Tech Brief:
Hardening the Constellation: Protecting Smallsats in Contested Space

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Introduction:
Contested Space, Russia as the Spoiler in LEO Operations

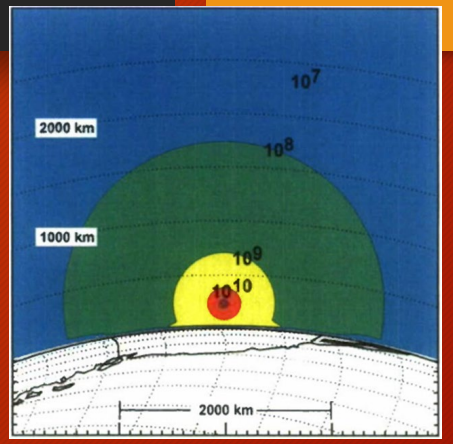
For the Second time in less than 3 years, Russia has threatened the development and use of “Mass Disruption LEO Weapons:

- 2024 US intelligence surmises Russia is building a High Altitude EMP (HEMP) Weapon: creating both immediate blast effects and long-term radiation belt pumping
- In December 2025, a second intelligence inquiry found Russia is developing a “Zone Effect” LEO Weapon to flood a specific orbital plane with hundreds of thousands of small, high-density pellets.

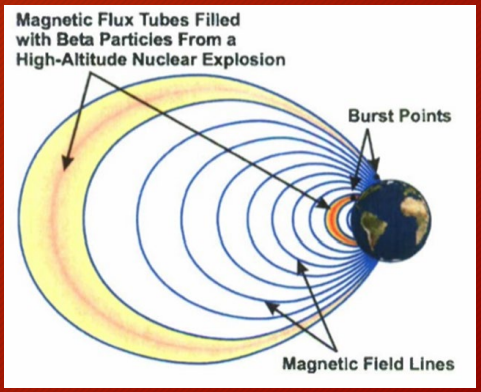
Why use such an indiscriminate weapon?

- Russia has failed to successfully jam/disrupt Starlink – critical to the Ukraine War
- Russia has little to lose as its space program falls further and further behind the US, China, and soon, New Zealand

It’s all a bluff –typical of President Putin’s “Puffery” – yet if pushed to the brink, use of such weapons is a possible



Delayed Gamma Radiation from a 1 Mt 200 Km altitude HEMP blast



"Pumped Belts" of captured beta particles from HEMP burst

SPACE, Contested or Crowded?

It makes no difference if it impacts Satellite Requirements

- Sheer volume of Satellites in LEO creates a “self-contested” environment
- US Space Force tracks **49,700** objects
  - 12,400 active payloads
  - 16,900 analyst objects (till identified)
  - 20,400 debris
- Space Situational awareness and space vehicle mobility: Minimum Capability
  - SpaceX performed 293,100 collision avoidance maneuvers in 2025
  - A maneuver every 1.8 minutes, 4 per satellite per month
- “Fun Fact”: Every China Long March 3 Launch creates even more space debris
  - The spent upper stage
  - A few hundred smaller debris fragments in orbit

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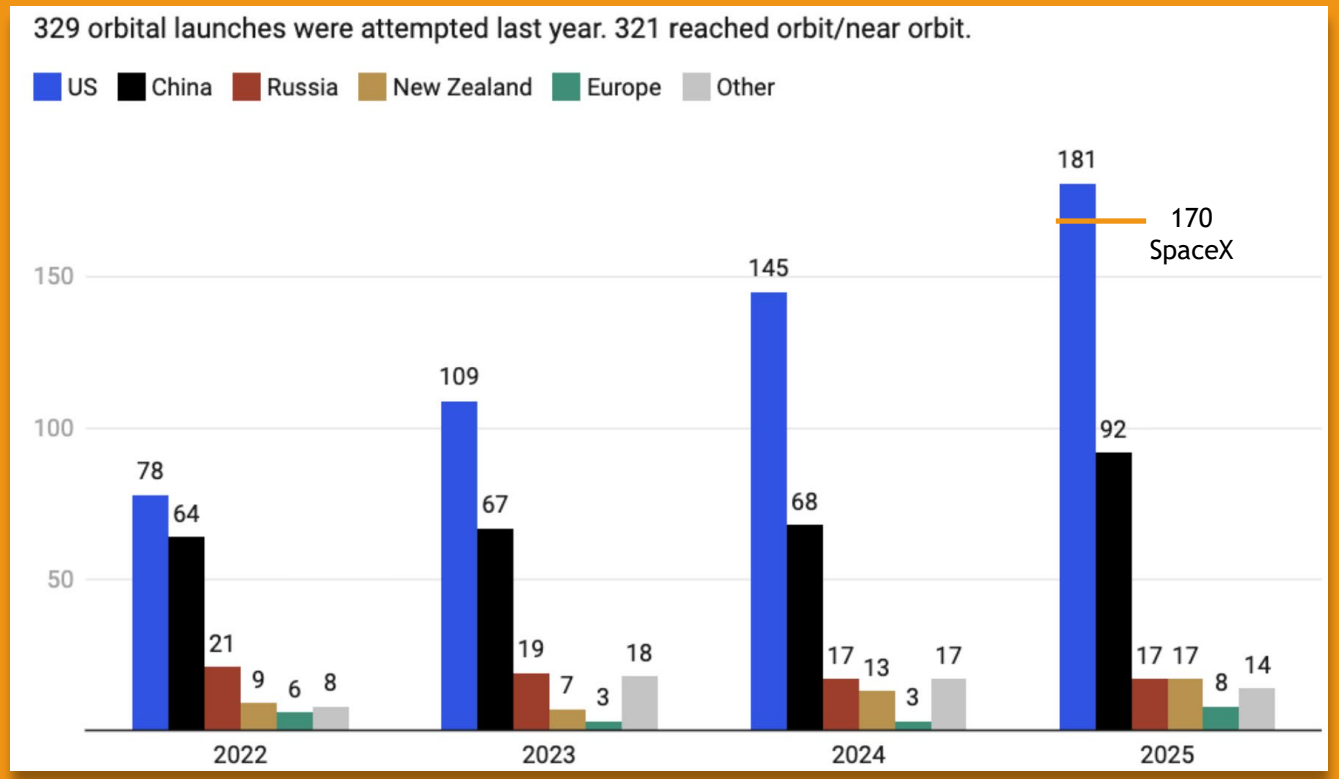


Note: US Launches: Falcon 9: 165, Starship: 5, ULA: 6, Atlas V: 6, Vulcan: 1, Blue Origin: 2, Firefly: 1 Northrop Grumman: 1 -- Rocket Labs had 21 fights, including suborbital tests

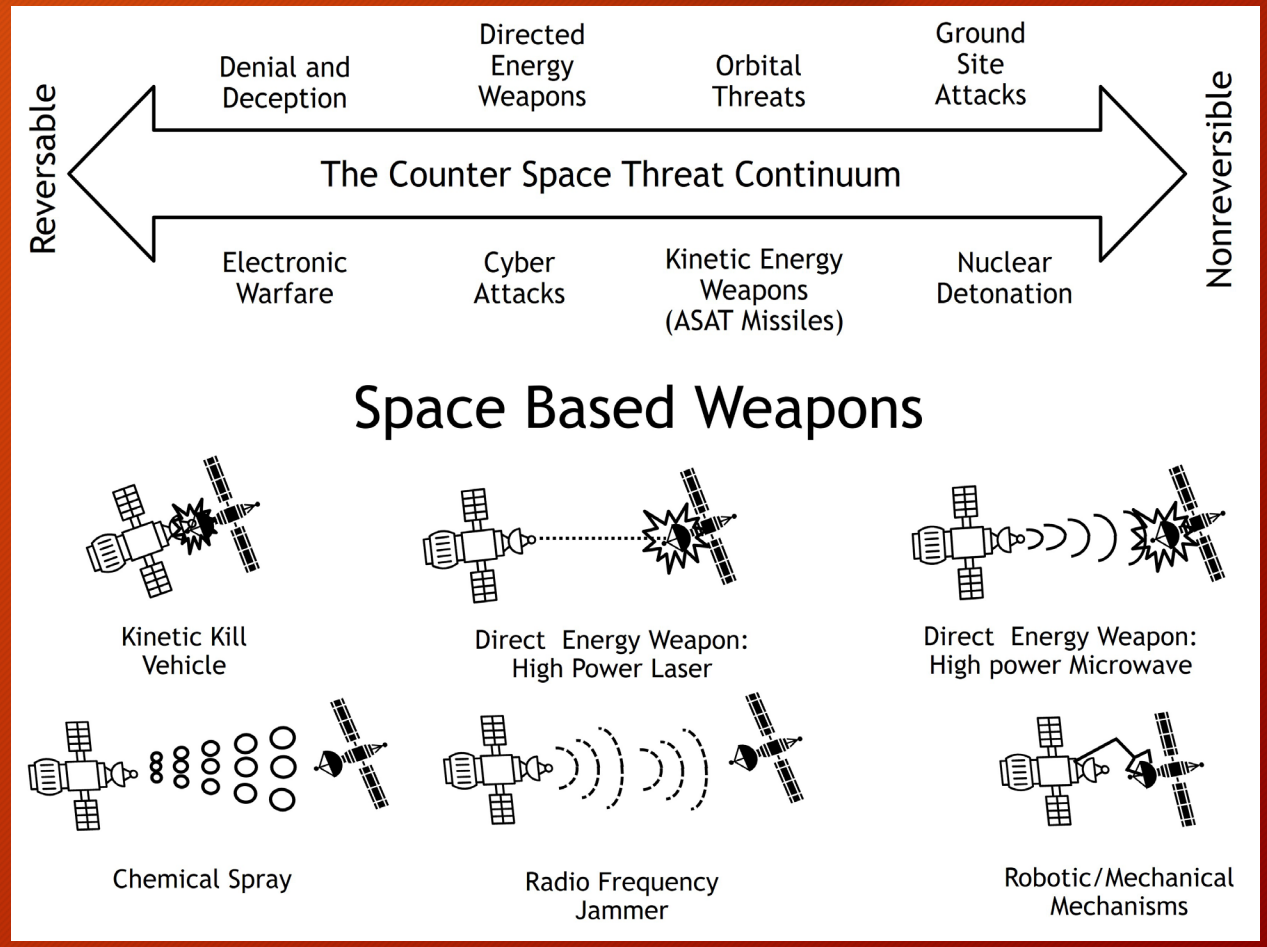
- The US (SpaceX), China, and Allies (Rocket Labs) dominate launches
  - RUSSIA IS LAGGING
- **5 Major Mega Communications Constellations are in build-out**

SpaceX:	9,357	Planned: 42,000
OneWeb:	650	650
Amazon Leo:	200	3,236
Space Sail:	180	14,000 (China – Quinfan)
Guowang:	35	12,992 (China – state sponsored)
	(10,422)	**(72,293)**

The Weaponization of Space:
The Counterspace Threat Continuum in Contested Space

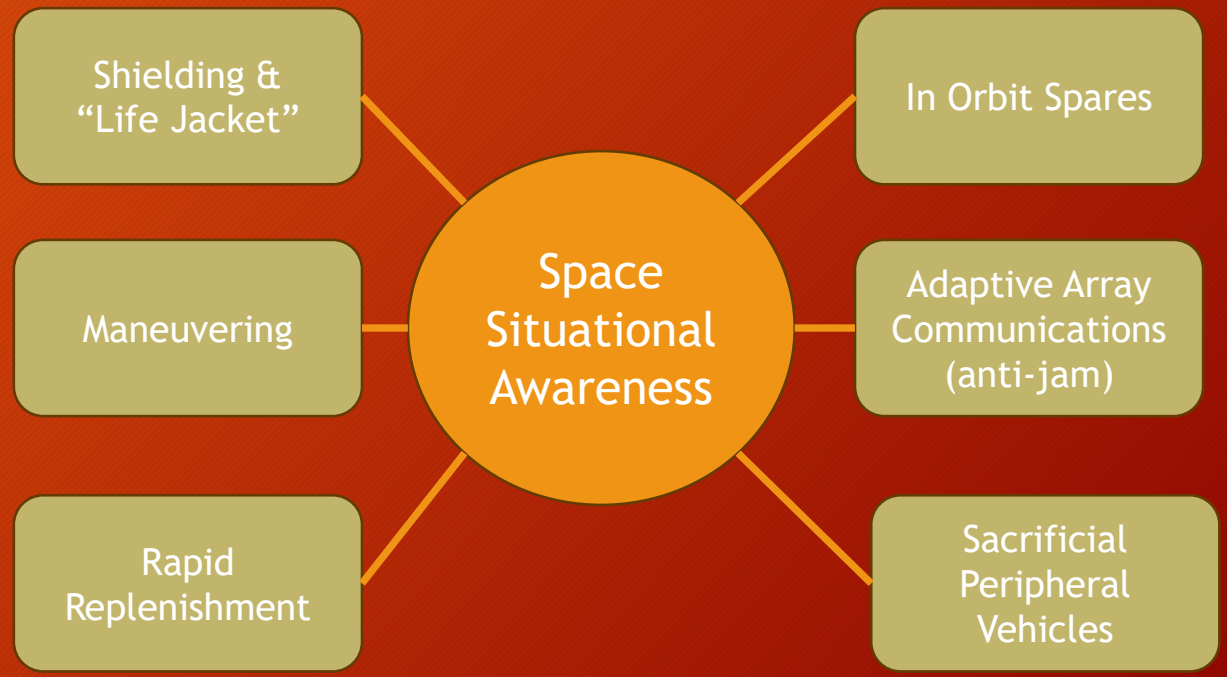
China and Russia are fielding ground and space-based weapons to neutralize US and Allied satellites. These include:

- **Ground-based Directed Energy Weapons**
  - (lasers) to blind our IR and Optical satellites and will, at some point, achieve power levels to disable spacecraft
- **Space-based Directed Energy Weapons**
  - (lasers and RF) to disable spacecraft
- **Space-based mechanical systems**
  - grapple our satellites and effectively alter their orbits to burn up in the atmosphere
- **Ground-based anti-satellite missile systems**
  - Creates extensive space debris
- **Upper Atmospheric Nuclear Weapons Release**
  - EMP, direct radiation, and charge pumping of the Van Allen belt



Many Threats, But What are the Countermeasures?

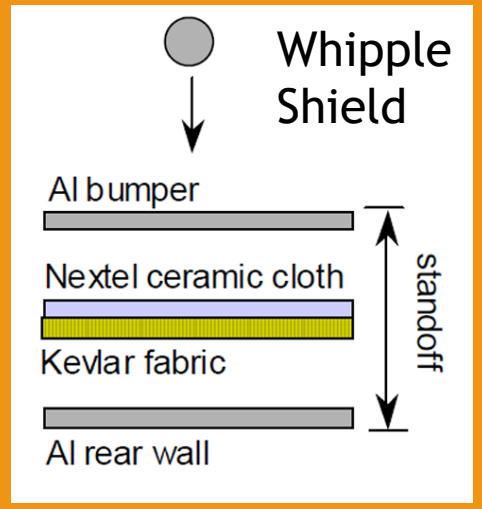
- Baseline countermeasures
  - Access to space situational awareness data
  - Maneuvering thrusters and fuel budget
    - Inertial / reaction wheel as an option
- Communications
  - Adaptive Array (very effective for Starlink)
  - Cross satellite links (backup)
- Replacement
  - In Orbit – to include satellite swarms
  - Rapid Replenishment (i.e., launch capability)
- Shielding
  - Kinetic
  - Energy (light and EMP/RF)
- Sacrificial Peripheral Vehicles
  - Active defense against an intentional satellite-on-satellite hostile act or intelligence gathering
  - "Loyal Wingman in Space"



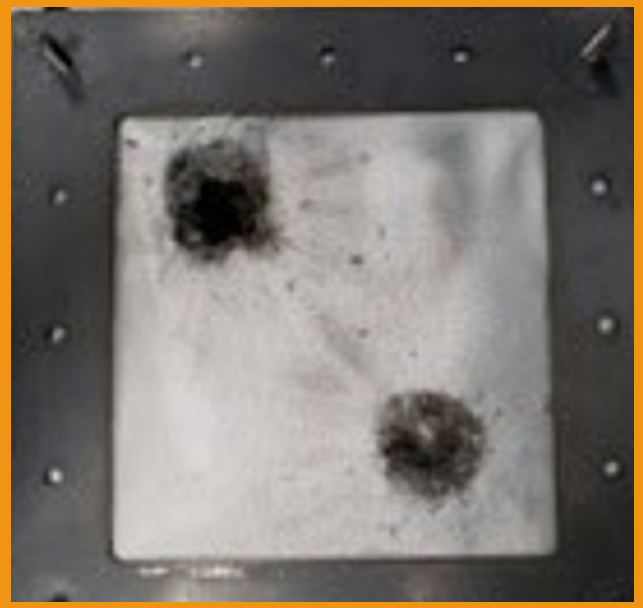
Shielding:
Whipple shield for kinetic protection

- Satellites generally have basic radiation shielding for the space environment, but little or no kinetic protection shielding
- Maneuver can protect against large objects
- Whipple Shields are used to protect against micrometeorites and debris
  - Layered shield to break up and absorb impact debris
  - Layer 1 – Aluminum (Al) bumper
  - Layer 2 – sheets of Nextel, Kevlar, or other material to absorption material
  - Layer 3 – Aluminum (AL)
- For Manned Missions – Space station, lunar, etc., panels are replaceable

Impact of a small piece of space debris on a typical unshielded aluminum space craft skin (0.5mm debris)



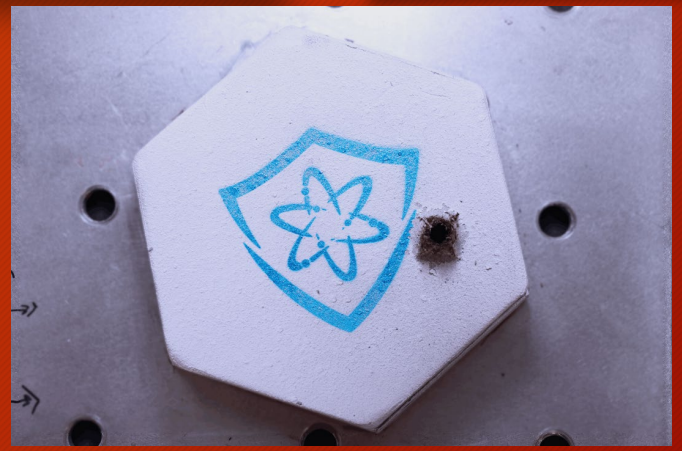
Whipple Shield with "Stuffed" Absorption Panel



Nextel absorption layer diffusing two hyper-velocity impacts

New Shielding Alternatives: Space Armor

- Atomic-6 Composite Tile ‘Space Armor.”
  - Fragmentation-resistant: stopping debris without creating harmful secondary ejecta that could threaten other spacecraft
  - Lighter and thinner than Whipple shields
  - RF Permeable – Can be used to protect Satellite Array antenna elements
- Two types of shielding
  - “Lite” for debris 3mm or less
  - “Max” for Debris up to 12.5 mm human spacecraft grade
- 1980s/90s SDI program had the concept of housing antisatellite missiles in a hardened “Life Jacket”



Space Armor
Stops Hypervelocity projectile

Shielding for Portal Space Systems 2026 mission

In Orbit Spares & Rapid Replenishment

- Assuming satellites are damaged in contested Space, there are 2 methods to maintain constellations:
  - In Orbit Spares
  - Rapid Replenishment (Reserve Launch capability)
- In Orbit Spares:
  - US Space Force is developing an “Orbital Carrier” concept
  - Allows for protected in orbit spares with the option for offensive kinetic operations
  - In March 2025, Gravitics Selected by Space Force for $60M STRATFI to Demonstrate Revolutionary Orbital Carriers
- Rapid Replenishment:
  - US Space Force Rapid Response Trailblazer Program: missions December 2024 and May 2025 – reduced replacement from 24 to 3 Months
  - SpaceX has a “Launch-Heavy” resiliency strategy as part of normal operations

Orbital Carrier: US Space Force concept to house & protect in orbit spares

Rapid Replenishment: SpaceX launch of US Space Force Rapid Response Trailblazer Program

Swarm Technology:
The Ultimate Contested Space Solution

DARPA, NASA (Starling Mission) , ESA, and the US Space Force/ SDA have launched swarm missions

- **Distributed Spacecraft Autonomy (DSA)** coordinating actions and navigating independently while minimizing reliance on ground control.
- **Robustness:** A swarm can lose one or more members and still complete its mission, providing greater resilience than a single-satellite system.
- **Flexibility:** Swarms can reconfigure their formation to adapt to new objectives or optimize observations.

StarShield and the Proliferated Warfighter Space Architecture are both based on swarm satellite architectures

$1.8 B NRO – SpaceX Starshield Program

- **Swarm Architecture:** intended to be more resilient to attacks compared to traditional, larger, and more expensive satellites – backed up by rapid reinforcement.
- **Intelligence and Surveillance:** provides continuous surveillance, tracking, and imaging for intelligence agencies.
- Secure Communications: Starshield is a distinct, secure, government-controlled network separate from Starlink. Optical satellite cross-links, High-speed internet (300-500 Mbps, and Link 16 tactical comms.

NASA's Starling six mission, based on a team of four CubeSats in low Earth orbit, to test spacecraft operating in a synchronized manner without ground control.

Thank You

Satellite Communications Strategic Surveillance are just part of the overall US and Allied Deterrence regime. Find out more in my new book:

About the Book

About Me

Thank You

Questions/Comments Contact: paul@struhsaker.com
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