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Counterspace Capabilities using Small Satellites: Bridging the Gap in Space Situational Awareness

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Introduction

- A great deal of work has been done recently with regard to smallsats
  - Also known as microsats, minisats, nanosats, picosats and cubesats.
- The low cost and rapid insertion into space is changing the face of the way we view satellites
  - Innovations in manufacturing, miniaturization and fabrication quality have made the concept of smaller, lighter and lower-cost satellites that perform mission critical functions a possibility.
  - Until recently, their development has remained mostly an academic practice advanced by universities and small research outfits, but this is changing.
- With these advancements also comes a threat.
- To date, at least 30 countries have operated microsatellites
  - China recently established the “world’s largest microsatellite industry park.”

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The Threat

- Advances in miniaturization and proliferation of space technology will provide rogue nations access to very small anti-satellite systems
  - Geopolitical drivers provide the motivation for countering the sovereignty of the United States in space.
- Small satellites have lowered the cost of entry into the once elite space club, thus allowing nontraditional countries to become players
- This openness to space also creates a new threat from hostile nations
- With access to the exact same technological breakthroughs, our nation's satellites become exposed to unmonitored attacks, crippling national security

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Capability Gap

One example: Results of a recent Air Force Space Command War Games assessment (Schriever War Games 5):

Conclusion:

"an enemy with more advanced space assets can disable U.S. force capabilities, largely through the use of small satellites which cannot be tracked, monitored, or assessed."

- General C. Robert Kehler
- Lt. Gen. Larry James
USAF 14th Air Wing

Example of U.S. shortfall, sensors weren't able to pick up eight small satellites launched by the Japanese earlier this year until after they flew over the South Pole through the U.S. sensor network. This is the same problem U.S. commanders face with launches from China.

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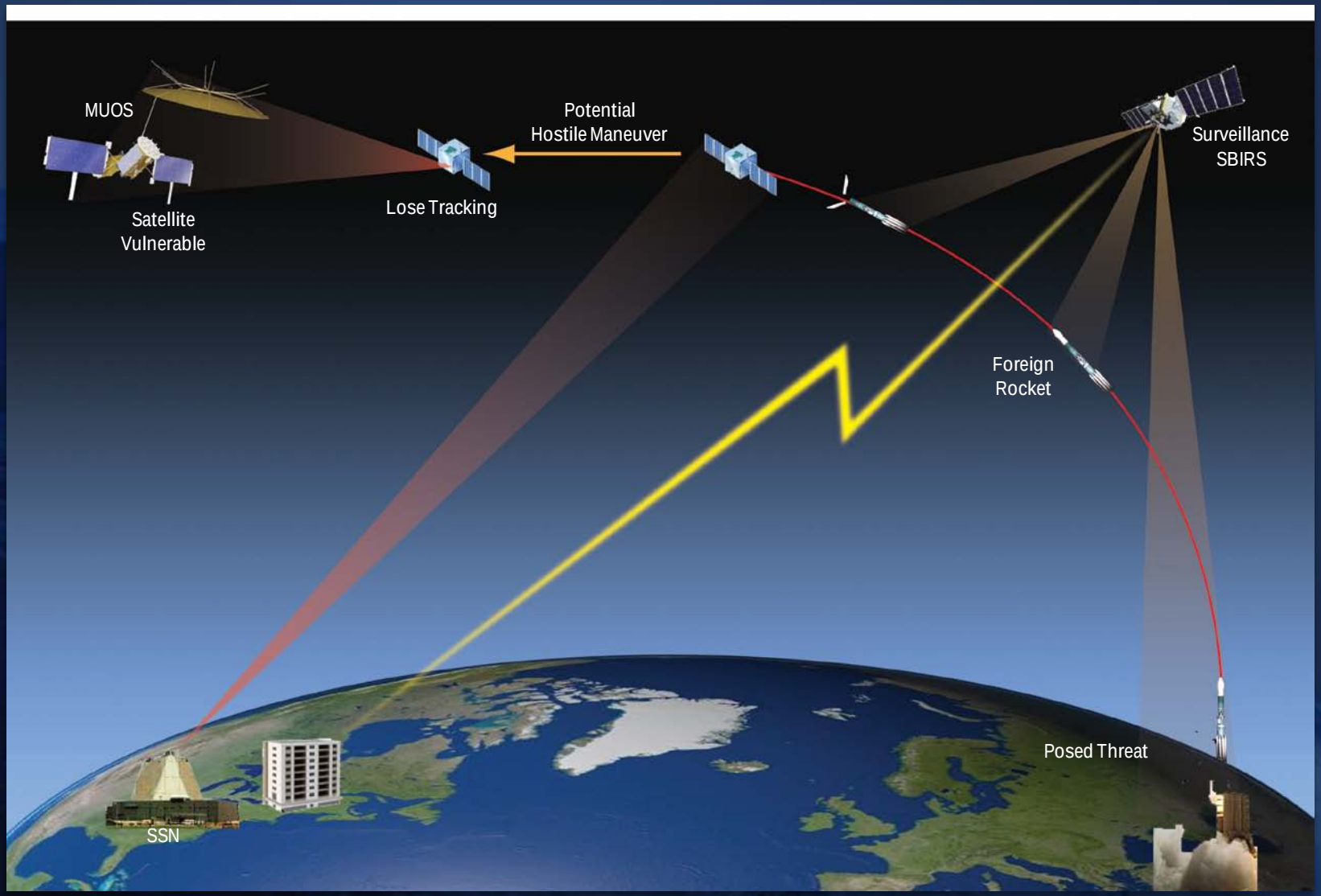
Hypothetical Scenario (AS-IS)

What looks like a typical comm satellite is launched and placed in orbit

Later, undetectable swarm of smallsats deploy in vicinity of a U.S. asset

U.S. asset is disabled- all comms are lost



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Hypothetical Scenario - Details

Time	Location	Operation
0915Z 11 Jul 2019	Somewhere in the Pacific Ocean	The USS Ronald Reagan loses its satellite communications (SATCOM) link to Headquarters, U.S. Pacific Fleet. Nearby, a nuclear attack submarine surfaces to make contact with headquarters during its designated reporting window, but is unable to acquire its SATCOM link. The sub commander directs the communications officer to try again using the alternate link.
0917Z	Joint Space Operations Center (JSpOC), Vandenberg AFB, CA	The Senior Space Duty Officer (SSDO) is notified that the Advanced Extremely High Frequency (EHF-4) has entered safehold mode after experiencing an unknown anomaly. The space weather officer reports that solar activity is high so the satellite may have experienced a "single event upset" due to solar radiation. The SSDO requests an update on the situation in 10 minutes.
0919Z	JSpOC, Vandenberg AFB, CA	The SSDO sees an alert on her Common Operating Picture display indicating that U.S. Pacific Fleet is experiencing communications problems. As she reads the alert, she receives a call from the watch officer at the Wing Integrated Operations Center (WIOC) at Schriever AFB. The WIOC watch officer reports that the 50th Space Wing has lost contact with the Mobile User Objective System 5 (MUOS-5) satellite. Prior to losing contact, all systems were within normal operating limits; however, the satellite is aging and well past its design life and this isn't the first time they've had problems with bird 5. The WIOC watch officer reports that MUOS-5 had been servicing U.S. Pacific Fleet.
6 Months Earlier	Jiuquan Space Facility, China	A Long March 6 rocket lifts off carrying the Indonesian IndoCom-7C communications satellite. The satellite is placed into geosynchronous orbit (GEO) to provide wideband communications. The U.S. Space Surveillance Network (SSN) observes the launch, and within minutes, the Space Based Space Surveillance (SBSS) system computes the IndoCom-7C orbit and verifies that it has been placed into the pre-announced orbital slot. SBSS continues to watch as IndoCom-7C completes its deployment maneuvers and unfurls its solar arrays. After verifying that the IndoCom launch appears nominal, SBSS-2B is re-tasked.
Fast forward to 1 Jul, 2019 2034Z	22,000 miles above the earth, somewhere over the Pacific	What looks like a radiator panel on the side of IndoCom-7C swings open. Thirty-two cubes, each about 10 centimeters across, fly out of the IndoCom opening. This event is not detected by the SSN. The cubes automatically configure themselves into an autonomous cluster and silently navigate to their destination.
11 Jul, 2019	Near MUOS-5 satellite	A swarm of miniature satellites, operating as a virtual cluster, approach the MUOS-5 spacecraft. Undetected by any U.S. system, the cluster identifies the main electrical panel onboard MUOS-5 and attacks. Seconds later, MUOS-5 powers off its transponders as the onboard computer malfunctions. Twenty-two thousand miles below, the USS Ronald Reagan loses its satellite communication link
	Over the Pacific Ocean	All U.S. military satellites previously operating over the Pacific Ocean are now inoperative, and all of Pacific Fleet is deaf.

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Premise of Concept

1. Current space tracking systems will never be able to watch everything all the time, especially given the proliferation of small satellites

2. Even if this were possible, no current capability exists to discern between those with hostile intent

3. Further, there are no effective, existing, space-warfare simulations that adequately capture the emerging technologies in small-satellite development

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Challenges

- There is no methodology to model and simulate the system-of-systems needed to provide end-to-end situational awareness for complete traceability of a potentially hostile satellite back to its host country

- Any new methodology must also provide enough information to determine whether a satellite is active -- and its capabilities

- The solution must be able to maintain "knowledge custody" of all space objects from the moment of launch
  - if a hostile space attack occurs, the system can produce an "indisputable chain of evidence".

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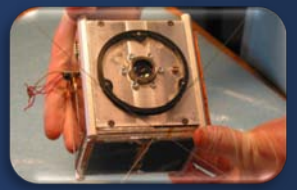
Why Smallsats as part of the solution?

- Quick response (i.e., able to load and launch more rapidly)
- Low-cost risk (smallsats are very inexpensive to build/test)
- Inherently invulnerable as a whole
- Wide range of surveillance
- Close proximity for ASAT observation and data gathering
- Highly maneuverable



With small satellite capabilities emerging, the tools we have foster the ability to rapidly incorporate these new capabilities into the solution.

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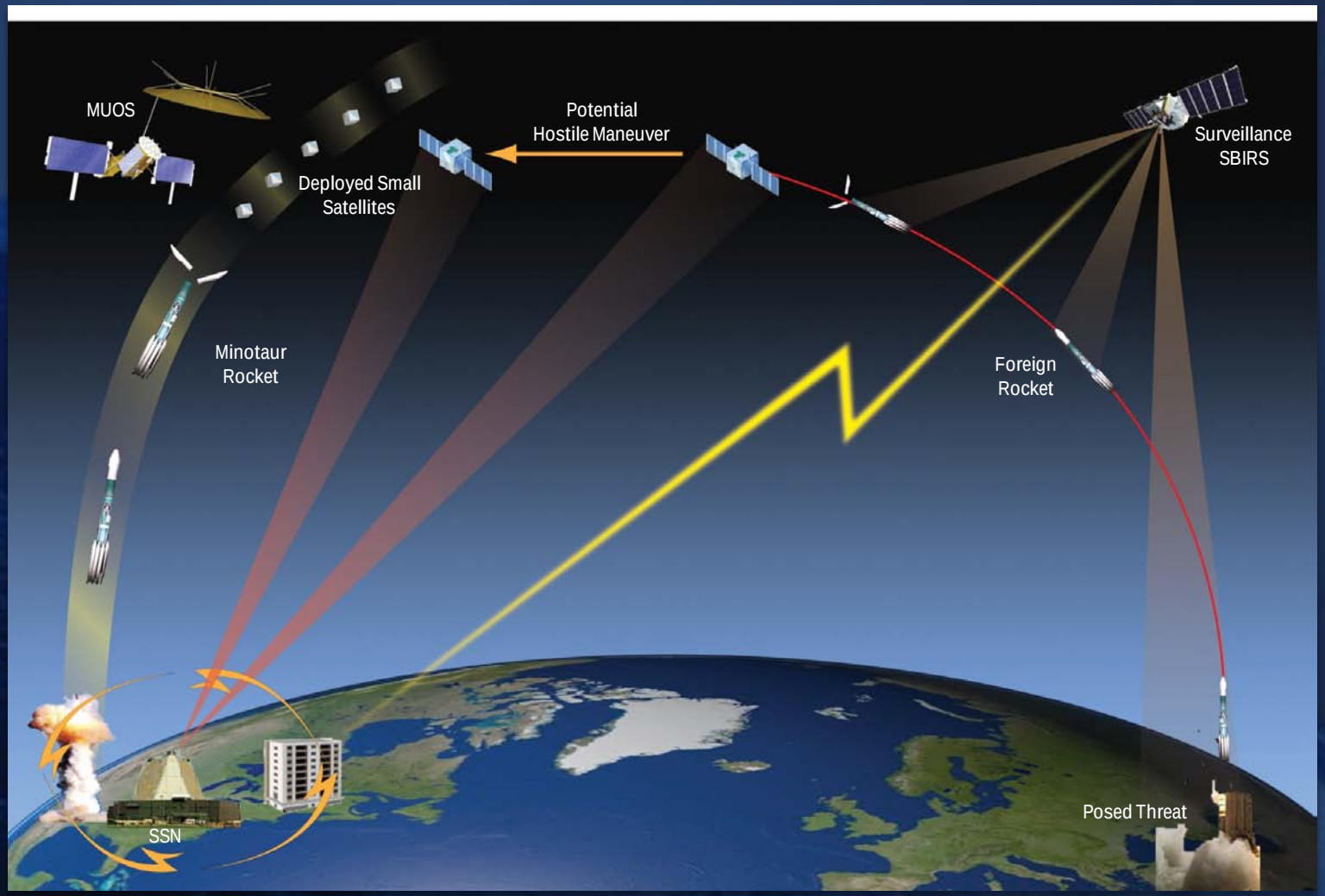
Envisioned Capability (TO-BE)

Through integration of several systems -coordinating these activities provides critical space situational awareness

Tracking ability of a potentially rogue vehicle back to its host country

Sufficient forewarning of a potential hostile attack, we can initiate the launch of small satellites in rapid fashion to likely prevent such an attack



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Our Research So Far - Macro

TECHNOLOGY GOALS:

1) enabling technologies and methodologies, advanced concepts and algorithms, and artificial intelligence for protection against small satellites

2) advanced research into improving space situational awareness (SSA) given the threat of adversarial small satellites

Current work under way has led to the development of a series of predictive computer models

For example, for a set of mission objectives, the system will be able to tell the user the best fit (economics and performance) be it large, small, mini, micro, nano, pico, femto, or a constellation combination

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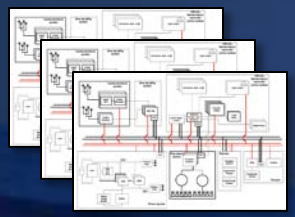
Our Response - Micro

- As part of a systems-of-systems solution, develop and deliver a capability in the form of an analytical framework
- Make extensive use of advanced modeling and simulation tools and algorithms that capture the current surveillance architecture, as well as current and future satellite capabilities most importantly including small satellites
- This framework can then be leveraged to determine the best way to assess hostile intent and to protect our national—and commercial—assets
- The end result system will lead toward an “indisputable chain of evidence” leading to attribution

Initial Tools and Processes Used

Architectures



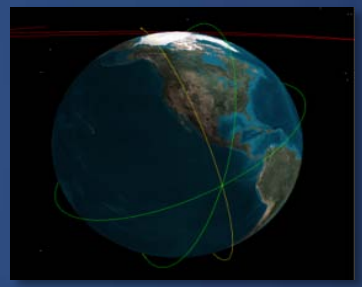
- *Space-Based Surveillance Systems*
- *Ground-Based Processing*
- *Small Satellite*

Scenarios

- *Major System Roles*
- *Small Satellite Roles*
  - *Observation and Data Gathering*
  - *Data Communication*
  - *Maneuvers*
  - *Offensive and/or Defensive Actions*

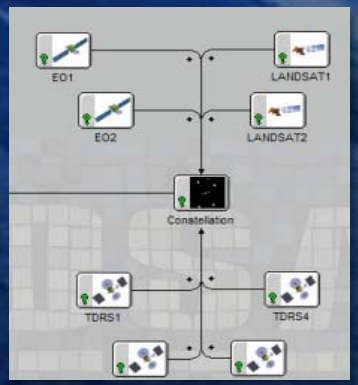
Driven by Real-World Architectures & Scenarios

Physical World Model and Visualization



- *Scenario Entities and Payloads*
- *Orbit Dynamics and Maneuvers*
- *Monte Carlo Simulation End-game*

Integrated using MOSAIC



- *Functional Flow Diagrams*
- *Decision Logic & HITL*
- *Tie Points to Physical Models*

Discrete Event Simulation

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Other Technologies (Wild Possibilities)

Ladar / hyperspectral characterization of the micro sats

> determine their fingerprint so they can be recognized whenever they come and go through our net

> enabling detailed tracking and anomaly recognition (for example when orbit changes)

COMINT characterization of the satellites

> how often and with what density do they communicate, and with whom and where

> build models of the types of satellites based on their comm??

MASINT (if active sensors are on board)

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Also Make Use of SSN/Space Fence

- Through modeling and simulation, a set of designs can be better integrated to provide the capability to track an asset from launch to de-orbit.
- Tracking of the launch to deployment via SSN is followed by the space asset until the launched vehicle is in its initial orbit
- Tracking could then be handed over to the formation of small satellites to get "close-up" pictures and other data from the potentially hostile satellite

	Current AFSSS	Space Fence System
Frequency	VHF	S-Band
Observations per Day	170,000	750,000
Catalog Size	Nearly 10,000 Objects	400,000 Objects
Radar Coverage	12,000 km Maximum ±90° E-W	250 km Minimum 22,000 km Maximum ±60° E-W
Object Detection	30 cm or Larger	5 cm or Larger
Detection Sensitivity	Classified	LEO: 95% Prob. Of Detect. MEO: 90% Prob. of Detect.

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End Result - Operationally Speaking

- Ability to track satellites from launch through to de-orbit, including any potentially hostile maneuvers
  - U.S. would be ready to act with fully informed decisions
- Quickly converge on what satellite(s) may be causing the problem in the vicinity of the lost communication satellite
  - traceability back to the host nation that launched the vehicle(s).
- With rapid deployment of a swarm of small satellites, (for example), we would be able to take near-real-time defensive or offensive action directly on the invasive hostile satellite(s)

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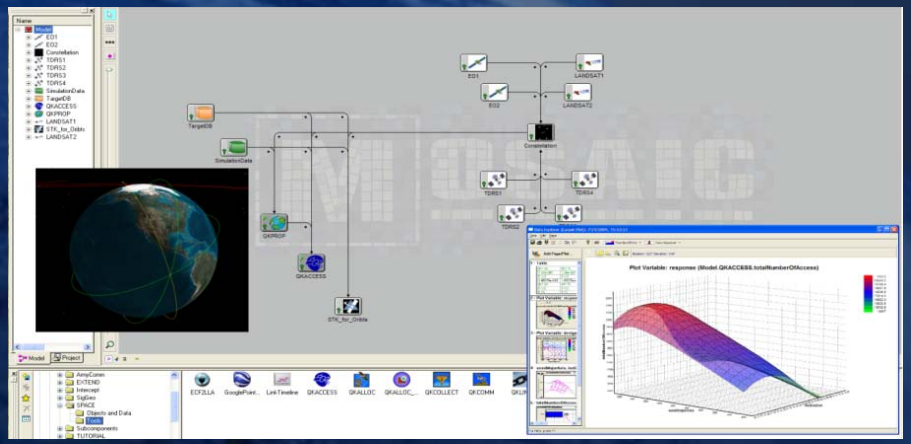
Conclusion

- The threat of small satellites being used against the U.S. is real
- Not a matter of IF -- but WHEN
- Very little has been accomplished to date to have a solid retaliation plan
- The time is now to begin to develop truly innovative models that lead to real-world solutions



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Thank you for your time!

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