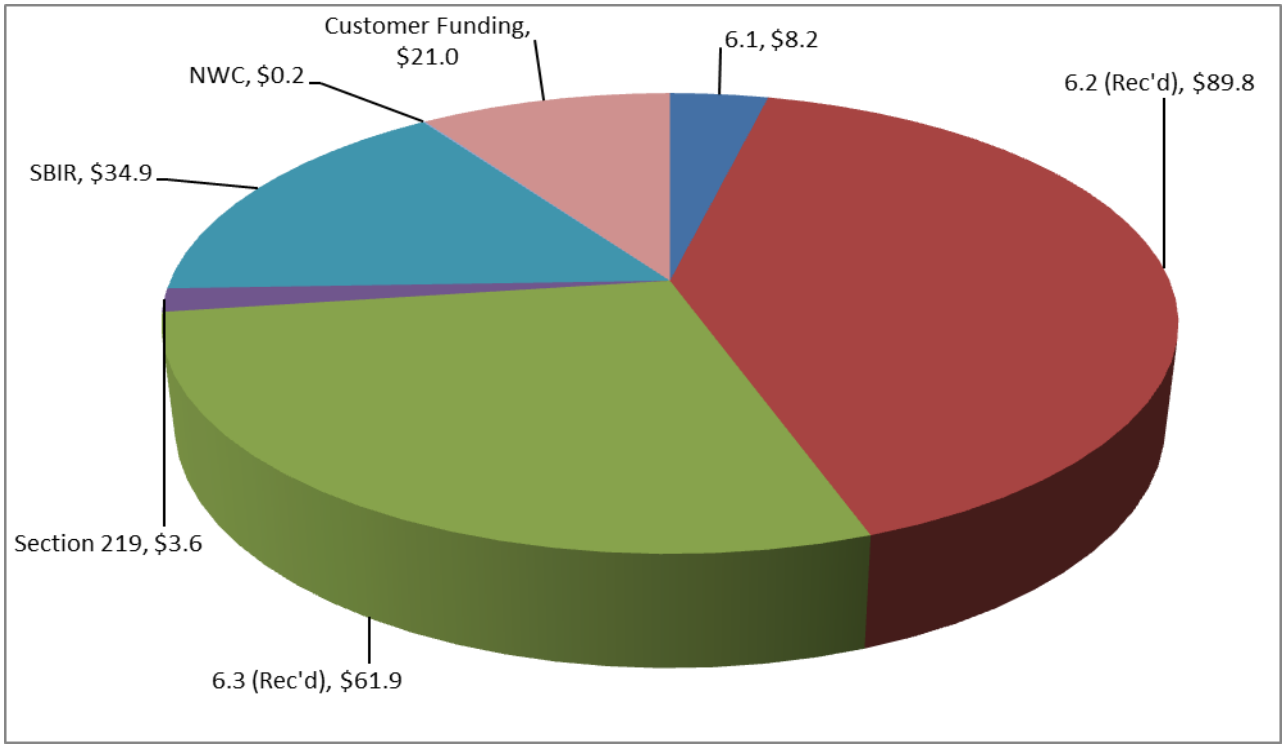
Integration & Operations
Mr. Steve Clark
(Acting) Division Chief

Contracting
Ms. Jean Barnes
Division Chief

Financial and Program Management Division
Ms. Carol Santistevan
(Acting) Division Chief

Information Management Division
Lt Col Martin Martinez
Division Chief

FY15 Funding Break Out
Received Amounts with Customer Funding
AFRL/Space Vehicles Directorate



$219.6M
FY15 Funding
20 Jul 15

$ in Millions

Science and Technology	**163.5M**
Other Funding	**56.1M**
Total	**219.6M**

*All funding is shown as **Received**. Direct Cite/Reimbursable figures were obtained from the CCaR Incoming Document Report. S&T Funding consists of 6.1, 6.2, & 6.3 amounts. CRI pass-thru funding is not included.

World Class Facilities

AFRL/Space Vehicles Directorate

Existing Facilities – 55 Bldgs

- 420,000 Sq Ft – Kirtland AFB, NM
- 36,000 Sq Ft - Holloman AFB, NM
- 31,000 Sq Ft - HAARP, Alaska

Fabrication and Testing Capabilities

Unique Test Equipment

EO/IR Facilities

IRREL characterizes Focal Plane Arrays

Space Electronics Facilities

Nuclear Radiation Simulation Lab

Imaging Spectroscopy Calibration Lab

Cold Atom Lab

Comprehensive integration & test facilities for small, experimental satellites or spacecraft components at different security levels

Ionospheric research

** Now operated by UAF

Balloon operations

Solar observations

Space Vehicles Directorate

Mission: Stay One Step Ahead in Space

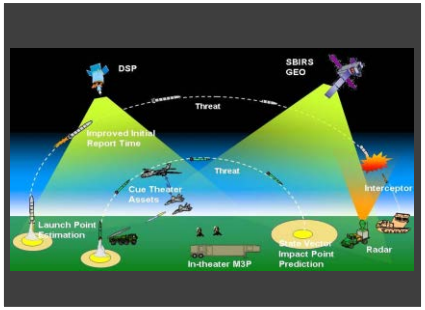
Technical Mission Areas

Space Situational Awareness

- Search, discover, track, and maintain custody of space objects
- Provide unique object ID and discrimination
- Understand and predict space domain behavior
- Characterize, assess, and resolve anomalies/attacks on space systems

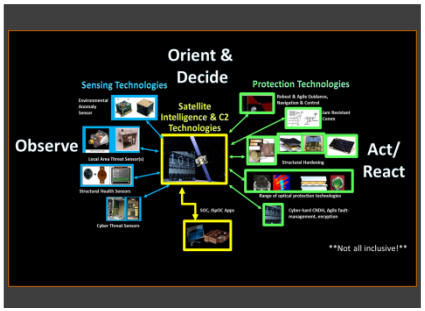
Space Communications/ Position, Navigation & Timing

- Extend frequency tradespace for space communication
- Address projected jamming threats
- Develop technology and create options for future GPS spacecraft



Intel, Surveillance, & Reconnaissance

- Support SBIRS and DoD unique terrestrial weather systems
- Provide capability to warfighters for over-the-horizon and traditional space-based ISR systems
- Provide key nuclear explosion monitoring technology



Defensive Space Control

- Evolve space resilience
- Holistic local awareness sensors
- Satellite intelligence technologies
- Passive protection and active agility
- Associated modeling, sim, assessment & testing

Vision: Be indispensable to our nation in improving AF and DoD space capabilities

AFRL

Strategic Context

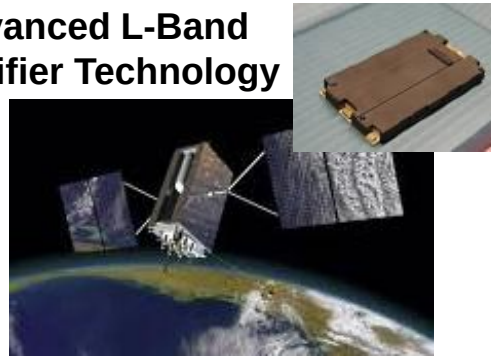
- Growing commercial investment in and utilization of space
- Increased competition and diversity of launch options
- Acceleration of connectedness but mounting security stove-pipes
- Lag in government business practices
- Growing threats to space and launch systems
- Realization we can't concede space
- Emerging DoD Space strategy
- Drastic increase is use of cubesats/smallsats
- Advanced manufacturing availability...additive and robotic

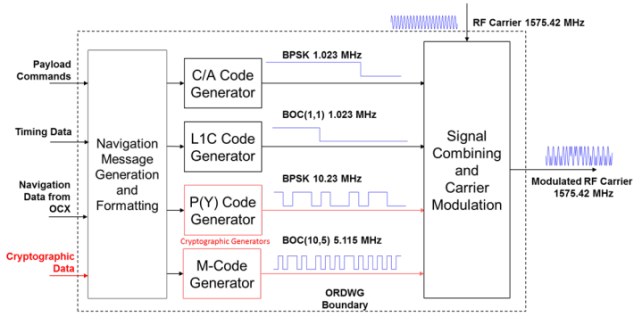
AFRL Advanced PNT Technology and Next Flight Experiment

Advanced GPS Technologies

Technologies	Capabilities
• High efficiency GaN amplifiers • On-orbit Reprogrammable Digital Waveform Generators • New antenna concepts • Supporting electronics • Algorithms and new signal combining methods • Satellite bus technologies for lower SWaP/ increased resiliency • Advanced cyber technology	• Lower-SWaP spacecraft OR higher power signals • Increased signal flexibility after launch • Lower cost OR increased capability payload • Increased signal strength • Information assurance designed-in from the start

Advanced L-Band Amplifier Technology





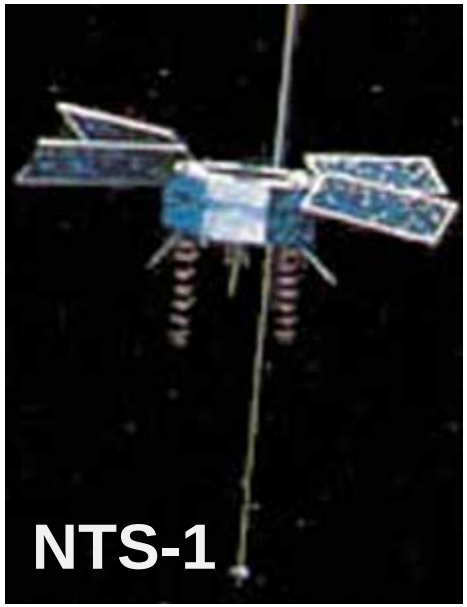
Functions of an L1 band On-Orbit Reprogrammable Digital Waveform Generator

Advanced Military User Equipment

Navigation Technology Satellites (NTS)

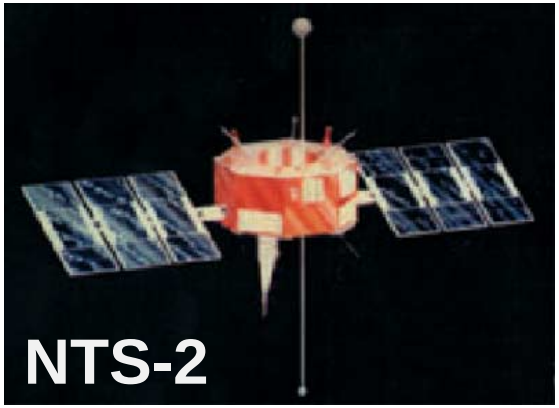
NTS-1 (Launched: 1974)

- “Timation” and “621B” programs merged to become NAVSTAR GPS program.
- NRL'S Timation 3 satellite re-designated the NTS-1
- Two rubidium-vapor frequency standards (clocks)



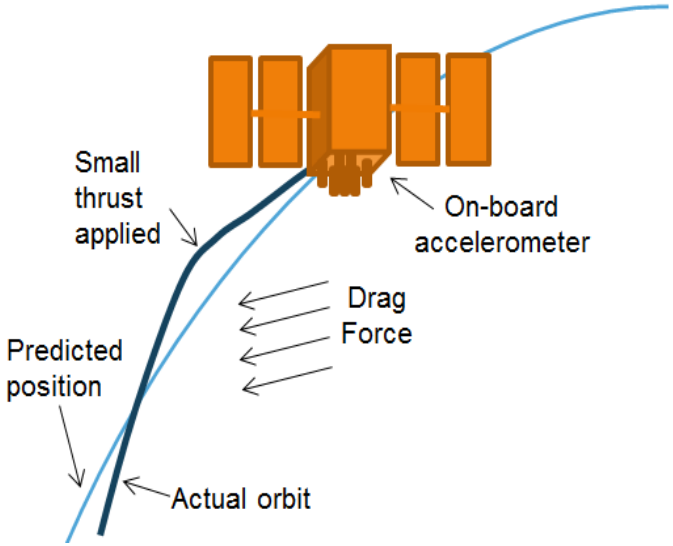
NTS-2 (Launched: 1977)

- 1st NAVSTAR GPS Phase I satellite
- Cesium frequency standards (clock)
- Nickel-hydrogen battery
- Worldwide network for data acquisition
- Verified Einstein's relativistic clock shift



NTS-3 is AFRL's Next Flight Experiment

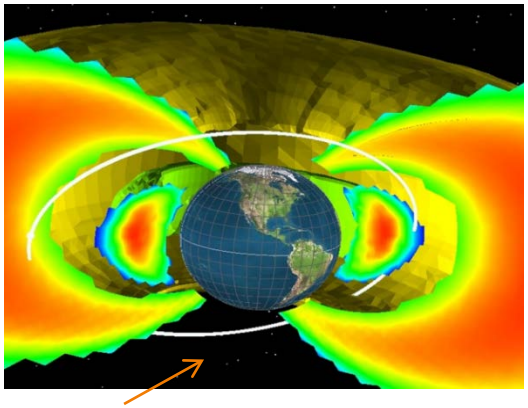
- **Advance state-of-the-art satellite hardware and software**
  - High gain antennas
  - High Power Amplifiers
  - Flexible digital payload
  - Atomic Clocks
- **Explore new operations concepts**
  - Know ephemeris though active control
  - Alternate TT&C and ground
  - Hosted payload
- **Conduct wide variety of science experiments**
  - Integrated space, ground and cyber
  - Examples: relativity experiments, advanced signals, active maneuver with precise OD, tactical TT&C, localized signals



Near-term & Current AFRL Space Experiments

DSX- Mission Objectives

- **Nominal orbit: 6000 x 12000 km, 42 degree inclination**
- **Launch Sep 2016 on STP-2 Mission**
  - **SpaceX Falcon Heavy launch vehicle from KSC**



MEO slot region orbit

- **<u>Three Main Science Experiments</u>:**

1) Wave-Particle Interactions (WPIx) – prime payload

- **Determine efficiency of injecting VLF waves into space plasmas *in situ***
- **Determine distribution of natural & man-made ELF-VLF waves**
- **Characterize & quantify wave-particle interactions**

2) Space Weather (SWx)

- **Map MEO radiation & plasma environment**
- **Determine in-situ environment for wave generation experiments in (1)**

3) Space Environmental Effects (SFx)

- **Quantify MEO environment effects on technologies (electronics, materials, coatings)**
- **Determine physical mechanisms leading to materials' breakdown in MEO radiation**

MEO = Medium Earth Orbit, ELF = Extremely Low Frequency, VLF = Very Low Frequency, KSC = Kennedy Space Center

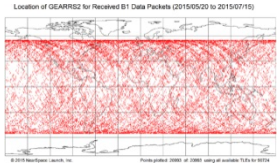
Small Satellite Program

Small satellites provide an extension of the lower-cost, higher-risk satellite paradigm that AFRL has helped pioneer (XSS-11, Tacsat-3, ANGELS) to even lower-cost, larger mission-assurance ranges

CHOMPTT

- 3U CubeSat precision timing satellite equipped w/ an atomic clock synchronized with a ground clock
- Demonstrate technology for enhanced GPS and future disaggregated navigation systems

GlobalStar…PNT Enabler



- Enables near-global PNT data availability
- Affordable method to gather TLM data

ARMADILLO – FOTON GPS

- Dual-Frequency GPS receiver with Nano-Satellite SWaP & Improved precision
  - 0.5U form-factor (8.3 x 9.6 x 3.8 cm)
  - ~1.5W orbit average w/ duty cycling

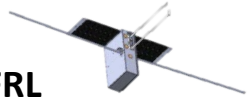
Namaru GPS (Australian)

- Developed by AUS Defense Science and Technology Group (DSTG)
- Sub-Meter relative position accuracy when multiple units flown in formation

SHARC

- Demonstrate the capability to perform critical calibration of over 120 Tri-Service C-Band radars
- Investigate the performance of Hypervisor on-orbit for DARPA
- Launch: April, 2015

VPM



- Critical augmentation for the AFRL Demonstration and Science Experiment (DSX) satellite
- Answers key DSX physics: Can we transmit VLF across the space plasma sheath into the far-field.

AFRL Test Bed for Space Situational Awareness Algorithms

JSpOC Mission System

Background

AFRL & AF Space Missile Command Delivered Joint Space Operations Center (JSpOC) Mission System (JMS) Inc. 1

- Net Centric Service Oriented Architecture (SOA)
- User Defined Operating Picture (UDOP)

2013

Space Missile Command JMS Inc. 2 Program

- Message Processing (C2)
- Observation Association
- Special & General Perturbations Catalog
- Conjunction Analysis & Break-up
- Reentry & Launch Assessment

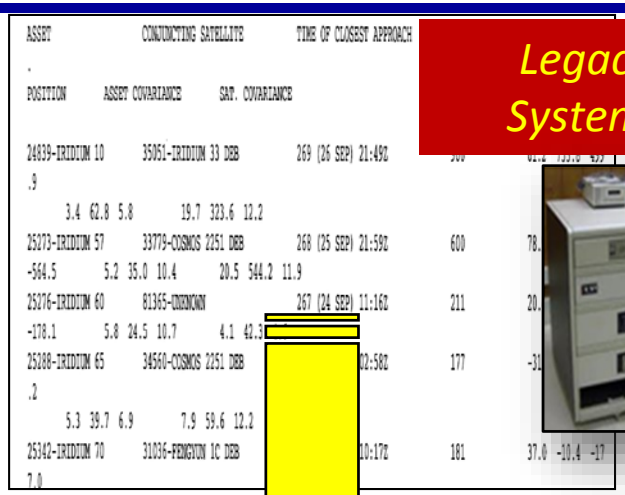
2014

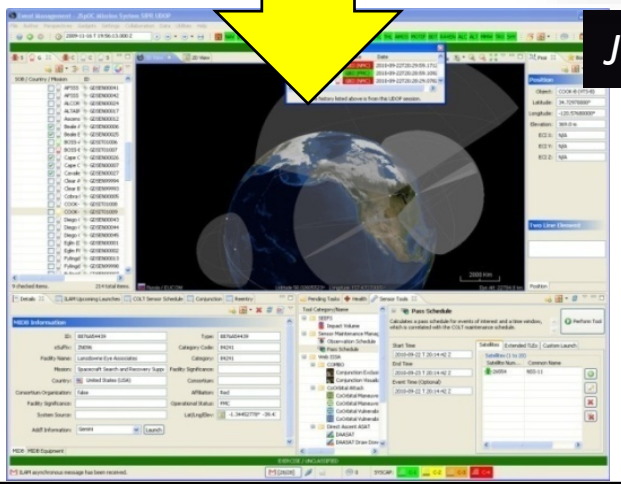
Final Delivery: 2016

JMS Inc. 3 – *Draft Requirements*

- ***Threat Indications and Warning***
- Spectrum Common Operating Picture
- Modeling and Simulation/COA Development

Inc.3 Program: 2016-2021

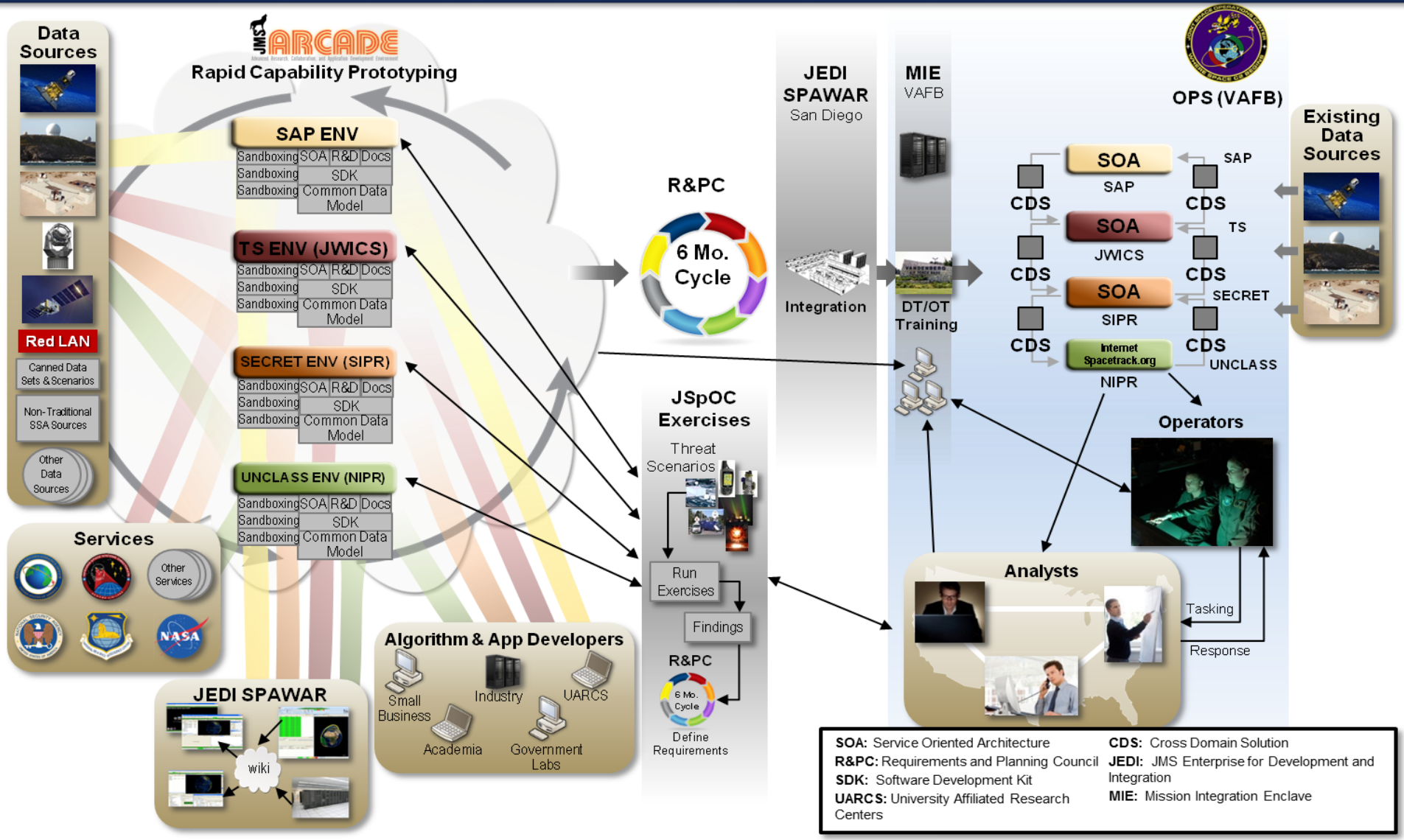




Air Force is delivering JMS to space operators – *How do we keep adding capability?*

Vision for ARCADE

An incubator for Joint Space Operations Center (JSpOC) Mission System (JMS) related applications



SOA: Service Oriented Architecture
R&PC: Requirements and Planning Council
SDK: Software Development Kit
UARCS: University Affiliated Research Centers
CDS: Cross Domain Solution
JEDI: JMS Enterprise for Development and Integration
MIE: Mission Integration Enclave

Challenge and Conclusion

- **“Space”scape is changing therefor we must:**
  - **Reorient to Resiliency**
  - **Induce Innovation**
  - **Seek Strategic Strengths**
  - **Prioritize Synergistic Partnerships**
  - **Greatly Grow GPS ☺**
- **AFRL is committed to a strong space S&T investments consistent with National priorities**
  - **SSA, Propulsive ESPA, space cyber, PNT, resilient pervasives, continued community experimentation**