



# **Multi-Mission Ground Based Radars and Advanced Processing for Space**

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## **EXECUTIVE SUMMARY**

### ***Background***

Trends in Space are clearly running against the US. The consequences of these adverse trends are much broader than just disadvantage in space. The US has used space as a sanctuary to provide information and decision advantages; to enhance the effectiveness of maritime, land, and air systems; and to expand the battle space and to control the tempo of Joint Operations. Now adversaries are using troublesome new technologies to contest the US advantage in space; and deploying potent space capabilities of their own – with the intent of both blinding US decision makers and rendering ineffective US conventional warfare options: maritime, land, and air.

The US needs to redress the erosion of conventional dominance - with capabilities that build on programmed US and Coalition theater war fighting investments.

### ***Mission Imperative***

Augment current catalog based Space Awareness (latency of hours to days) with Real Time Capabilities that are seamless with Joint Operations in a Theater:

Status and Threat Warning for all Blue Space Assets involved in Joint Operations

Theater based Find, Fix, Track, Target, Engage, Assess (F2T2EA) of Red Space ISR elements that target Blue Maritime, Land, Air and Space Operations

### ***Enabling Technologies***

1. Expanded, Diversified, more Precise and more Agile Sensing of Red Space (end to end)  
US /FMS 3D radars: Bi-static apertures; Ground and Space ELINT; On-Board Sensors  
State Vector based Single Pass Orbit Determination; and Sensor to Sensor Tip and Cue
2. Object Based Characterization Strategies (including Formations)  
Coordinated Long Dwell, Multi-Aperture, Multi-Int Collection  
Fusion Processing that yields function of objects and connectivity of formations
3. Activity Based Awareness and Warning on Tactical Timelines  
Sort and Spotlight of Red ISR & Threats to Blue Space Supporting Theater Operations  
Integrated Activity Assessment of Red Space and Red Ground
4. Integrated Battle Management  
Threat Warning for Blue Space and Blue Joint Forces  
Analysis of Courses of Action (COAs): Maneuver, Re-constitution, Attack Options

### ***Deploying Space Warning and F2T2EA Capabilities to the Theater***

1. Add Space Assets to joint planning and engagement operations to allow the integration of Space with maritime, land, and air operations. Include status displays of Blue Side end to end functionality and re-constitution options for all blue space functionality.
2. Set up the sensor data sharing standards, agreements, cross domain protections, and connectivity to allow use of the many new and precise US and Coalition Large Phased Array Radars for sensing, TT&C, and communication. Allow direct down link of threat data from Blue Space on-board sensors. Set up sensor to sensor tip and cue.
3. Deploy the real time (high clock rate to match tactical velocity) object based processing and activity based intelligence algorithms /virtual agents to deliver warning and analysis of threatening red space activity to theater C2 & decision nodes..
4. Provide Joint Force Commanders with threat warning, assessment and contingency courses of action for space threats and for countering Red ISR contributions to A2/AD.

## Space: Blue Space Status /Warning and F2T2EA of Red Threats

Trends in Space are clearly running against the US. The consequences of these adverse trends are much broader than just disadvantage in space. This Whitepaper discusses redressing the erosion of conventional dominance - with capabilities that build on programmed and emerging US and Coalition theater war fighting investments and that directly buy back war fighting advantage.

### *Background*

The US has used space effectively since the end of the Cold War to provide information and decision advantages; to enhance the effectiveness of maritime, land, and air systems; and to expand the battle space and to control the tempo of Joint Operations. Initially space was a sanctuary; now adversaries are deploying troublesome new technologies to contest the US advantage in space; and deploying potent space ISR capabilities of their own – with the intent of both blinding US decision makers and minimizing the effectiveness of US conventional warfare options: maritime, land, and air.

#### **Problem 1: Challenges to the US Use of Space**

Space is integral to recent US advantage on the battlefield, but this advantage is waning. Space has provided the US with an overwhelming offensive and intelligence advantage, from target identification to precision-guided munitions to long-haul communications, allowing US forces to impose significant costs on an adversary. Yet the US space force structure was not designed to go into harm's way. Adversaries are aware of this vulnerability, and are deploying advanced technology capabilities to threaten, interfere with, damage, and destroy reconnaissance, navigation, and communication satellites.



**Figure 1: Examples Space Borne Threat Technologies** <sup>1,2</sup>

Space borne threats include direct ascent ASATs (kinetic kill); small and stealthy ‘companion’ satellites (non-cooperative rendezvous, jamming, explosive threats); and dual purpose repair and ‘space tug’ satellites (robotics to dismantle and / or reposition blue space).

These threats come at a time when US Joint Operations are increasingly reliant on Space, and because the US space force infrastructure is so fragile, the situation is becoming strategically unstable.

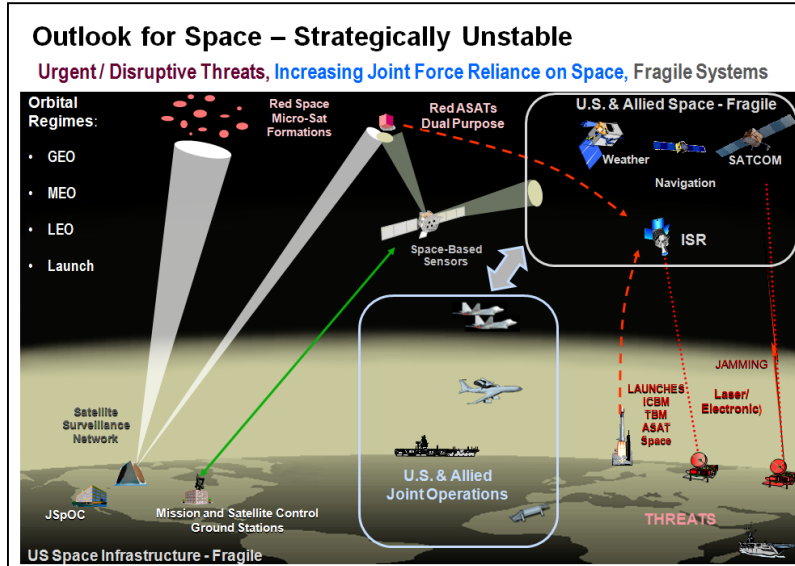


Figure 2: Challenges to US use of Space

**Problem 2: Near Peer Investments in Space to enable Strike and Anti Access/Area Denial**

Adversaries are investing in their own space capabilities: to provide information and decision advantages; to enhance the effectiveness of strike systems and attack operations; to expand the Battle Space and to control tempo; with the broad intent of blinding US decision makers, and minimizing the effectiveness of US conventional warfare options: maritime, land, and air.

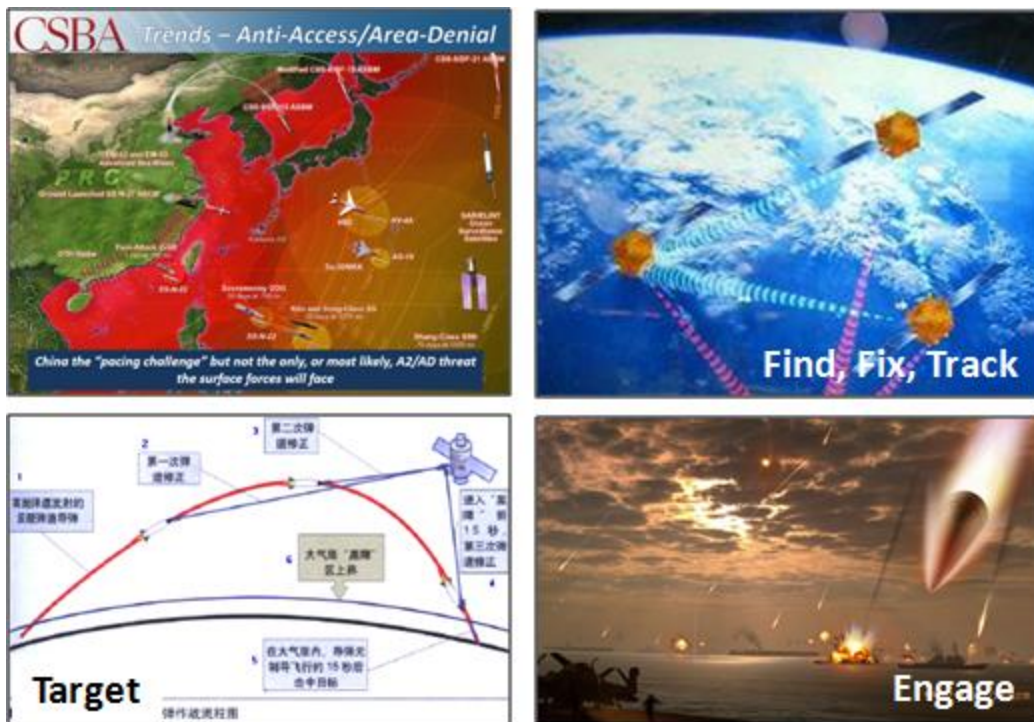


Figure 3: China Investments in Space Enabled F2T2EA for Anti-Access and Area Denial<sup>3,4</sup>

Adversary investments are yielding sophisticated and troublesome capabilities. China, as one example (Figures 3 and 4), is coordinating the operation of constellations of ELINT, radar imaging, and EO imaging satellites (with connectivity to missiles) to provide 24/7 find, fix, track, target, engage of Carrier Battle Groups.

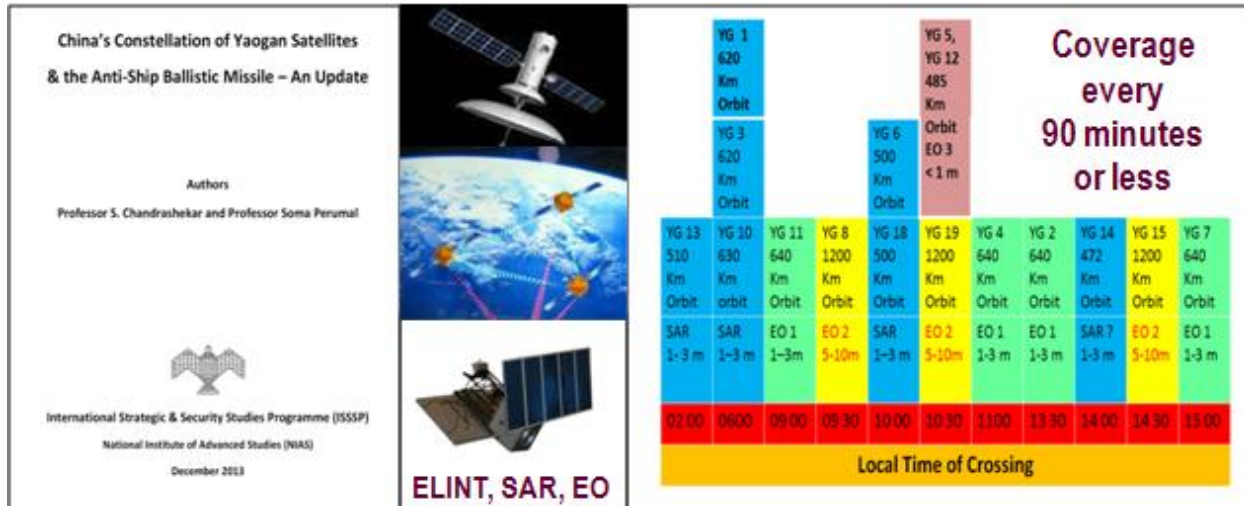


Figure 4: Red ISR - supporting A2/AD with ELINT, SAR, and EO <sup>5</sup>

### *Mission Imperative*

The Red Side Threats to US Space and Red Side use of Space for A2AD have adverse consequences that are much broader than disadvantage in Space, and therefore the framework for solution must be broader than just Space. The framework for solution must also include leading edge technology, and must support the velocity of tactical war fighting.

Leading edge technology is needed because the Red Side Threats are sophisticated. The Threats synergistically incorporate stealth; the miniaturization and sophisticated Electronic Warfare signal processing enabled by modern electronics; the complex formation / constellation CONOPS enabled by digital control and modern digital sensors; and the ambiguity introduced by dual use capabilities like on-orbit repair robots.

This white paper offers technology elements of a solution within the broader framework of Coalition and US Joint Warfighting, These technology elements extend investments in theater precision sensing, communication, big data analytics and high velocity decision to augment current catalog based Space Awareness. The product is:

Low Latency Blue Side status: and Threat Warning for all Blue Space Assets involved in Joint Operations – to include threats from ASATs and satellites on the pad, and compromises to ground sites, links and networks.

Theater based Find, Fix, Track, Target, Engage, Assess (F2T2EA) of Red Space Threats to Blue Space; and F2T2EA of Red Space ISR elements that target Blue Maritime, Land, and Air Operations - in the hands of the Joint Force Component Commanders

## Enabling Technology

### Framework for Solution

The solutions offered in this concept paper align with the themes of Joint Publication 3-14 “Space Operations”. These themes expand Space Situational Awareness Functional Capabilities in the face of emerging threats to provide fine grain characterization of Red Space; real time monitoring of Space and Ground Based threats; Data Integration (including Multi-Sensor Fusion) and Exploitation: all to support Space Defense Designs and Joint Force Planners, Operators and Decision Makers.

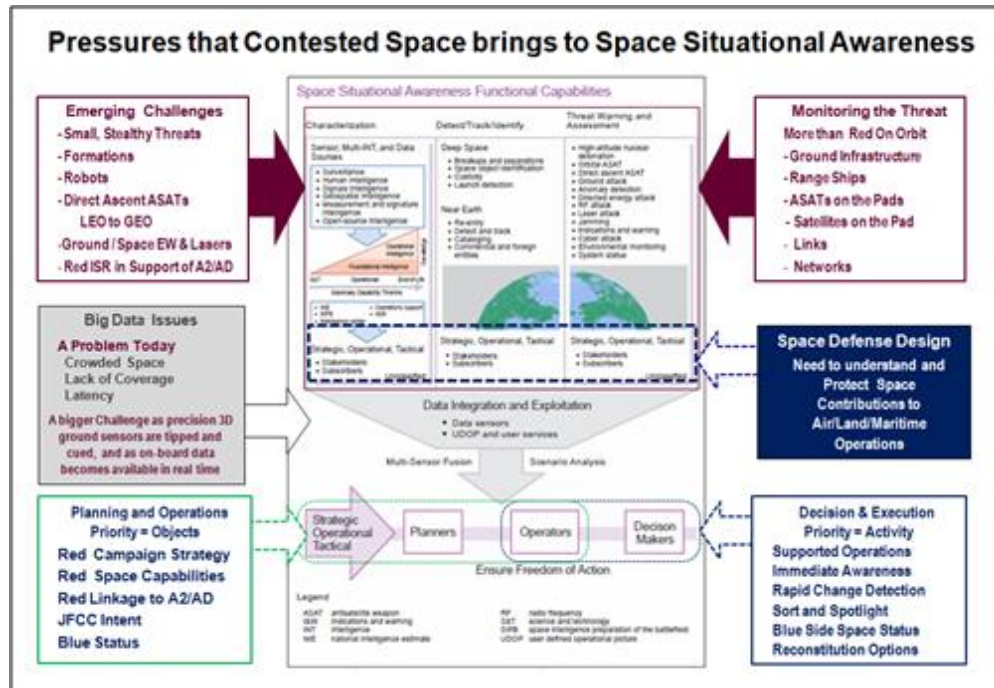


Figure 5: Joint Pub 3-14 Fig II-1 - Annotated to highlight key Space Operations Themes <sup>6</sup>

### Current Capability

The DOD has a new generation Space Fence in development to augment the dedicated but outmoded sensors at Eglin and Cavalier. Space Fence will have the capacity to collect against crowded space and the sensitivity to see all relevant Red Space objects.

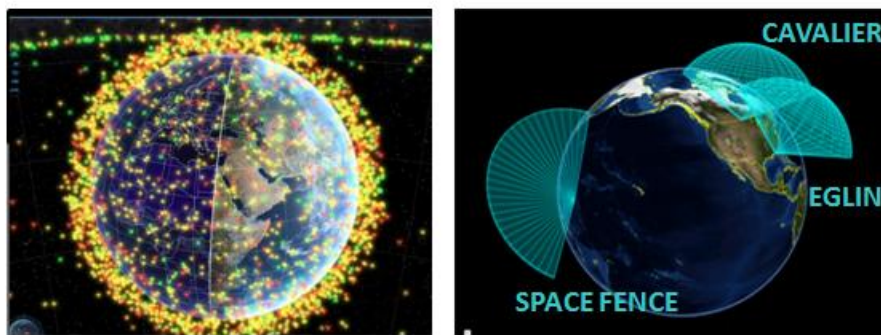


Figure 6: Current Ability to Collect Against Crowded Space

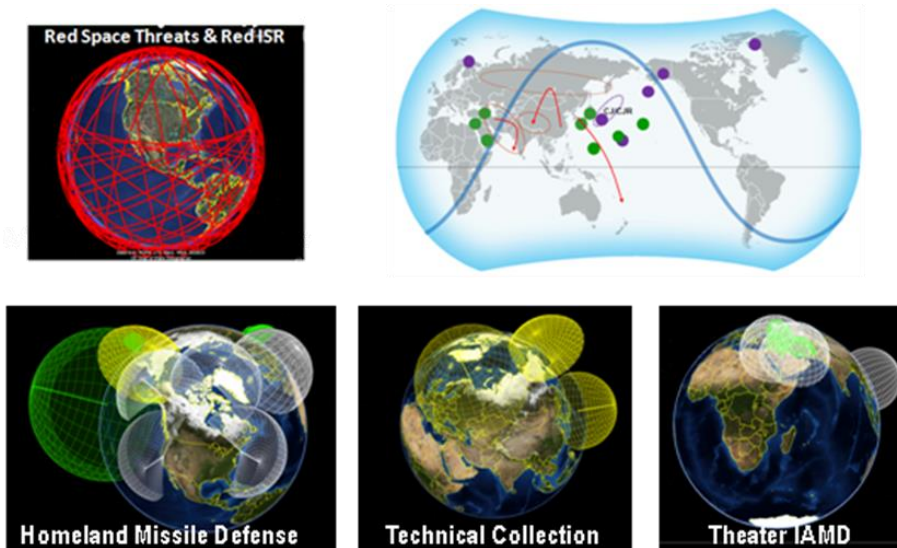
However, as a single site, Space Fence will be able to only see activity for a few minutes every 24 hours, and it lacks coverage of CENTCOM, EUCOM and PACOM Areas of Responsibility.

**Proposed Solutions and Required Technology Investments**

The solutions offered below deliver (globally and to the theaters) the expanded Space Situational Awareness Functional Capabilities called for in Joint Publication 3-14, on the tactical timelines needed by the Joint Force Planners, Operators and Decision Makers

**a. Expanded Diversified, more Precise and more Agile Sensing of Red Space**

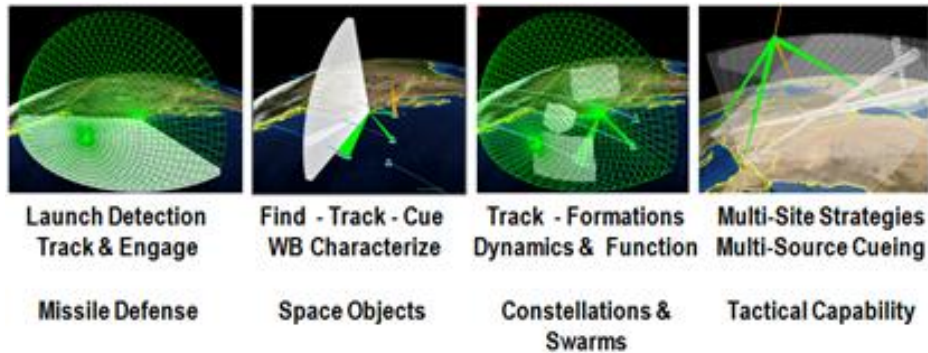
There are many available sensors (US and Coalition) that observe Space with the bandwidth, sensitivity and precision needed to collect against emerging threats. One set of sensors is the Missile Defense and Technical Collection Large Phased Array Apertures that are being deployed in important sites in CENTCOM, EUCOM, NORTHCOM, and PACOM. These apertures are built to operate with other ground and space sensors to provide precision track of launch complexes, and lethal object determination in the presence of debris and decoys. These apertures could be readily adapted to also collect against orbital objects and formations. In aggregate they provide substantial global and theater specific collection across UHF, S, and X bands; and could provide (without hardware changes) single pass orbit determination and wideband radar characterization of space objects; and could receive direct downlink of on-board data.



**Figure 7: Adding US and Coalition Radars to get Theater Collection and Global Coverage**

There are CONOPS, radar waveform and data product tasks needed to move Missile Defense and Technical Collection radars from sub-orbital collection to Multi-Site, Multi-Source collection against formations of Red Satellites. Experiments performed for AFSPC and MDA at Vandenberg AFB indicate that needed technologies could be matured rapidly and would deliver important military capabilities. Technologies that need to be refined include: State Vector based Single Pass

Orbit Determination for formations; Tip and Cue of active and passive apertures at other sites; real time tip and cue of ground and space ELINT; direct downlink and integration of on-board sensing, and scalable role based access control for collected processed data.



**Figure 8: CONOPS, waveform, and data product work to add collection of formations of Red Satellites**

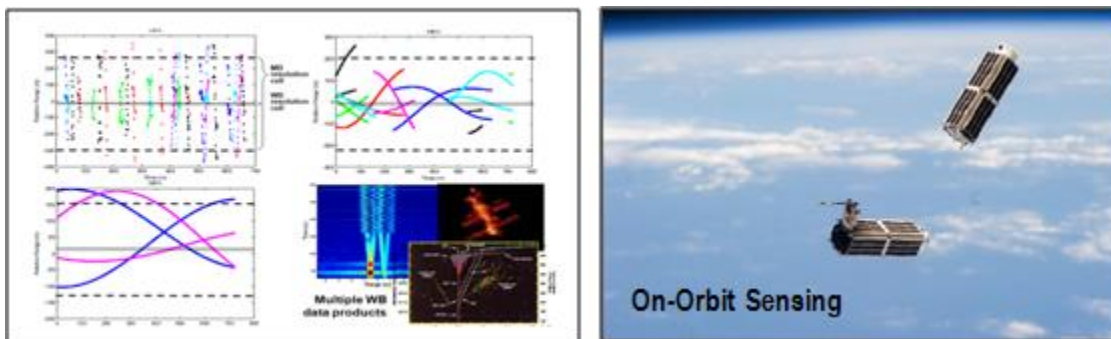
**b. Object Based Characterization Strategies**

As sensing is expanded to meet the 24/7 global and theater requirements it will create what is referred to as a TPED (Task, Process, Exploit, Disseminate) Problem or a ‘Big Data’ Problem. Part of this problem comes from the complexity of characterizing Red Space end to end.



**Figure 9: Complexity of Characterizing Red Space - On-Orbit and Ground<sup>7</sup>**

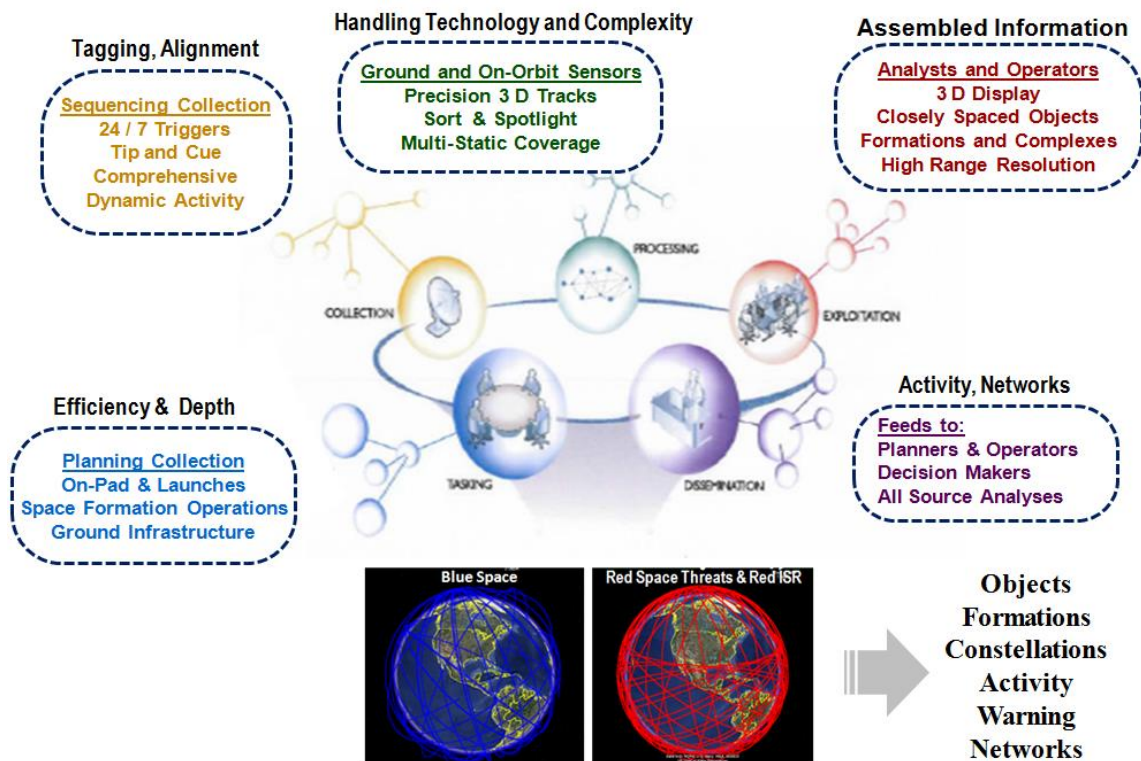
Another part of the problem comes from the volume, precision and diversity of the data products that are available from modern digital sensors when they collect against crowded space.



**Figure 10: Volume, Precision, and Diversity of Data Products. Photo Credit NASA**



Object Based Processing (OBP) is one new organizing framework for handling the volume and velocity of data that comes with Contested Space. If applied to Space, OBP would provide the methodology to coordinate Long Dwell, Multi-Aperture, Multi-Int Collection against Red Space Threats and Red ISR; and to condition this collection to yield comprehensive fusion products.



**Figure 11: Object Based Processing Applied to Space** <sup>8</sup>

Applying OBP to Space would deploy relatively mature missile defense and Intelligence Community ‘Big Data’ technologies to a new and important area. These ‘Big Data’ technologies could potentially deliver real time integration, sort and spotlight of high velocity data streams and could yield the functionality and connectivity of Red Space formations. The details fall in the category of ‘emerging technologies that can be rapidly matured to offer new military capability’

**c. Activity Based Awareness and Warning on Tactical Timelines**

Adversaries are deploying troublesome new technologies to contest the US advantage in space (Figure 1); and deploying potent space ISR capabilities of their own (Figures 3 and 4) to threaten US maritime, land, and air operations. The Joint Force Component Commanders need insight into all Red activities in these two areas; and need this insight linked to their own planning, decision making, and execution. Beyond insight, Commanders need Indications and Warning.

Activity Based Intelligence (ABI) methods have grown out of Community experiences working dynamic targets for Special Operations, and could yield what the JFCCs need. Generically, ABI enhances Object Based Characterization by linking activity to objects and supplying the analytics

to pull subtle behavior changes (Red Space and Red Ground) out of overwhelming big data. ABI can be deployed as virtual digital analytic agents that identify complex events in multi-int data.

In the world of Joint Force Planners, Operators, and Decision Makers, ABI is important because it extends real time awareness both backwards and forwards in time. We show an example from the Air and Missile Battle, where ABI of tracks provides detail on what has happened, and analytics that project the future implication of current activity.

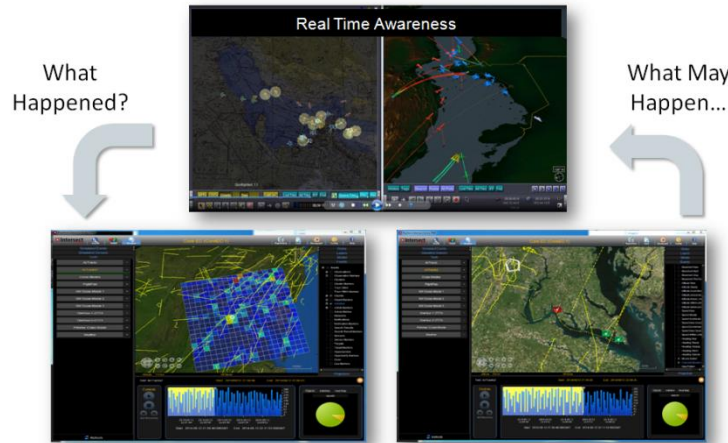


Figure 12: ABI - Extending Real Time Awareness Backward and Forward in Time

#### d. Integrated Battle Management

The Air and Missile Battle example of the previous section is particularly relevant when one

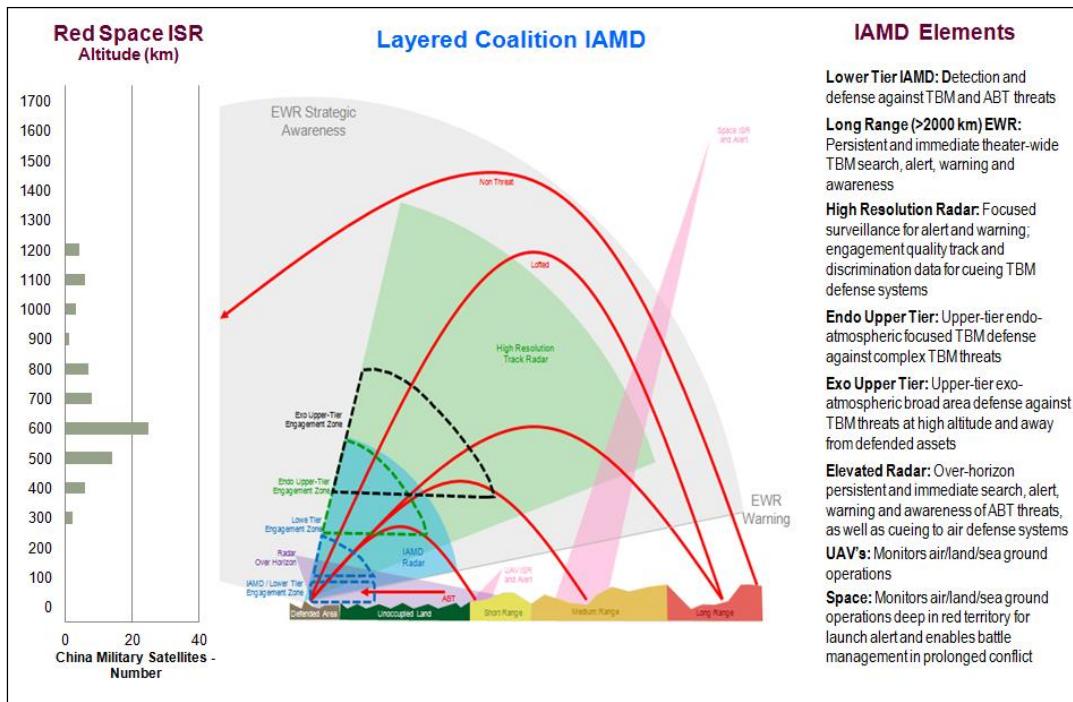


Figure 13: Space and Missile Threats are in the same Battle Space <sup>9</sup>

recognizes that Red Space ISR and Red Missile A2/AD occupy the same Battle Space. As Object Based Red Space Awareness and Red Space Activity are generated they must be integrated into Joint Force Battle Management. The technology to do this is a direct extension of the algorithms, the decision aids, and the displays that are being inserted into Integrated Air and Missile Defense to combat emerging Red Side A2/AD systems and technologies. CONOPS experimentation will be needed to converge to the best methods to analyze Blue Courses of Action: including Maneuver, Re-constitution, and Attack Options.

### *Deploying Capabilities to the Theater*

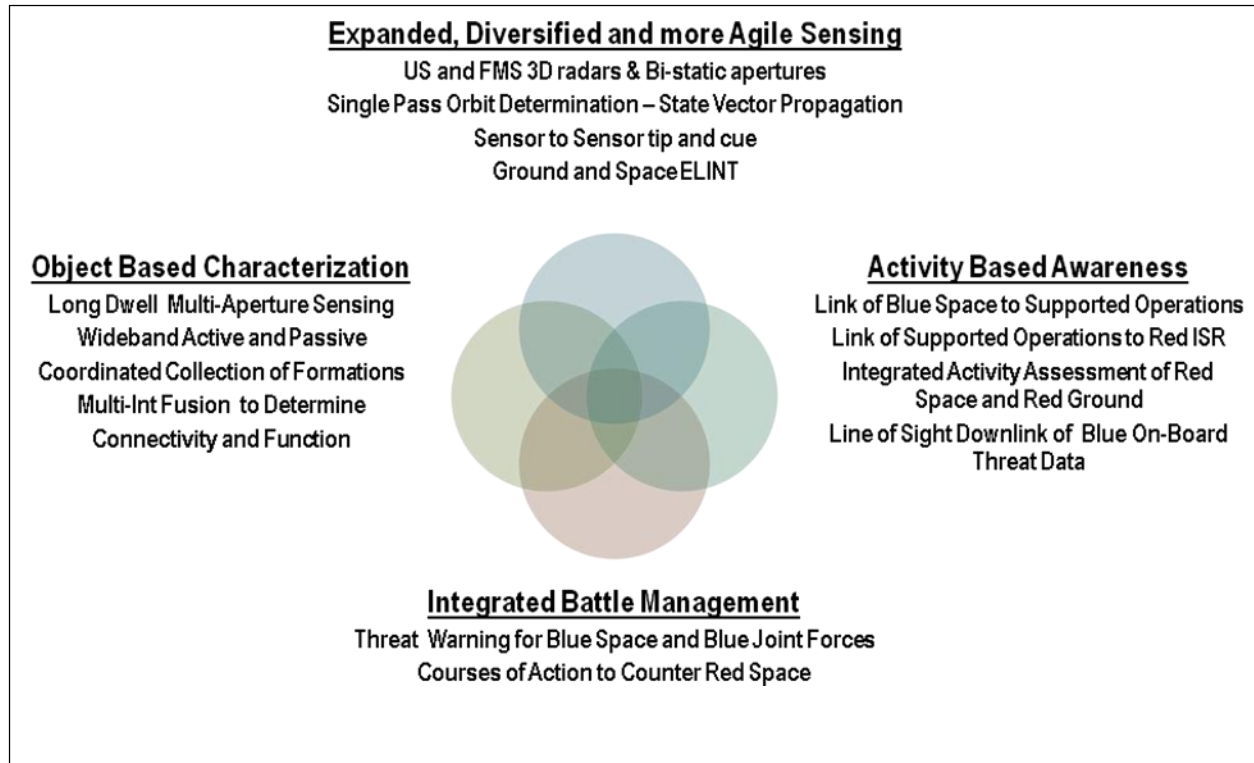
The following tasks need to be pursued as part of any approach to address Red Threats to Blue Space and to counter the Role of Red Space ISR in A2/AD:

- Refine (real time, precise position) status of Blue Space Assets used in joint planning and engagement operations process to allow integration of Contested Space decision making with maritime, land, and air operations. Include status displays of Blue Side end to end functionality re-constitution options for all blue space functionality.
- Set up the sensor data sharing standards, agreements, cross domain protections, and connectivity to allow use of the many new and precise US and Coalition Large Phased Array Radars for sensing, TT&C, and communication. Allow direct down link of threat sensor data from Blue Space. Set up sensor tip and cue of ground and space sensors.
- Deploy the real time (high clock rate to match tactical velocity) object based processing and activity based intelligence algorithms needed to deliver surveillance and warning of red space activity (launches, radars, links, maneuvers, reconfigurations) to theater C2 & decision nodes..
- Provide Joint Force Commanders with threat warning, assessment and contingency courses of action for space threats and for countering Red ISR contributions to A2/AD.

### *Summary*

Trends in Space are clearly running against the US and the consequences of these adverse trends are much broader than just disadvantage in space. This Whitepaper discusses redressing the erosion of conventional dominance – using enhanced Space Sensing, Characterization and Analytics as a framework to integrate Space Awareness and C2 into Joint War Fighting.

Red Side Orbital and Sub-Orbital Threats use the same troublesome technology base (low signature, advanced digital sensing, etc); occupy the same battle space; and are integrated (by the Red Side) into potent Anti-Access / Area Denial capabilities. To counter these threats the US needs to both deploy appropriate technologies; and to commit to seamless use of Maritime, Land, Air, and Space capabilities.



**Figure 14: Technology Framework to Counter Emerging Red Space Threats to Tactical Operations**

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