

P 1.2 ENVIRONMENTAL SPACE SITUATION AWARENESS AND JOINT SPACE EFFECTS

Lt.Col. Kelly J. Hand, Maj. Richard Benz, Maj. Thomas Holts , Capt. Travis Longmire,

nd Lt. Benjamin T. Hendrickson

Headquarters Air Force Space Command, Peterson AFB, CO

Col. Martin France

United States Air Force Academy, USAFA, CO

1. INTRODUCTION

“Know yourself, know your enemy, your victory will never be endangered. Know the ground, know the weather, your victory will then be total...”[1] -Sun Tzu, 500 B.C.

Successful military operations rely on our ability to effectively integrate weather information into the planning and execution of land, air and sea operations. The implications of environmental effects on space capabilities and the subsequent impact on the delivery of joint space effects to the warfighter are not fully understood, but require expert analysis to reduce risk to mission capabilities.

Through Space Situational Awareness (SSA), Air Force Space Command (AFSPC) is able to provide insight into the impact of the environment on space systems and missions. AFSPC has the capability to integrate environmental effects information into space operations in the context of SSA and deliver space effects to the warfighter. The desired end state of environmental SSA is to mitigate negative impacts on and improve performance of our space systems, and exploit potential space environment impacts on enemy systems. SSA is foundational to the success of the space superiority mission. Therefore, effectively characterizing environmental effects is a critical part of that foundation. Space superiority operations ensure the continued delivery of space force enhancement to the military campaign, while denying those same advantages to the enemy. Successful and sufficient achievement results in the maintenance of space superiority, reduced “Fog of War” for commanders, lowered risk of space fratricide, rapid assessment of attacks on all space systems, and a more rapid military execution cycle.

From a Defensive Counterspace (DCS) perspective, confirming or eliminating the environment as a factor enables us to respond in a

much more effective way to protect our systems. From an offensive perspective, superior knowledge provides potential to exploit environmental effects on enemy space capabilities. To achieve a credible environmental SSA capability requires a system of systems (SoS) approach that includes the three system components of environmental sensors, data processing and storage, and data fusion. These critical components are needed to assure viable environmental SSA well into the 21st century. But before examining these components it would be helpful to provide some context by first looking at SSA doctrine.

2. Space Situation Awareness (SSA) Doctrine

USSTRATCOM defines Space Situation Awareness (SSA) as “the requisite current and predictive knowledge of space events, threats, activities, conditions and space system (space, ground, link) status, capabilities, constraints and employment – to current and future, friendly and hostile – to enable commanders, decision makers, planners and operators to gain and maintain space superiority across the spectrum of conflict.” [2]

Figure 1 illustrates the various components of this doctrine[3]. Ultimately, SSA information needs to be integrated into and made available through a Single Integrated Space Picture (SISP). From top to bottom in the figure, the SISP consists of relevant information from intelligence systems concerning threats to our space capabilities such as characterizing red and gray space threats and courses of action (COAs)—Space Intelligence Preparation of the Battlespace (SIPB). Additionally, space surveillance systems provide space system and object characterization to the SISP via the Space Surveillance Network (SSN). Weather information from space and ground-based weather sensors, models and applications (such as the SSA Environmental Effects Fusion System—“SEEF”) provide actual and forecast environmental conditions and its impact on friendly and enemy space capabilities. Finally, space force

status information such as asset availability is provided by our blue space forces. Practically speaking, the SISP provides decision-makers and users at the strategic, operational, and tactical level an accurate, up-to-date, and intuitive understanding

of the situation. Combined with military judgment, this allows identification of emerging patterns, discerns critical vulnerabilities, and concentrates space combat power where it can have its greatest effect[4].

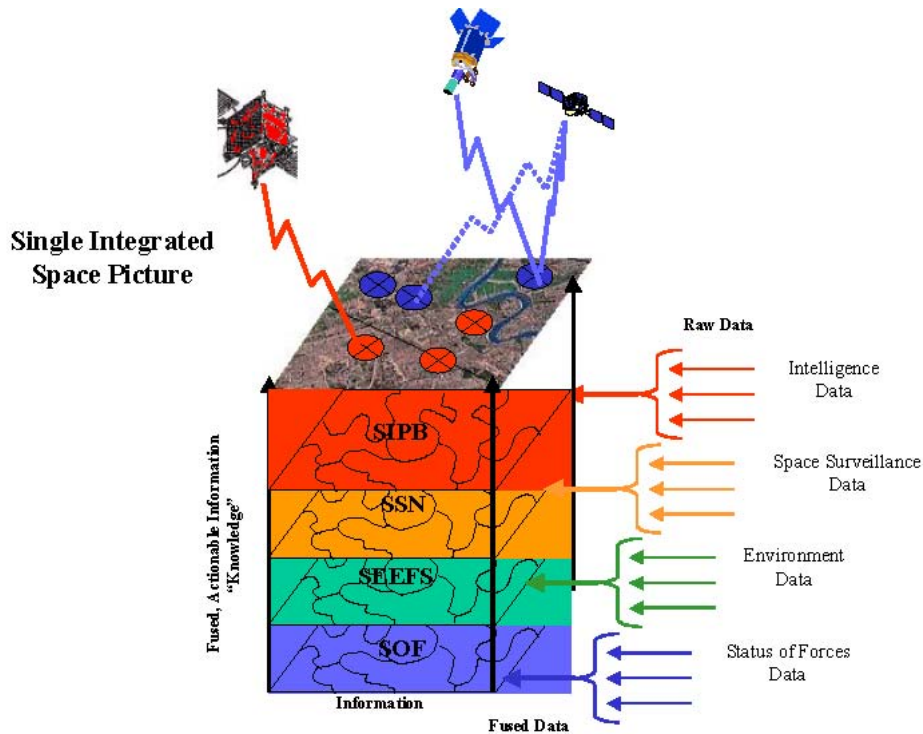


Fig. 1. Single Integrated Space Picture (SISP).

Because the focus here is primarily on the environmental aspects of SSA, the following definition of “environmental SSA” is provided in the context of the USSTRATCOM SSA definition: “The requisite knowledge of current and predicted environmental conditions and the effects of those conditions on space events, threats, activities and space systems to enable commanders, decision makers, planners and operators to gain and maintain space superiority across the spectrum of conflict.”[5]

3. Needed Capabilities

The warfighter’s environmental SSA needs are defined within the AFSPC Space Superiority Functional Concept.[6] The first capability below describes the need to gather information concerning environmental conditions relevant to effecting space systems and missions. The subsequent capabilities refer to the application of that information to military decision making or Situational Awareness:

- Monitor and characterize environmental conditions relevant to space system and mission effects. Access to actual and forecast terrestrial, near-space and space environmental information to allow friendly

forces to predict, respond to, mitigate, and exploit environmental effects on friendly and adversary operations.

- Assess and forecast natural environmental effects on blue/red/gray space systems and missions, including user impacts.
- Assess and predict effects of man-made changes (e.g., High Altitude Nuclear Detonation) to the environment on blue/red/gray space systems and missions, including user impacts.
- Support Munitions Effectiveness Assessments (MEA) related to environmental factors (e.g., scintillation effects on GPS-aided munitions accuracy).
- Support anomaly resolution/attack characterization for blue space systems related to environmental factors (e.g., help DCS distinguish natural from hostile effects).
- Support development and execution of the environmental portion of the Space Tasking Order (STO).
- Assess environmental vulnerabilities of blue, red and gray space forces and assets.

For effective SSA it is important to realize environmental conditions can significantly affect a space system's performance and survivability and therefore may impact its ability to bring intended space effects to the joint warfighter. For example, satellite systems, spacecraft components and their payloads, communication links for satellite command and control and mission data, and the satellite's respective ground sites can all be affected by the environmental conditions in which they operate. Likewise, ground-based space systems like surveillance or missile tracking radars that contribute to the space control and missile warning missions can also be affected by the environment. Thus, the degree to which the environment impacts these systems and how environmental information can be applied to improve performance or protect the systems defines the type of information needed for effective SSA. That said, relevant space system environmental information must include both terrestrial and outer space conditions—mud to sun. While most people are aware of the terrestrial environment such as rain, high winds, clouds, temperature and pressure, fewer are aware of the outer space environment. So before discussing the linkage between environmental effects and warfighter impacts, and ultimately the desired effects of environmental SSA, it would be helpful to describe the outer space environment.

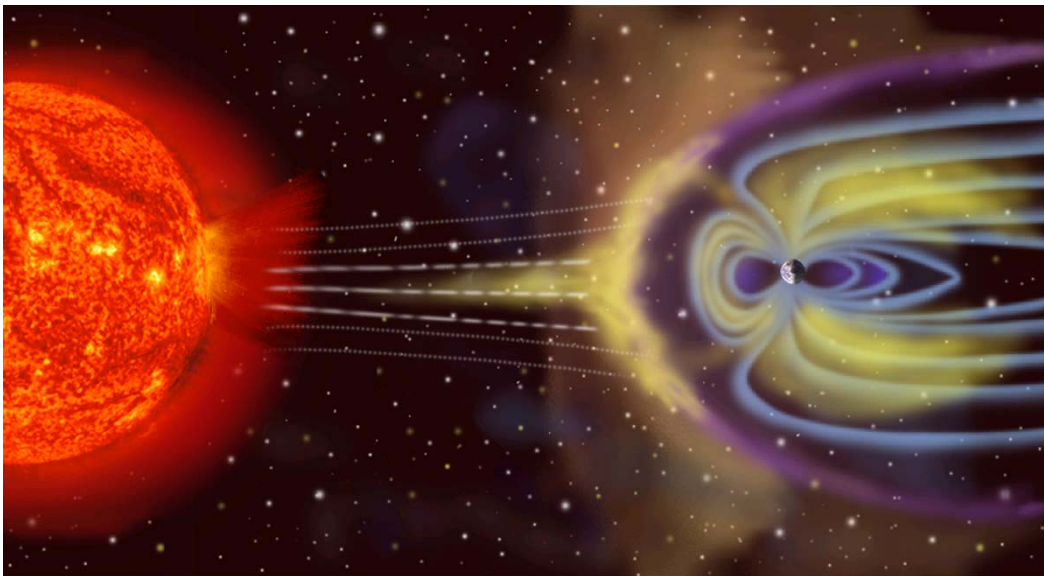


Fig. 2. The Outer Space Environment (Courtesy of NASA)

4. The Outer Space Environment

The natural outer space environment illustrated in Figure 2 consists of the Sun, the space between the Sun and near-Earth called interplanetary space, and the near-Earth space environment. The Sun is a medium sized star with extreme mass made of mostly hydrogen and a little helium. Nuclear fusion takes place in the Sun's center resulting in the release of huge amounts of energy. The energy is emitted in two forms, electromagnetic and particle energy. Electromagnetic energy travels at the speed of light, taking about 8 minutes to travel the 93 million mile distance from the Sun to the Earth. The form of electromagnetic energy includes the visible light you see, the infrared energy you feel and the ultraviolet energy that reacts with your skin's melanin (the sun also emits X-ray, gamma ray, and radio energy). The second form of solar energy emitted is particle radiation. The same nuclear processes that produce the extreme amounts of electromagnetic energy described above expel massive amounts of hydrogen and helium nuclei called protons and alpha-particles and an equal

number of electrons. This makes up the solar wind. This solar wind travels straight out from the sun at about 800,000 miles per hour, plus or minus a few hundred thousand depending upon solar conditions. In addition to the solar wind, solar events known as solar flares and coronal mass ejections emit high energy solar particles that can impact spacecraft components. These particles can travel near the speed of light. At the near-Earth environment, the solar wind first encounters the magnetic field of the Earth (the geomagnetic field) at about a million miles between the Earth and the sun. This creates a teardrop shaped magnetic shell surrounding the globe called the magnetosphere. This shell is formed due to the balance between the Earth's magnetic field pressure and the pressure exerted by the solar wind. The tail of this shell extends many millions of miles away from the sun (on the leeward side of the Earth). Contained within the magnetosphere are the radiation belts (Van Allen Belts) and other radiation phenomena that can affect spacecraft components. Closer to Earth's upper atmosphere, the "ionosphere", is the ionized portion of the atmosphere that exists from about 1000 miles altitude down to about 50 miles.

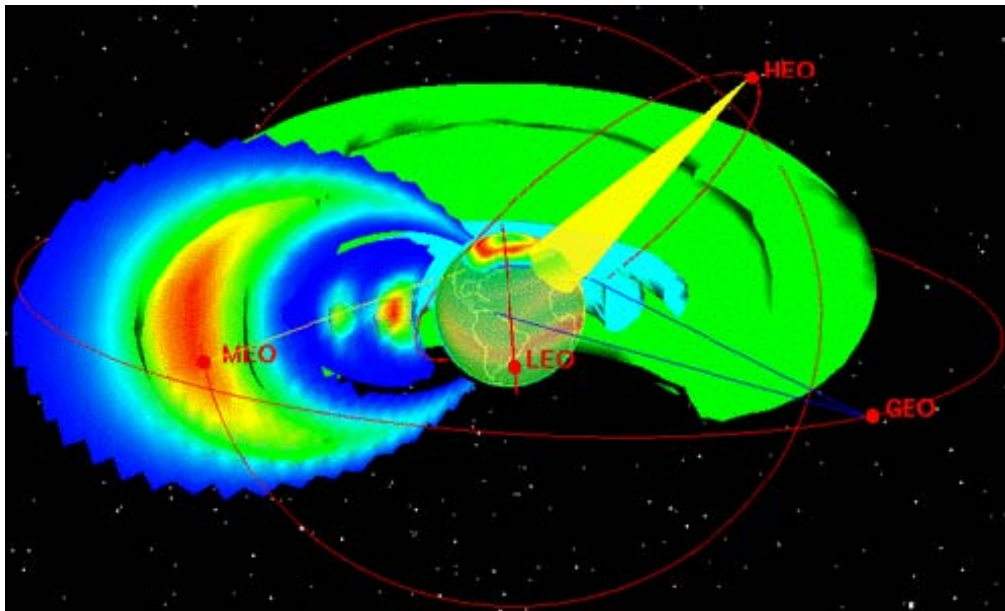


Figure 3. Cross section of the inner and outer radiation belts, as well as the types of satellite orbits.

Figure 3 illustrates the complexity of this environment in the context of low-earth orbit (LEO), medium earth orbit (MEO), geosynchronous orbit (GEO) and highly elliptical orbit (HEO) satellites. High above the Earth, the figure shows a color cross section of the inner (1500-8000 miles altitude—just outside most LEO satellite orbits) and outer radiation belts (8000-25,000 miles altitude—affects MEO) above the earth. The variation in colors on the globe is meant to illustrate variations in conditions within the ionosphere and upper atmosphere.

Low Earth Orbiting (LEO) satellites such as the Defense Meteorological Satellite Program (DMSP) operate through the upper atmosphere (at about 600 miles) and are affected by atmospheric drag, trapped and solar particle radiation. Medium Earth Orbiting (MEO) satellites such as the Global Positioning Satellites (GPS) operate in the Van Allen radiation belts at about 11,000 miles, and are subject to constant bombardment by the highly energetic electrons that populate this region. These particles can cause anomalies in on-board computer systems and degrade inadequately shielded sensors, structures, and materials. Geostationary satellites, like the Defense Satellite Communication System (DSCS) satellites, are at the outside of the radiation belts, but operate in a region where charging and discharging can occur on the surface of the spacecraft. Also, GEO satellites experience effects from highly energetic cosmic and solar radiation not as prevalent at LEO altitudes. Finally, all satellites and some ground-base space systems must propagate their radio frequency (RF) signals through the ionosphere to

reach terrestrial users. Depending upon the frequency of the radio signal, the ionosphere can significantly degrade the associated weapon system's performance because of the refractive effects of the ionosphere.

5. Environmental Impacts

Ultimately, it is the environment's effects on space systems that concern us. To effectively determine what environmental information matters to space operations and capabilities, the source of significant environmental effects need to be linked to system effects and, in turn, to associated warfighter impacts. It is the space system program office's responsibility to design space systems to operate within their specific operational environment as determined by their specific mission. But the environment can only be engineered away to a certain degree before additional costs begin to impinge on other priorities, and trades are made depending upon the desired system life time and performance requirements. For example, radiation hardening prevents parts from wearing out prematurely in the space environment, but adds weight and, therefore, cost. Satellite Communication (SATCOM) power requirements account for the effects of some terrestrial conditions such as rain rate, but again add weight and complexity. Severe radiation or meteor events may require other means of system protection, such as sensor shuttering or satellite maneuvering that can best be enabled by timely and accurate operational, environmental SSA. The table below provides some example linkages between environmental cause, effect, and warfighter impact.

Space Capability Joint Effect	<u>Environmental Cause</u>	<u>Environmental Effects</u>	<u>Warfighter Impacts</u>
Comms on the Move	Ionospheric scintillation, ionospheric refraction	Degraded/broken communication link, anomalous radio wave propagation	Loss of command and control, lives/missions at risk
Intelligence, Surveillance and Reconnaissance (ISR)	Upper atmospheric density change, ionospheric refraction and scintillation	Inaccurate space object identification and tracking	Space object collision (e.g. shuttle), inaccurate enemy space force position
Missile Intercept	Aurora, upper atmospheric density change, ionospheric refraction and scintillation	Degraded warhead detection and tracking	Decreased probability of missile intercept, lives at risk
Precision Engagement	Ionospheric scintillation, ionospheric refraction	Degraded GPS system performance	GPS guided weapons miss target, increased collateral damage/civilian casualties
Intelligence	Aurora, upper atmospheric density change, ionospheric refraction and scintillation	Decreased intelligence system performance	Inaccurate enemy position data
Spacecraft anomaly assessment	Solar/Magnetospheric particle radiation, Upper atmospheric density change, ionospheric refraction and scintillation	Satellite system anomalies, increased operational downtime of space system	Decreased operational space system utility (GPS, Space-Base Infra-Red System (SBIRS), Space Radar (SR), etc.)
Attack Assessment	Solar/Magnetosphere particle radiation, auroral, upper atmospheric and ionospheric changes	Enemy and friendly weapon system performance degradation	Inability to meet attack assessment timelines, inability to distinguish hostile attack from natural effects

Table 1: Links between environmental cause, effect, and warfighter impact

This matrix illustrates the potential for linkages between missions, space environmental conditions, environmentally induced system anomalies and warfighter impacts. Ultimately, if we are completely ignorant of environmental stressing effects, the resulting potential warfighter impacts are described in the right hand column. For example, Comms-on-the-Move (OTM) is a capability provided by SATCOM. If space weather interferes with tactical SATCOM at certain times and the user has adequate warning, they can effectively plan for the disruption, switching to terrestrial communication or using more robust SATCOM. Another example is precision engagement. If the accuracy (Circular Error Probable or CEP) for certain GPS aided munitions is affected by space weather, the weapons planners need to know about it in order to more effectively plan for the type of weapon system to be employed—or they might delay the mission in order to avoid potential collateral damage. Still another example is satellite operations and the requirement to unambiguously determine the source of a spacecraft anomaly. For the warfighter, this is especially noticeable if the satellite in question is dedicated to their area of responsibility (AOR) for communications, navigation, weather, or missile warning. Having the ability to rapidly determine the source as environmental not only helps get the system back on line faster, it can also help distinguish from other sources such as hostile attack.

6. Desired SSA Effects

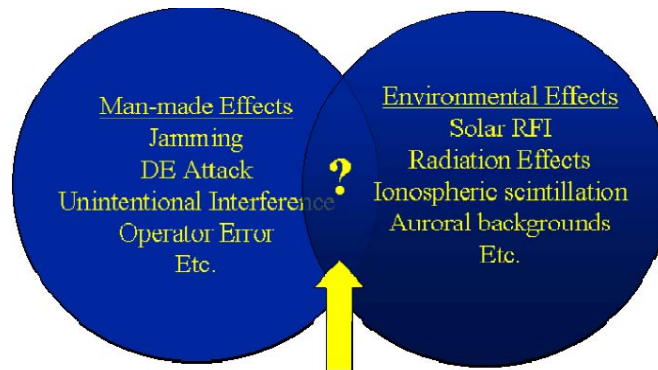
The desired end state of environmental SSA is the

effective application of environmental SSA information—that is, to mitigate negative impacts on and improve performance of our space systems, and exploit potential space environment impacts on enemy systems.

SSA is foundational to the success of the space superiority mission and effectively characterizing environmental effects is a critical part of that foundation. Space superiority operations ensure the continued delivery of space force enhancement to the military campaign, while denying those same advantages to the enemy. When SSA is successfully and sufficiently achieved, the following effects can be achieved:

- Maintenance of Space superiority
- Reduced “Fog of War” for commanders
- Lowered risk of space fratricide
- Rapid assessment of attacks on all blue, gray, or red space systems
- Shortened kill chain and targeting cycle
- Verification of space-related treaty compliance

Figure 4 illustrates desired effects using a satellite anomaly as an example. The circle on the left represents the set of anomalies caused by sources other than the environment. The circle on the right represents anomalies characteristic of the environment. Where there is overlap in characteristic between the two, there is uncertainty (i.e., “fog of war”).



Area of Uncertainty

Figure 4. Desired SSA effects using a satellite anomaly

Ultimately, superior knowledge of both circles will enhance advantages over an adversary from both an offensive and defensive perspective. From a DCS perspective, confirming or eliminating the environment as a factor enables us to respond in a much more effective way to protect our systems. From an offensive perspective, superior knowledge provides potential to exploit environmental effects on enemy space capabilities.

7. Environmental SSA System of Systems

In order for environmental SSA to provide optimal support to our national space infrastructure, we need to analyze the capabilities that make up the environmental SSA System of Systems (SoS) — their current status and how they are envisioned in the future to support Space Superiority and Force Enhancement operations. Figure 5 is a high level view of the SSA architecture. It shows all the pillars described in section 2 and that together, information from these SSA areas, supply actionable information required for the command and control of space capabilities to support the warfighter. Figure 6 drills down deeper into the environmental SSA pillar and reveals the three components of the environmental SSA SoS: Sensors, Models (includes net-centric database), and data fusion capabilities.

Like a three-legged stool, all legs of this SoS are needed in order to meet SSA requirements. AFSPC has analyzed the current and desired state of these three components in the context of SSA task satisfaction. The current state shows a need to develop new capabilities in all three areas, but specifically data fusion capabilities must be developed to make the best use of already available information. Environmental SSA fusion effectively merges environmental information and system performance parameters in order to objectively characterize and forecast the degrading effects of the environment on the performance of space systems and the resulting impact on military operations. The current project underway to perform this mission is the SSA Environmental Effects Fusion System (SEEF). This network centric capability takes environmental information and merges it with system performance data (for mock-up see Figure 8), and then provides decision relevant results to the SISP and other network centric user defined systems. In this example, the effects of solar radio noise are merged with SATCOM terminal performance to show the Sun as a potential source of radio frequency interference (RFI). In this case this capability can be used to resolve electromagnetic interference (EMI) issues.

Referring back to Figures 1 and 6, one can see that multiple data sources can be used at the tactical and operational level. In the previous example, at

the tactical level, one could objectively analyze specific equipment RFI issues. At the operational level, this information could be aggregated from many users or operators to identify trends and potential vulnerabilities. Figure 8 is only one example of the capabilities SEEF will bring. SEEF will provide analogous support to the example space capabilities and systems illustrated in Table 1. This provides the means to minimize valuable time spent on analysis and efforts pulling data from multiple sources and better focuses resources on warfighter tasks.

Appendix A provides a list of national space environmental data sources. It describes the source provider, observations, and the associated space weather phenomena or conditions of interest. In order for SEEF to be effective it must have access to environmental parameters that are validated and processed through operational models and databases developed and maintained by the Air Force Weather Agency (AFWA) and NOAA Space Environment Center. Additionally, specific system parameters related to the performance of specific space systems must be obtained in sufficient detail and timeliness in order to objectively and rapidly assess if system performance is or will be significantly affected by the environment. These parameters may have both dynamic as well as static elements. A notional form of validation of these parameters is outlined in figure 7.

The validation process will need to be further defined as systems develop and requirements change. In general, automated algorithms can remove prediction output errors to some degree. For example, computer forecast model biases could be reduced. Decision parameters that are not directly predicted are derived from environmental parameters. This step can occur centrally or in the decision-makers' decision aid systems. During a validation step, automated algorithms compare predicted values against available measurements to assess the accuracy of the decision parameters. Predicted values that are diverging from measured values are flagged for possible human adjustment or to advise decision-makers of the added risk associated with taking action based on potentially inaccurate values. When proven procedures are in place, AF weather and space personnel adjust the automated output to improve its accuracy. Finally, the results of this entire process are published in the net-centric data repository and are then available to space system operators and users, environmental support experts and ultimately decision-makers.

The large array of current and future sensors and models are developed from data requirements intended to meet US military and civilian requirements. Currently sensing required for

complete coverage of the space environment is accomplished via multiple types of space and ground-based sensors. Space-based sensors include NASA solar wind and coronal mass ejection sensors, NOAA GOES X-ray monitors, and a variety of DoD, DoE, and NOAA in-situ electric field, magnetic field and particle sensors. Ground-based sensors include ionosondes, solar optical and radio telescopes, Total Electron Content (TEC) sensors, scintillation monitors, magnetometers, neutron monitors and riometers. Together these national capabilities provide continuous monitoring for the detection of background and impulsive solar, magnetospheric, upper atmospheric and ionospheric effects.

Currently ionospheric modeling consists of the Parameterized Real-Time Ionospheric Specification Model (PRISM) and the Wide-Band Model (WBMOD). PRISM provides a global scale specification of the ionosphere. Hourly, the conditional climatology is modified by limited real-time data and index inputs. WBMOD supplies forecasts of scintillation S4 index and signal fade. This model incorporates climatology by time, season, solar activity satellite, location, and data from SCINDA sites every two hours, or on demand. In the near future AFWA plans on replacing PRISM with the Global Assimilative Ionospheric Model (GAIM). GAIM will employ state-of-the-science

assimilative techniques to best use new ionospheric sensor sources coming on line like the DMSP Special Sensor UV Limb Imager (SSULI) and Special Sensor UV Spectral Imager (SSUSI).

Magnetospheric models are conditioned by input from NASA's ACE solar wind satellite, DMSP particle and in-situ plasma, electric field and magnetic field sensors, and a number of ground-based sensor derived geomagnetic indices. AFWA's Magnetospheric Forecast and Specification Model (MSFM) focuses on the inner and middle magnetosphere and provides a forecast capability at three hour intervals and is critical to predict the particle environment affecting our nation's satellite systems.

In total the overall environmental SSA SoS integrates multiple military and civilian data collection sources. This provides an opportunity for intentional partnership development between the federal enterprise, researchers and university systems. These efforts allow increased leveraging of existing governmental and civil capabilities, thus minimizing duplication of effort when it comes to operational environmental support to our national space interests. The result is best use of taxpayer dollars and more importantly enhanced protection of the nation's space capabilities.

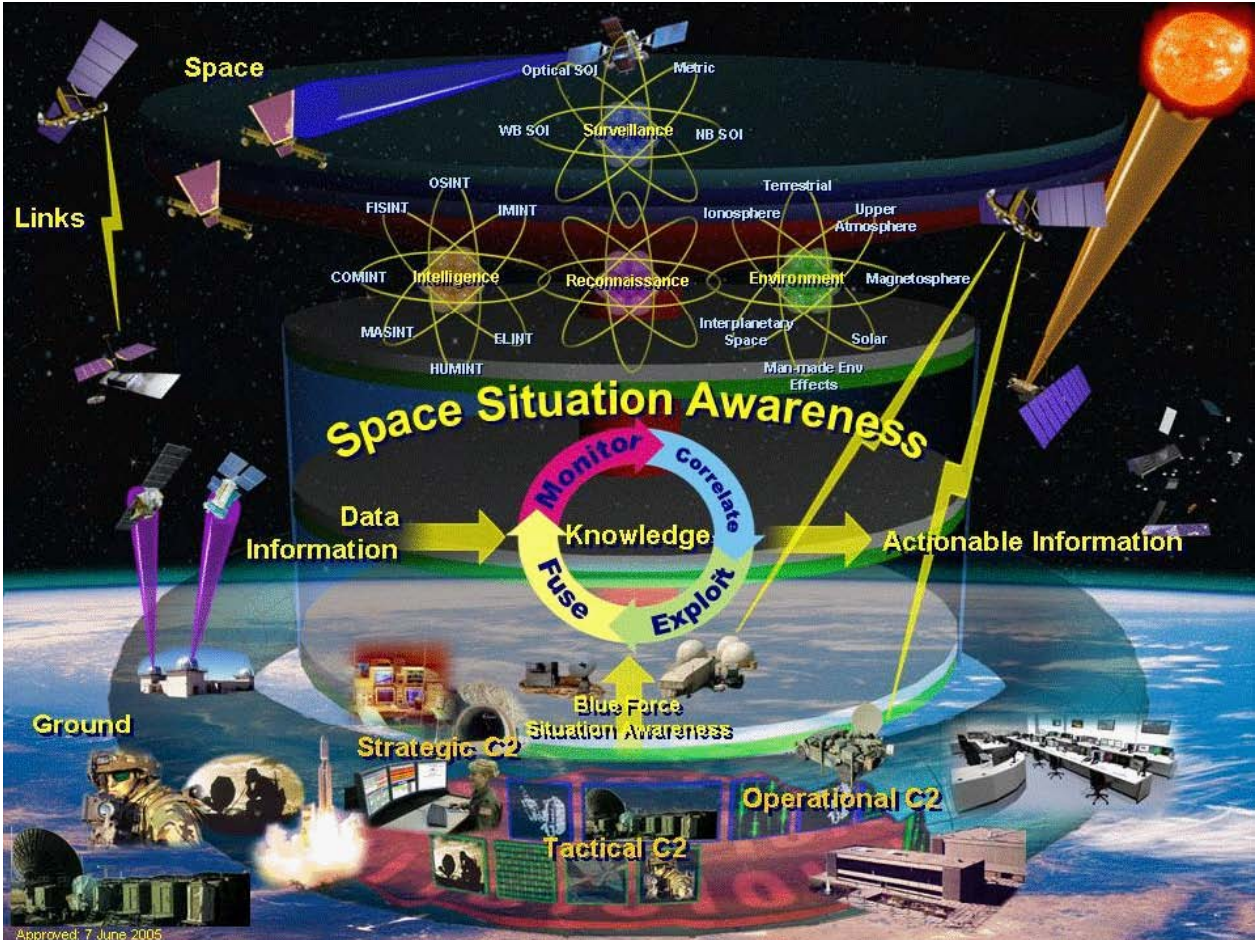


Figure 5. High Level View of the SSA Architecture

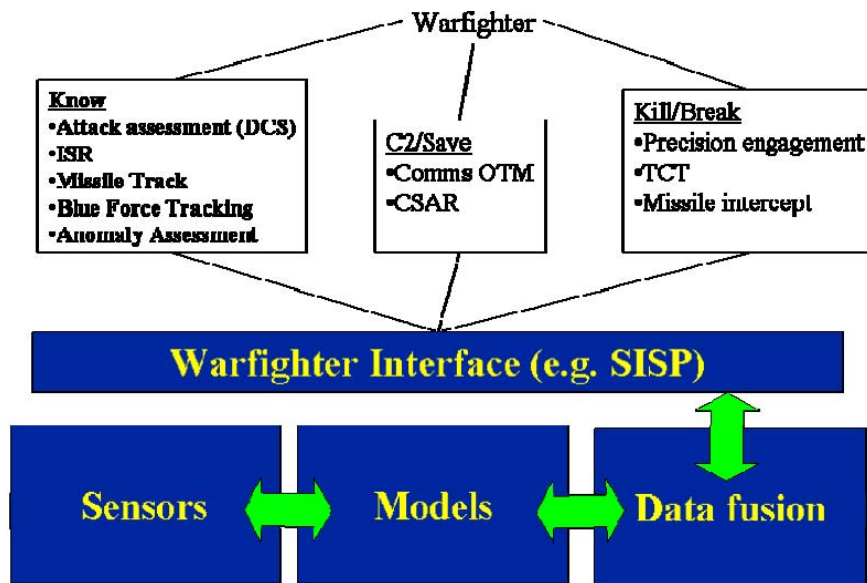


Figure 6. Environmental SSA Sensor to Shooter Context

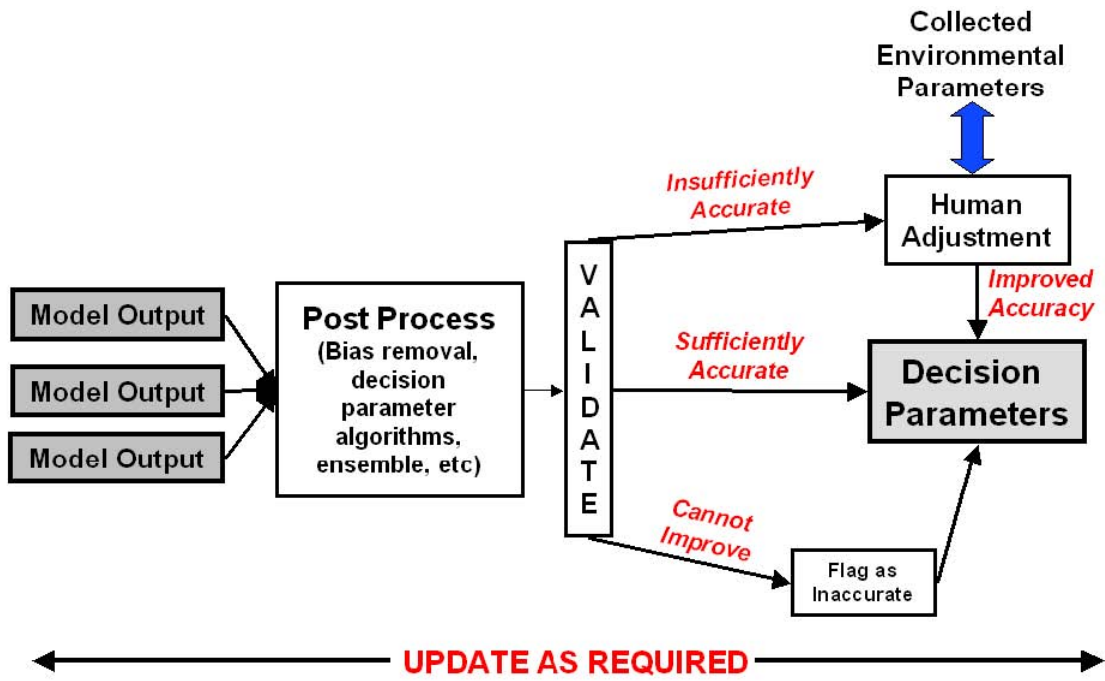


Figure 7. AFW "Produce Decision Parameters" Concept Model

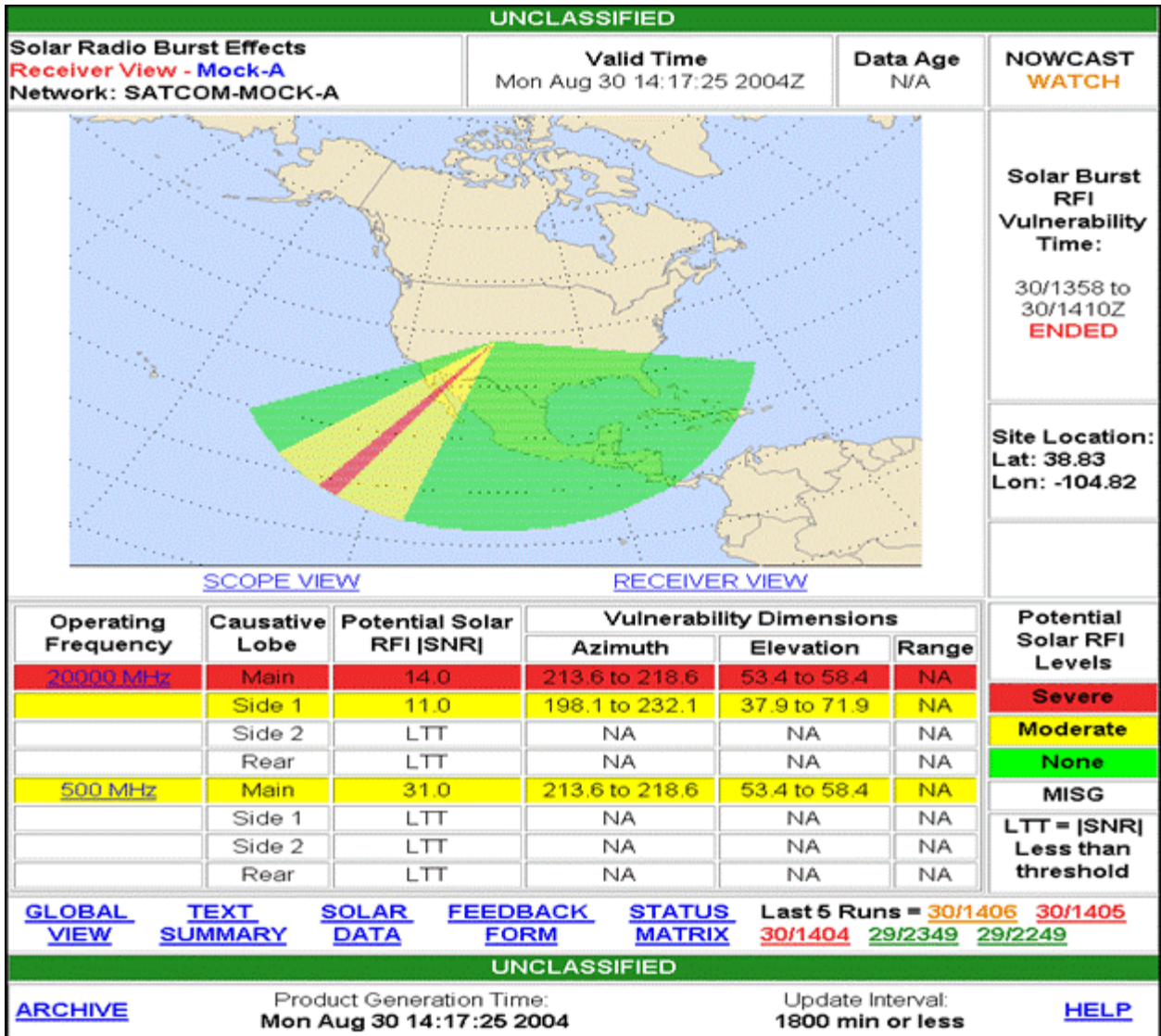


Figure 8. SATCOM RFI Analysis Display

8. Conclusion

Because of the critical nature of joint space effects to successful military operations, our adversaries will seek ways to degrade or destroy our space capabilities and ways to enhance their space capabilities. This elevates the importance of SSA within space superiority and makes its directly

analogous to Situational Awareness for air superiority. Although not as well appreciated, environmental effects on space superiority must be on our radar screen. AFSPC is addressing this concern through careful analysis and is equipping our forces with the kind of environmental effects information that is relevant to maintaining and improving desired joint space effects.

References:

1. Sun Tsu, The Art of War
2. USSTRATCOM Space Control CONOPS, 2004
3. SSA Fusion Concept, Gary Barrette, Jan 2005.
4. Marine Corp Doctrine Publication 1-3, Tactics, 30 July 1997
5. AFSPC Counterspace Mission Area Plan for 2008 and Beyond
6. AFSPC Space Superiority Functional Concept, 2005

Appendix A

Table 6-10. Space Weather Data Source and Observations

GBE = Ground Based Element

SBE=Space Base Element

Space Weather Data Source	Sensor	Data Provider	GBE	SBE	Observations	Phenomena
DMSP Block 5D-2	OLS	DoD		X	Visual aurora	Aurora boundary, intensity, characteristics
	SSIES			X	Electron fluxes, scintillation meter, ion drift and retarding potential analyzer	Characteristics of space plasma above the F region peak
	SSJ/4			X	Precipitating electron and proton fluxes	Auroral boundary
	SSM			X	Geomagnetic fluxes	Geomagnetic conditions
	SSUSI			X	EUV Airglow Image	Ionospheric and upper atmospheric density
	SSULI			X	EUV Limb Scan of Airglow	Ionospheric and upper atmospheric density
TIROS	TED	DoC		X	Total Energy Detector 300 keV-20 keV electrons and protons	Auroral boundaries, total energy input
	MEPED	DoC		X	Medium energy proton and electron fluxes	Auroral boundaries, South Atlantic anomaly, intensity of outer radiation belts
GOES	SEM	DoC		X	Solar x-ray fluxes (.5-4A and 1-8A)	Solar flares with x-rays
				X	Energetic proton, alpha particle and electron fluxes data	Trapped outer-zone and solar particles (E1,P1)
				X	Geomagnetic field measurements	Geomagnetic conditions
	SXI			X	Solar X-Ray Images	Flare and CME launch positions
LANL		DoE		X	Energetic particle data	Space vehicle anomaly assessments
RSTN	RIMS	DoD	X		Solar radio bursts, background flux	Solar radio bursts, background radio fluxes
	SFIR			X	Solar radio noise	Solar radio noise disturbance
SOON	H-alpha telescope	DoD	X		Solar chromospheric features	Solar flares, disk and limb activity, active region characteristics
	White light telescope			X	Solar photosphere	Sunspot characteristics
	Magneto-graph			X	Solar magnetic field	Active region magnetic gradients
DISS	Digital Ionosonde	DoD	X		Bottom side ionospheric parameters	Ionospheric conditions
IMS (includes SCINDA)	GPS Receiver	DoD	X		Total electron content, ionospheric scintillation	Ionospheric conditions

Space Weather Data Source	Sensor	Data Provider	G B E	S B E	Observations	Phenomena
SHIN	Ionosonde	Australian Gov	X		Bottom side ionospheric parameters	Ionospheric conditions
USGS	Magneto-meter	DoI	X		Magnetic field measurements	Geomagnetic conditions
DoD Satellite	Particle detectors	DoD		X	Electron and ion particle fluxes	Solar/Magnetospheric particles
GPS Satellite	Particle dosimeter	DoD		X	Electron and ion particle fluxes	Trapped particle radiation
ACE	Solar wind ions, particles and mag field sensors	NOAA/NASA		X	Solar wind	Geomagnetic disturbances
Thule Geopole	Riometer		X		Ionospheric absorption	Polar Cap Absorption (PCA)
Thule Geopole	Neutron Monitor		X		Secondary cosmic radiation greater than 500 Mev	High energy particle fluxes
Mt Wilson Observatory	Magnetogram		X		Sunspot magnetic field	Sunspot classification
NSO Observatory	10830 Angstrom measurement, coronal observations	NSO	X		Magnetogram, coronal lines	Coronal hole
Australian Observatory	Solar optical & radio observations	Australian Gov.	X		Solar chromospheric features, Solar radio bursts, background flux	Optical flares, radio bursts, solar active region analysis
DARO	2800 MHz radio telescope	Canada	X		Radio flux	F10 Standard
CEASE	Compact Environmental Anomaly Sensor	DoD		X	In Situ Particle Measurements	Anomaly producing space weather conditions
STEREO		NASA		X	CME measurements	Magnetospheric conditions affecting satellite operations

