

Overcoming Technical Challenges from Low Earth Orbit to Cislunar



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Commercial and National Interests Drive 2nd Space Age

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amazon **SPACEX**

x3200

x12,000

India tests anti-satellite weapon

-Space News, 2019



Russian and US satellites collide

-BBC 2009

OneWeb
ACCESS FOR EVERYONE

x2500



Virgin GALACTIC

BLUE ORIGIN



DSI
DEEP SPACE INDUSTRIES

LUNAR
RESOURCES

1969	Today	2030+
~1500 objects	~10 ⁴ objects Car-size, human-operated	~10 ⁶ objects Shoebox-size, autonomous
<= GEO, Lunar, Keplerian	<= GEO, Keplerian	Cislunar sphere, non-Keplerian
~7 nations in space	~12 Space faring nations ~90 nations w/ satellites	?? Nations, non-state actors, corporations



Space Strategy in a Changing Environment

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DESIRED CONDITIONS:

The space domain is secure, stable, and accessible. The use of space by the United States and our allies and partners is underpinned by sustained, comprehensive U.S. military strength. The United States is able to leverage our use of space to generate, project, and employ power across all domains throughout the spectrum of conflict.

CENTRAL PROBLEM:

The U.S. defense space enterprise was not built for the current strategic environment. The intentions and advancements of potential adversaries in space are threatening the ability of the United States to deter aggression, to protect U.S. national interests, and to fight and win future conflicts.

SPACEPOWER:

The sum of a nation's capabilities to leverage space for diplomatic, information, military, and economic activities in peace or war in order to attain national objectives.

DEFENSE SPACE STRATEGY
SUMMARY



JUNE 2020

Space Capstone Publication

SPACEPOWER
DOCTRINE FOR SPACE FORCES



UNITED STATES
SPACE FORCE

USAF created out of the United States Army Air Forces to address the growing role of the air domain



Challenges in Air Have Parallels to Space

Rise of Air Forces in WWII

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Achieving decisive, independent effects from the air had many challenges, some were solved technically



Survivability

Distance

Communications

System Employment



Higher altitude & speed to avoid threats

Range from safe bases to strategic target

Flight dynamics & control

Domain effects on payload



Life Support: Pressurized cabin & oxygen

Propulsion and supercharged engines

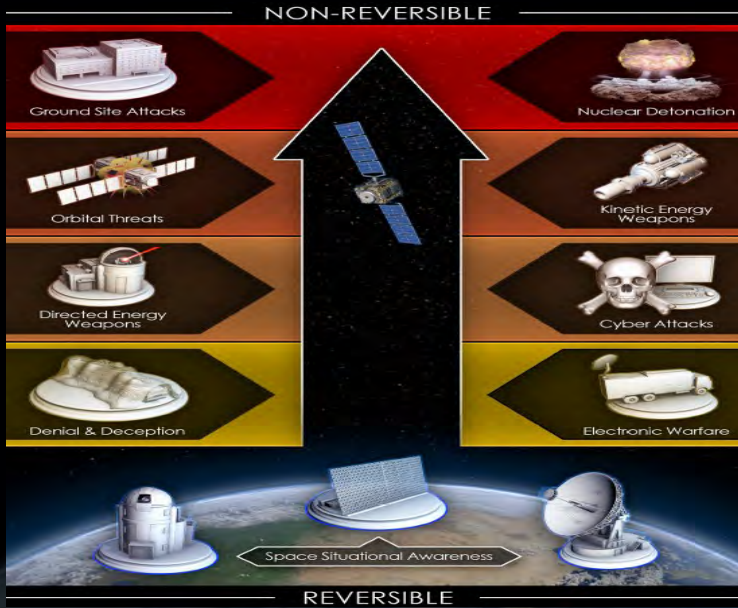
Stabilized bombsight integrated with aircraft autopilot (and later radar)

Challenges in Air Have Parallels to Space

Rise of Space Forces

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Achieving decisive, independent effects from space will also have many challenges, including technical

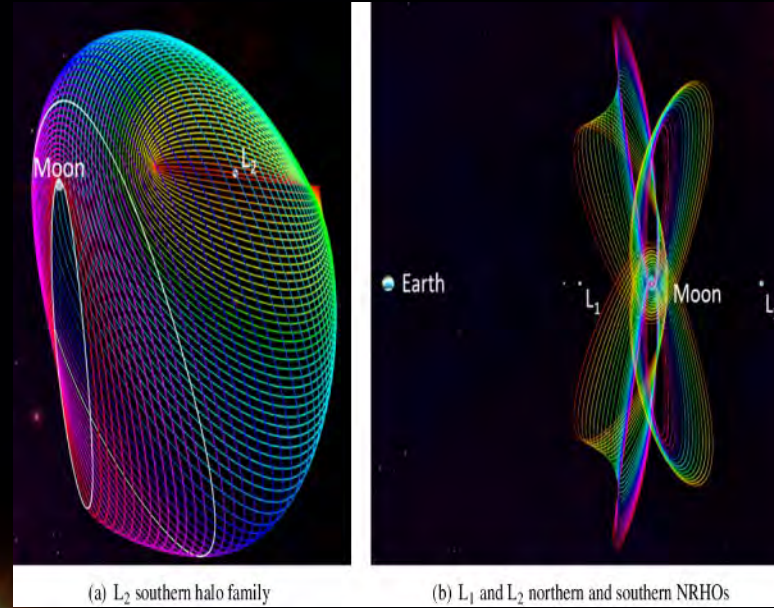


Survivability

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Life Support: Pressurized cabin & oxygen

On-board autonomy

Propulsion and supercharged engines

Stabilized bombsight integrated with aircraft

autopilot (and later radar)

Space domain awareness integrated with autonomous decision making



Space Domain Awareness Challenges

from VLEO to XGEO

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100 km

1,000 km

10,000 km

100,000 km

1,000,000 km

VLEO

LEO

MEO GEO

XGEO

- Altitudes only previously considered as part of de-orbit
- High drag environment
- Constant thrust

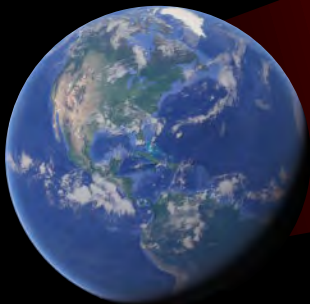
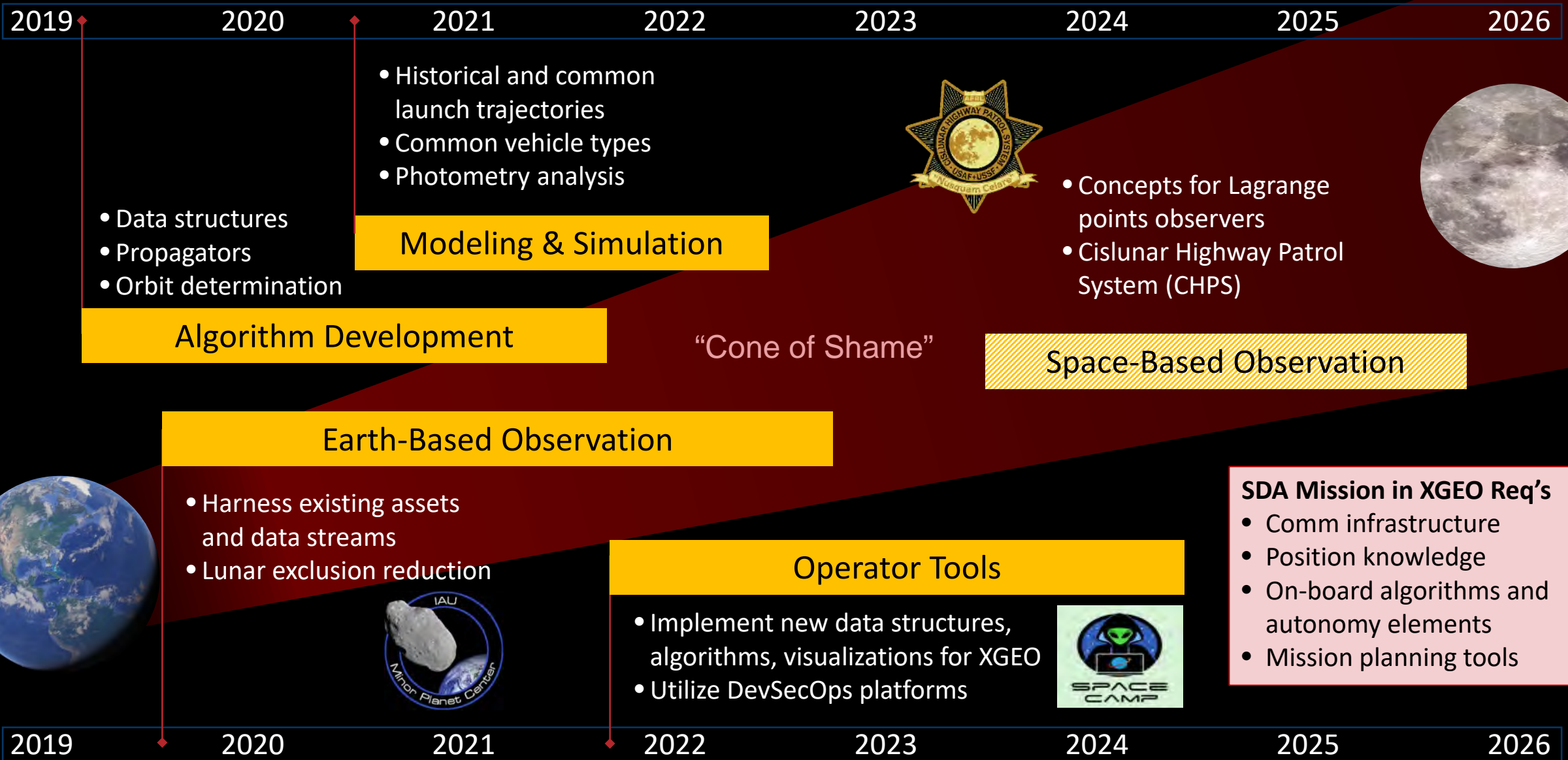
- Highly congested environment
- Advanced tools to ingest and combine, allied, commercial, & government data
- Ground-based anti-satellite threats

- Harsh radiation environment that is not well characterized
- Critical GPS services for national infrastructure

- Most USSF assets
- Increasingly congested
- Need advanced SDA techniques beyond dot-tracking

- New, vast regime
- Complex orbital dynamics
- “Cone of Shame” limits ground-based SDA
- Enabling potential lines of commerce

AFRL XGEO Domain Awareness Ecosystem



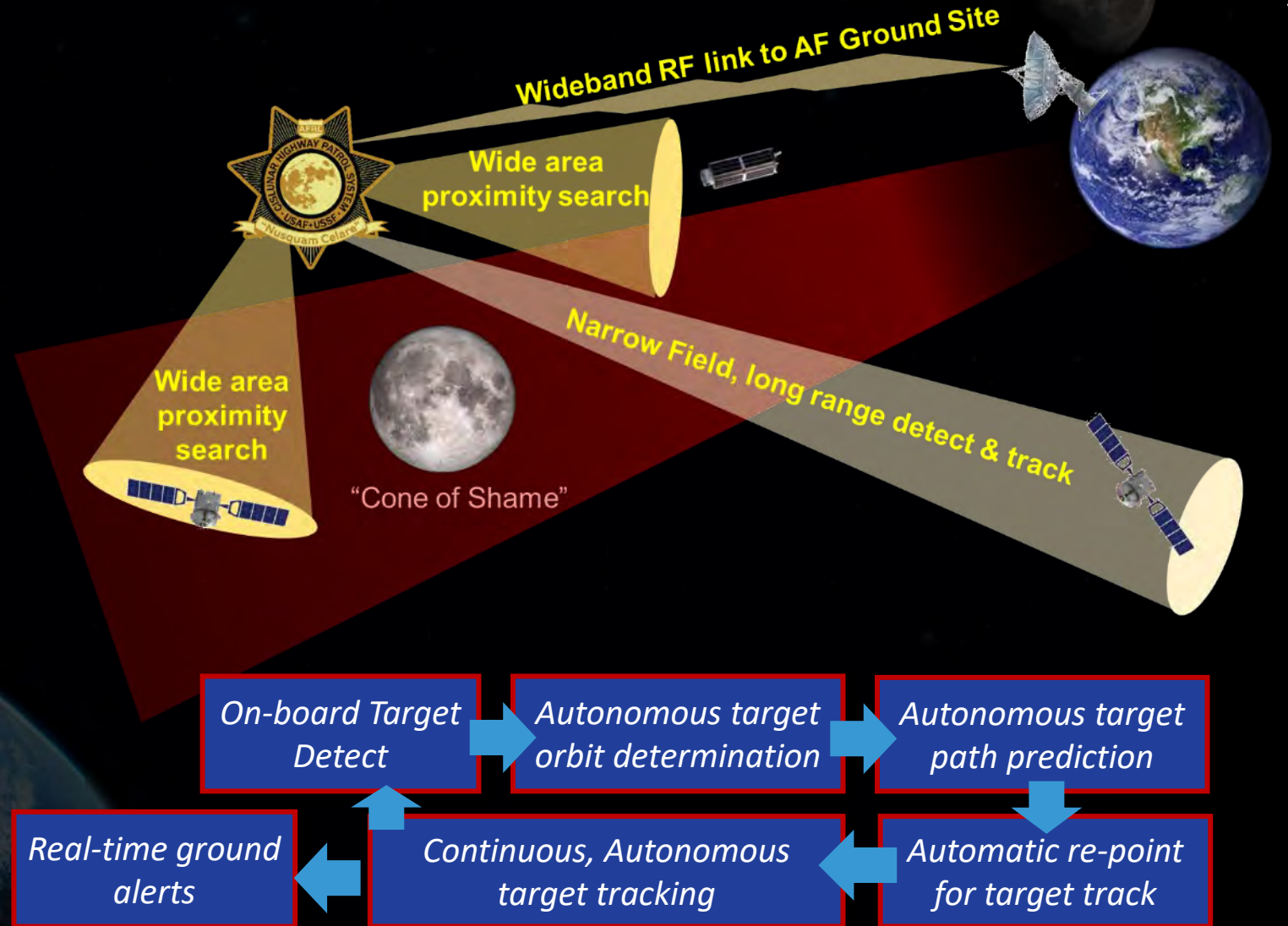
Cislunar Highway Patrol Systems (CHPS)

Objectives

- Find, fix, and track objects in lunar exclusion zone aka “Cone of Shame”
- Increase maturity of onboard SDA processing techniques
- Demo tip & cue with existing assets
- New techniques to perform orbit determination on cislunar objects
- Assess novel navigation techniques

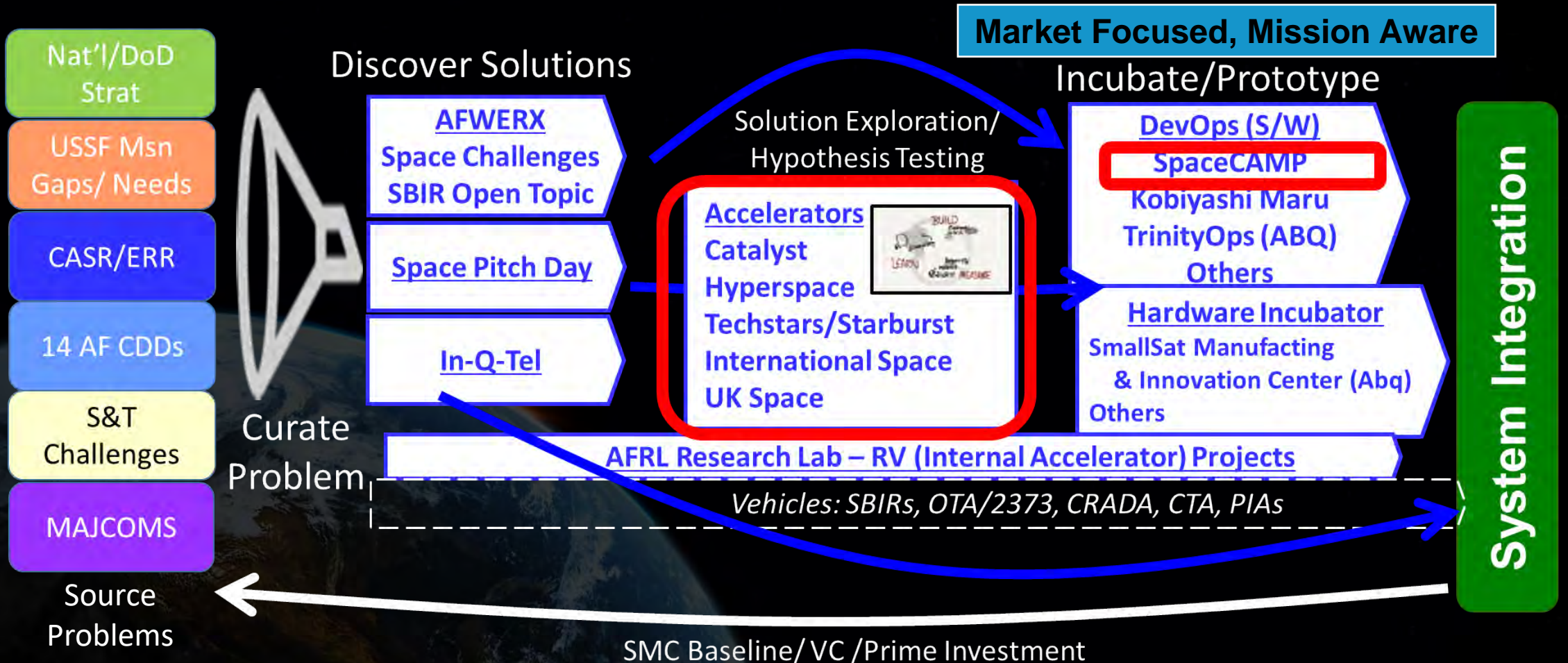
Technical Challenge

- 3-body effects are chaotic
- Predicting trajectories
- Tradeoffs between infinite orbits and off-the-shelf sensors



Accelerating S&T Innovation Pipeline

Objective: A collapsed acquisition process that couples accelerators for *concept exploration* with rapid prototyping & other gov't investments to reduce idea-2-ops timelines using non-traditional partners.



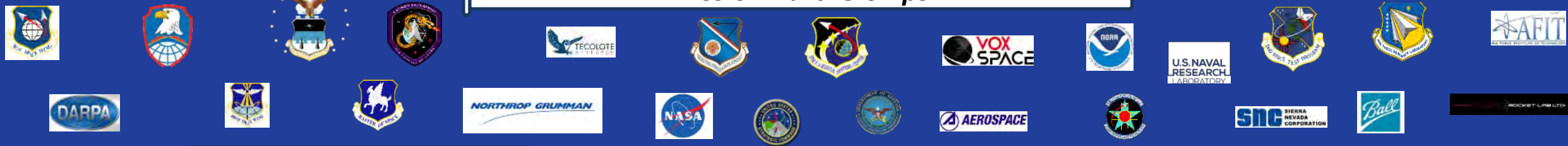


SMC's Innovation & Prototyping Directorate

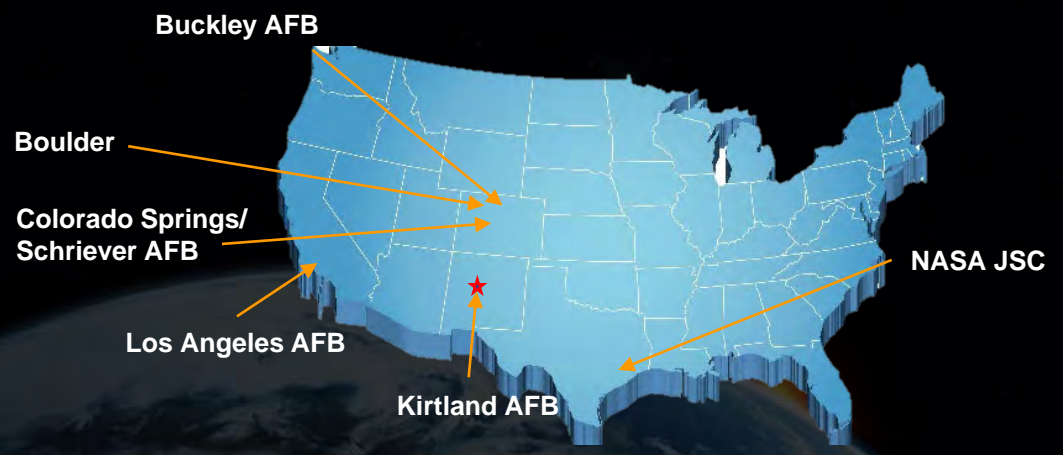
Increasing Opportunities to Prototype & Experiment

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Mission Partnerships



Locations



Portfolio

Enablers	Prototypes	Missions

Recent Mission Successes

5 May 19 Onenui Station, NZ	25 Jun 19 Cape Canaveral	28 Jan 20 Deployed from ISS



Space Enterprise Consortium (SpEC)

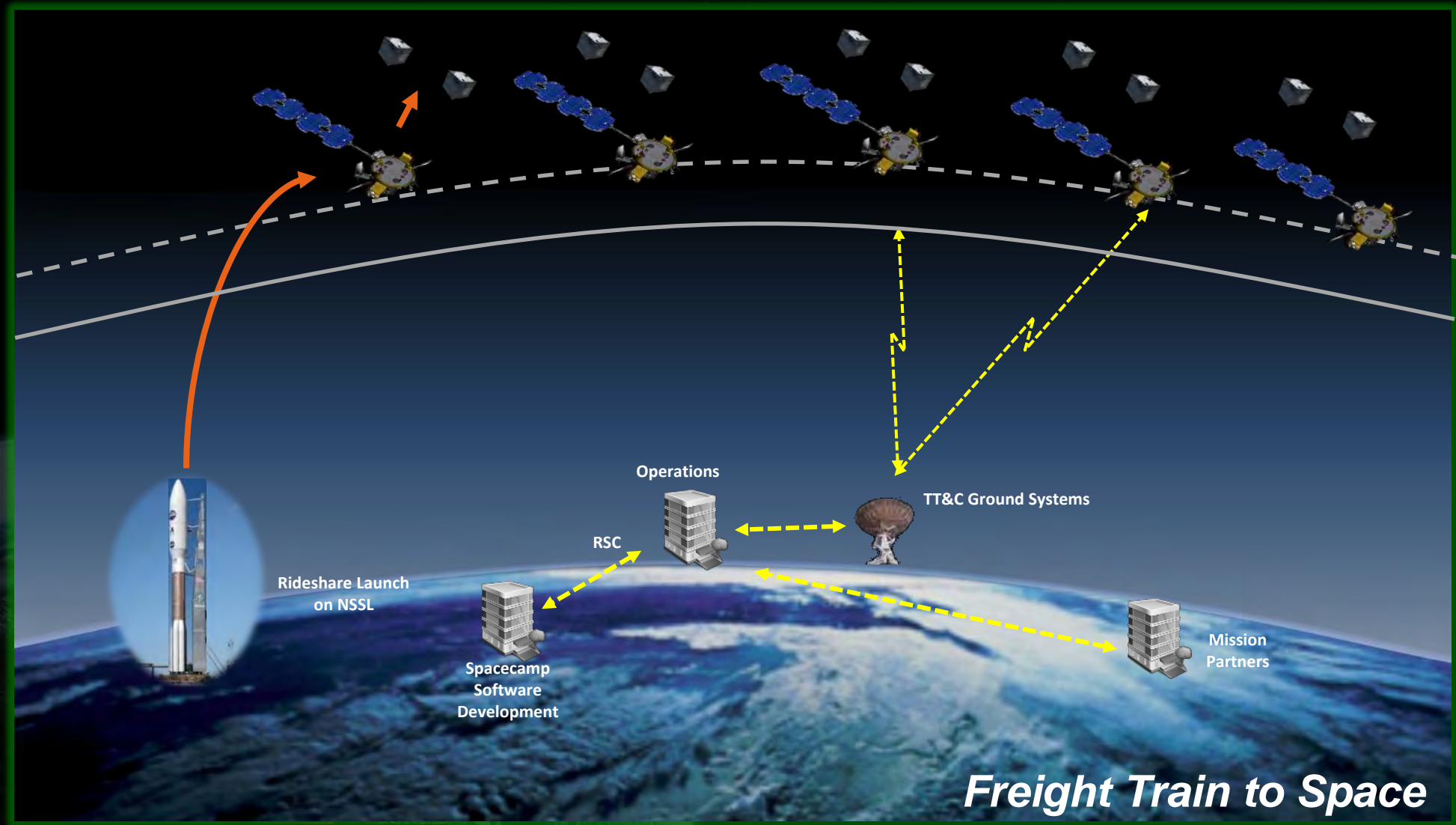
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USSF's Acquisition Tool for Accelerating Innovative Prototyping



Rapid On-Orbit Space Technology Evaluation Ring (ROOSTER)

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Rapid Agile Launch Initiative (RALI)

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USSF's Pathfinder for Using Commercial Small Launch Vehicles to LEO

VOX Space



Astra Space



Rocket Lab



RDT&E Support Complex (RSC)

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Delivers Agile Satellite C2 Ops: Enabling On-Orbit Test, Experiments, and Rapid Prototyping

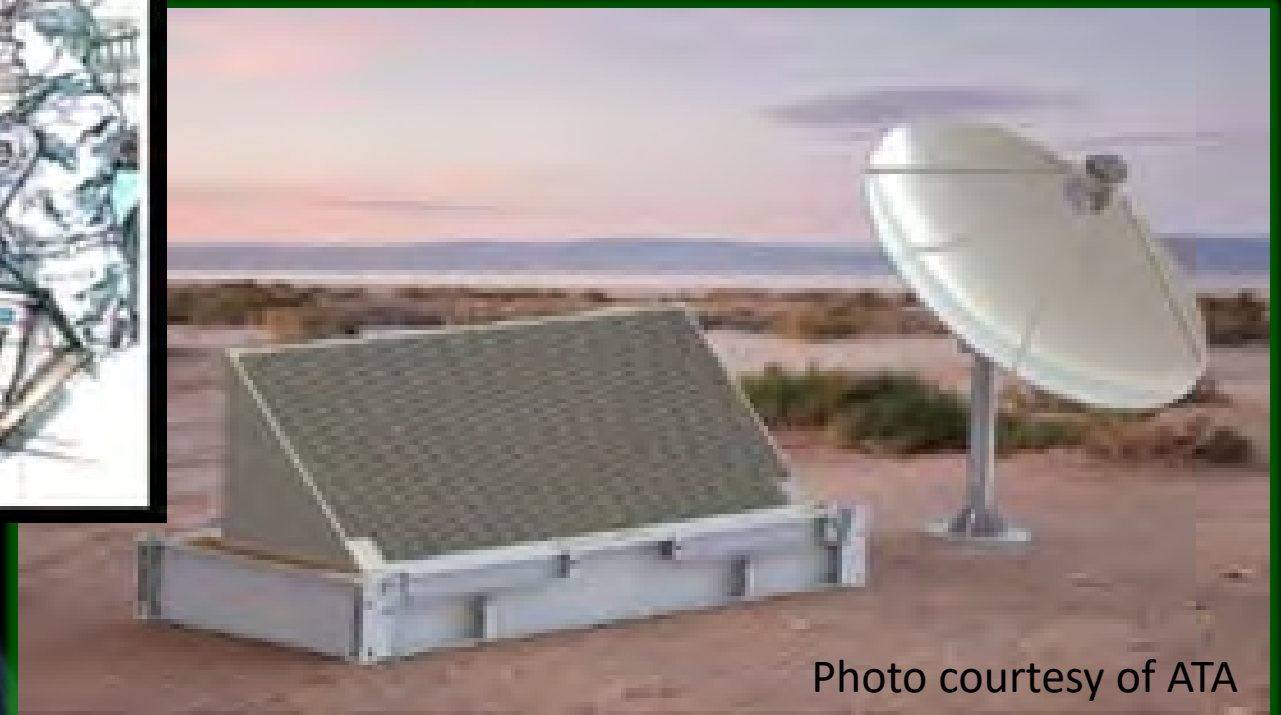
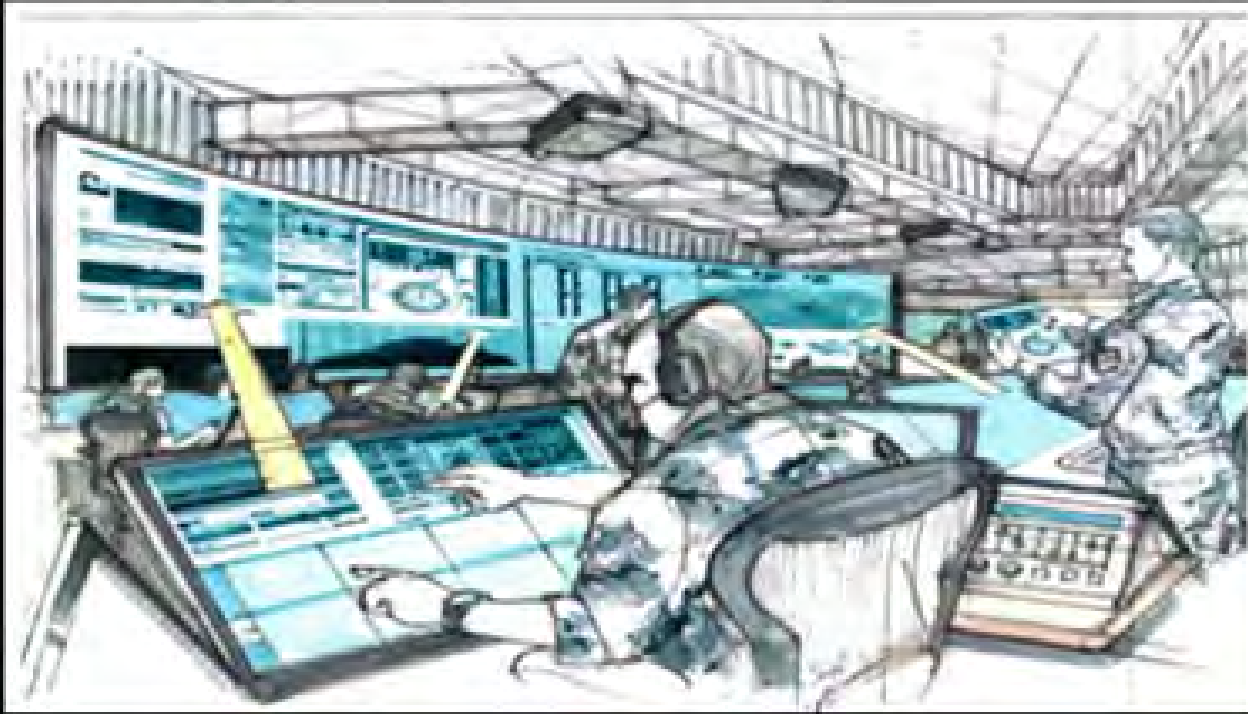
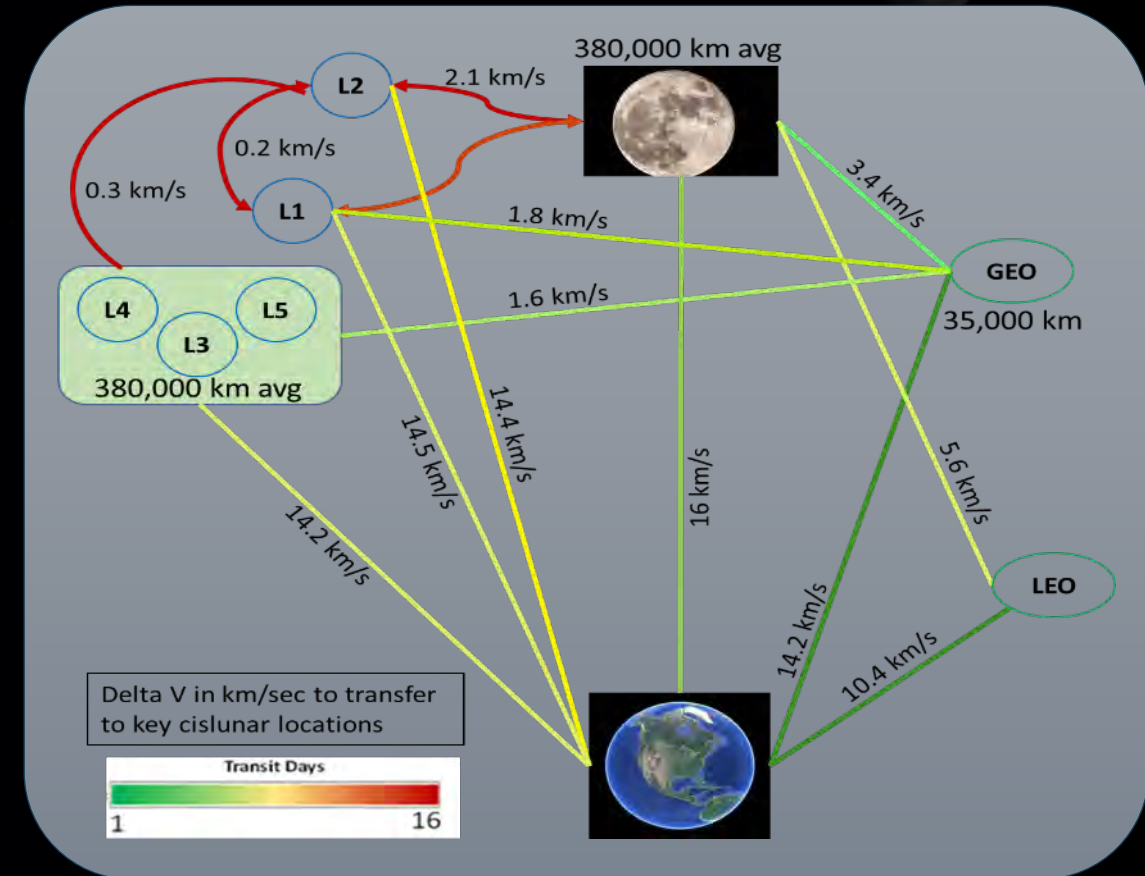


Photo courtesy of ATA

Challenges for the SDA community

- Increased congestion with wide array of state and non-state entities
- Data fusion from multiple sources: government, allied, commercial
- Advanced techniques beyond dot tracking in GEO
- New orbital regime challenges
 - VLEO – High drag & constant thrusting; regime normally considered “re-entry”
 - XGEO – Huge domain; complex dynamics & orbits; “cone of shame”



Huge domain: LEO to GEO is <1% volume of XGEO
Small ΔV make big impacts increasing reachability



Questions?