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A Broader Look at Dynamic Space Operations:
Imposing Multi-Dimensional Dilemmas on Adversaries

Col Charles S. Galbreath, USSF (ret)

Calls for Change

AFA Warfare Symposium, 2021

"And, as a combatant commander, I won't support the development any further of ***large, big, fat, juicy targets****. I won't support that.* ***We are going to go down a different path****. And we have to go down that path quickly."*

– General John Hyten
Commander, U.S. Strategic Command
2017


Mitchell Institute's Schriever Spacepower Series 2024

*"****There is a lot implied when we start to unpack what we need to conduct dynamic space operations****, whether it is on-orbit refueling, on-orbit maintenance, responsive launch, or other ways to achieve sustained maneuver and in-domain logistics on orbit."*

– General Stephen Whiting
Commander, U.S. Space Command
2024

Failure to execute more dynamic space operations puts all future military operations at risk

THREAT: China is Advancing at an Alarming Rate

- **Space Domain Awareness**
  - Increasingly capable global network of sensors can track Geosynchronous Space Situational Awareness Program (GSSAP) satellites—the most frequently maneuvered USSF satellites
  - They can find, fix, track, and target any U.S. or Allied satellite
- **Counterspace Weapons**
  - Adding to their already large stockpiles and methods
- **Use of Space**
  - Consistently increasing launch rate and number of satellites on orbit
  - Numerous intelligence, surveillance, and reconnaissance (ISR) satellites, creating a kill-web to extend their anti-access and area denial ability
- **On Orbit**
  - SJ-21 has demonstrated grabbing and repositioning a satellite
  - Demonstrated multi-satellite “dogfighting”
  - In 2025, performed on-orbit refueling extending the mission performance of SJ-21

Threats and risks are increasing

RISK: Existing U.S. Architecture Based on an Outdated Assumption

- **Orbital**
  - Bespoke satellite placed in specific orbits, where they remain unchanged until end of life
  - **Our s**
- **Terrest**
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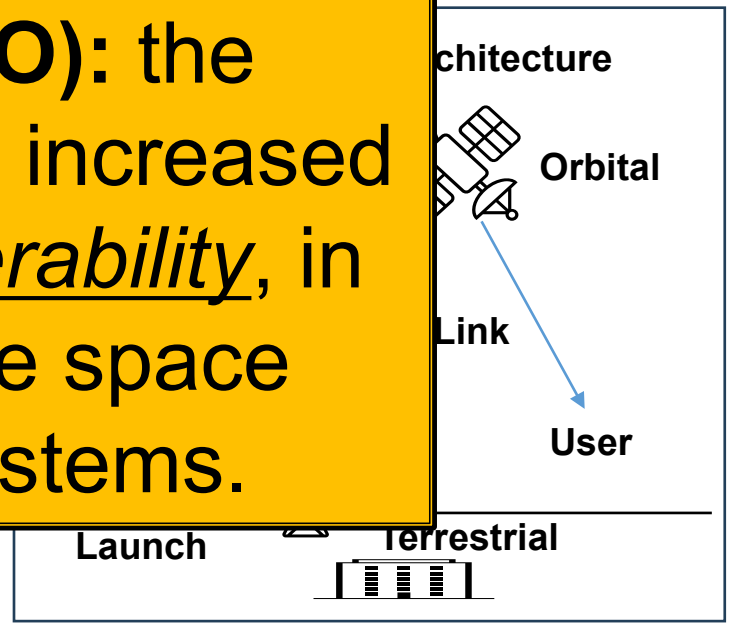
    anter
  - **Limit**
- **Link**
  - Well
  - **Can b**
- **Launch**
  - Scheduled months/years in advance from two primary locations
  - **Limits access to space and is susceptible to attack and natural disaster**

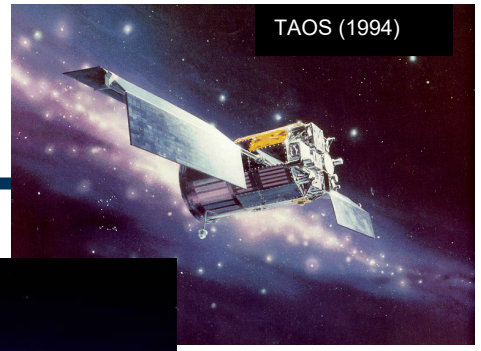
Dynamic Space Operations (DSO): the employment of methods that leverage increased *versatility*, *adaptability*, and *maneuverability*, in physical space and spectrum, of the space architecture and its component systems.

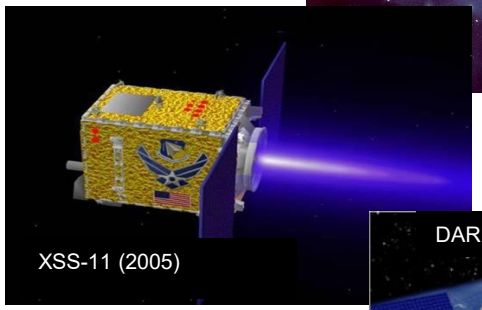


Predictability Creates Vulnerability

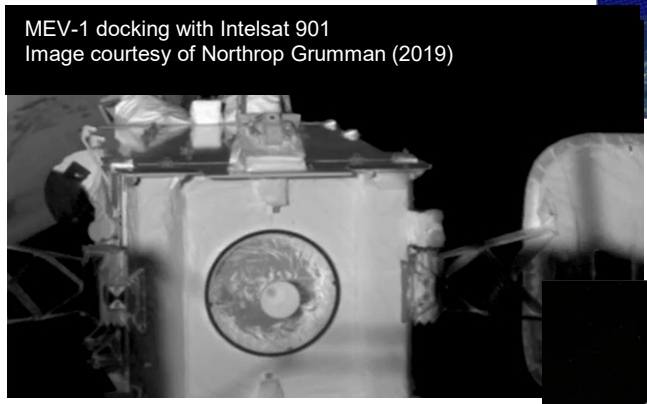
Orbital Segment: Increasing Maneuver

- **Autonomy, Rendezvous, and Refueling pave the way to DSO**
  - Decades of demonstrations have matured the technology
  - Refueling enables more frequent and larger maneuvers
  - Pre-emptive maneuvers can complicate adversary tracking and targeting
  - GSSAP replacement to be refuelable
- **Alternative Propulsion**
  - Nuclear thermal, electric, and plasma can increase maneuverability
  - Must consider thrust, Δv, and technical maturity


TAOS (1994)


XSS-11 (2005)


DARPA's Orbital Express (2007)


MEV-1 docking with Intelsat 901
Image courtesy of Northrop Grumman (2019)


GAS-T (2027)
Image courtesy of Northrop Grumman

Refueling technology is mature and ready for operations
More development needed to mature alternate propulsion

Orbital Segment: Increasing Flexibility and Adaptability

- **Modularity**
  - "Plug and play" approaches, like X-37 and ROOSTER, can increase operational flexibility and adaptability
  - Enables repair, upgrade, or change to mission performance
- **In Space Servicing, Assembly, and Manufacturing (ISAM)**
  - Construct, upgrade, enhance, and repair satellites on orbit to complicate adversary understanding
  - Can build satellites on orbit not limited by launch constraints
- **Software Reprogrammability**
  - Adjusting waveforms and software can change/add capabilities on a satellite
  - Can alter mission performance and type of mission

John Grunfeld and Richard M. Linnehan, STS-109, servicing the Near-Infrared Camera and Multi-Object Spectrometer (NICMOS) on the Hubble Space Telescope (NASA)

ESPAStar as an earlier version of Rapid On-Orbit Space Technology Evaluation Ring (ROOSTER) program
Image courtesy of Northrop Grumman

Increasing flexibility and adaptability can help achieve surprise and seize the initiative

Terrestrial Segment: Increasing Maneuver and Flexibility

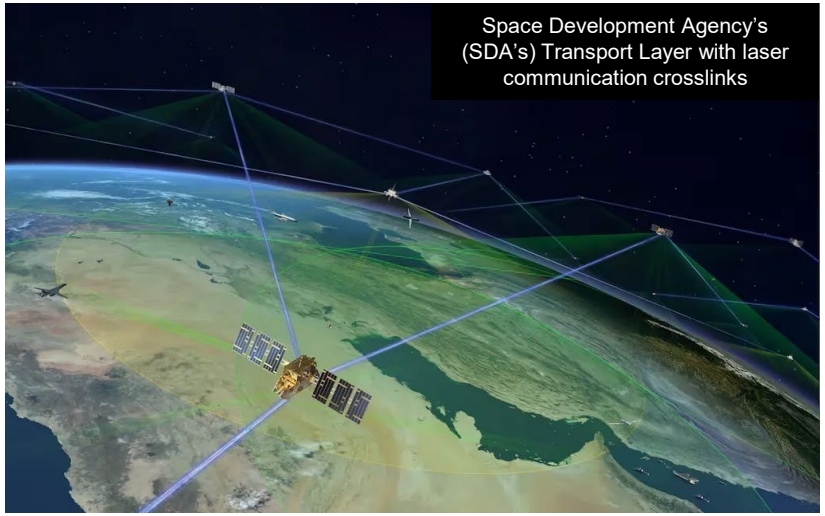
- **Web-based Command and Control (C2)**
  - Demonstrated with Rapid Resilient Command and Control (R2C2)
  - Can increase the resilience of satellite C2 by enabling Guardians to operate from more locations
- **Phased Array Antennas**
  - Demonstrated by Satellite Communications Augmentation Resource (SCAR)
  - Enables transportable, electronically steerable connectivity to multiple satellites simultaneously
- **Mobile Ground Stations**
  - Nuclear Command, Control, and Communications and missile warning use mobile terminals to increase resiliency
  - Leveraging web-based C2, phased array antennas, and global high-speed communications can expand this to new missions

Mobile Ground System (MGS) photo from 137th Space Warning Squadron (2013)

Augment existing C2 with dynamic and mobile options to increase resiliency

Link Segment: Increasing Flexibility and Security

- **Frequency Hopping**
  - Used since World War 2 to provide secure, jam-resistant communications
  - Expanded use can provide augmented security
- **Path Agnostic Connectivity**
  - Proliferation in Low Earth Orbit (LEO) creates multiple pathways to connect operators, satellites, and end-users
- **Laser Crosslinks**
  - More secure than Radio Frequency communication and with greater bandwidth
  - Space-to-Space, Space-to-Ground, and Space-to-Aircraft have already been demonstrated



Space Development Agency's (SDA's) Transport Layer with laser communication crosslinks

Sep 2025--General Atomics and Kepler Communications successfully demonstrate air-to-space optical communications capability for SDA

Dynamic links increase resiliency, security, and effectiveness

Launch Segment: DSO Begins with Dynamic Launch

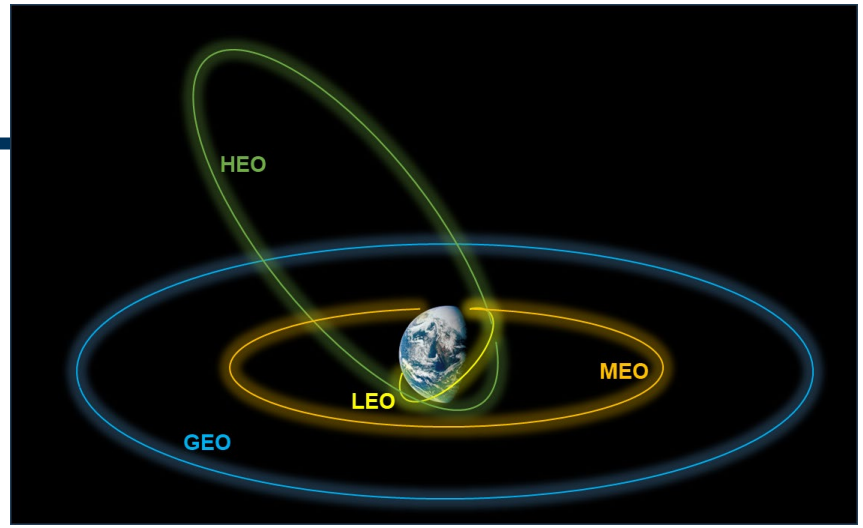
- **Dynamic Manifest Planning**
  - The increasing launch cadence and standardized buses create opportunities to re-manifest more dynamically
  - Enables swap of payloads to support operational needs or launch from different locations
- **Launch Site Diversification**
  - Increasing options within the United States and internationally
  - Adds resilience and flexibility
- **Launch Vehicle Diversification**
  - Increasing launch vehicle diversity decreases the consequence of failures or delays
  - Increasing use of small boosters and emerging potential for super heavy boosters expands options to access space

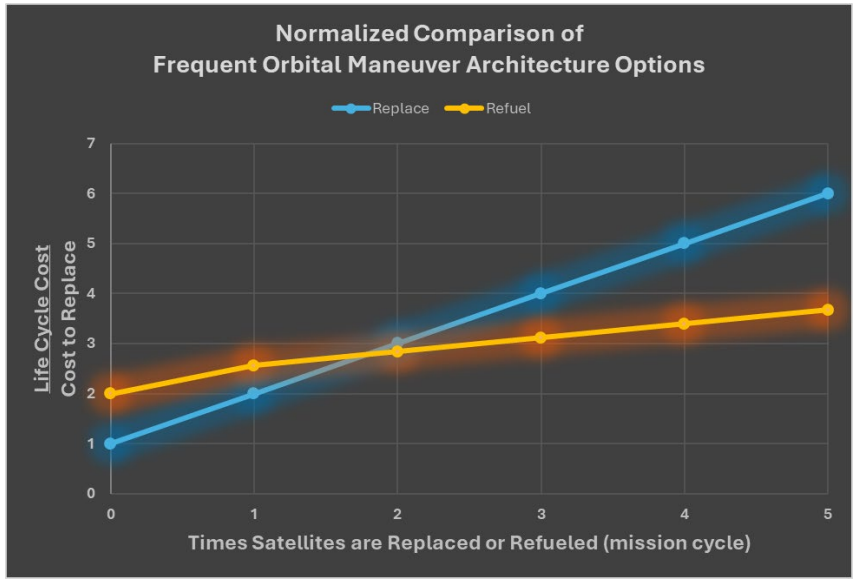
Victus Nox Tactically Responsive Space (TacRS) demonstration 2023

Dynamic launch operations assure access to space and decrease vulnerabilities

Planning Factors

- **Missions**
  - All missions can utilize aspects of DSO, but few will require all
  - Offensive and Defensive Space Control and ISR are most viable for broad application
- **Orbital Regimes**
  - Different orbits will be better suited for different DSO approaches
- **Resupply or Disposal**
  - The orbit and mission impact whether DSO through resupply or disposal is more appropriate
- **Supply Chains and Costs**
  - DSO approaches have different cost implications
  - Initial costs to transform architecture will be overcome with decreased sustainment costs

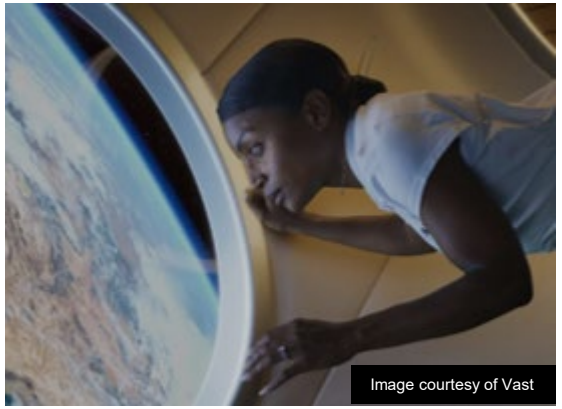




Planners must understand where and how to apply DSO

Strategic Considerations

- **Chicken and the Egg**
  - Space system developers are waiting for government, while government is waiting for a commercial logistics infrastructure to mature
  - A bold decision is needed
- **Organizational Alignments**
  - On-orbit logistics does not currently exist
  - USSF organization and presentation of forces to U.S. Space Command will need to evolve
- **Roles for Crewed Missions**
  - Human adaptability has been proven time and again in space
  - Astronaut Guardians might execute missions that cannot be accomplished through remote operations



Decisions must be made today with an eye for the future

Recommendations (1 of 2)

Orbital Segment

- Design and field an on-orbit logistics infrastructure
- Procure a refuelable and ideally modular GSSAP replacement
- Operationalize flexible systems like X-37B and ROOSTER
- Pursue in-space assembly
- Operationalize software reprogrammability

Terrestrial Segment

- Advance and scale application of web-based C2
- Expand use of phased array antennas
- Invest in capabilities to exploit mobile C2 of satellites

Link Segment

- Expand employment of frequency hopping
- Build a network of laser communication satellites and create a path agnostic web

Launch Segment

- Use standardized satellite buses and form factors
- Increase launch site and launch vehicle diversification

Recommendations (2 of 2)

Overarching and Enabling

- U.S. Space Command must continue to demand flexible operational capabilities
- The Space Force should embrace the opportunities of a dynamic space architecture and on-orbit logistics in their 15-year plan
- Congress must provide reliable funding growth to operationalize what has been demonstrated
- The Space Force should continue to invest in basic and applied research
- The Space Force should establish a program office focused on in-space logistics infrastructure

Conclusions

- Space is a warfighting domain and China wants to be the world's preeminent space power
- Traditional space operations are predictable, static, and vulnerable
- Technology is mature and ready to change space operations
- By applying DSO, the United States can improve resilience and effectiveness
- All elements of the U.S. space architecture can benefit from DSO
- Taking these steps will help preserve space superiority for the United States

The race for space logistics and dynamic space operations is here

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