Space Strategies Center (SSC)

White Paper

Has China Pre-Positioned to Attack GPS Satellites?

Focus Areas: Space Situational Awareness (SSA); Space Predictive Battlespace Awareness (PBA); Predictive Modeling of Adversarial Counterspace Threats; Space Courses Of Action (COA) Prediction; Data Fusion of INTEL Data for the Space Domain; Anticipatory Threat Assessments; Understanding Adversarial Counterspace Intentions

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Has China Pre-Positioned Assets to Attack GPS Satellites?

ISSUE TOPIC 7 INTRO – Most people believe that for many countries, especially the United States, loss of outer space capabilities would have a significant impact on their ability to conduct terrestrial warfare. Probably the best way to take out a country's space assets would be to attack as swiftly and as undetectably as possible. A National Defense University study of some of the major conflicts of the 20th century showed that, on average, surprise attacks gave a favorable 1:14.5 casualty ratio compared to a 1:1.7 casualty ratio for attacks without surprise. Though we are not talking about major casualties in space wars, surprise can only be even more beneficial to an attacker due to most space events being obscured from ground sensors. An attack in space may precede terrestrial attacks, so as to blind your opponent, and deny or delay communications to forces. Space may provide a strategic tripwire to warn of impending terrestrial attack, and one may even prevent these terrestrial attacks if a country serves a strong response after detecting an impending space attack.

Employing the Space Warning and Assessment Tools (SWAT) unclassified software that I previously developed, certain orbital anomalies were automatically detected concerning Chinese satellites that may have an impact on national security satellite vulnerabilities. I initiated discussions on this topic at the following LinkedIn website.

1. Medium Earth Orbit (MEO) Navigation Satellite Constellations

Figure 1 shows the orbits of Chinese Beidou satellites and Global Positioning System (GPS) satellites at Medium Earth Orbit (MEO). At first glance, it does not appear that these constellations intersect, since they are in slightly different inclinations and altitudes.

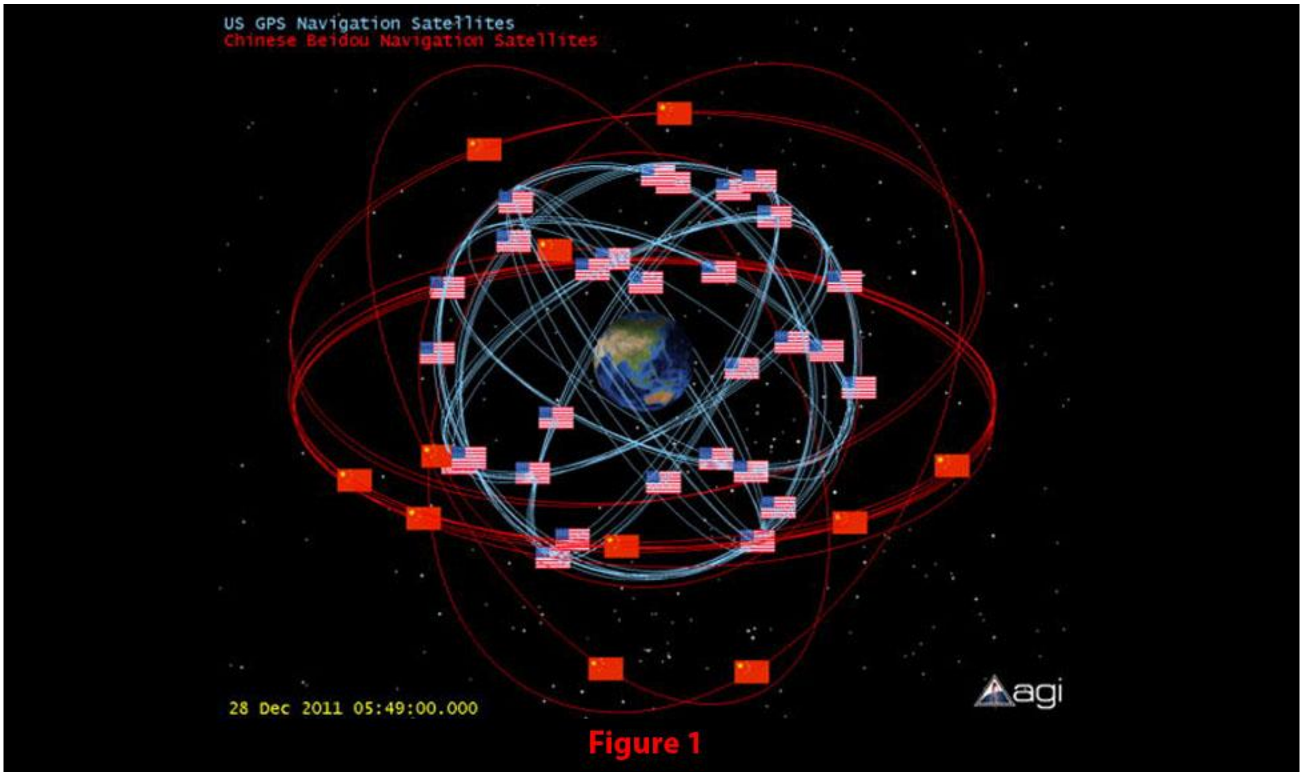

Figure 1. GPS and BeiDou Navigation Satellite Constellations

2. GPS Navigation Satellite Constellation Vulnerability to Easy Intercepts

However, **Figure 2** shows how close one of these BeiDou satellites comes to the entire GPS constellation (each color line is a different GPS satellite) over a 30 day period. Over this time period every GPS satellite comes within 250-2,500 km distance, which is a small amount of delta-v (maneuvering capability) for BeiDou to intercept every GPS satellite. I will note that an anti-satellite (ASAT) weapon does not necessarily have to match the orbit of its target – it just has to have an intercepting orbit. Remember the Cosmos satellite that crashed into Iridium (COSMOS 2251 and Iridium 33) a few years ago, where the differences in inclination was 12 degrees, so the COSMOS certainly did not patiently sneak up on the Iridium and conduct a close-in attack. As the BeiDou satellite comes close to each GPS orbit, it is possible to deploy a smaller space mine (ASAT) against several or all GPS satellites. You do not need to take out the entire GPS constellation to have a major effect on its mission. I am not stating that this possible attack setup is intentional true – only a possibility that would be very difficult to detect or defend against.

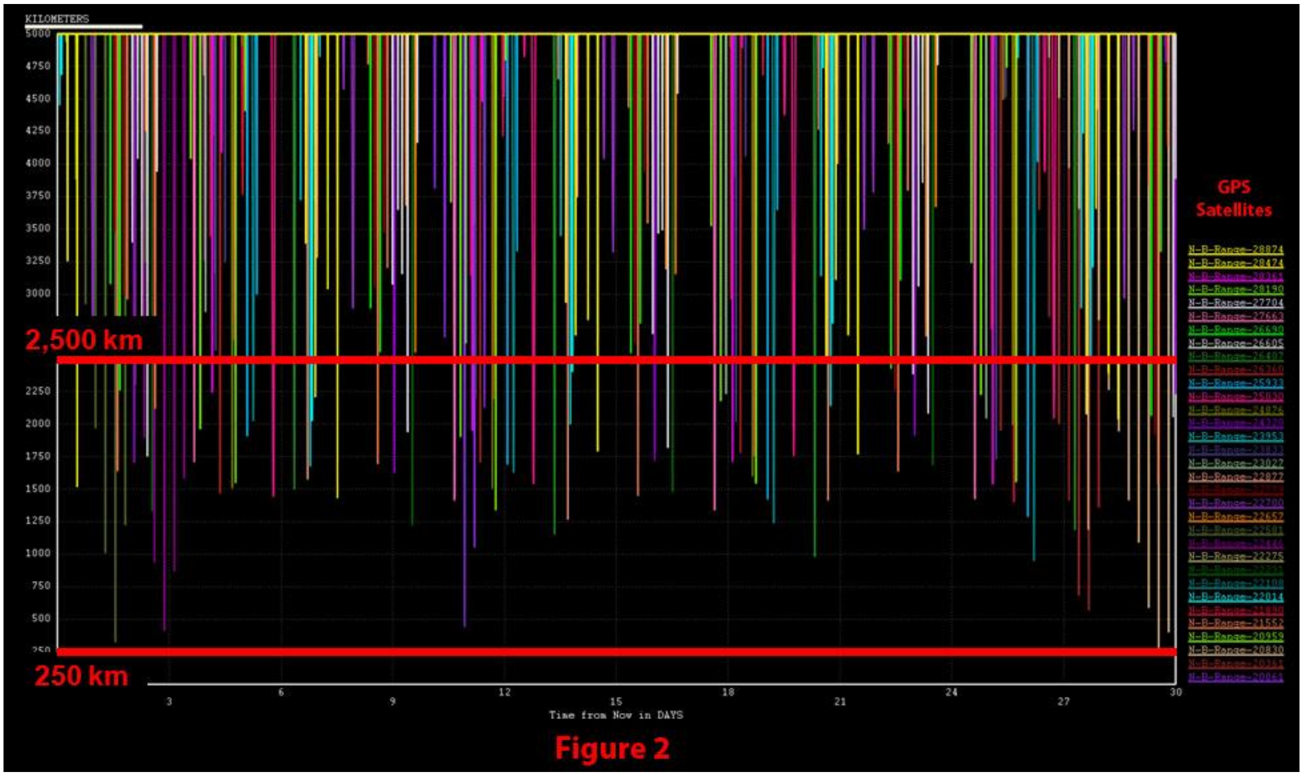

Figure 2. BeiDou Satellite Gets Close to Entire GPS Constellation

3. Geostationary BeiDou Satellite Unusual Behavior (Possibly Playing Dead)

Another BeiDou satellite (1D), originally in Geostationary orbit, later entered into graveyard orbit much earlier than design life under mysterious circumstances. **Figure 3** shows that even though BeiDou 1D is listed as "failed", its orbital inclination and eccentricity have continued to improve. Due to gravitational perturbations (primarily Earth, solar and lunar) and solar radiation pressure, these orbital parameters should be getting worse, not better. This implies that BeiDou 1D was still being controlled, and possibly had not failed, and may have gone on to other missions traversing the geostationary belt, flying near other nation's critical satellites.

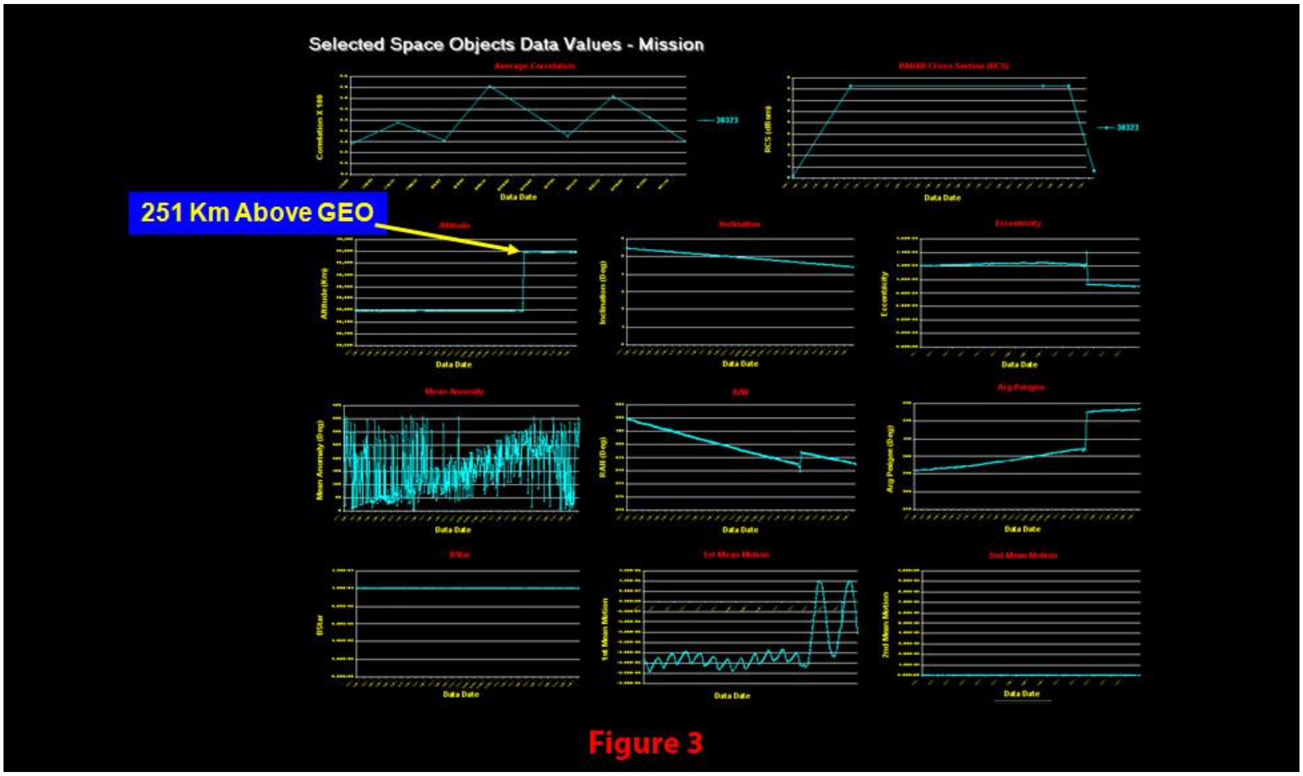

Figure 3. History of Geostationary BeiDou Satellite Orbital Parameters

4. Chinese SY Satellites Mirror-Matching Attitudes

Figure 4 shows another mystery concerning Chinese satellites. This figure shows the RADAR Cross Section (RCS) of each of 2 Chinese SY satellites in Low Earth Orbit (LEO) over a period of time. It is interesting how these satellites have near mirror RCS values at the same time, implying synchronized orientations, even though they are in different orbits. See discussion for theories on this.

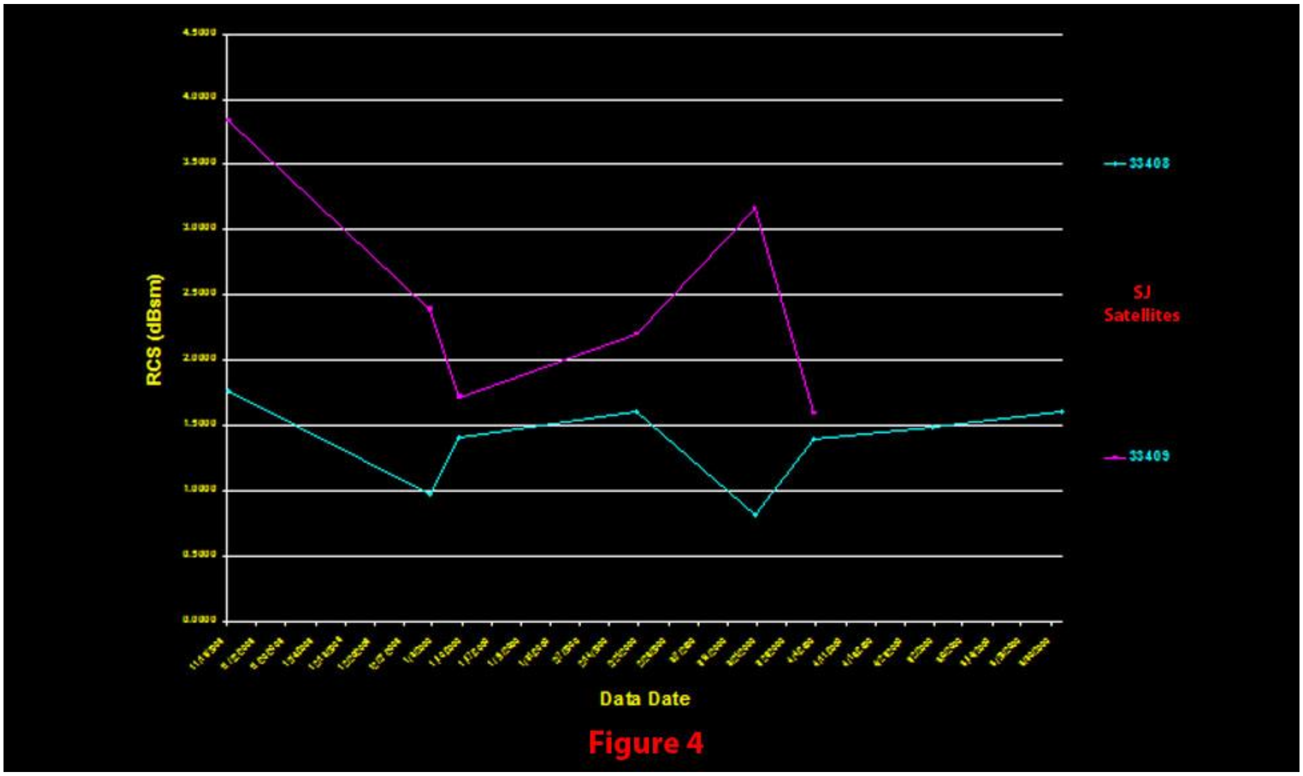

Figure 4. 2. Chinese SY Satellites Mirror-Matching Attitudes

5. Imagery Satellites Bunched Close to Chinese Microsatellite

Figure 5 shows example orbits of Earth imagery satellites in Sun-Synchronous orbit, and how close they get to each other to achieve roughly the same shadowing constraints for picture taking (coming over Earth targets approximately 10:30 AM). The delta-v (orbital change capability) numbers are the values required for the Chinese Naxing satellite (in yellow) to match the orbits (Rendezvous & Proximity Operations – RPO) of the other satellites.

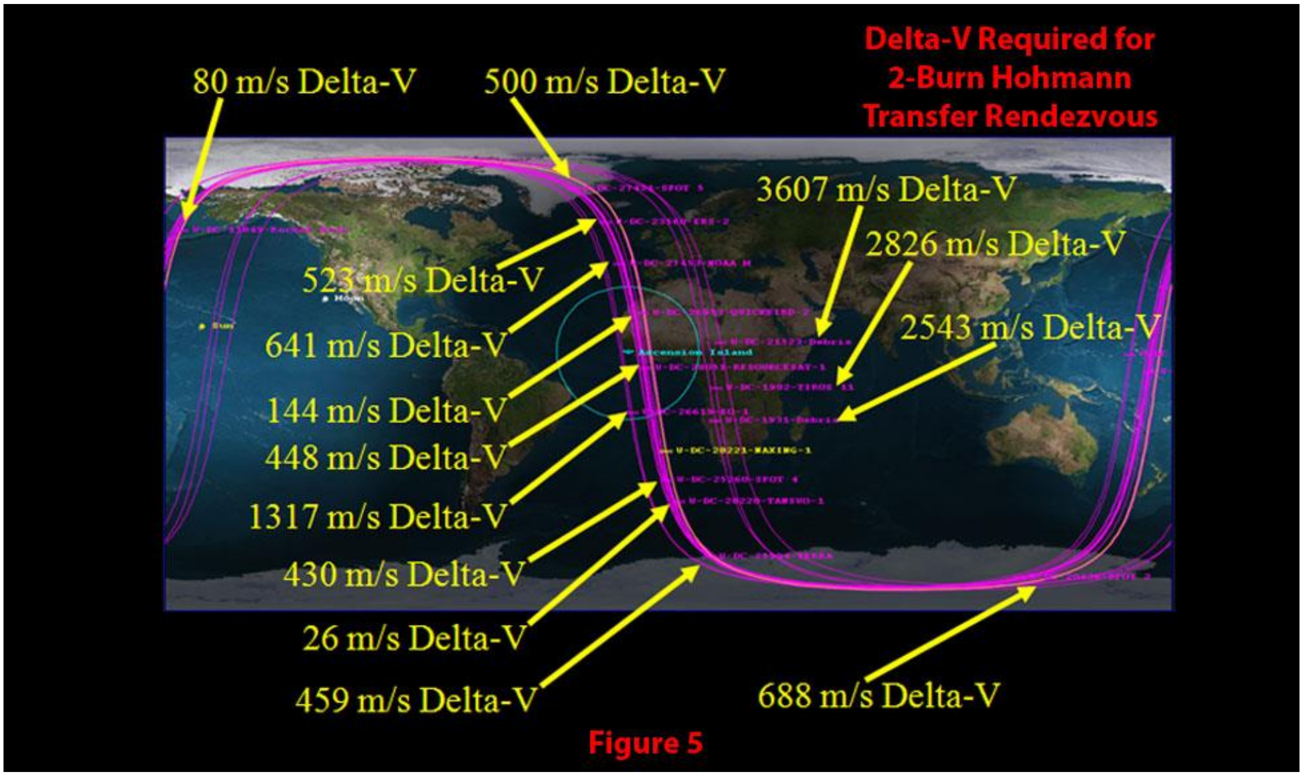

Figure 5. Closely Aligned Space Objects in a Sun-Synchronous Polar Orbit

6. Chinese Space Objects in Nominal Blue Orbital Zone (Space Choke Points - Space Defense Zone)

Figure 6 illustrates a Space Situation Map that I invented to indicate significant space positioning and maneuvers that may be an ASAT threat. This graph plots all space objects by Altitude verses Inclination, since these two orbital parameters are the main indicators of potential adversaries' attack setups. The lines also show where space objects have maneuvered over time (for example, maneuvering from Low Earth Orbit to Geostationary Orbit). The boxes around several space objects (alive and dead) designate those objects that have had the most change of state during a user-selected period. This chart also shows significant space "choke points", where satellites (or space objects playing dead) concentrate. Note the bunching of space objects in certain regions according to country of origin (Blue = allies; Green = neutral; Red = potential adversaries). This is mostly due to the longitude of the launch site. However, the several Chinese Red space objects in the normally Blue zone around 25 degrees Inclination brings up the question of what was launched by these rocket boosters that may be threats, and are these boosters themselves potentially ASAT systems?

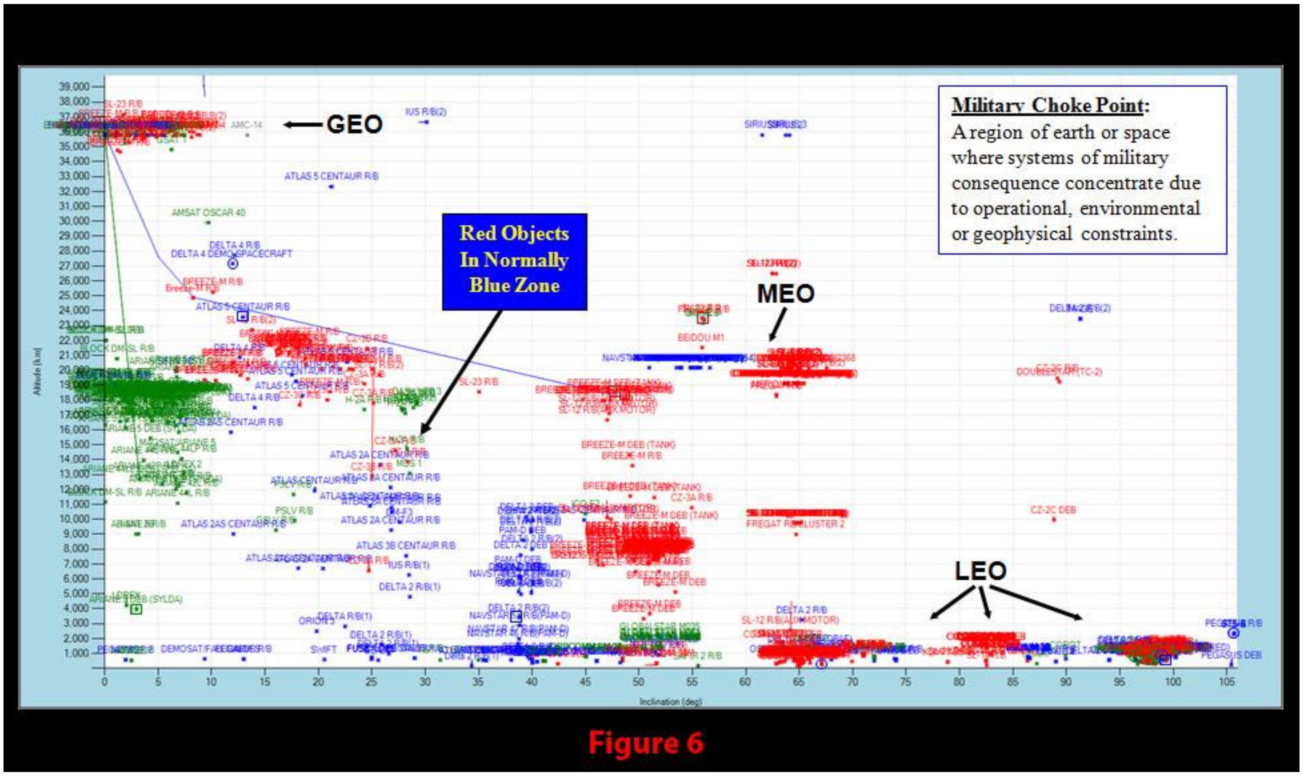

Figure 6. SAW (Satellite Attack Warning) Map

7. Easy Maneuver to Attack Space Choke Points

Figure 7 illustrates another Space Situation Map for LEO satellites that shows how "close" critical satellites get to potential threat space systems with minimal delta-v (100 m/sec) rendezvous requirements. The concept of "close" in space can be counter-intuitive, as I define "close" to be minimal, or at least reasonable, amount of fuel to quickly approach, rendezvous, or at least intercept another potential target satellite. Due to orbital mechanics, two satellites may be "close" to each other delta-v wise (especially using bi-elliptic orbital transfers), yet physically occupy opposite sides of the Earth.

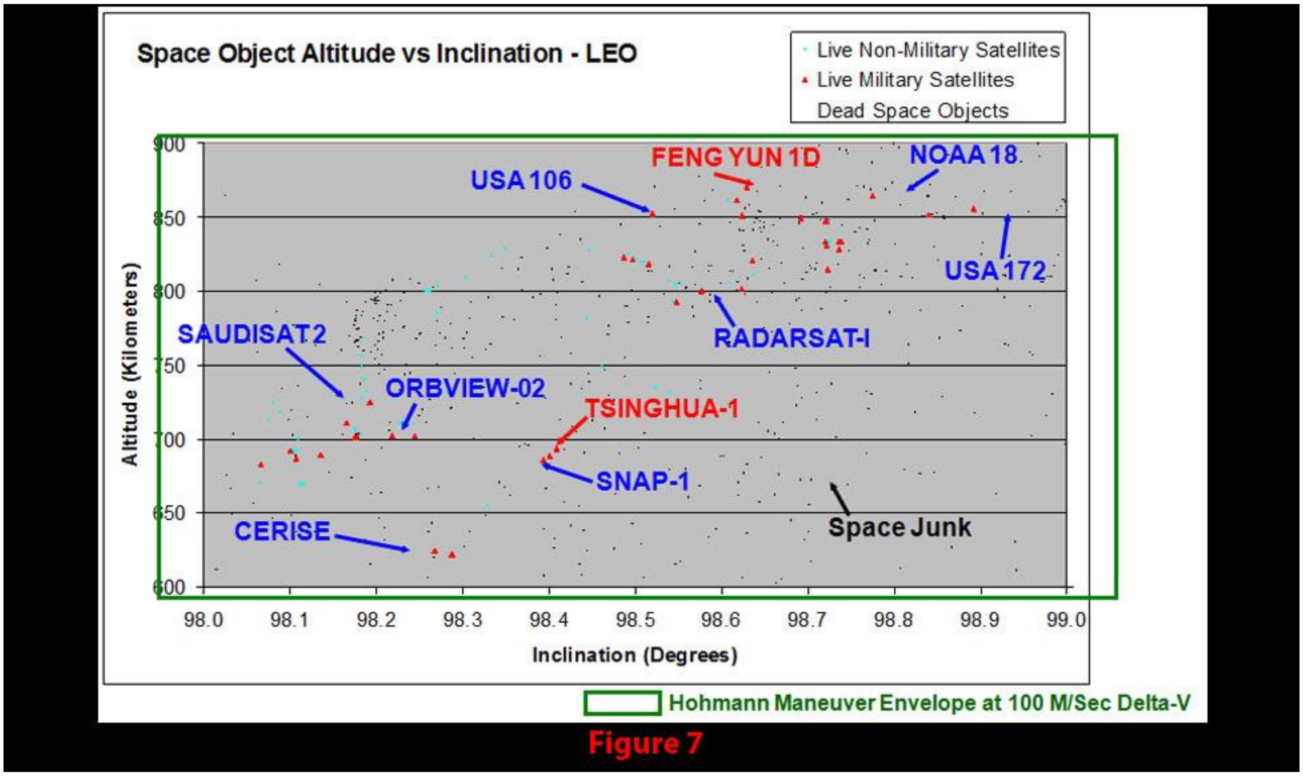

Figure 7. Closely-Spaced Satellites Within Easy Maneuvering Envelope

8. Many Satellites Missing from US Sensors

Many observers believe that, due to the openness of space without masking terrain or clouds, any movement of satellites can quickly be detected. This cannot be farther from the truth. It is actually easier than most people think to "lose" the location of a satellite. Any kind of maneuver (e.g. in the South Pacific with no coverage from U.S. sensors) can confuse the next set of sensors that cannot correlate their tracks with a known space object. Some space objects have been "lost" for many years, and have only been found when some other country publishes information about the satellite. One Russian satellite was lost for 20 years. Some of these "lost" objects are very large [Radar Cross Sections (RCS)], as illustrated in **Figure 8**.

Figure 8 illustrates how often satellites get "lost" to Air Force space surveillance sensor systems. This chart shows how many satellites had unknown locations (probably Un-Correlated Targets – UCT's), divided into altitude regimes and RADAR Cross Section (RCS – approximate satellite size). One can see that it actually may be relatively easy to hide a satellite in space, especially if it has an eccentric orbit, and maneuvers before the start of a conflict at the Earth's Poles and Southern Hemisphere where there are no space surveillance assets. Another way to confuse space surveillance sensors and their associated processing algorithms is to continuously thrust at the start of a conflict so the orbital equations of motion are no longer valid for calculating future positions.

The GOCE satellite actually used continuous thrusting for almost 5 years to complete its mission, so it is certainly technically possible to enable sensor-confusing, continuous thrusting for the few hours or days that a space conflict will complete, from start to finish (a study I conducted showed that most satellite-to-satellite attacks can occur within 24 hours of initial maneuvering). Thus, one can "hide" potential space weapons to be used during terrestrial or space conflict. See this discussion for a review of the potential Chinese threats in space.

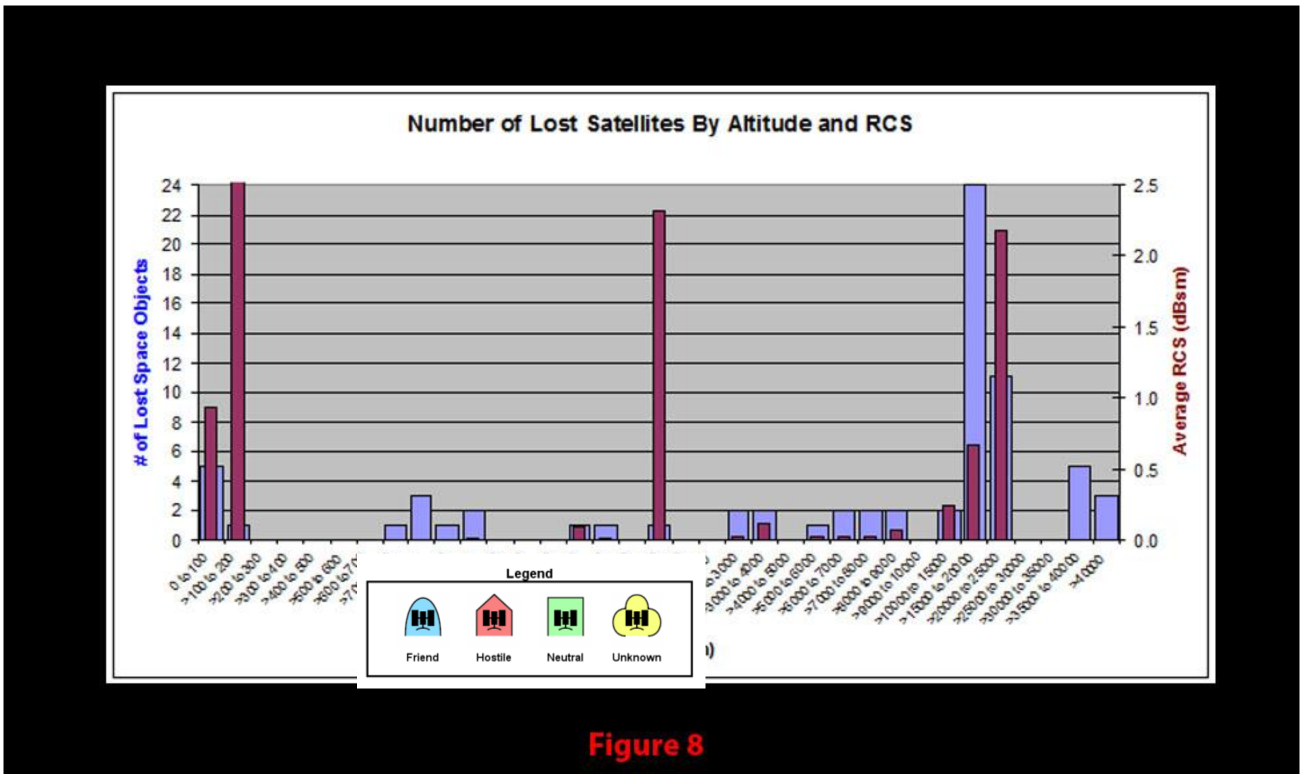

Figure 8. Statistics for Satellites "Lost" to US Sensors

9. Reduce Satellite Detectible Signatures

A potential adversary can manipulate the Space Surveillance Network (SSN) to remain hidden for years. The SSN have known fixed sites with incomplete global coverage that must contend with tens of thousands of space debris objects and try to determine what is alive, what is dead, and what may constitute a threat. This is a very daunting task given the complexities of the numbers, types, materials, spin, structural configuration, reflective properties, etc. for space objects that are not trying to hide, which can only get astronomically more complex for adversaries who are attempting to hide Anti-Satellite (ASAT's) systems. **Figure 9** illustrates a 1970's patent for a possible stealth satellite system (http://www.space.com/637-anatomy-spy-satellite.html) that would try to minimize its RADAR and optical signatures.

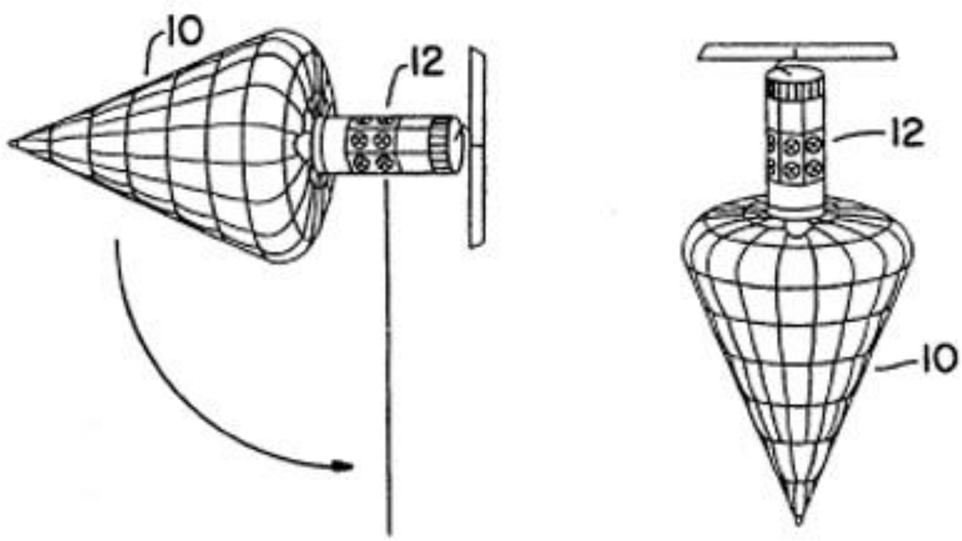

Figure 9. Possible Stealth Satellite U.S. Patent

Simply orienting the attitude of a satellite's flat surfaces directly away from an adversary's surveillance systems can significantly reduce its ability to be detected, without any kind of RADAR or optical absorbing materials (for light absorbing carbon nanotubes research see: http://www.geek.com/articles/geek-pick/nasa-creates-groundbreaking-super-black-light-absorbing-material-2011119/). In addition, satellites are getting smaller and smaller (actually repeating the small size of satellites launched at the dawn of the space age, though, with vastly improved technologies now). These will prove very difficult to detect from tens of thousands of miles slant range away from Earth-based sensor networks, especially at geosynchronous orbits where most of the world's communications satellites reside.

10. Unusual Orbits

Many in the space community appear interested in defense of geosynchronous (GEO) orbits only, and assume that an ASAT attack would come by a snuggler only (called Neighborhood Watch). I do not believe anyone is attempting to detect a "glancing" attack at GEO. ASAT's can come screaming in from Trans-Lunar space and attack GEO targets with very little delta-v. It actually takes more fuel to get to GEO than to orbit the Moon. A few years back a crippled satellite was actually slung around the Moon twice to achieve geosynchronous orbit (http://www.spacetoday.org/Satellites/SatBytes/MoonCommsat.html). In addition, it takes less delta-v to change inclination the higher your altitude is. Placing ASAT's at Lagrangian Points (http://en.wikipedia.org/wiki/Lagrangian_point) puts them at the top of the energy peak, and it takes very little to push them back down the energy well towards GEO. I do not think anyone is searching Lagrangian Points or Trans-Lunar space for potential ASAT's the size of basketballs. In addition, some very highly eccentric orbits are difficult for the Space Surveillance Network to get an accurate orbital dynamics algorithm solution, thus making them difficult to track.

11. Hide Satellite Among Many

With the millions of space debris objects (http://en.wikipedia.org/wiki/Space_debris) orbiting (some are heavily influenced by solar pressure, such as delaminated thermal insulation sheets, and do not follow classical Keplerian orbital dynamics exactly), an adversary can easily hide among this space junk. I mentioned in ISSUE TOPIC 1 the idea of having two ASAT seekers on the same booster, so that the second one can hide in the debris field created by the first attack. Another concept is to hide an ASAT inside the exhaust cone of an old 1960's booster while waiting to attack when out of sight of the Space Surveillance Network. These exhaust cones are as big as a room, and the booster has already completed half of the Hohmann transfer maneuver to a possible target orbit. No one would waste the fuel and maneuver to inspect all of these boosters up close, especially when they are in orbits poorly matched to any potential satellite inspector vehicle. **Figure 7** shows the "closeness" in altitude-inclination space of some military satellites to many other supposedly "dead" satellites, space junk, rocket boosters and live satellites from other countries. It would be easy to hide in this Sargasso Sea of dead space objects while waiting for the optimal attack moment. It would be a very difficult problem to figure out which orbital objects are benign, and which are threats, especially during high-paced orbital attacks that most likely will occur when out of view of space surveillance assets. In addition, a potential threat satellite will not have a red star painted on its side for easy identification like some MIG fighter aircraft. As a matter of fact, probably a good percentage of the components on a threat satellite would come from friendly Western manufacturing sources.

Figure 5 shows this same bunching of satellites for sun-synchronous polar orbits and the amount of fuel (delta-v) that a threat satellite would use to get to the various imagery satellite platforms illustrated in this orbital graphic. Any satellite inspector in the local area might have a difficult time understanding whose satellite is whose, especially on a quick timescale when various threat satellites and decoys have maneuvered since the last time their orbital elements were calculated. The space community lives in a fantasy world believing that they will track every satellite and every object from launch to death, and thus know the country of ownership. This is a very difficult job under good conditions of cooperative satellites that are not trying to hide and when the surveillance sensors (RADAR and optical telescopes) have days and weeks to get around to tracking space objects of interest. I remember a story an Air Force officer told me about the Soviet MIR space station. This station threw out the "honey bucket" from its toilets and NORAD tracked this honey bucket thinking it was the very large space station until someone noticed the RADAR Cross Section (RCS) was not large enough, and they fixed their mistake. What if an adversary inflated a decoy from a threat satellite while over Antarctica (no terrestrial space surveillance assets covering this region) and then ejecting a much smaller "space mine" to do some future mischief? Would we detect this ruse and take appropriate actions? At the same time, many rocket boosters have multiple satellite deployments (**Figure 6**) and can we be so sure we discovered all of them?

12. Strategic Confusion in Space

Because the World has not yet experienced a full-out space war, it is difficult to assess what the likely conditions, battlefield tempo, strategies and tactics would underlay a future space conflict. Nevertheless, it is likely that some potential adversary of the United States is currently devoting considerable resources to designing systems that can conduct surprise assaults on strategic space assets of U.S. and allied countries. Due to the distant (up to 36,000 km and more) and un-manned nature of satellite systems, detection of these attacks would be difficult, and currently may only be of the "post-mortem" variety. Even with major resource allocations by nations towards intelligence gathering through all mediums, history is replete with examples of major surprise attacks that should have been detected, but were not (Pearl Harbor, Battle of the Bulge {in spite of 11,000 Ultra message decryptions indicating buildup of major German forces for this attack}, Yalu River in Korea, most Israeli-Arab conflicts). The 1973 Yom Kippur war saw the Israeli Suez Canal Bar-Lev Line receive 90% causalities due to intelligence and military overconfidence. I've seen the same overconfidence in the space intelligence community in assuming we will be aware of any ASAT development and deployment preparations. They believe that adversary doctrine, training, and operations indicators will be strategic tripwires to allow countering actions by the U.S. The U.S. had an operational nuclear ASAT system in the 1960's at Johnston Atoll (Program 437: http://en.wikipedia.org/wiki/Program_437) and development of the F-15 ASAT system in the 1980's (http://en.wikipedia.org/wiki/ASM-135_ASAT). I do not recall any doctrine or space strategy changes appearing as a consequence of these programs. We still do not have such things today, so these are poor indicators of a nation's intentions, and not equivalent to intelligence indicators for development and deployments of tanks, aircraft, ships, etc.

The ability to detect attacks in distant space can only be more difficult and less certain than these terrestrial examples. The "Fog of War" (or more colloquially, "Shit Happens") can only be more valid for space warfare than terrestrial warfare (see **Figure 10**). Possibly the biggest problem is identifying the attacking country, which may not be the country we are directly at war with at the time. I believe senior decision makers will not allow military responses until the attacker is fully identified, which may take weeks or months, if ever, and the space war will be over by then. We may very well be our own worst enemy, and self-deter from taking any meaningful actions. Even if we do identify the attacker, it would be even more difficult to identify their intent. Was the attack just a show of force to deter us? Is the attacker's intent just specific to one theater of operations? Are they going after strategic communications, missile warning (prelude to nuclear confrontation?), navigation satellites to reduce our bombing accuracies, etc.

In addition, there are many examples of new weapon technologies that provided considerable advantages to their first user, and fundamentally changed the correlation of offense vs. defense in their respective theaters, at least for a period of time (catapult vs. Greek fortifications, cannon vs. castle walls, crossbow vs. shield, musket vs. body armor, ironclads vs. wooden warships, tank vs. machine gun, shaped-charge vs. bunker, airplane vs. battleship, etc.). More than likely the side that first employs offensive weapons against space systems, will "win" the space war, and unbalance US and allied use of space systems to support the terrestrial battlefield, at least over the short duration of any probable future conflict.

I can readily imagine a scenario where one nation takes a small portion of its space engineers and scientists, and devotes them to developing a covert space weapon. One threat country currently has 100,000 people working in space. Taking just 5% of these, and devote these 5,000 engineers and scientists for 10 years to a covert project whose sole purpose is to fool a captain in a space watch center at 3 am into thinking that everything is all right, but he is about to lose billions of dollars of space systems. Who do you think will win this contest – 5,000 PhD scientists and engineers working for 10 years on some devious technology, or some poor captain not long out of college who has little if any true space warfighting training, with no support structure that has even attempted to sensitize him to fundamental space war issues? Few people realize that in the beginning of World War II, the allies had better technology tanks and more tanks than Germany (France and Great Britain had 17 times the number of tanks deployed in France than the Germans did; also, allied tanks had better armor and guns), yet still spectacularly lost to superior German doctrine that led to the quick fall of France in just six weeks. Close to half of German troops at this time were 40 years or older, and half of all their troops had only a few weeks of training. A good part of German military transportation was horse-drawn vehicles. The Germans used their superior doctrine for armored warfare to negate and surpass France's technological and numerical superiority to defeat them with Blitzkrieg Warfare. The United States may have superior technology in space, and more satellites, but without adequate doctrine to guide its decision making processes in reacting to space warfare, there is a good chance for spectacular failure.

One idea I had to help solve some of these issues is for some space-aware Government organization to contract with a team of physics-based space experts, military operations-based space experts, and some innovative consumers gaming developer to put together an interesting, but entertaining, space war game. We would then give this to the young officers at the Air Force academy, and have them constantly play this to establish space war doctrine, strategies and tactics, while training our future military leaders to be sensitive about space warfare issues. We could award the top winner of this fun wargame $100 every week to assure motivation at the Academy (only $5,200 per year, which isn't even in the noise in typical military budgets). They would approach playing this game with a fresh perspective, while applying their newly learned military history knowledge. They can then develop innovative space warfare doctrine, strategies and tactics. Then later, when they are part of some space watch center, they will be able to recognize certain adversary moves that would be similar to what they have already simulated in this space war game, and be able to react in an intelligent manner.

Some of these fundamental space warfare issues such as Space Domain Awareness (SDA), Space Situational Assessment (SSA), Satellite Attack Warning (SAW) and Space Predictive Battlespace Awareness (PBA – being able to predict future space systems attacks before they occur) are summarized in **Table 1**. Some example space intelligence indicators are given in **Table 2**.

Figure 10. An Example of the "Fog of War" for Space Systems

Table 1. Fundamental SDA / SSA / SAW / PBA Questions

1) Will Space Systems be Under Attack In the Near Future?
2) Are Space Systems Currently Under Attack?
3) Who Is Attacking?
4) What is the Adversary's Attack Strategy?
5) What Damage Has Been Done to Blue Space Systems?
6) What Are the Optimal Blue Courses of Action Responses?

Table 2. Example Space Attack INTEL Indicators (Partial).

Are a small number of Blue and Gray satellites experiencing anomalies over a long time period
Are a small number of Blue and Gray satellites losing contact with terrestrial controllers
Are a small number of new Red satellites appearing in orbit
Are a small number of Red satellites changing orientation
Are a small number of Red satellites changing shape
Are a small number of Red satellites changing thermal signatures
Are a small number of Red satellites concentrating towards potential Blue and Gray satellites
Are Red ASAT forces appearing to line up in a sequence of timed attacks against Blue and Gray assets
Are Red forces capable of attacking space-related terrestrial sites in Blue countries appearing to line up in a sequence of timed attacks
Are Red SIGINT assets appearing to line up in a sequence of timed operations against Blue and Gray Communications assets
Are there indications of Red aircraft activities that appear to concentrate on space-related terrestrial sites around the world
Are there indications of Red missile activities that appear to concentrate on space-related terrestrial sites around the world
Are there a small number of new satellite launches from Red facilities

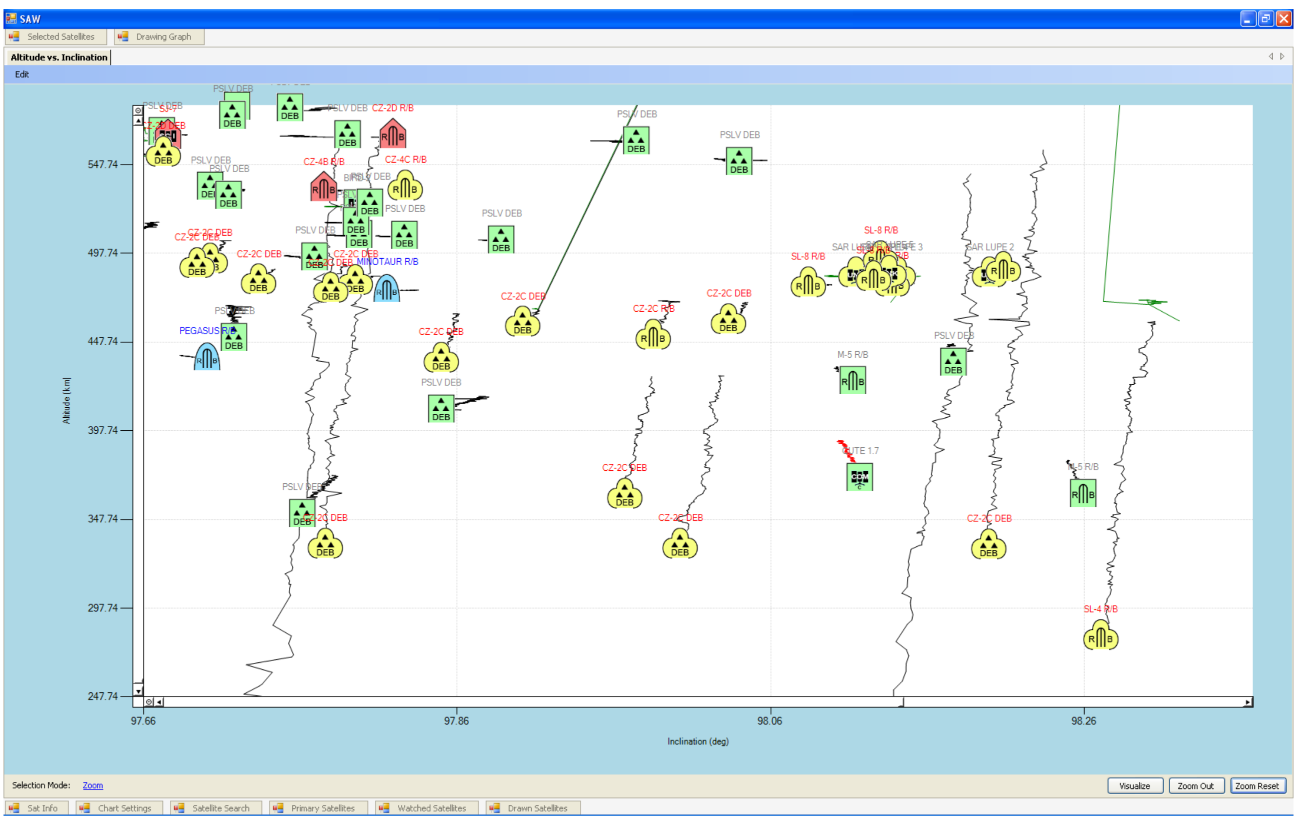

Figure 11. Example Time-Phased Satellite Situation Map.