

# AFRL/RV



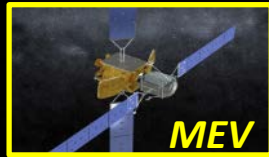
**Col Eric J. Felt, Director**  
**Space Vehicles Directorate**  
**Air Force Research Laboratory**

**October 2020**

# 21<sup>st</sup> Century Space

## 2<sup>nd</sup> Space Age Economic & National Interests

**SPACEX**  
x12,000  
**amazon**  
x3200



India tests anti-satellite weapon

-Space News, 2019

Russian and US satellites collide

-BBC 2009

“Cone of Shame”



**Virgin GALACTIC**  
**planet.**  
See change. Change the world.  
**BLACK SKY**  
Be The First To Know

1969	Today	2030+
~1500 objects	~10 <sup>4</sup> objects; human-operated	~10 <sup>6</sup> objects, autonomous
GEO, Lunar, Keplerian	GEO, Keplerian	Cis-lunar, non-Keplerian
~7 nations in space	~90 nations; commercial	?? nations, commercial; non-state

**DSI**  
DEEP SPACE INDUSTRIES  
**LUNAR RESOURCES**  
**PLANETARY RESOURCES**

# Historical Perspective

We've Been Here Before

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



# Rise of Air Forces in WWII

## Challenges in Air Have Parallels to Space

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

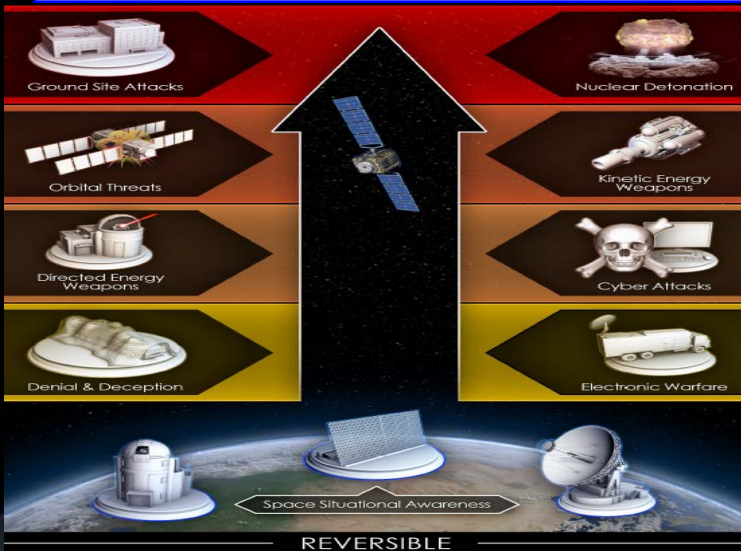
Stabilized bombsight integrated with aircraft autopilot (and later radar)

# Rise of Space Forces

## Challenges in Air Have Parallels to Space



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

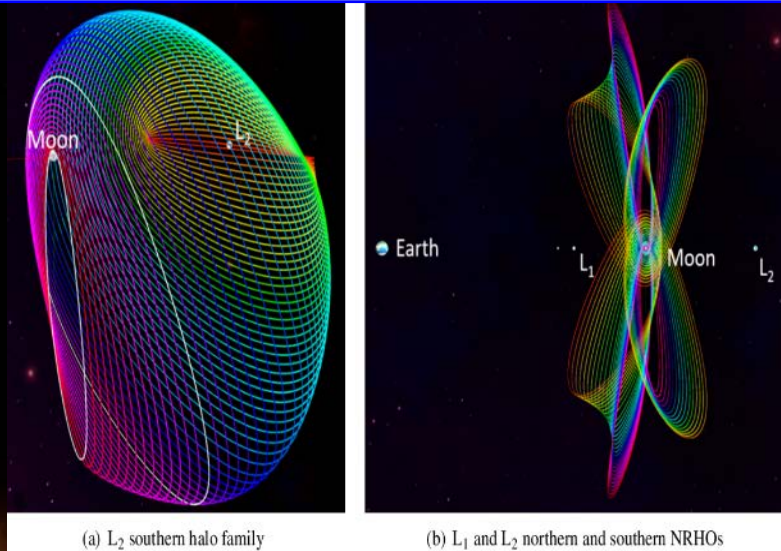


Survivability

Distance

Communications

System Employment



Higher altitude & speed to avoid threats

Range from safe bases to strategic target

Flight dynamics and control

Domain effects on payload



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*

# AFRL/RV Mission Areas

## Position, Navigation & Timing



- Reprogrammable signal generator
- Explore high gain antenna configurations
- Software defined receivers
- Enterprise Ground System compatible



- Novel detectors, materials & algorithms
- Hyper-temporal imaging (HTI)
- Data processing and integration
- Infrared Radiation Effects Lab (IRREL)



- Wave impacts on radiation belt dynamics
- Map MEO radiation environment
- Characterize material degradation
- Specify, forecast, mitigate and exploit

## Pervasive Technologies



- Power, structures, thermal, electronics
- Guidance and control systems
- Resilient, low SWaP-C components
- Ultra-compact, deployable structures

## Satellite Communications



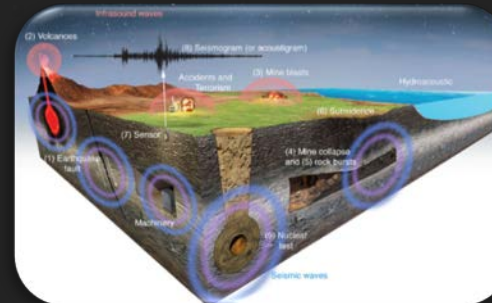
- Space combat cloud
- Protected satellite communication
- Wideband and narrowband comm
- Advanced user terminals

## Space Control



- Local space situational awareness
- Unified Data Library open marketplace
- Low-cost satellite protection technology
- Space system cyber protection

## Nuclear Deterrence Operations



- Advanced inertial navigation systems
- Nuclear Explosion Monitoring
- Hypersonic modelling and simulation
- Modernization Technologies



# Space Domain Awareness

## Challenges from VLEO to XGEO



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

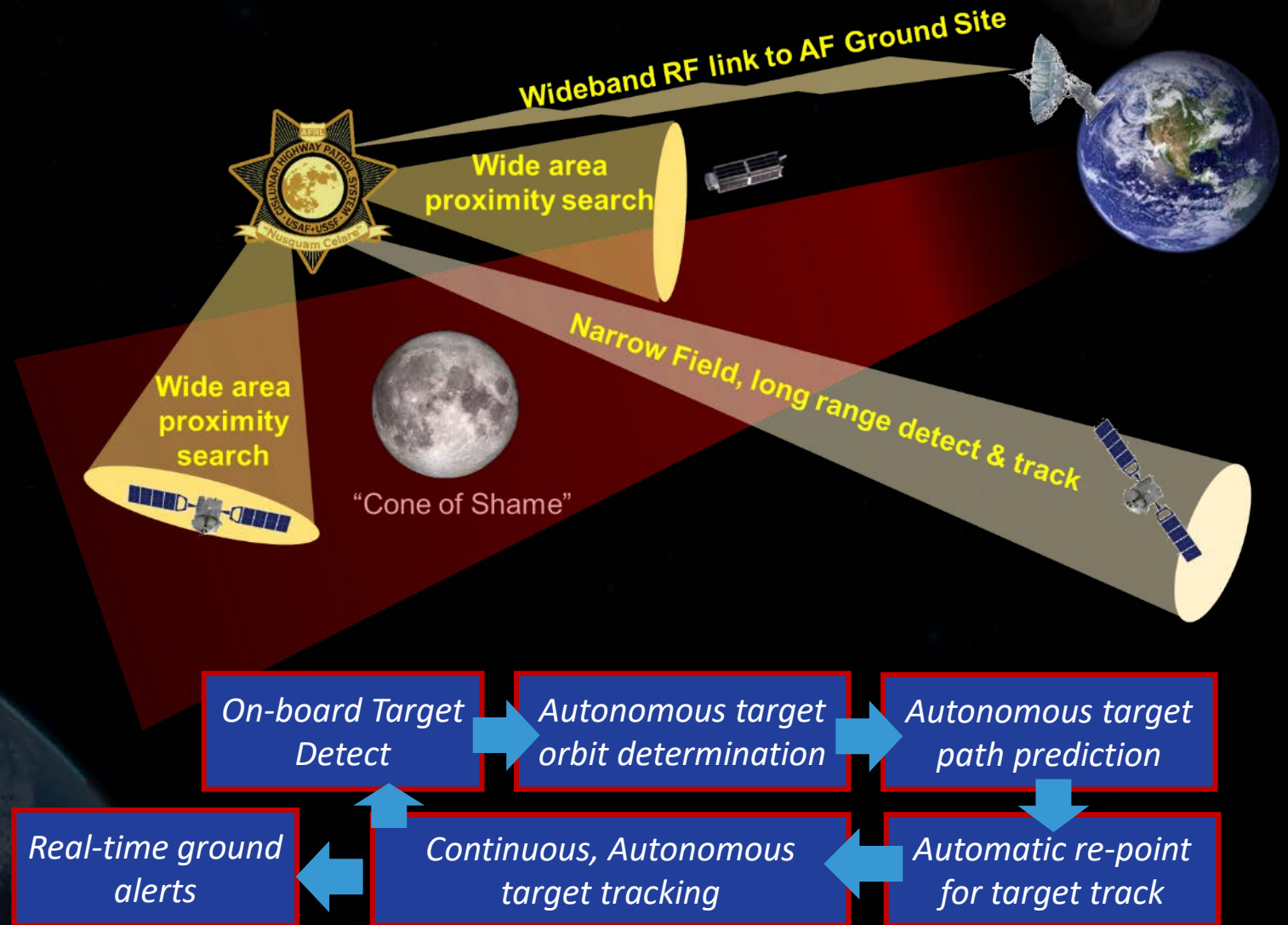
# AFRL Cislunar Highway Patrol Systems (CHPS)

## • 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





# Micro-Satellite Military Utility

## 9-Nation Project Agreement

Inform a space enterprise that provides military users with reliable access to a broad spectrum of information in an opportunistic environment

### RIMPAC 2018: Exploring military utility of heterogeneous satellite architecture

- Traditional government sensors
- Commercial sensors
- Small satellites
- Multiple phenomenologies
- Simulations of future satellites
- Mission planning and sensemaking tools

220 satellites including:  
AISSat-1 & -2, BlackSky providers,  
DigitalGlobe, Kestrel Eye, Maerospace  
Corporation, NorSat-1 & -2, Planet's Dove  
Flock and SkySats, and RadarSat-2.

### Key findings

- Value of the heterogeneous architecture tends towards lower-tempo uses such as pattern-of-life
- There are clear gaps in the architecture where coordinated government investment is needed

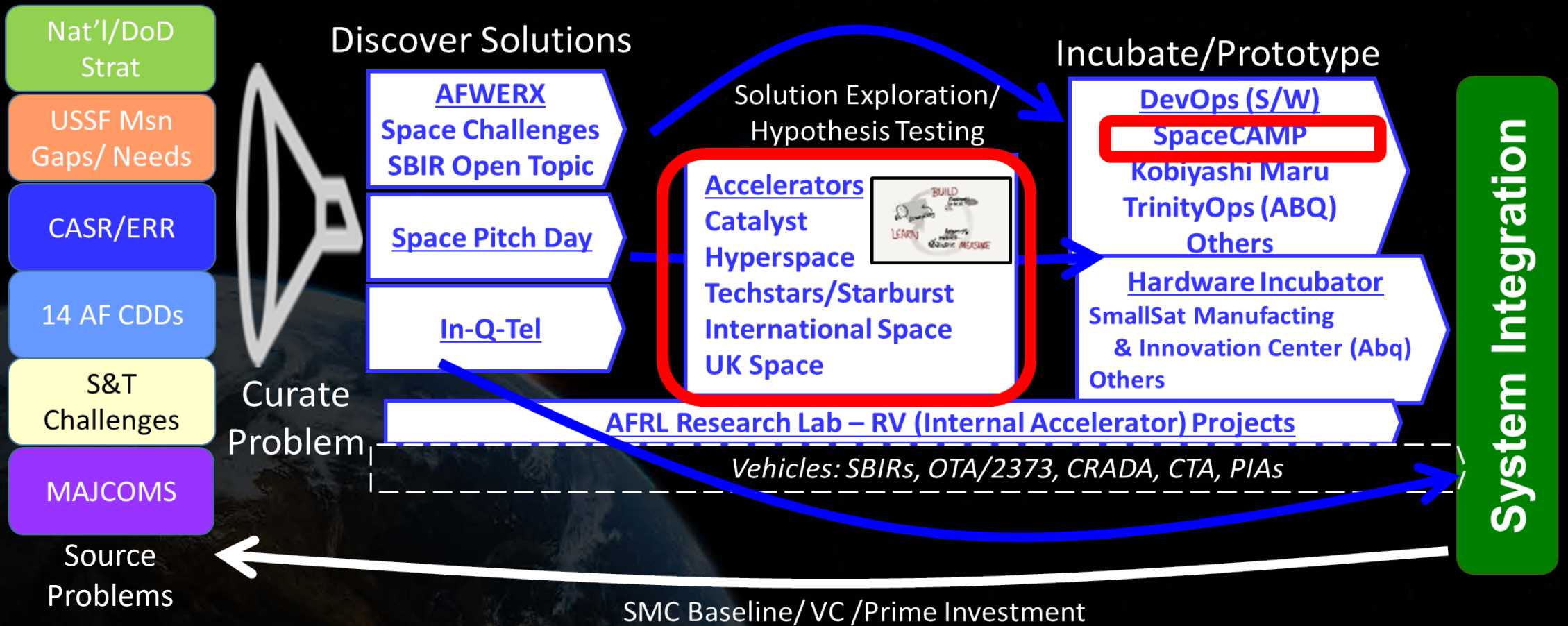


# Accelerating S&T

## Innovation Pipeline

Market Focused, Mission Aware

**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.



# RV Prioritized Initiatives

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1. Space Combat Cloud
2. Managing hybrid architectures
3. Low-cost satellite protection technologies
4. Autonomy, AI, and multi-agent collaboration
5. Space delivery (NASA small sample return)
6. Space cyber
7. LEO to cislunar space domain awareness
8. Modeling and simulation concept analysis for data-driven decision making
9. Space logistics, e.g. servicing/upgrade, assembly, and manufacturing
10. Space to surface sensing
11. Clean sheet command, control, and communications architecture
12. Space environment
13. Space-based terrestrial environmental monitoring

# Questions?