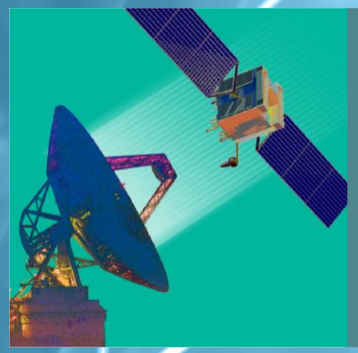


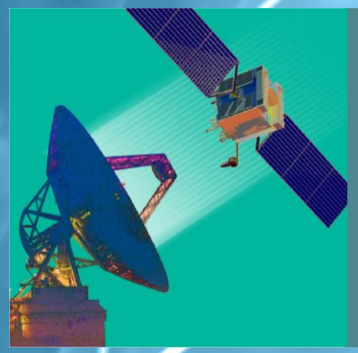
Ground System Architectures Workshop

Driving Innovation for Enterprise Integration

February 23–March 3, 2022 | Virtual Event

Welcome

March 2, 2022
11:00 PT



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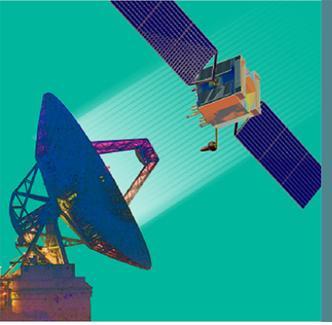
Working Group J: Space Enterprise Integration

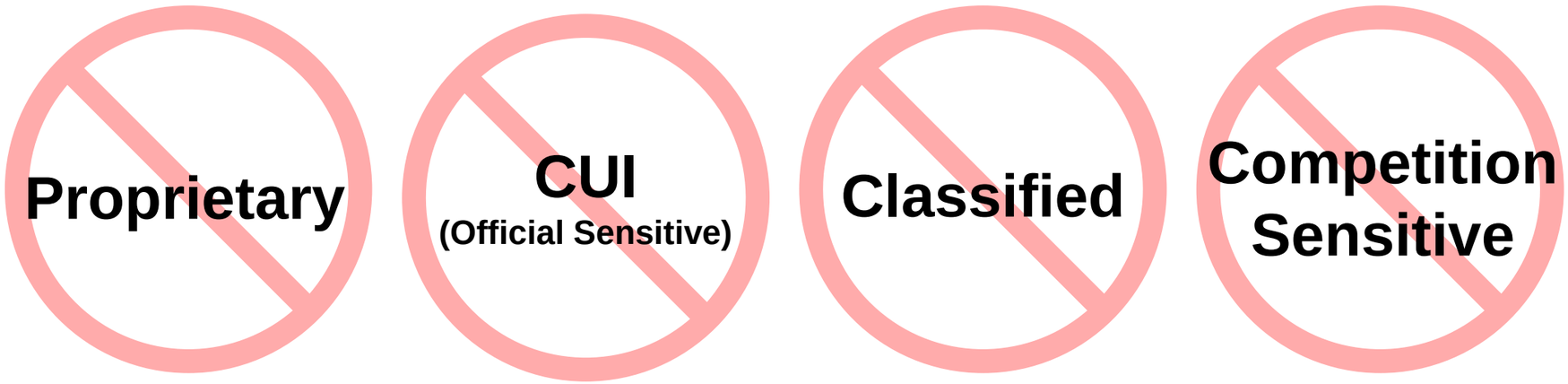
Lori Gordon, Ron Birk, Barbara Braun
The Aerospace Corporation

March 2, 2022

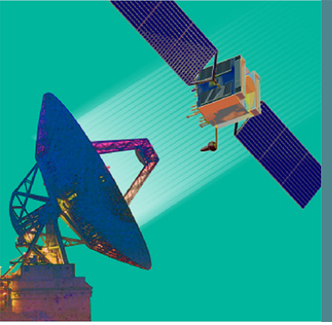


Rules of Engagement

- This workshop is entirely **UNCLASSIFIED**



- This workshop will be **recorded** for note-taking purposes



Housekeeping Notes

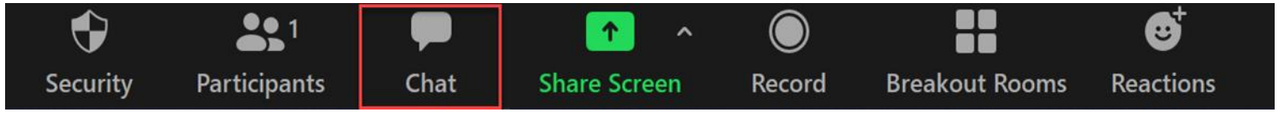
Reminders:

- *Please keep your mic on mute*
- *Use your full name (no nicknames) when logging into Zoom*
- *If you experience any Zoom issues, please refer to Troubleshooting Tips and Join Zoom Meeting instructions links found in the chat box.*

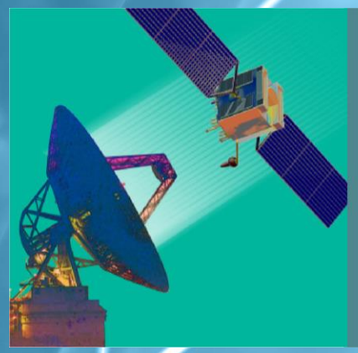
Attendees are encouraged to use the chat box for questions or comments:

- *The host, if time permits, may ask the speaker to answer questions, recap, or provide closing thoughts after their presentation is complete.*
- *The facilitators will help consolidate the questions entered through the chat box interface and deliver them to the speaker during the live Q&A session.*
- *Questions and comments should be professional, relevant, and related to the subject.*

Click on the Chat icon to:



- *Send questions/comments to everyone.*
- *You can also click on the **drop-down arrow** next to **Everyone** and select a particular individual to chat with privately.*



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This working group will address challenges and opportunities associated with Space Enterprise Integration for high profile use cases such as

- Advancing Space Traffic Coordination (STC)
- Integrating Space for Advanced Battle Management System (ABMS)
- Developing the Cislunar Neighborhood

U.S. government agency panelists address high profile use cases:

- Scott Leonard– Special Advisor to the Director, Office of Space Commerce
- Jeremy Leader – Deputy Director, Cross Mission Ground and Communications Enterprise, USSF
- Dr. David Spencer – The Aerospace Corporation

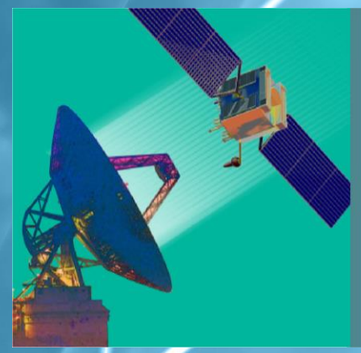
The workshop includes a leadership panel and a town hall.

Information @ link : Working Group J – Ground System Architectures Workshop (gsaw.org)

Scott Leonard

Jeremy Leader

Dr. David Spencer



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The discussion will be framed around a '3×3' approach to assess each of these three Use Cases through three lenses to gain insight into how organizations conduct enterprise integration:

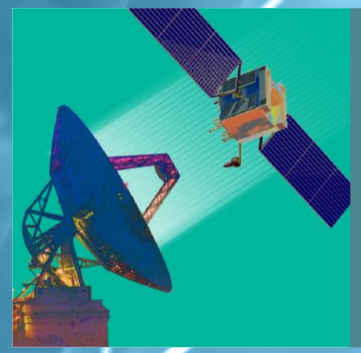
- Digital Integration (Digital Engineering, Digital Threads, Digital Twins)
- Operational Test (In-space Testbeds and Proving Grounds)
- Data Fusion (AI/ML, Authoritative Sources of Truth)

The working group session consists of two parts:

Part 1 will include a moderated panel session with presentations and discussions related to strategic foundational elements for space enterprise integration, outlining applicability to several use cases to advance U.S space capabilities in the national interest.

Part 2 will be a town hall meeting to include key representatives from government and private sector organizations sharing a common goal to advance space capabilities in the national interest.

Advancing understanding and best practices for enterprise integration



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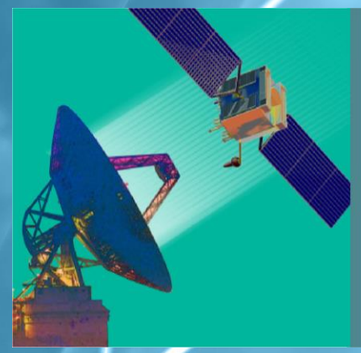
Space Enterprise Integration:

structured process of coordinating across stakeholders
to inform decisions
for assuring systems of systems operations
across the space enterprise
to deliver critical national benefits
in the face of evolving threats
and changing operating environments.

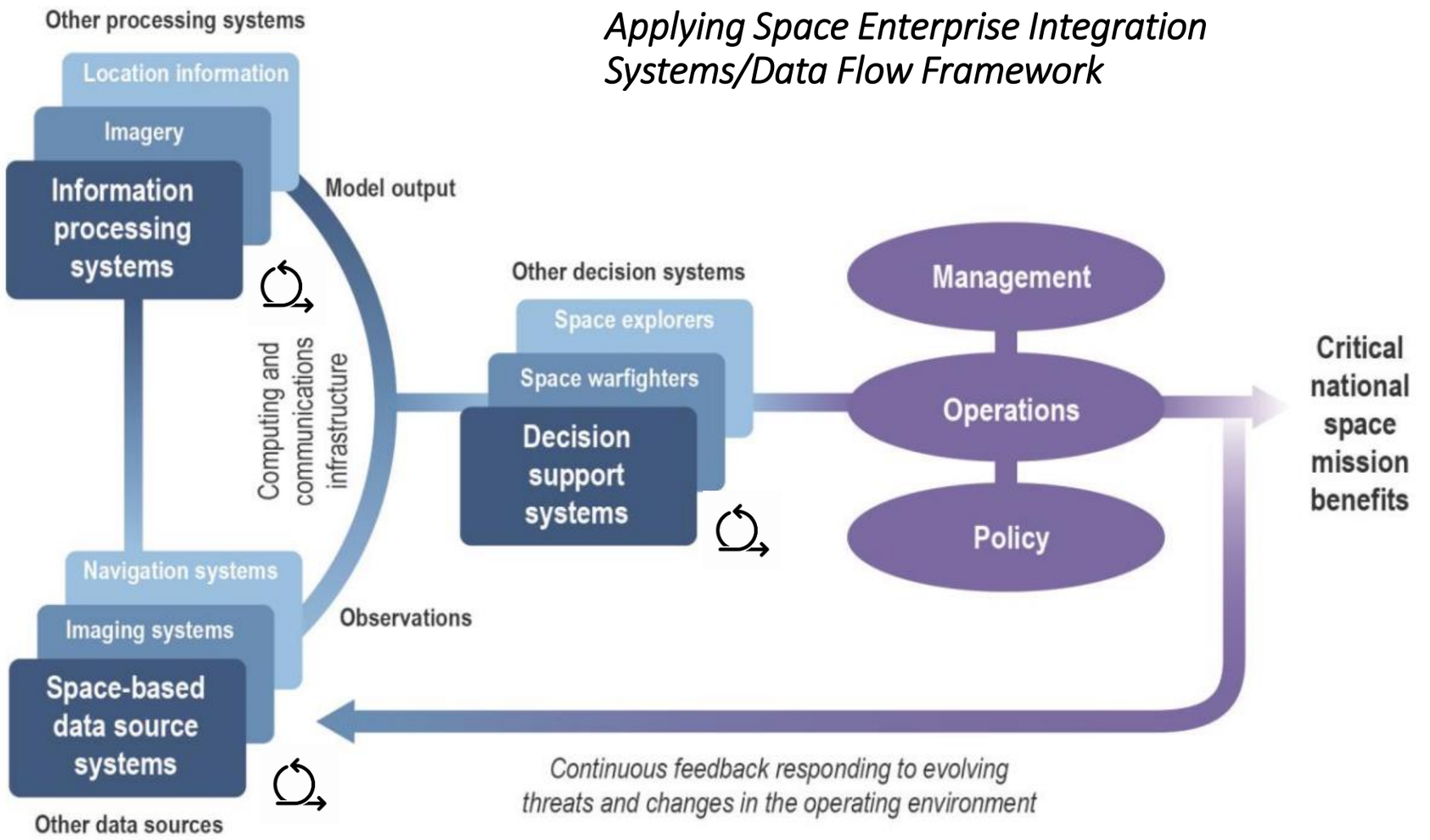
OODA – Observe Orient Decide Act

TPED – Tasking Collection Processing Exploitation Dissemination

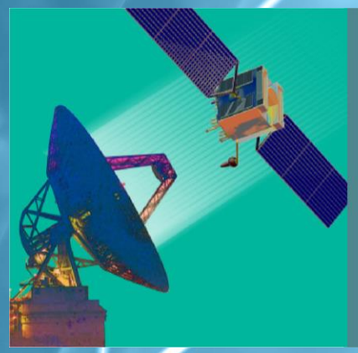


Ground System Architectures Workshop

Applying Space Enterprise Integration Systems/Data Flow Framework



End-to-end integration of systems, data flows, decision processes across an enterprise to sustain operations



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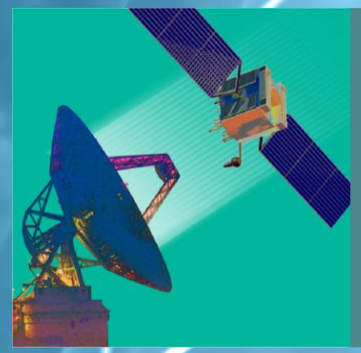
Space Enterprise Integration: structured process to maintain up-to-date information to assure continuity of real-time operations of critical national space missions through horizontal and vertical integration of systems interconnections, data interchange, data product exchange, and distributed computing and communications environments across participating organizations in continuously changing operating environment with dynamically evolving threats and opportunities.[1]

- Space Enterprise – all organizations contributing to space activities
- Participating organizations – stakeholders including owners, operators, developers
- Operations – spans life cycle from architecting to disposal
- Systems – anything or anyone who produces or processes information
- Data interchange – any mechanism for transferring data and/or information
- Data products exchange– information resulting from processing and/or manipulation
- Distributed computing – systems and services capable of processing and storing data

Adapted from community definition of "Enterprise Integration"



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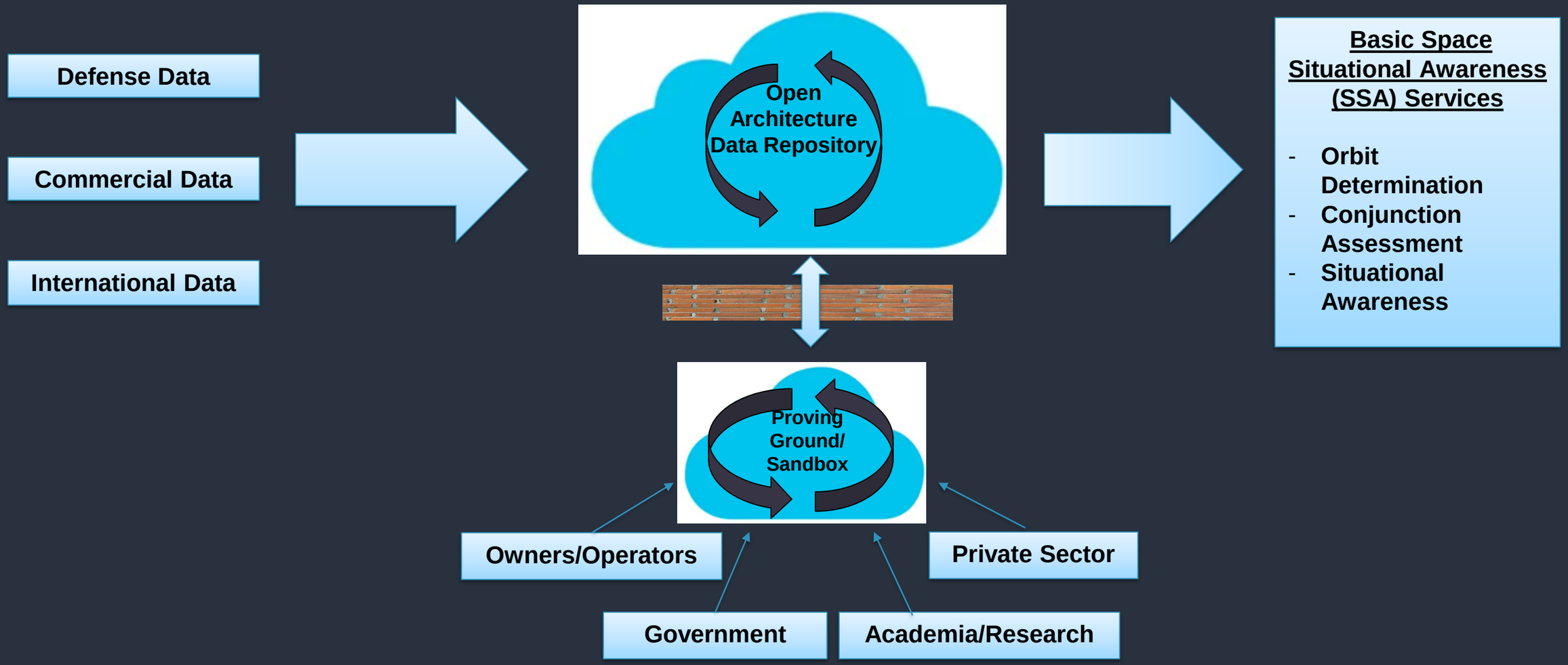
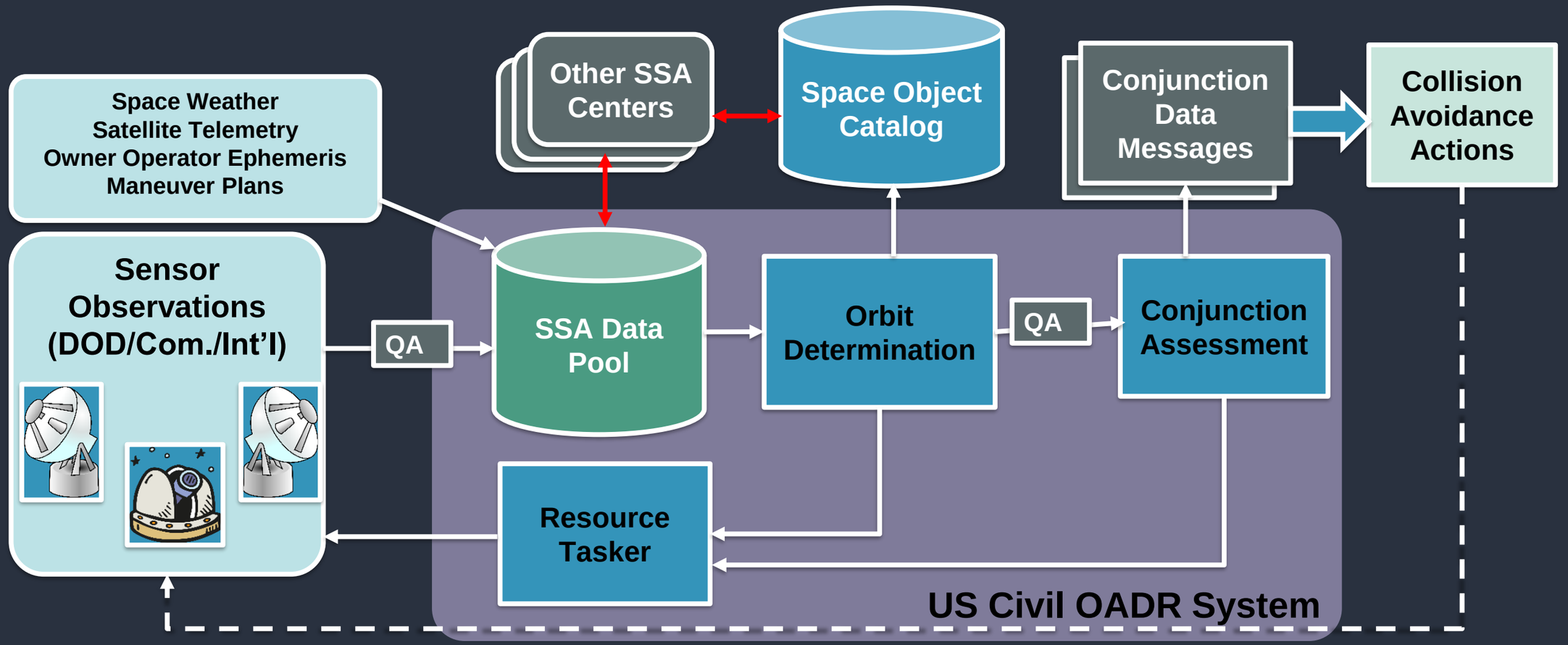
Scott Leonard

Special Advisor to the Director
Office of Space Commerce

OADR Prototype Overview

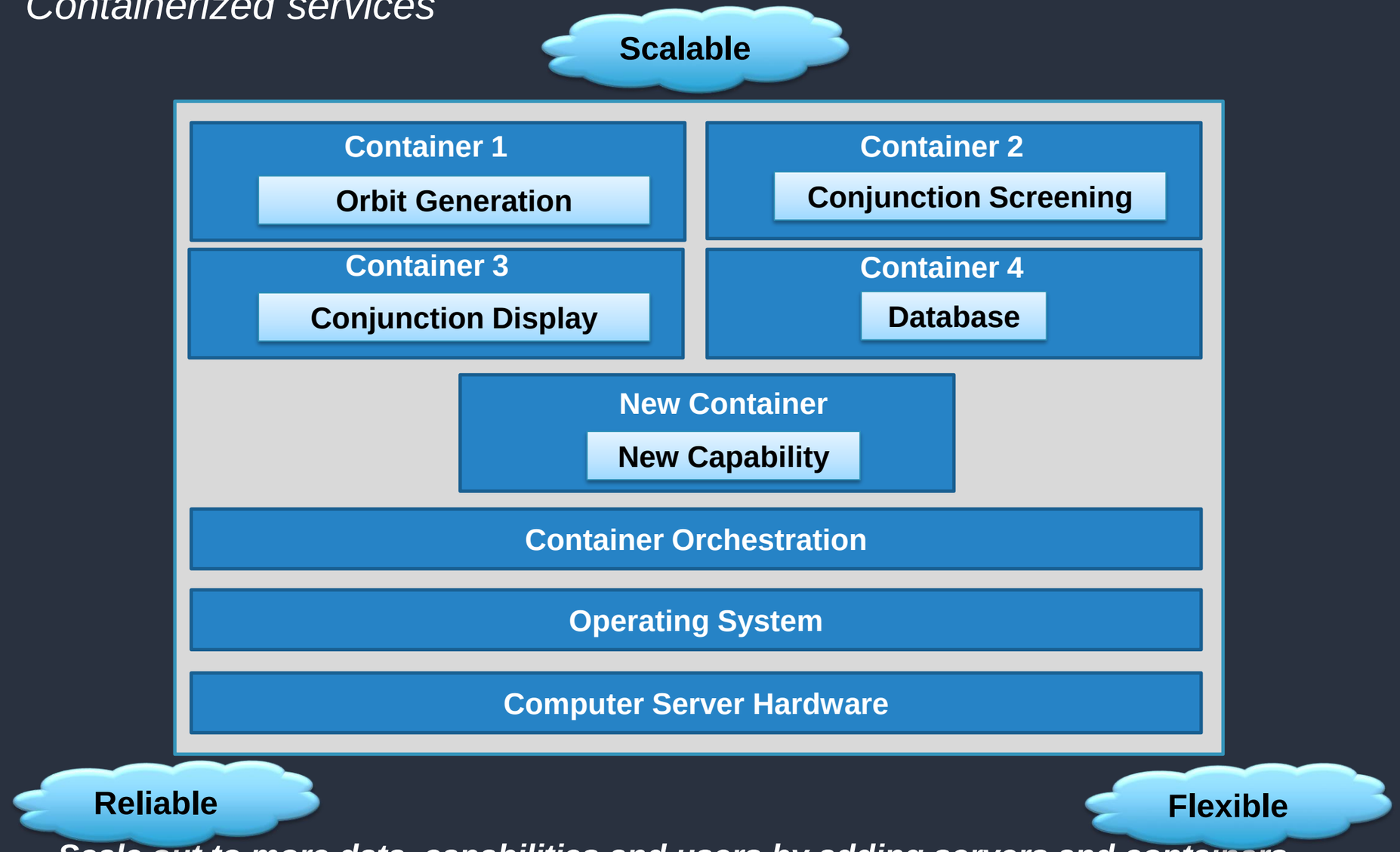


Notional SSA Safety Process



OADR Cloud Software Architecture

Containerized services



Scale out to more data, capabilities and users by adding servers and containers

Advantages of a Containerized Microservice Architecture

Containers package software with libraries and operating system required to execute

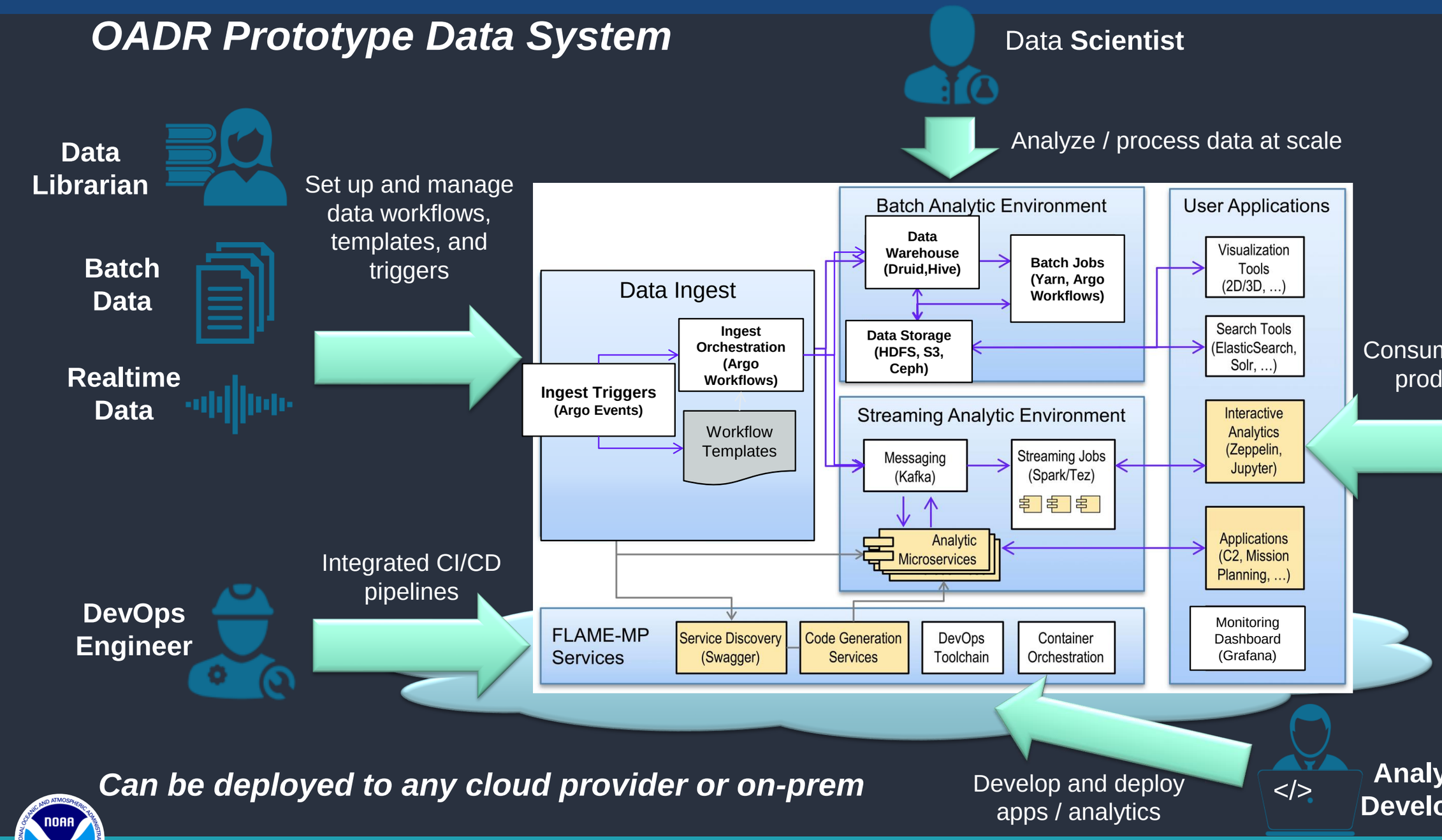
- Portable to any computer
- Efficient
- Allow developers to create and deploy software applications faster
- More secure and reliable
- Avoid cloud vendor lock-in

Microservices break a complex software application into small, specialized services that communicate over a common interface

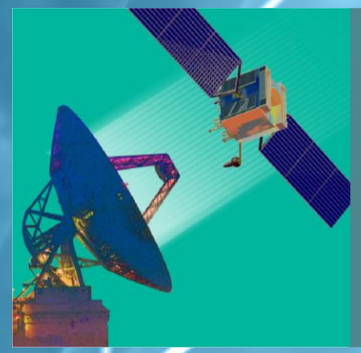
- Can update one part of software without affecting the whole application
- More reliable
- Faster development, testing and deployment

This is the industry standard way to develop modern data systems in the cloud.

OADR Prototype Data System



Can be deployed to any cloud provider or on-prem



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Jeremy Leader

Deputy Director
Cross Mission Ground
and Communications Enterprise
USSF

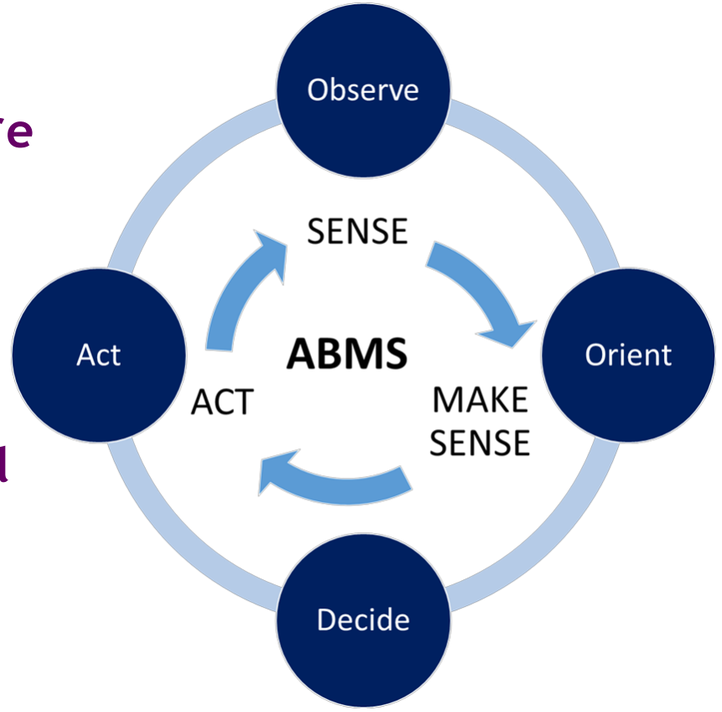
Space Integration with Advanced Battle Management System

February 2022

Maj Christa Schiesswohl
SSC Operating Location Lead
Advanced Battle Management System

Battle Management Infrastructure Problems…and Solutions

Today	Solution
Air-gapped, hard to maintain infrastructure	Resilient, distributed, multi-level security cloud and edge infrastructure
Fragile, unreliable comms	Managed, global transport across all means – commercial and military, ground and pLEO and GEO
Insecure, inaccessible data	Expose data APIs securely on a digital network supported by data tools
No machine-to-machine command and control	Secure digital network for machine enabled JADC2

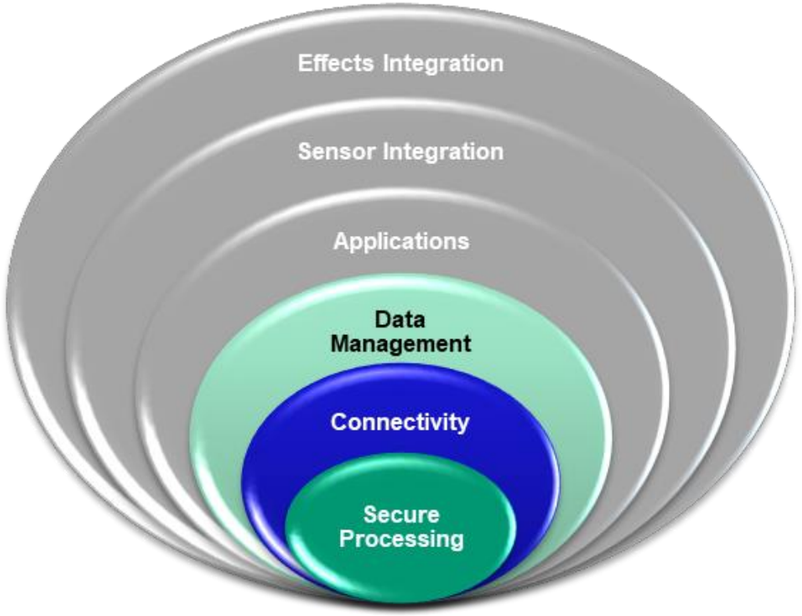


ABMS plans a 21st Century modernization of Battle Management leveraging best-of-breed Commercial technology

ABMS Program Overview

- Create secure military digital network environment leveraging proven digital infrastructure, commercial technologies, and applications
  - Build robust compute, network management, global data footprint for military applications
- Connect the joint force to enable All-Domain dynamic operations
  - Build the digital infrastructure that connects the Joint Warfighting force
  - Enable sharing of information across USAF, USSF, Joint, Allies/partners, and multi-domains
  - Provide decision superiority to tactical, operational, and strategic customers

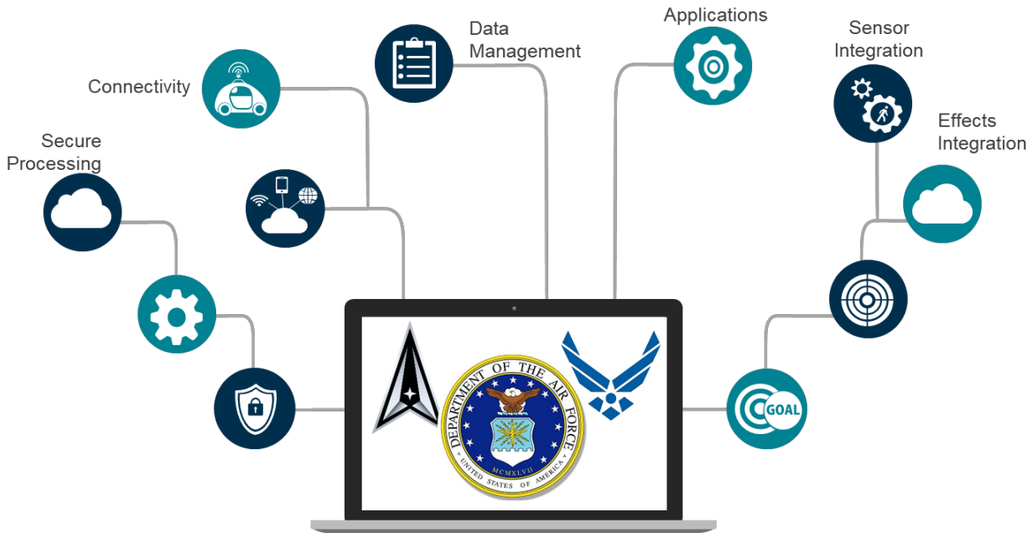
- Attributes to provide 21st Century warfighting capabilities:
  1. *Secure Processing
  2. *Connectivity
  3. *Data Management
  4. Applications
  5. Sensor Integration
  6. Effects Integration



*Digital Infrastructure

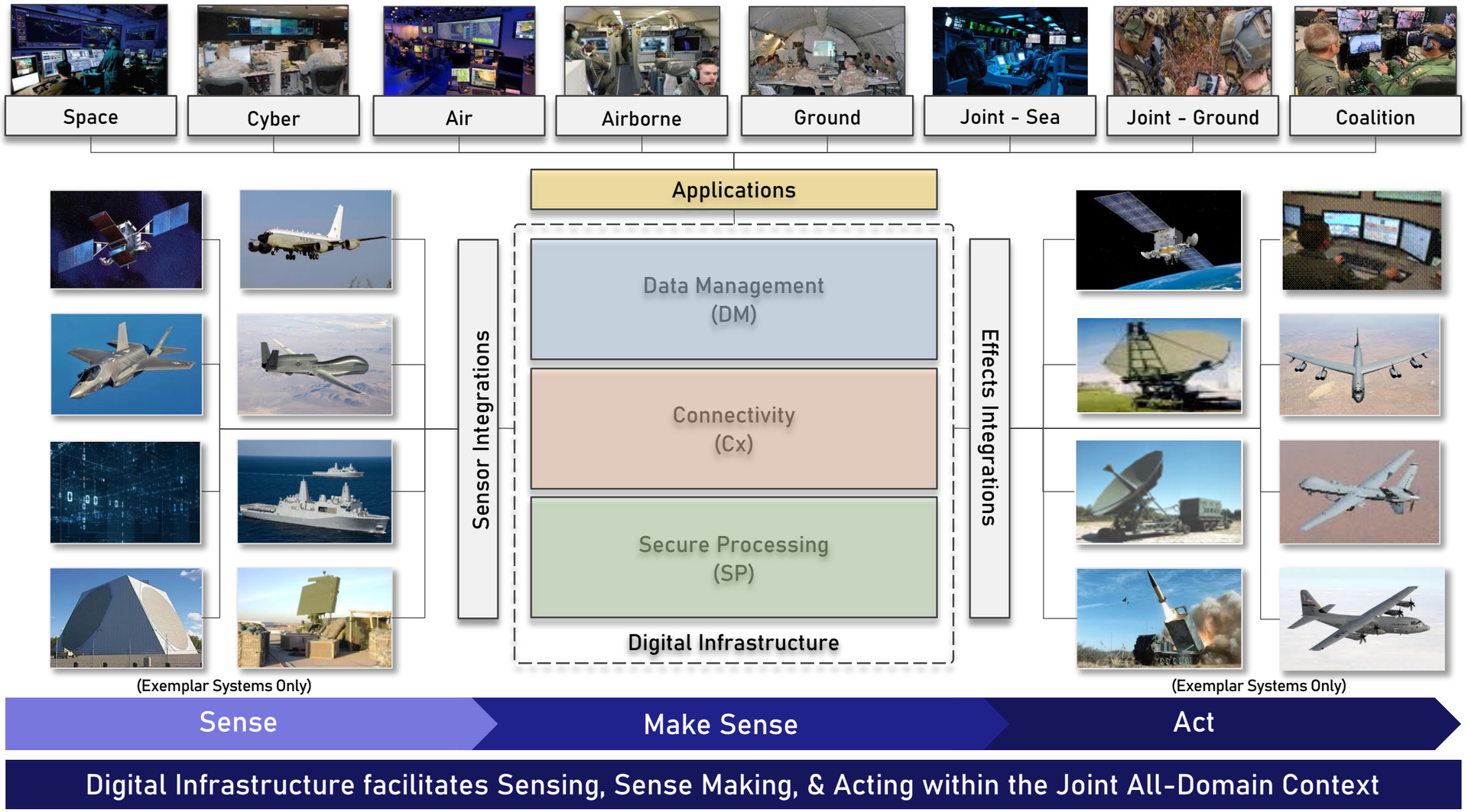
ABMS Acquisitions Attributes

- Secure Processing: Enterprise elastic compute capability that meets all applicable DoD standards for cyber-security, data storage, data transfer and rapid software development
- Connectivity: Secure Network manager intelligently routes data to appropriate user across all domains while managing data across networks
- Data Management: Expose data across Air and Space Force systems in multi-level security cloud infrastructure & leverage service-oriented Application Programming Interfaces (APIs)
- Applications: Create an environment to enable best-of-breed development of Artificial Intelligence (AI) / Machine Learning (ML) applications and services
- Sensor Integration: Standards for integrating existing and future sensor data into a network that provides automated tasking
- Effects Integration: Standards for integrating digital pathways expediting decision to effectors



Acquisition Efforts focused on these attributes build a digital infrastructure enabling information sharing across multi-domains & decision superiority for strategic, operational, and tactical customers

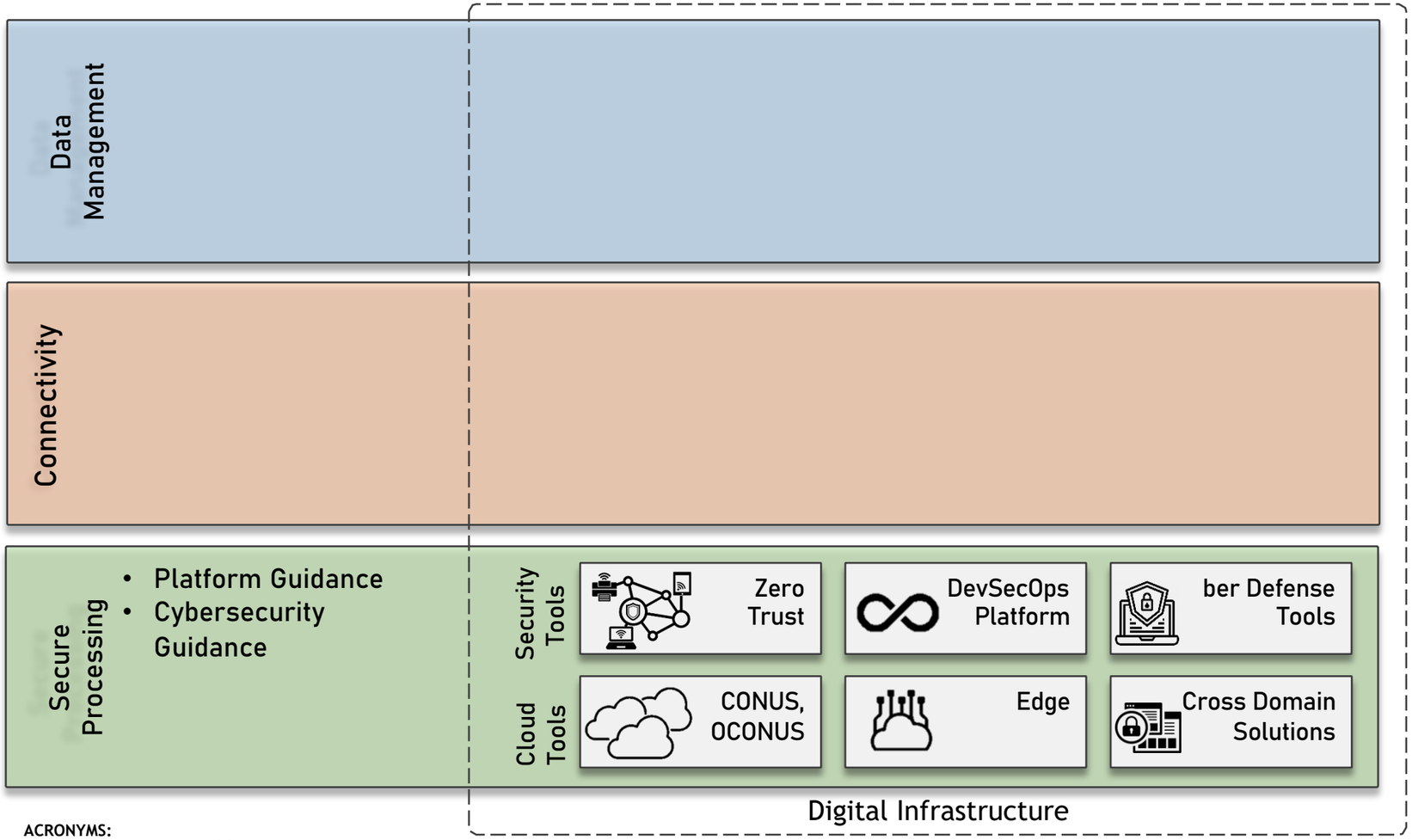
ABMS Architecture



Secure Processing

ABMS Guidance

Reference Architecture



ACRONYMS:
CONUS – Contiguous United States
OCONUS – Outside Contiguous United States

Potential Implementations

KOBAYASHI MARU

- DevSecOps agile development and rapid integration with operations
- Defensive cyber capabilities for space-specific operations

Connectivity

ABMS Guidance

Reference Architecture

Data Management

Connectivity

- Network & Waveform Standards

Transport Links

- Global BM Transport
- Network C2
- QoS Tools
- ftware Skills

Physical

- MILSATCOM
- COMMSATCOM
- Cellular/5G
- TDLs
- Fiber
- SCN

Secure Processing

- Platform Guidance
- Cybersecurity Guidance

Security Tools

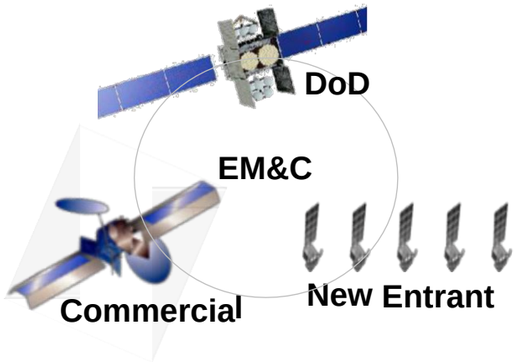
- Zero Trust
- DevSecOps Platform
- ber Defense Tools

Cloud Tools

- CONUS, OCONUS
- Edge
- Cross Domain Solutions

Digital Infrastructure

Potential Implementations



- Enterprise Management and Control (EM&C)
- Advanced DoD waveforms
- Enterprise ground networks

EGS

MESH ONE TERRESTRIAL

ACRONYMS:
API – Application Programming Interface
BM – Battle Management
C2 – Command and Control
CONUS – Contiguous United States
OCONUS – Outside Contiguous United States
QoS – Quality of Service
SCN – Satellite Control Network
TDL – Tactical Datalink

Data Management

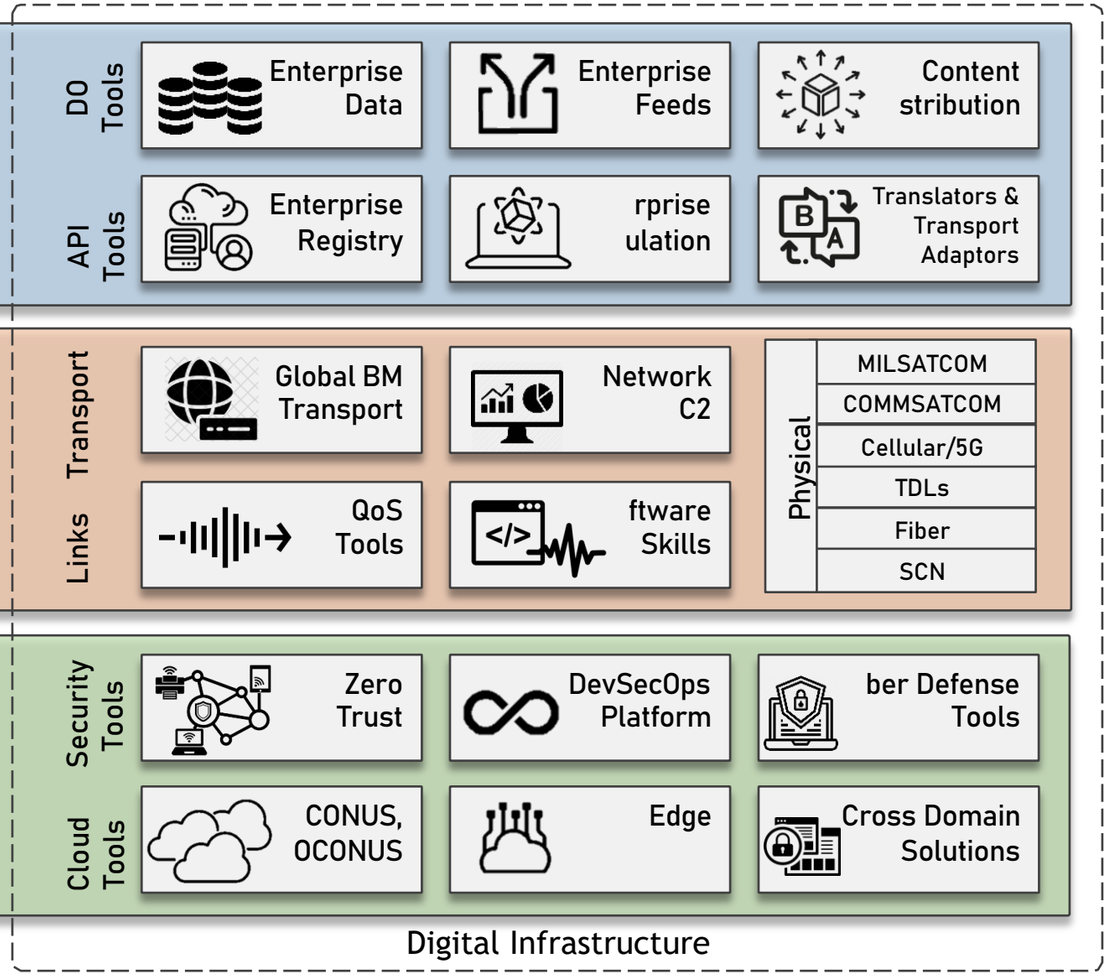
ABMS Guidance

Data Management
- Data Sharing Guidance
- Enterprise Simulation Guidance
- API Style Guide
- Message Standards (UCI…)

Connectivity
- Network & Waveform Standards

Secure Processing
- Platform Guidance
- Cybersecurity Guidance

Reference Architecture



Potential Implementations

Unified Data Library

WARP CORE

§ Single environment to integrate and unify space operational data

ACRONYMS:
API - Application Programming Interface
BM - Battle Management
C2 - Command and Control CDS - Cross-Domain Solution CONUS - Contiguous United States
DO - Data Orchestration
OCONUS - Outside Contiguous United States
QoS - Quality of Service
SCN - Satellite Control Network
TDL - Tactical Datalink
UCI - Universal C2 Interface

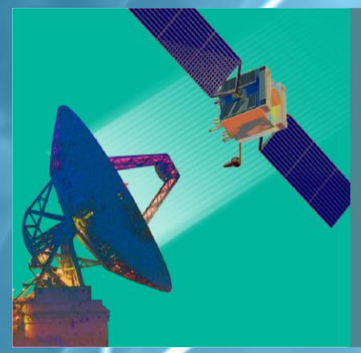
Architecture Principles

- Loosely-couple the System
  - Separate concerns between the layers in order to simplify management and enable simpler tech refresh
- Maintain Options
  - Manage (security, technical, program) risk by maintaining options
  - Manage more than one option at critical functions, where possible
- Own the Baseline
  - Government will own the technical baseline
- Provide Standards and Governance
  - Plan leverage of existing Department of the Air Force standards
    - For example Open Missions Systems and Universal Command and Control Initiative
  - Working with SAF/AQ, Air and Space Staff, Joint Staff, and others on additional emerging guidance

Contact Information

Thank you!

SSC Operating Location Lead
Advanced Battle Management System
Maj Christa Schiesswohl
christa.schiesswohl@spaceforce.mil



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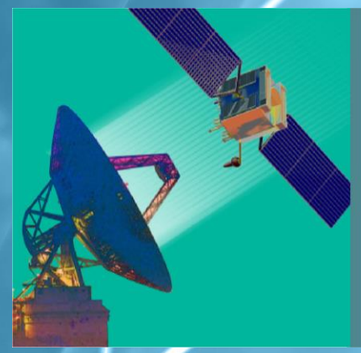
Dr. David Spencer

The Aerospace Corporation



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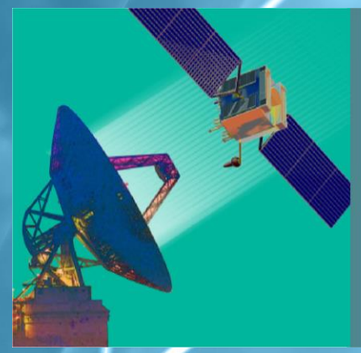
Break



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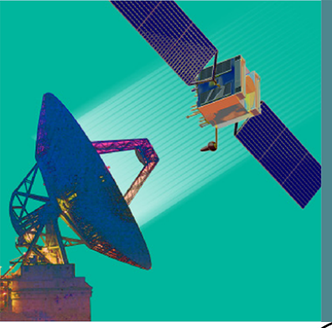
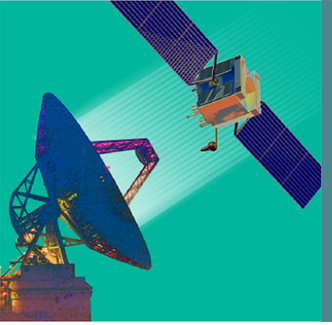
Q & A



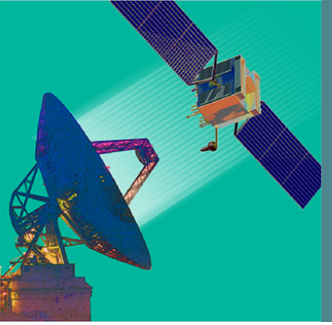
Town Hall Discussion

	Advancing Space Traffic Coordination (STC)	Integrating Space for Advanced Battle Management System (ABMS)	Developing the Cislunar Neighborhood
Digital Integration (Digital Engineering, Digital Threads, Digital Twins)	- Standards for tracking, position data - Integration of a diversity of data for improved accuracy - Space weather data to improve atmospheric density models - Astronomy community brings in a lot of valid data - Interoperability gets harder and harder at scale - Must balance interoperability and agility - Walk, jog, run approach - the first step is to modernize systems - Backward compatibility in the face of changing standards – “Tricking the TLE”	- Machine to machine interfaces - Digital integration in acquisitions - have to get the infrastructure right, systems need to be interoperable - Digital needs to be “Baked in vs. bolted on” - DoD Imperative: get ABMS right - Systems that we build terrestrially must support space - NASA’s Handbook for digital engineering acquisition is available as a reference - Digital engineering and especially digital twins are great “proving grounds” for missions that cannot tolerate risk	- Digital integration is going to happen whether we coordinate or not - do we want to repeat our historical mistakes? - Good models evolve, like gravity models for the earth and moon - tarted with a 4x4 gravity model for the moon; now we have a 12x12 gravity model for the moon - Should there be a model / digital twin of the cislunar neighborhood?
Operational Test (In-space Testbeds and Proving Grounds)	- Need for sandboxes, proving grounds for algorithms - Dual use technologies to test things out - Laser calibration satellites are an example of in-space testbeds; what’s next? - Need meaningful data and insight – testing ground should not just be just a playground with no path to operations - Containerization is an enabler of operational test - can run a lot of things in parallel without perturbing operational software	- What does “practicing a war” look like? - Need known tracking / known information to test out capabilities - Autotracking and priorities management: how to figure out which resource gets what? - Demonstrations are great, but what capabilities are left behind? - Dual-use capability can be enabling, and also risky - The “need for speed”, containerization, DevSecOps is opening up the aperture and giving the USSF the ability to turn requirements quickly – but there still a lot of risk aversion	- Stable (or quasi-stable) locations in the cislunar regime could be use for testing and experimentation before moving on to become commerce nodes, waypoints - What IS the cislunar neighborhood? Libration points, L1, L2, orbits that orbit those points. In orbit around the moon, down to the surface of the moon. Transit areas. - What infrastructure should we create at these critical points? - Navigation beacons, GPS, communication relays, “SNIPSAT” recycling satellite - Capstone small satellite testing elliptical lunar orbits - Need to operate in these arenas to improve our models and standards - NASA sees the ISS and the moon as testbed for going to Mars
Data Fusion (AI/ML, Authoritative Sources of Truth)	- Need for more data but not just ANY data; Need a DIVERSITY of data - Trusted data and understanding the provenance of data - Need a more modern system, and an understanding of what services we will provide – or not provide - The role of government vs. industry: basic services provided by the government, leveraging the rest of the industry for additional services - Lots of adaptability and agility in commercial - Need to identify the areas where the government can fund commercial	- We think “the more data, the better,” but sometimes more data increases uncertainty and makes it harder to find the needle in the haystack - Need to get information fast enough to be impactful, but not always possible to evaluate the veracity of the data in real time - Building trust over time is in tension with the desire for “right now” - Must also accept that there are data sources that are NOT helpful - Make data discoverable! People need to know where to get the data - Push / pull problem: some people know what they are looking for, some don’t. How do we curate and tag data? - Systems need to be able to ingest multiple formats, but at some point, you must set standards - People are connecting dots now; maybe AI / ML connects the dots for us in the future. - Articulation of needs for commercial, international partnerships: e.g, “we need data in the southern hemisphere” - Classification remains a challenge	- Need for a “basis” coordinate system in space, and other standards - Groups are studying the projected increase in cislunar traffic over the next ten years - Diversity of data – is this a problem here too? - Do we need tracking on the moon, like we need tracking below the equator? - We need computing, data storage on the moon - The bandwidth needed to transmit data back and forth is limiting



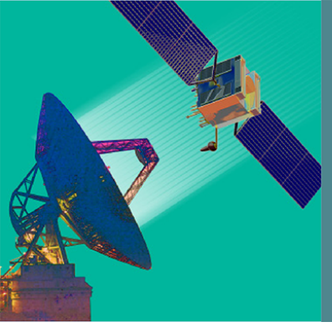
Town Hall Discussion
Big Take-Aways and Cross-Cutting Thoughts

- Data is needed, but what we really need is data diversity, quality, and better discovery; we also need to better articulate our data needs
- Standards can be enabling – or they can be obstacles
  - *We need to be cautious developing standards, but also recognize the disadvantages of indecision*
  - *Standards are easier to follow if set in advance, but it's harder to know in advance what will be successful*
  - *Standards need to evolve*
- We need affordable test, and our current technology allows for affordable test in space
  - *Use test beds to identify truly usable data*
  - *Force a demonstration of added value, versus a presumption of added value*



Town Hall Discussion
Big Take-Aways and Cross-Cutting Thoughts

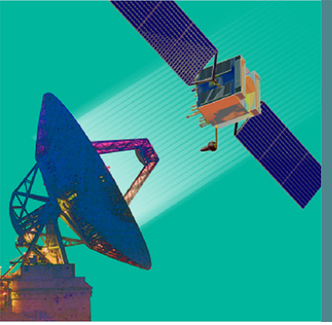
- If there is a commercial market, someone will meet that demand
  - *Government can provide infrastructure*
  - *GPS example teaches us that we can't always foresee what government investment will enable*
- Need to create a long-term plan for the design and deployment of the needed XGEO infrastructure to enable new ventures
- A lot of opportunity out there that hasn't been recognized – government investment could pay dividends.
  - *We are at the edge of an ability to really innovate*
  - *Government is on board with space, and space is a bipartisan issue.*



Town Hall Discussion
Space Traffic Coordination

- Digital Integration (Digital Engineering, Digital Threads, Digital Twins)
  - *Standards for tracking, position data*
  - *Integration of a diversity of data for improved accuracy*
  - *Space weather data to improve atmospheric density models*
  - *Astronomy community brings in a lot of valid data*
  - *Interoperability gets harder and harder at scale*
  - *Must balance interoperability and agility*
  - *Walk, jog, run approach - the first step is to modernize systems*
  - *The "TLE Story"*
    - Backward compatibility in the face of changing standards
    - "Tricking the TLE" to improve accuracy without changing format

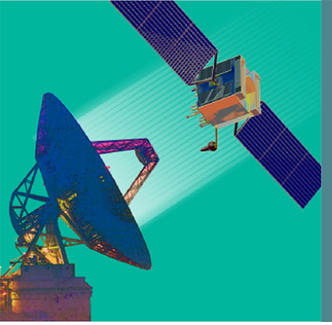
Standards are needed for interoperability, but we must balance interoperability and agility



Town Hall Discussion
Space Traffic Coordination

- Operational Test (In-space Testbeds and Proving Grounds)
  - *Need for sandboxes, proving grounds for algorithms*
  - *Dual use technologies to test things out*
  - *Laser calibration satellites are an example of in-space testbeds; what's next?*
  - *Need meaningful data and insight – testing ground should not just be just a playground with no path to operations*
  - *Containerization is an enabler of operational test - can run a lot of things in parallel without perturbing operational software*

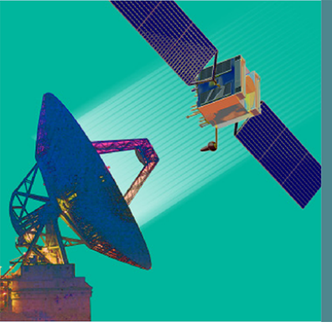
Sandboxes and containerization let us to try out new things safely, but "new things" must have a path to operations



Town Hall Discussion
Space Traffic Coordination

- Data Fusion (AI/ML, Authoritative Sources of Truth)
  - *Need for more data but not just ANY data*
    - Need a DIVERSITY of data (example of tracking stations below the equator)
    - Don’t need 100 observations – prefer five quality observations across the entire orbit
  - *Trusted data and understanding the provenance of data*
  - *Need a more modern system, and an understanding of what services we will provide – or not provide*
  - *The role of government vs. industry*
    - Basic services provided by the government
    - Leveraging the rest of the industry for additional services
    - Lots of adaptability and agility in commercial
  - *Need to identify the areas where the government can fund commercial*

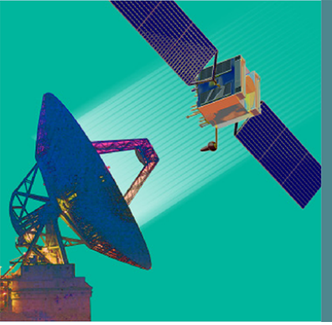
Diversity and quality of data is what drives accuracy, not just quantity; must articulate needs to industry



Town Hall Discussion
Integrating Space for Advanced Battle Management System (ABMS)

- Digital Integration (Digital Engineering, Digital Threads, Digital Twins)
  - *Machine to machine interfaces*
  - *Digital integration in acquisitions*
    - Have to get the infrastructure right
    - Systems need to be interoperable
    - “Baked in vs. bolted on”
  - *DoD Imperative: get ABMS right*
  - *Systems that we build terrestrially must support space*
  - *NASA’s Handbook for digital engineering acquisition is available as a reference*
  - *Digital engineering and especially digital twins are great “proving grounds” for missions that cannot tolerate risk*

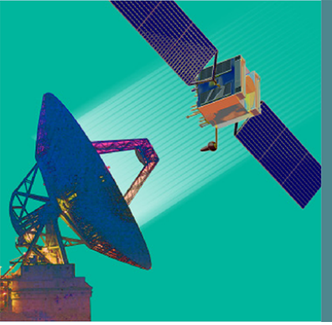
Infrastructure to support digital integration needs to be baked in, not bolted on



Town Hall Discussion
Integrating Space for Advanced Battle Management System (ABMS)

- Operational Test (In-space Testbeds and Proving Grounds)
  - *What does "practicing a war" look like?*
  - *Need known tracking / known information to test out capabilities*
  - *Autotracking and priorities management: how to figure out which resource gets what?*
  - *Demonstrations are great, but what capabilities are left behind?*
  - *Dual-use capability can be enabling, and also risky*
  - *Is the USSF losing momentum on technical issues?*
    - Not necessarily; the "need for speed" is opening up the aperture
    - Containerization, DevSecOps is giving the USSF the ability to turn requirements quickly – but there still a lot of risk aversion
  - *Space C2, cloud combat control are related fields*

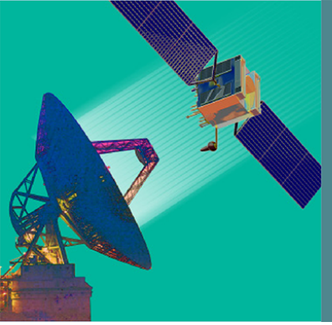
What does "practicing a war" look like?



Town Hall Discussion
Integrating Space for Advanced Battle Management System (ABMS)

- Data Fusion (AI/ML, Authoritative Sources of Truth)
  - *We think "the more data, the better," but sometimes more data increases uncertainty and makes it harder to find the needle in the haystack*
  - *Need to get information fast enough to be impactful*
    - But not always possible to evaluate the veracity of the data in real time
    - Building trust over time is in tension with the desire for "right now"
  - *Must also accept that there are data sources that are NOT helpful*
  - *Make data discoverable!*
    - People need to know where to get the data
    - Push / pull problem: some people know what they are looking for, some don't
    - How do we curate and tag data?

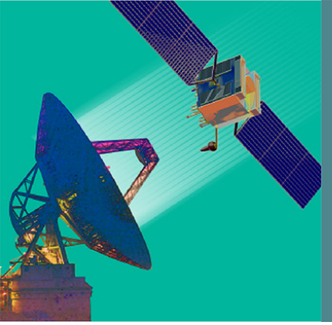
We need to make data discoverable, but more data isn't always better



Town Hall Discussion
Integrating Space for Advanced Battle Management System (ABMS)

- Data Fusion (AI/ML, Authoritative Sources of Truth) (cont.)
  - *Systems need to be able to ingest multiple formats, but at some point, you must set standards*
  - *People are connecting dots now; maybe AI / ML may connect the dots for us in the future.*
  - *Need to better articulate needs for commercial, international partnerships: e.g, "we need data in the southern hemisphere"*
  - *Classification remains a challenge*

We need to articulate our data needs more clearly

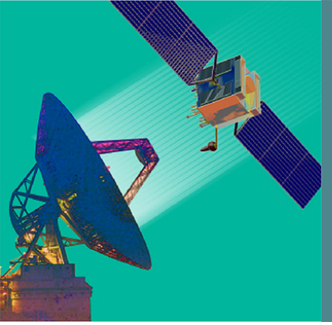


Town Hall Discussion

Developing the Cislunar Neighborhood

- Digital Integration (Digital Engineering, Digital Threads, Digital Twins)
  - *Digital integration is going to happen whether we coordinate or not - do we want to repeat our historical mistakes?*
  - *Good models evolve*
    - Like gravity models for the earth and moon
    - Started with a 4x4 gravity model for the moon; now we have a 12x12 gravity model for the moon
  - *Should there be a model / digital twin of the cislunar neighborhood?*

What does the digital model of the cislunar environment look like, and how does it evolve?

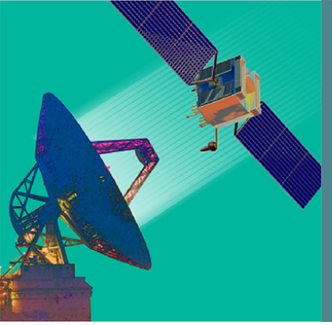


Town Hall Discussion

Developing the Cislunar Neighborhood

- Operational Test (In-space Testbeds and Proving Grounds)
  - *Stable (or quasi-stable) locations in the cislunar regime could be use for testing and experimentation before moving on to become commerce nodes, waypoints*
  - *What IS the cislunar neighborhood?*
    - Libration points, L1, L2, orbits that orbit those points.
    - In orbit around the moon, down to the surface of the moon
    - Transit areas
  - *What infrastructure should we create at these critical points?*
    - Navigation beacons, GPS, communication relays
    - “SNIPSAT” recycling satellite

What infrastructure is needed for the cislunar neighborhood, and how can we develop it?

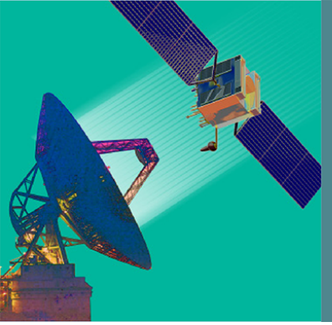


Town Hall Discussion

Developing the Cislunar Neighborhood

- Operational Test (In-space Testbeds and Proving Grounds) (cont.)
  - *Capstone small satellite testing elliptical lunar orbits*
    - Similar trajectories to NASA Gateway
    - Understanding the realities.
  - *Need to operate in these arenas to improve our models and standards*
  - *NASA sees the ISS and the moon as testbed for going to Mars*

In our current age, we have the ability to do low-cost test in space

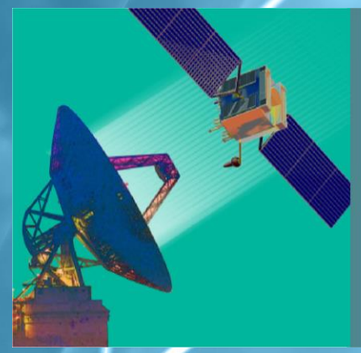


Town Hall Discussion

Developing the Cislunar Neighborhood

- Data Fusion (AI/ML, Authoritative Sources of Truth)
  - *Need for a "basis" coordinate system in space, and other standards*
  - *Groups are studying the projected increase in cislunar traffic over the next ten years*
  - *Diversity of data – is this a problem here too?*
    - Do we need tracking on the moon, like we need tracking below the equator?
    - We need computing, data storage on the moon
    - The bandwidth needed to transmit data back and forth is limiting

Standards and infrastructure are needed



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Thank you