Adding the "Local" Layer to Space Situational Awareness

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CONFERENCE PAPER

The heritage of Space Situational Awareness (SSA) has been limited to Earth based observation of space to support collision avoidance and space object identification. In part, this has led to reliance on multiple CONUS locations for optical and non-optical ground based observation. It has also led to the specialization of many fields and industries, which are highlighted at conferences like AMOS through discussion of state-of-the-art of observation capabilities. This paradigm alone no longer addresses the current needs for situational awareness of space assets in the changing space culture. Events in recent years have shown that space based sensing capabilities are increasingly critical as complements to ground based radar and optical systems. The SSA community would be better served by adopting the concept of "local" SSA and proliferating technologies to accomplish this. The traditional definition of SSA would expand to encompass an understanding of the immediate natural and manmade environment of the satellite. Multiple insights would be enabled, including baseline trending to support anomaly identification and resolution, catastrophic failure investigation, and anomaly and/or failure attribution. Additionally, protection measures could potentially be enabled to ensure space asset availability. Moving forward with a combination of traditional SSA and "local" SSA capabilities would allow a potential "global" SSA picture to be developed. This enhanced understanding would consist of ground observations in addition to the satellite's "first person" perspective. The potential for an exponentially increased comprehension of SSA is created by this powerful combination. The first step toward demonstrating this combination of SSA knowledge has been achieved with data from the SASSA technology demonstration.

1. ADAPTING THE SSA CULTURE

In our mission area, the phrase "Space Situational Awareness" unambiguously refers to a single concept – the utilization of ground assets, and only very recently space assets, to identify space objects and their locations [1] [2]. This "cultural norm" has transpired despite the existence of much more comprehensive definitions. USSTRATCOM has defined SSA as:

> "the requisite current and predictive knowledge of space events, threats, activities, conditions, and space system (space, ground, link) status capabilities, constraints, 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"

Despite such a broad and far reaching definition, we as an SSA community appear to consistently slip back into the definition as a simple equation: SSA = Object Tracking [3][4][5]. It has even been suggested by some that the community move away from more comprehensive definitions to adopt a narrow object tracking focus [6].

Ultimately, SSA is performed for a primary purpose – to assure access to, and operation of, critical space assets. Objects are observed, tracked, and catalogued, with catalogue updates occurring as often and as accurately as possible. This approach has been sufficient for quite some time in our history in space. Upon recognition of the risk of a catastrophic event, appropriate actions are taken if successful avoidance of the event is likely. On occasion, and notably, an unexpected or unavoidable catastrophic event occurs. The Chinese ASAT test in 2007 [7] and the Iridium Cosmos collision 2009 [8] were the most prominent recently. However, as early as the 1970s [9], predictions have been documented that state that the amount of debris residing in space will become unmanageable and problematic. Models have been created. Warnings have been given. Trends and estimates of the amount of space debris continue to fall in line with predictions and models over the last 35 years, yet SSA operations have appeared to continue at the status quo. The definition of SSA has remained the same as it was first used and our focus continues to remain strictly on how to identify space objects and their locations.

Is the SSA community truly continuing with business as usual? If so, examining our current development efforts within major SSA programs should help answer the question definitively. The Air Force has a three pronged plan underway to bolster SSA efforts in the near term [10]. The first consists of ensuring that the best data is available from all sensors used for SSA. This includes a significant effort to translate disparate data formats into a common format, as well as fusion of data in order to facilitate use by the war fighter and mission partners. The second prong of the plan is to improve the space fence to track smaller objects with higher accuracy. The third prong of the plan is to evolve the deep space search capability to locate smaller objects with potential for Geosynchronous Earth Orbit (GEO) belt collisions. Additionally, international cooperation to upgrade space fence capabilities is evident per the pact signed on November 8th, 2010 with the Australian Defense Department. This cooperation will allow the US to place cooperative radars in Australia to allow additional tracking of debris and Low Earth Orbit (LEO) satellites [11]. Other agencies stateside, such as the Los Alamos National Laboratories (LANL), are also contributing to improvement of the debris tracking capability. RAPTOR, or Rapid Telescopes for Optical Response, is part of LANL's "Thinking Telescopes" effort to optically monitor space debris and other objects, and to decrease the cost of space surveillance radars [2]. Other significant efforts underway to bolster SSA include cooperation among operators, and SSA data sharing among nations. The US recently announced a five year data sharing agreement with Canada [12] with "more tentative arrangements with Australia, France, and Japan" [13]. While this is not an exhaustive list of current efforts (as will be discussed later with the SASSA program), this is a fair representation of the major efforts underway. Each major development activity is being accomplished under the same paradigm – that executing SSA equates to enhancing the ability to track objects in space.

What is the response, however, if a request to define the term "Situational Awareness" is posed to operators of machines on land, in the sea, or in the air? Ask aircraft pilots what SA means to them [14][15][16]. Ask a Navy Captain what SA means to them [17][18][19]. Ask an Army infantryman, mechanized cavalry, or convoy leader what SA means to them [20][21][22][23]. The SA concept has even become commonplace in the medical [24][25] and information technology fields [26]. Situational Awareness represents a comprehensive understanding, most significantly in the immediate surroundings, of the current environment. However, SA also includes a significant amount of additional information broader than the immediate surroundings. SA can include information such as weather conditions, location of friendly or non-friendly forces, condition and capability of all assets, an understanding of electromagnetic phenomena (such as signals of various types), and the potential impact of each of these things on the mission (e.g. detecting missile lock for a fighter pilot). In all cases, to our to operators of machines on land, in the sea, or in the air, Situational Awareness represent a more comprehensive and significantly What if there was an arguable case for the future of Space SA to be required to handle all of the same issues that the foundational air, land, and sea counterparts have had to overcome in their respective technological histories? Would this highlight the fact that the treatment of Space SA is fairly narrow in scope? Or possibly more telling, does the limited scope of the current definition reveal historical narrowness in the thinking behind the methodology to assure operations of critical space assets? Is it myopic to believe that, via strictly looking up and out into space, operations of space assets can effectively be assured? These are questions that we as an SSA community must address moving forward.

Our collective SSA strategy has been consistent to date: objects are observed, tracked, and catalogued. We must also ask ourselves, "how long will it continue to be effective", as a critical question. If this and other questions raised about the long term adequacy of our current SSA approach are valid, then what are the indicators as to whether the current approach is effective and will continue to be so? Consider the following:

- The quantity of space objects (active assets and debris) in key orbits appears to be increasing at a greater than linear rate with time [27].
  - Depictions like Figure 1 and Figure 2 have become so commonplace that often, the importance of such images are no longer emphasized.
  - There are no substantive active and pervasive actions being taken to reduce space debris [9].
- There is a technological race between the ability to process the data related to the resolved objects and the actual number of objects that exist.
  - There is a theoretical limit, which we get closer to with time, to the amount of data that can be processed into usable tracking information.
- Collisions between space assets and/or debris will become increasingly probable as the number of objects increases [28].

    - It is not apparent that current space asset designers are adapting designs, or are being given requirements to adapt designs, into the future to address collisions or SSA issues.
- Space is becoming more critical, dynamic, congested, and contested [10][29].
    - The relative importance of every space object will only increase with time.
- Space is rapidly becoming more accessible to more countries/groups around the world, which in turn populate space with increasing speed.
- Adverserial “active denial” events, either ground or space based, are likely to increase as not all nations/ groups will “play fair” [27][30] in space.
    - Most current space assets do not have the ability to distinguish between natural or manmade events or attribute the source of denial.

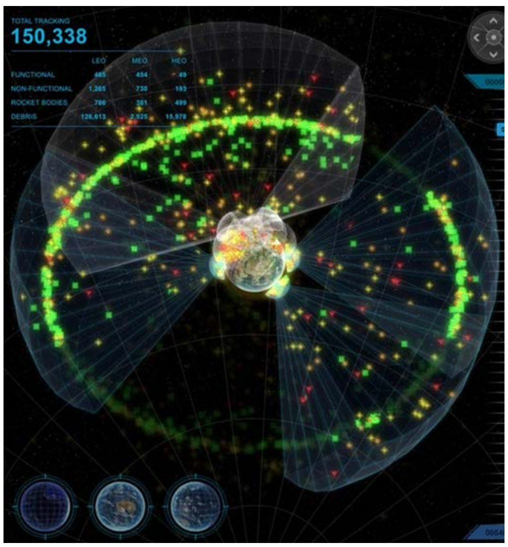

Figure 1: STK Depiction of Space Objects in LEO

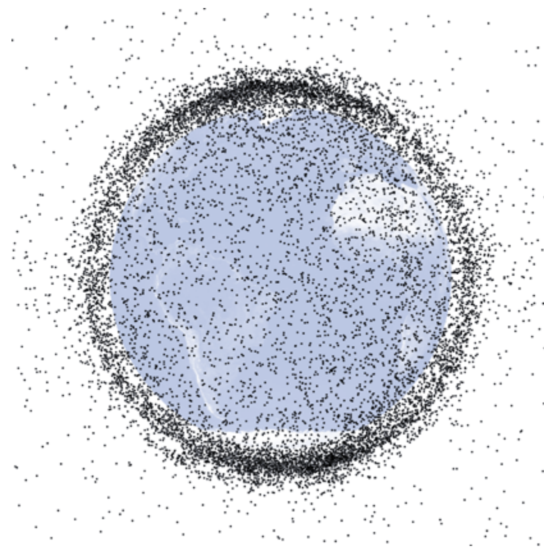

Figure 2: Artist Rendering of LEO Space Objects

The goal upon considering these points is to recognize trends that are, at present, inadequately addressed and will absolutely affect the ability to assure operations of our space assets [29]. This includes issues that affect SSA and are not currently enveloped within the accepted definition of SSA-type issues. The current SSA definition reveals that we are neglecting significant portions of information critical to assuring operation of our space assets. *The existence of a critical mass of unaddressed issues indicates that it is a likely time to begin revamping the way SSA is discussed and considered.*

A few examples of such issues may illustrate the point further. First, if all nations continue to populate orbits with space assets and debris, but there is no significant deviation in the approach to debris removal, then there is a very predictable equation which will yield results not quite on the scale of the Disney Pixar movie WALL-E, but still significant. In the traditional SSA paradigm, the approach would likely include addressing topics such as the minimum resolvable object size, algorithms for accurate prediction of trajectory paths, total number of objects which can be tracked continuously, and the total catalogue update time without lost objects. While not a comprehensive list, this demonstrates that all are “symptom management” approaches. This approach may help in the near term, but it does not provide any long-term solutions that address the actual issue. The root problem is that space will be increasingly too congested for an asset to safely and consistently perform its mission. Even a theoretically perfect understanding of the location of every object at any given time will not provide aid to space assets for navigation of the debris field. The current SSA paradigm fails to address the root issue.

Another example of such an issue is adversarial efforts to deny service to a space asset. Theoretically, this could involve a variety of activities with varying degrees of complexity. Space-to-ground activities could include communications jamming or lasing, resulting in temporary to permanent degradation effects [27]. Space-to-space activities could include any activity which degrades or prevents critical space vehicle functions necessary for mission accomplishment. This could cover a spectrum of activities – on one end for example, simply shading/blocking solar arrays to prevent battery recharge, and at the other end, a space-to-space or ground-to-space ASAT which removes the function of the space asset entirely. Currently, space assets have little to no ability to sense activities of this type in situ. The operator would simply experience a degradation or cessation of operation. Cause and attribution would be determined postmortem through analysis, if possible at all. There is limited ability to understand whether the causal event was natural or manmade. This is also true of the ability to understand whether the causal event was internal (initiated within the space asset) or caused by an external entity. In the case of denial of service actions, it is possible that the subtle shift from tracking space objects using SOSI (and other forms of tracking technologies) to performing a higher fidelity targeting track is unseen by the asset. Pattern and phenomenology recognition from the vantage of the space asset, with an adequate understanding of "normal", is one of the most effective ways to distinguish the two. If the current SSA paradigm is not poised to encompass issues like those discussed in these two examples, then there is evidence that the SSA approach needs to be broadened.

Moving into the future, if the current definition of SSA is too narrow to adequately address all elements required to assure operation of critical space assets, is there a better alternative? One suggestion is to alter the traditional meaning of SSA and expand it to resemble that of our land, air, and sea brethren, while preserving the current SSA heritage. This would take the form of an SSA perspective from both the external "looking up and out" as well as from each space asset's perspective, to include the fusion of all available data into nodes. "Local SSA" would encompass an understanding of the immediate natural and manmade environment of the satellite from a "first person perspective". "Global SSA" would be the composite of all of the local SSA inputs, the larger understanding of types and locations of objects from our traditional SSA heritage, and all other elements (intelligence, other data sources) of assuring operation to our space assets. This transition and expansion of the SSA definition allows for new solutions to be pursued within the SSA mission area, such as new approaches for object/debris management and prevention of adversarial denial activities. This enables new potential solutions which can surpass strictly symptom management options and instead pursue root cause resolutions within the SSA mission area. Adopting this broader definition, and thereby a broader paradigm in which to address SSA issues, better positions the community to address all relevant aspects of SSA into the future.

2. LOCAL SSA ENABLES CAPABILITIES

As the definition of SSA broadens to keep current with growing SSA mission needs, the concept of "local SSA" has been proposed as a necessary addition to the SSA vocabulary. Local SSA represents the space asset's understanding of the immediate natural and manmade environment in situ. This understanding of the "local" environment by each space asset would represent a significant change from the status quo in SSA thinking and data generation and enable a variety of unprecedented capabilities.

The first major capability that local SSA could enable is a comprehensive understanding of various phenomena relevant to SSA that reside in the electromagnetic spectrum. Commonly, current space assets only have sensors directly relevant to their primary mission. Any SA (or SSA in this context) data gained from these sensors is happenstance. On the contrary, a local SSA sensor suite would routinely observe various EM phenomena. Spectral bands such as radar, laser, microwave, space weather, and bands useful for proximity detection would provide constant feedback about the immediate surroundings [27]. An increase in the type and quantity of available SSA data would result.

A comprehensive set of observed SSA phenomena also enables a second relevant SSA capability – change detection. Regularly collected phenomenology easily and quickly establishes a baseline of conditions for the nominal environment. With established parameters for normal conditions, any significant deviation can be quickly recognized, assessed, and categorized by potential source or by phenomena. Subsequently, a change detection approach enables a third feature – identification of the source of the deviation as natural or manmade. This understanding, combined with knowledge of orbital parameters, can provide lengthy strides towards attribution of concerning events experienced by our space assets.

An additional feature enabled by local SSA is increased timeliness of SSA information. This is particularly important as related to identification of manmade versus natural events. As technological capabilities of other nations increase, consequently the probability of active threats to our space assets also increases. To borrow a page from the military strategist USAF Colonel John Boyd [31], the OODA (Observe, Orient, Decide, Act) loop depicted in Figure 3 is only going to shrink over time as applied to space assets in an effort to maintain availability. The inclusion of a ground operator in the decision loop for a space asset will become ever more ineffective, increasing the need for accurate information in the timeliest manner. Should a manmade event be detected, indicating an attempt to deny service of a space asset, the response time to preserve full functionality will be paramount.

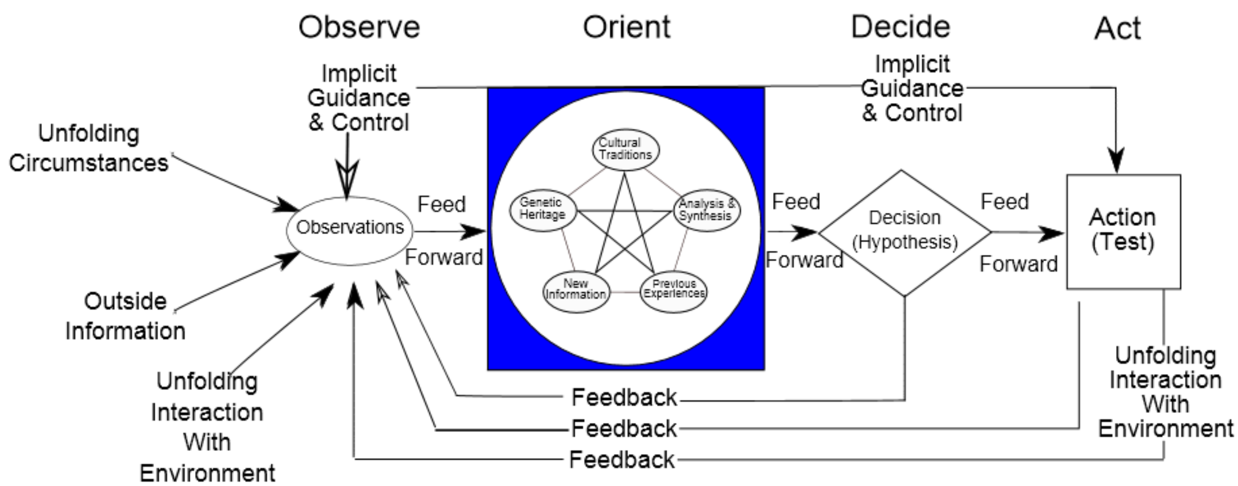

Figure 3: John Boyd's OODA Loop

In summary, having local SSA could provide:

1. A comprehensive measurement and understanding of various phenomena relevant to SSA; providing a large body of data to work with
2. Change detection for baseline monitoring and management
3. Natural versus manmade determination of events
4. Attribution of denial of service events
5. Increased opportunity for timely response options

3. THE GLOBAL SSA PICTURE

Global SSA is the natural counterpart to local SSA, and completes the proposed expanded definition of SSA. This topic should be the discussion of its own paper and is only mentioned briefly here to help complete the full SSA definition. Traditional SSA uses ground (such as AMOS) and space assets (such as SBSS) to identify and track space objects. Local SSA provides for "first person" sensing of SSA phenomena at the local satellite level. Global SSA then would be the composite of traditional SSA as well as the inputs from all local SSA data collected from all local SSA collectors, as well as any other information from other intelligence or data sources which provide SSA relevant information. This "Global SSA view" would account for the complete, multi-source SSA picture for assuring operation of space assets.

As an analogy, consider the following rough example. A passenger aircraft has its own instrumentation to help characterize its immediate environment, providing useful feedback to the pilot. This is analogous to local SSA to a space asset. Additionally, there are objects or events pertinent to the path of flight which are beyond the individual sensing capability of an aircraft. Those items are monitored by an aircraft control tower. The aircraft control tower has an aggregated understanding of everything in its airspace based on its own sensors in addition to inputs from individual aircraft instrumentation. This would be analogous to a "Global SSA" node (such as an advanced JSpOC). An aircraft control tower has the capability to receive information from aircraft in flight, and it can in turn pass pertinent information to other aircraft in the same general vicinity. This is analogous to the global SSA picture for space assets. Inputs from all sources, both external observation of space assets from ground and space as well as local SSA from multiple space assets combined into a global SSA picture. This information can then be exploited to assure the operation of our critical space assets.

4. AN ENTERPRISE QUESTION

A critical underpinning to global SSA, enabled by local SSA, is the ability collect, capture, synthesize, and process source data into usable information. Shifting the SSA paradigm to include global and local SSA concepts must include planning and implementation at the enterprise level (encompassing the entire system). The enterprise question highlights the dependency between the usefulness of data from multiple sources (no matter how exquisite) as a function of the ability to integrate and propagate that data. Data which cannot be integrated/fused or propagated to necessary users has only a limited contribution to the larger SSA mission.

Current enterprise level thinking and solutions do exist in various states of maturity. For global and local SSA to be successful these activities will need to continue to mature and be developed. The Joint Space Operations Center (JSpOC) Mission System (JMS) is the leading edge of development addressing the enterprise issue for SSA data aggregation and processing. It is described below [32]:

> "The Joint Space Operations Center (JSpOC) Mission System (JMS) is the program of record tasked with replacing the legacy Space Defense Operations Center (SPADOC) and Astrodynamics Support Workstation (ASW) capabilities by the end of FY2014 as well as providing additional Space Situational Awareness (SSA) and Command and Control (C2) capabilities post-FY2014. To meet the legacy replacement goal, the JMS program is maturing a government Service Oriented Architecture (SOA) infrastructure that supports the integration of mission applications while acquiring mature industry and government mission applications. Future capabilities required by the JSpOC after 2014 will require development of new applications and procedures as well as the exploitation of new SSA data sources"

Air Force Space Command Commander, General William L. Shelton, stated [33]:

> "The JMS program will have a huge impact on just about everything we do in space. Acting as the hub, JMS will revolutionize Space Situational Awareness capabilities, taking inputs from a huge variety of radar and optical, ground- and space-based, space weather, and many other types of sensors."

A capability such as a mature JMS is critical to solving the enterprise question and to enable local and global SSA to become a reality. This ability to receive data from multiple sources of varying types and transform it into actionable information is foundational to achieving a global SSA picture and a framework to work within to address SSA mission needs. Without such a capability, even very mature sensors acting independently will not be sufficient to assure the operations of our critical space assets in the near future.

5. LOCAL SSA ENABLERS

Both the value and validity of local and global SSA concepts have been presented. Activity must take place to get from today's technology towards making local SSA a reality. These are local SSA enablers. Presented here are two broad categories of enablers: first, those which enable use of local SSA payloads on orbit, and second, those which enable the actual local SSA sensing technology.

Until a time when local SSA payloads are the norm for space assets, there will be hesitancy to support pervasive local SSA. As this change takes time to permeate, there will be hesitancy to support from financial, philosophical, and design standpoints. In the interim, there are promising initiatives that are enabling local SSA to mature as a concept and gain a greater audience in orbit. The first of these is a greater acceptance and organization of hosted payloads. This is occurring even to the extent that the US Air Force has created a Hosted Payload Office [34]. Hosted payloads can be accommodated if organizations build-in or acknowledge available margin in space asset design for size, weight, power, and data bandwidth [35]. This allows the possibility to fly adjunct payloads as a secondary or tertiary mission on a non-interference basis. This is a win-win for the military and commercial industries. SSA payloads would be able to mature technically without a great financial burden by eliminating the need to launch or dedicate individual space assets solely to local SSA. Space assets likewise would be able to fully utilize design capability and margin and benefit from the fruits of the hosted adjunct.

A second enabler to local SSA would be a shift in the space asset design paradigm. Current space asset design, especially in satellites, uses a fairly standardized set of design subsystems for the development of support functions, also known as the satellite bus. This is a traditionally distinct development effort separately managed from the primary payload of the space asset. Examples of these subsystems include power (e.g. solar panels and battery), attitude control, flight computer, software, thermal management, and structure. A notable exception in this list, which appears in terrestrial based counterparts (aircraft, naval vessels, military vehicles), is some type of sensing subsystem to address the collection of situational awareness (SA) data. If the technological developmental history of land, sea and air machines is indicative of a similar path for satellites, then it is inevitable that space assets will also reach this point. If space asset designers, and more importantly the organizations that develop space asset requirements, embrace local SSA as a necessary and integral step moving into the future, then shifting the design paradigm to include local SSA sensors as a standard space asset subsystem can occur.

A major factor to enable local SSA is to advance the technology of local SSA sensors ***and*** the means by which they interface to space assets. Sensors of various phenomena need to be integrated into suites which function as a unified mission area rather than a collection of disparate, individual technologies. Currently, sensor types exist for a variety of SSA needs including radar, laser, space weather, proximity detection and multiple other portions of the EM spectrum. These exist in a variety of technology readiness levels (TRLs) however the vast majority of these are too large to create a comprehensive set for a feasible local SSA sensor suite. Complicating the endeavor is the trade space for where the collection, synthesis, and fusion of the various sensor data will take place. The most elegant solutions conceived accomplish this in space in order to provide for the most timely response options. There is a non-trivial analysis weighing the advantage of on-board processing at the expense of greater SWAP and technology risk. Ultimately these SSA sensor suites must strive to strike the right balance between adequate mission capability and SWAP (size, weight, and power) that is consistent with space asset design needs to effectively enable local SSA. Removing this potentially extremely intensive processing burden from the host to the interface unit is another key enabling advantage.

Another critical enabler to local SSA is the implementation of an SSA-sensor-to-host-space-vehicle adaptor or integration unit. This is a vital element for the near term efforts for local SSA technology development. Consider the fact that all sensors induce an “overhead” burden on any space asset. Power, data, memory, timing, telemetry, and commanding are just some of the functions which require interaction between a payload and the host space asset. The greater this burden for an adjunct or hosted payload, the less likely the host is to integrate or fly the payload. The originating issue causing several of the burdens listed is the number and type of interfaces required by the adjunct. The greater the difficulty in accommodating varying physical and software interfaces (whether standard or custom), the more challenging and time consuming it is for the host space asset to integrate and subsequently operate the adjunct payload. An adaptor or interface unit could create a manageable design bridge between typical space asset interface designs and local SSA sensor interfaces. This unit could consolidate physical and software interfaces, manage the various commanding and data exchanges within the sensor suite, and manage those between the sensor suite and the host. This would isolate, as much as possible, all adjunct-internal traffic and physical interfaces from the view of the space asset as depicted in Figures 4 and 5. This idea in effect presents a simplified and organized interface to the host, exposing it to only the minimal necessary interfaces.

In summary, enablers for local SSA include:

1. Hosted payloads by space assets
2. The acceptance and inclusion of a “SSA Subsystem” as a standard design practice in space assets
3. The creation of SSA suites that function as an integrated system and mission area
4. The utilization of “adaptor units” between the SSA Sensor suite and host space asset

6. SASSA AS A PATHFINDER

Expanding the definition and concept of SSA to include Local and Global terms, even with a solid enterprise solution, is not a panacea. It will take a variety of concerted efforts to address the emerging issues in assuring the operation of our space assets now and into the future. The Self Aware SSA program, or SASSA, is one such effort. SASSA is an Air Force technology demonstration program which has been proving out key aspects of local SSA enabling concepts in its design and testing since 2008 and is currently proving them out with on orbit demonstrations.

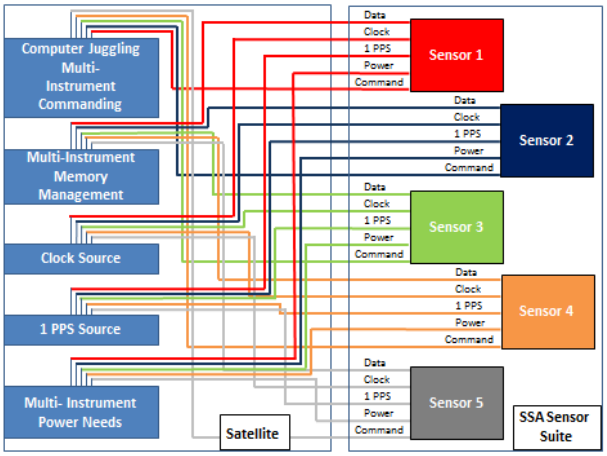

Fig 4. SSA Suite with "Normal" Satellite Interfaces

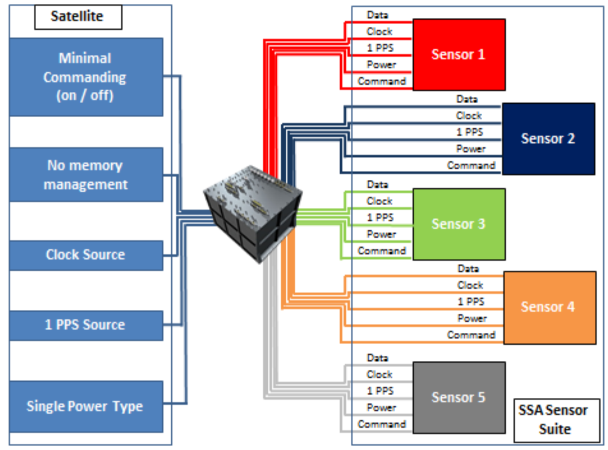

Fig 5. SSA Suite with "Interface Unit"

Initiated in late 2008 as an SSA adjunct payload technology demonstrator, the SASSA program went from idea to delivery of hardware in 30 months. By taking advantage of non-traditional acquisition approaches and tailoring traditional systems engineering processes [36] for rapid development, the SASSA program was able to develop a robust demonstrator design and hardware in a short development timeline. By July of 2010 the SASSA program and its prime contractor (Assurance Technology Corporation (ATC) out of Chelmsford, Massachusetts) had delivered two separate SSA flight units in adapted host configurations, two accompanying ground stations, two test beds, and four engineering development units (EDU's).

The fundamental aspect to SASSA was to demonstrate that an SSA payload could be designed "host agnostic" and could be developed and fielded quickly to enable SSA payloads on other host spacecraft easily and quickly. This meant developing as much of the payload to be flexible, adaptable, modular, and scalable such that it was not designed for a single specific host satellite but rather could be adapted easily and quickly to work with a variety of host satellites. The key enabler to this approach was the development of the Common Interface Unit (CIU). The CIU enables rapid integration and development of an SSA sensor suite on a large variety of host satellites by centralizing and simplifying the interfaces to both the SSA sensors and the host. Figure 6 depicts how the CIU approached this aggregation of interfaces.

Fig 6. SASSA "CIU" Approach

A key result of centralizing and simplifying the interfaces to both the SSA sensors and the host is capability for the commanding, processing, data storage, and other features to be off loaded from the host onto the CIU. The current design allows for completely independent commanding and processing from the host for only the minimal burden of passing very common information (position, velocity, timing, attitude, and ephemeris) and power to the SASSA payload. In return the SASSA payload completely orchestrates the integrated SSA sensor suite operation including some level of on board processing. A second critical feature is that the CIU was built with flexibility and growth in mind. The current design is "over built" and underutilized. What this means is that the current SASSA demonstrator is not maxing out the full capability of the designed unit. The same "build to print" design could handle 2-3 times more SSA sensors than are currently being flown with room to expand the memory and processing capability. SASSA has demonstrated in design and test, and again with host vehicle integration, that it has achieved a scalable, flexible, easily adaptable, and expandable design.

The full success on orbit of SASSA is currently being proven however SASSA has already made impact with its successful design and test during development. The SASSA tech demo has proven that local SSA is within reach of many host satellites through the utilization of a CIU and there is an existing proven design to back it. SASSA has shown that if a host space asset can provide the physical location for the sensors and the CIU, and a basic power and data interface, that the CIU is capable of handling the SSA mission tailored to fit the needs of the host space asset. Additionally, with the development of more sophisticated processing and fusion software loaded into the CIU, SASSA would be able to accomplish more data synthesis on orbit to provide less overall data back to the host but more information based on SSA knowledge gathered from all the sensors correlated together in complete local SSA picture and not just from a single sensor view. While not the final operational answer, the SASSA tech demo has made great strides to prove that local SSA is an affordable reality now and in the near future.

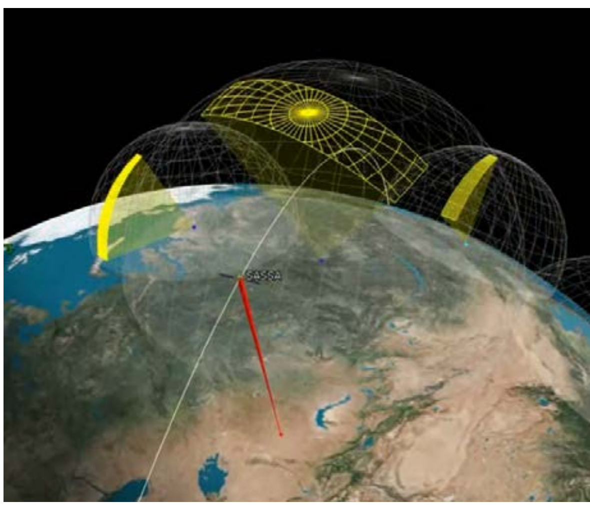

Fig 7. STK Depiction of SASSA HPM Detection

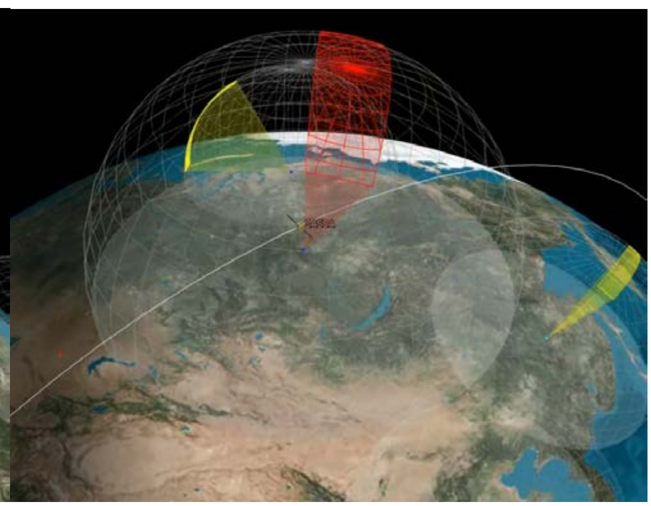

Fig 8. STK Depiction of SASSA Radar Detection

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