Summary of the AMOS Dialogue
September 12, 2013

Co-hosted by the Maui Economic Development Board (MEDB) and Secure World Foundation (SWF)
At the Advanced Maui Optical and Space Surveillance Technologies (AMOS) Conference, Maui, Hawaii

On September 12, 2013, the Maui Economic Development Board (MEDB) and Secure World Foundation (SWF) co-hosted the inaugural AMOS Dialogue during MEDB's 2013 Advanced Maui Optical and Space Surveillance Technologies (AMOS) Conference, held on the Hawaiian island of Maui, September 10-13, 2013. The AMOS Dialogue was a small, half-day, invitation-only workshop intended to foster dialogue among space situational awareness (SSA) providers and end users, thereby promoting greater collaboration and cooperation toward SSA-enabled safe and responsible space operations. The workshop convened representatives from current SSA sharing programs and initiatives and a variety of end users and stakeholders from around the world. Topics addressed included the current status of SSA programs and sharing initiatives, identification of areas for further improvement or collaboration, gaps in coverage or meeting end user needs, and future steps. The AMOS Dialogue was held under Chatham House Rule, meaning that while topics can be summarized in this report, specific remarks or opinions will not be attributed to any particular participant.

Main takeaways from the discussion include that the space community needs to broaden its view not only of what SSA encompasses, but also of how to engage in burden-sharing and division of labor to arrive at a more complete and accurate SSA picture. No one entity, government or company can provide this complete picture on its own. As the community works together toward improved SSA, it must also think about what comes next, which will require incorporating non-traditional partners and emerging space actors.

The AMOS Dialogue was divided into two main sessions. The first session focused on an overview of current services offered by some of the major SSA providers and a brief update on future plans for expanding current SSA program capabilities. The moderator used the following key questions to foster discussion amongst the participants: Where are the major SSA providers going in terms of services and offerings? Are there opportunities for collaboration and cooperation among current SSA providers? What trade-offs exist between building new capabilities and expanded collaboration?

An update on U.S. Strategic Command (USSTRATCOM)'s SSA Sharing Program highlighted the three-tiers of services offered through the program. The majority of services offered through the program are Emergency Services, which do not require a pre-existing agreement. Through this program, USSTRATCOM provides Conjunction Summary Messages (CSMs) on an as-needed basis to all satellite owner-operators. The second tier - Basic Services - are received through a user profile created on Space-Track.org and include satellite catalog two-line element sets, reentry assessments, and access to

information on recently cataloged or decayed objects. The top tier of services is comprised of Basic Services plus seven Advanced Services including anomaly resolution, collision avoidance, conjunction assessment, deorbit and reentry, end-of-life and disposal, launch support, and electromagnetic interference investigation. This tier of services is only available to those who have signed an SSA Sharing Agreement with USSTRATCOM.

USSTRATCOM's goal is to invert the pyramid of services so that more satellite owner-operators have signed SSA Sharing Agreements and are receiving Advanced Services through regular, operational, and reliable relationships with USSTRATCOM. To date, 38 commercial entities and two national governments have signed SSA Sharing Agreements with USSTRATCOM. Nine more commercial and ten more international agreements are currently being negotiated.

Overall, USSTRATCOM has been very pleased with the progress it has made toward greater cooperation and collaboration on SSA since it was granted the authority to make such arrangements with commercial entities in 2010 and international partners in 2011. However, it is still learning from the process and is open to cross-exchange and education with partners, which makes the AMOS Dialogue a relevant forum. Ultimately, USSTRATCOM wants its products and services to be useful, meaningful, and improve operations for all space actors. Another way it is attempting to do this is through operator engagement talks, some of which were hosted in May 2013 at Vandenberg Air Force Base in California. Additionally, USSTRATCOM maintains robust security dialogue and working group discussions with its counterparts at the Department of Defense and the Department of State.

There was also an update on the non-traditional data pre-processor that is being developed by USSTRATCOM J8, Capability and Resource Integration, in conjunction with Air Force Space Command. The machine-to-machine interface of the new processor will enable automated data inputs to the Joint Space Operations Command (JSpOC)[1] from owner-operators. This will eliminate the need for JSpOC operators to manually enter the data into their system. Testing of the data pre-processor will commence in the fall of 2013 with the goal of coming online in 2014. The pre-processor is being designed to ingest a variety of formats and translate that data into JSpOC's language. This would require no previous certification, but would necessitate some testing for fidelity to verify that incoming data met a standard of quality. Initial testing will take place with Australia.

Next, an update was given on the private sector-initiated Space Data Association (SDA) and its current efforts at SSA sharing. SDA primarily supports operators located in the geostationary (GEO) belt with its SSA services and products. These are the most difficult satellites to track with current SSA capabilities both because of their distance and propensity to maneuver. As such, the design of the SDA, which incorporates owner-operator data on current positions and planned maneuvers with the JSpOC catalog, works very well. Additionally, SDA has mostly solved the issue of ingesting a variety of data formats into one SSA system, though its Space Data Center (SDC) is constantly validating data to ensure smooth operations.

[1] Under USSTRATCOM, the Joint Functional Component Command for Space (JFCC-SPACE) performs the SSA mission. JFCC-SPACE is responsible for the Joint Space Operations Center (JSpOC), which uses the Space Surveillance Network (SSN) to gather, catalog, and analyze the SSA data.

The SDA was largely created out of a need to supplement the SSA products and services most of these owner-operators were receiving from JSpOC, which they believed to be insufficient for safe spaceflight and operations. The SDA routinely works with both its members and the JSpOC to validate data, identify discrepancies, and eliminate problems. The SDC has found in working with SDA members that when one receives a CSM or warning from JSpOC, they simply want the best data available so they can make their own, most informed decision. If both SDA and JSpOC come up with the same possible conjunction or warning, then the decision is easy. However, if the two say different things, they try to work together to solve the issue. Thus, the most important thing is to have an ongoing dialogue among all players.

It was acknowledged that uncertainty is an area that the astrodynamic community needs to work on. For example, the way the Space Surveillance Network (SSN) collects data leads to optimistic assumptions of conjunctions, meaning it may register more conjunctions than what is actually taking place. All players need to find a way to collect, process, and present data in a meaningful way. Additionally, many owner-operators are generating covariances, but are not sharing or providing them. There is a need for the community to work together to develop a standard practice in this area.

The discussion shifted slightly to explore the legal regime under which the SDA operates since liability is a recurring concern with SSA sharing efforts. All members must sign binding legal agreements that prohibit any use of data that is not explicitly permitted. Additionally, the SDA was formed specifically on the Isle of Man because it allowed third party beneficiary rights.[2] In the event of non-permitted use of data, members are able to sue and win unlimited monetary compensation. Every member must agree to the same terms, with the exception that government members receive waived sovereign immunity. Together with heightened cyber security mechanisms, this strict legal regime has, thus far, effectively deterred misuse among SDA members. Ultimately, though, the Liability Convention makes States responsible and liable for any accidents in space.

The SDA never advises whether or not to maneuver, which shifts risk back to whoever ultimately makes the decision. It was pointed out that liability will be a major concern for any potential commercial SSA provider in the future. The SDA paradigm provides a good model to follow in that data is provided under best efforts, but the ultimate decision is up to the owner-operator. Similarly, this concern extends to even the U.S. government (USG). When U.S. Congress authorized the SSA Sharing Program, they claimed sovereign immunity so that the USG could not be held responsible for anything that happened as a result of its sharing SSA data.

A question was asked regarding how a country might be convinced of the need to invest in indigenous SSA capabilities since USSTRATCOM is already providing it all for free through JSpOC. It was pointed out that it is not always certain that JSpOC is right. In fact, some have found that the CSMs coming from USSTRATCOM are not always accurate or actionable. Part of this is because the JSpOC cannot currently routinely monitor and track everything in space. Its SSA is largely based on looking back in time and predicting for the future. Combined with the fact that JSpOC is not able to ingest planned maneuvers, for example, their predictions are sometimes off. It was pointed out that its SSN was initially designed

[2] Third party beneficiary rights mean that a party can sue on a contract even if they were not originally an active party to that contract.

for a different task and so owner-operators relying on its data need to account for that. Some separate or independent capacity is needed simply to verify data and information received. Additionally, the SSN does not currently provide global coverage. Additional sensors operated by other countries could contribute to a more comprehensive, global SSA picture.

Moreover, dispersed capabilities will only serve to validate and cross-check SSA data and provide an overall more accurate picture. One can envision a future where multiple centers of gravity provide elements of the overall SSA picture. JSpOC is responsible for the "lion's share" of the positional information and debris catalog, but there are many other critical elements in SSA. Perhaps one country could be the expert and main source of another SSA component. This future of specialization and shared contributions would be in everyone's best interest.

Participants also emphasized that because JSpOC's main duty is to support the warfighter, it provides support for civil, commercial, and international operators as resources are available. As such, additional SSA sources like SDA can effectively augment the JSpOC's services by reducing support that the SDA's members require from the JSpOC and allowing the JSpOC to allocate limited resources more effectively. For example, in late September 2012, the U.S. National Oceanic and Atmospheric Administration's (NOAA's) GOES-13 weather satellite experienced an anomaly resulting in loss of all imagery and sounding data. NOAA needed to very quickly move its replacement GOES-14 into position from its on-orbit storage location. Since all GOES satellites share operational locations in GEO with commercial satellites, NOAA needed to coordinate the drift maneuver very carefully with numerous other spacecraft operators. NOAA relied heavily on SDA to coordinate and perform key analyses before and after maneuvers in a timely manner. Given its limited resources and many national security space customers, the JSpOC would not have been able to provide the timely data NOAA needed during this critical period, which lasted for nearly 30 days. NOAA was able to quickly maneuver GOES-14 eastward with the support of SDA and was thus available to provide key Hurricane Sandy monitoring data following GOES-13's return to operations on October 18, 2012.

This topic concluded with the observation that even the USG is looking to augment its system and capabilities through mutually beneficial relationships with other countries and partners above and beyond USSTRATCOM SSA Sharing Agreements. For example, the USG is looking forward to incorporating data from a C-band radar that will be installed in Australia and from Canada's space-based SSA satellite, Sapphire. Other countries can explore opportunities for more transactional partnerships through their own investment in unique or niche capabilities.

For example, Canada has received top-tier SSA products and services from the USG as part of its NORAD partnership, but decided to invest in its own SSA sensor on orbit, Sapphire. Its rationale was a combination of national prestige considerations, the advantages of owning and operating its own sensor, a desire to build up industry in a niche mission area, and its belief in burden-sharing. Canada believes that it has a responsibility to contribute to keeping the space environment safe and sustainable for all. As such, it sees Sapphire as a way to improve, and not compete with, existing SSA capabilities. Canada also wants to be able to trust, but verify, the SSA already shared. Additionally, the Canadian

Space Agency provides some of its own conjunction assessment with the goal of supporting all Canadian satellite owner-operators.

This coincides with the fact that, according to the Outer Space Treaty, it is the responsibility of national governments to oversee the safe space operations of entities within their jurisdiction. Scientific and research institutions, because they are not able to sign their own SSA Sharing Agreements with USSTRATCOM, must rely on Space-Track.org for all of their SSA. These are additional arguments for investing in national SSA capacity, but many already feel a responsibility, as the Canadians do, to contribute to the overall picture and share the burden of SSA. Many are not comfortable with simply receiving a service that requires a significant amount of resources to sustain: they want to be contributing partners, too. The German National Space Strategy, for example, clearly states the need to build a national SSA capability, primarily by leveraging existing resources. The intent here is not to create another JSpOC, but rather, to fill in gaps and make the whole better.

Not many appreciate that SSA is a larger issue than just collision avoidance and, as such, progress can still be made in many other areas as well. For example, space weather can severely impact safe space operations, but only some consider it an element of SSA. NOAA's Space Weather Prediction Center (SWPC) conducts most space weather observations and forecasting, but needs continued support and international participation to improve its services. Additionally, it still is not clear, even within the USG, who is responsible for providing these services and to whom. Currently, SWPC is more in the business of data-giving, rather than sharing. While international collaboration works well for space weather forecasting in the areas of ground-based measurements, data exchange, and collaborative tracking of assets in space, it is more difficult in the area of expensive space-based missions, which could significantly enhance predictions. It was pointed out that Canada houses its own space weather expertise and should be put in contact, if it is not already, with SWPC. There is a need to distribute capabilities and work together, instead of duplicating efforts, in this realm.

One possible area for collaboration on space weather is in developing a portal for compiling information on space weather anomalies that have occurred and affected spacecraft. Inspired by forensics work conducted after the space weather anomalies of Intelsat's Galaxy15 and Lightsquared's SkyTerra1, the SWPC in Boulder has started working on such a database. However, the initiative suffers from a lack of funding and inputs to the database. Some satellite owner-operators are hesitant to share information about anomalies for fear of revealing proprietary information. It was suggested that perhaps SDA could play a role in collecting this useful information as it already has an effective mechanism for protecting proprietary information.

The second session of the AMOS Dialogue focused on an overview of end user needs. It featured perspectives from SSA end users in the satellite operations and scientific community, specifically on what SSA capabilities they need to operate safely and efficiently in the space environment. The moderator posed the following questions to start the discussion: Are the current SSA services helping satellite operators make informed decisions about risks in space? Are end users confident in the quality of current SSA services?

The conversation started with an overview of the experience of DigitalGlobe, a low-Earth orbit (LEO) satellite imagery provider. It was pointed out that the public and private sector in this case really depend on each other. Commercially-provided satellite imagery is necessary for public services such as disaster management, but these providers rely on the government for SSA. The relationship between these providers and JSpOC has improved over time and data-sharing has expanded to improve SSA overall. However, because military assets are given higher priority for conjunction assessment and collision avoidance support, sometimes the private sector entities do not get the information they need or, if they do, do not receive it in a sufficient timeframe to respond. It was noted that if these owner-operators had perfect information, they would likely never conduct avoidance maneuvers. As it is, they mostly maneuver around uncertainty, expending precious fuel to do so. In the case of DigitalGlobe, only one of the satellites recently maneuvered was unquestionably in danger of collision.

With that said, SSA in LEO has certainly improved in recent years with increased trust and confidence on both the owner-operator and JSpOC sides. Most of the remaining difficulty is in instances with short timeframes. An anecdote was provided that Iridium, another LEO satellite owner-operator, felt they received good service from JSpOC, but they often had to wait days, and sometimes weeks, to receive answers to simple queries. Many of their questions need quicker answers than that, in what they see as a "business meaningful timeframe." In GEO, collision risk is typically between two operational spacecraft, so coordination can greatly reduce the chance of accidents. This is not so for LEO, where operators risk collision mostly with debris, not other satellites. Shorter response is often needed in that case.

It was agreed overall that matters had improved both qualitatively and quantitatively in recent time, especially over the past five years. While the quality of JSpOC-provided data and information has improved, much progress is also thanks to improvements in relationships between SSA providers and recipients, leading to enhanced trust and confidence. For example, in May 2013, Lieutenant General Susan Helms invited a group of satellite owner-operators to Vandenberg Air Force Base to discuss JSpOC SSA products and services. These owner-operators spent a day and a half with the entire command team having a frank and open discussion about the JSpOC's current capabilities and limitations. It was a very positive exchange and demonstrates the vast improvement in this realm in recent years. However, there are still limitations and opportunities to working together for more improvements. There is a recognition that the USG is making a concerted effort to be more responsive to end user needs, but everyone wants to contribute to making SSA better overall instead of just relying on the USG to improve. This would be not just in the traditional areas of conjunction assessment and collision avoidance, but also on electromagnetic and radiofrequency interference. The conclusion was that the trend in recent years is good, but still needs work.

It was also emphasized that satellite owner-operators have no interest in denigrating the work that JSpOC does. They all recognize that JSpOC is doing the best it can with the antiquated system and architecture handed to it and within a very constrained primary mission and resource environment. Some of the issues have to do with communication, too. In an effort to improve its products and services, the JSpOC recently made a change to the way it generates general perturbations (GP) two-line element sets (TLEs). It now generates them from the special perturbations (SP) state vectors using

smoothing algorithms. However, the JSpOC did not have the resources to test the change and did not communicate it to recipients and, as a result, did not catch a small, but key, error in the calculations. SDA identified the issue by running the new TLEs against its members' ephemerides and alerted the JSpOC of the problem. This highlights the importance of good communication between all actors for cross-checking data and information and resolving issues as soon as possible. More improvements are planned for Space-Track.org and for the products and services provided by USSTRATCOM to users with existing agreements. USSTRATCOM intends to run beta tests and pilot projects on those improvements. As part of this, it will reach out through JSpOC to ask owner-operators to participate in testing those improved products and services before they are fully rolled out so as to prevent another scenario like the one described above. Another suggestion made by participants in the discussion was to follow the model used by NOAA's SWPC, which sends out a service change notification to all subscribers any time it changes the underlying format of its products.

Another SSA issue has to do with personnel. It takes time to train an orbital analyst, but JSpOC operators often rotate out within a few years, taking their expertise and experience with them. There is an opportunity for others to contribute in the form of analysts and personnel to help share the load currently borne by JSpOC. For example, Canada has contributed personnel through its NORAD agreement with the United States for the past 25 years, sending operators to JSpOC to work alongside their U.S. counterparts. Going a step further, one suggestion envisioned a Canadian cell conducting orbital analysis and feeding it back into the JSpOC from Canada. For this to work, there has to be a willingness and openness on the United States' part to trust and rely on partners to share the SSA load. This is a niche area that other allies can easily fill if the United States were willing to relinquish a piece of the SSA mission set to others. It is a difficult thing to do, certainly, but it may be the right time for more openness and trust, especially at the military-to-military level and with established allies.

Another anecdote of the personnel issue comes from EUMETSAT, the European meteorological organization, and its experience with JSpOC over the years. As a foreign entity, it took several years to reach the top-tier of USSTRATCOM's SSA services. Even when it began receiving the full spectrum of basic and advanced services, EUMETSAT realized it could not rely on JSpOC for all of its SSA. As a result, EUMETSAT built up its own flight dynamics shop that ingests JSpOC data and runs its own collision avoidance and conjunction assessment calculations. This generally works well when the relationship with JSpOC is well-established, but it seems that every time EUMETSAT's operators get comfortable with a JSpOC counterpart, that operator rotates out of JSpOC for another assignment and EUMETSAT must start over again.

The conversation shifted here to look at another meteorological entity, NOAA, and its SSA experience. NOAA relies on three sources for its SSA: the JSpOC, SDA, and NASA's Goddard Space Flight Center. NOAA is a special case in that it has many assets requiring protection, three of which share orbital positions with commercial satellites in GEO, and only one that can maneuver out of harm's way. Most of NOAA's spacecraft were built before the days of debris mitigation guidelines that require satellites to be de-orbited or transferred to a graveyard orbit at end of their lives. Consequently, all of NOAA's polar satellites, for example, will become very large pieces of debris when they expire.

Another interesting point is that weather forecasting and climate monitoring is truly an international job. For example, NOAA receives a variety of data and information from partners around the world and even relies exclusively on EUMETSAT for midmorning polar data. However, not all of its international partners have access to the same level of SSA services from the JSpOC as NOAA does. NOAA can, and has, brokered SSA Sharing Agreements for some of these partners, but it cannot force them to work closely with JSpOC as it does.

In addition to improved burden-sharing and communication, there is also an opportunity to improve SSA through optimizing the software and analytical tools used to process the data. The ideal goal should be software that can ingest any type of data and compute for any orbits, including the exotic ones. This should then be shared with the broader SSA community. Europe is already working on developing a series of improved analysis and extrapolation tools and plans to share it with the community. Another area for improvement is to attempt to validate the conjunctions predicted by JSpOC. This requires specific sensor tasking, which is difficult to do with current capabilities. However, Germany has plans to do this kind of precise radar orbit determination, with the goal of focusing on a supposed conjunction, monitoring it, and then feeding the information back to the JSpOC to be used to improve their analyses.

The AMOS Dialogue discussion to this point focused on traditional SSA end users such as satellite owner-operators. A different use for SSA is to strengthen norms of responsible behavior in space activities. There are currently a few international initiatives attempting to codify “rules of the road” for space, but just like with traffic rules, some form of monitoring is needed to verify that actors are following those rules. Without monitoring and verification, the rules will have no effect on behavior. SSA, even very low-fidelity SSA, can be this source. In general, this use for SSA can be accomplished with the existing data available, but in some cases, extra or special data may be needed.

For this purpose, burden-sharing in SSA is beneficial as well. If a space actor were to engage in irresponsible behavior, there may be a need to verify and attribute that bad action through a non-USG source, especially if the irresponsible actor and the United States have a tense relationship. If two to three independent SSA sources all attribute and verify that action, it “names and shames” the bad actor more effectively than if just one source claims it happened. In this case, the intention of independent, non-USG SSA sources is not to duplicate the work of the JSpOC, but rather to improve everyone’s ability to distinguish between accidents and hostile activities in space and, in the event that hostility does occur, to provide another perspective on what has taken place.

Returning to the traffic analogy, it was pointed out that current SSA capabilities are still a long way off from being able to underpin a credible space traffic management (STM) regime. Even in GEO, where a governance regime operates somewhat effectively, there is the issue of “paper satellites,” or countries registering spacecraft to reserve orbital positions without ever deploying an actual spacecraft. The International Telecommunication Union (ITU), the governing body that oversees the GEO belt, must trust the word of nation-states in these cases because it lacks access to SSA capabilities that could effectively monitor the orbital region.

Another participant agreed that it was early days for STM and argued that a naval analogy might be better suited for space. It is hard to imagine any sovereign nation voluntarily constraining its freedom of action in space. Most space actors know more than they are willing to share with others and, given the strategic value of the space domain, this is understandable and not likely to change. In the maritime domain, submarines know to stay away from each other without being completely open and transparent about their positions and capabilities. One might argue that we will never get to a fully transparent space environment where all SSA data is freely available and shared, but could a similar situation in space exist as there is in the maritime domain? Instead of trying to draw a black line between data and information that can and cannot be shared, is it possible to simply share where something is and where it is going, without giving away what it does?

The discussion came to a close at this point and some main takeaways and concluding remarks were provided. It was agreed that SSA is broad and encompasses many elements, not just collision avoidance. The space community needs to broaden its view not only of what SSA encompasses, but also of how to engage in burden-sharing and division of labor to arrive at a more complete and accurate picture of what is happening in space, which would benefit all involved. Part of this will be identifying what each actor can contribute and ensuring that the others trust, but verify, what is being received. Regardless of the benefits of distributing capabilities and sharing the SSA burden, the fact is that no one entity, government or company, can provide the full SSA picture on its own. As the community works together toward improved SSA, it is also necessary to think about what comes next: enhancing SSA for future space activities and needs, not just for what the environment looks like today. A key element of this will be incorporating non-traditional partners and emerging space actors.