



2014 Status Report of AGI's Commercial Space Operations Center and other AGI SSA Initiatives

The number of objects in space has significantly proliferated since 1957, with more than 17,000 objects bigger than 10 cm and more than 1,000 active payloads currently being tracked. Coupled with the ever-increasing reliance on space by the commercial and worldwide defense communities, the need to track and get information about activities in space is more important now than ever before — to predict and prevent collisions between space objects, predict atmospheric reentry, monitor spacecraft behavior and detect threats to spacecraft.

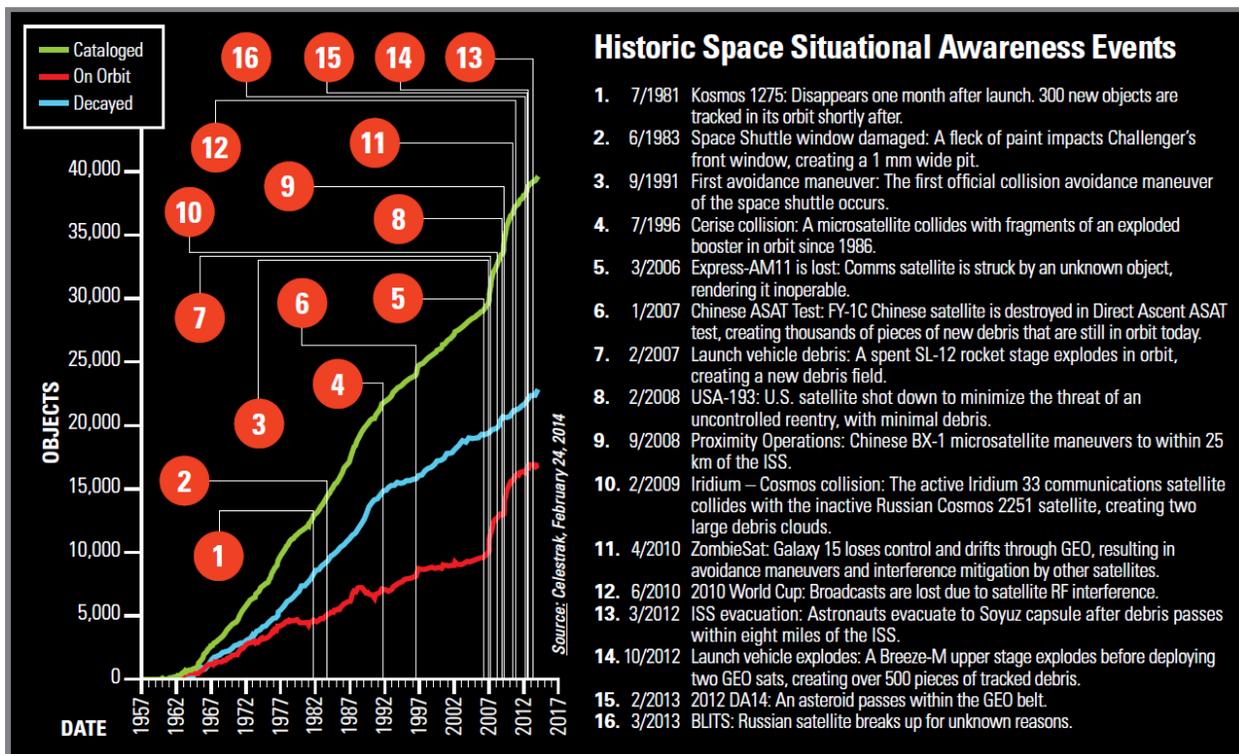


Figure 1. Historic Space Situational Awareness Events

Analytical Graphics, Inc. (AGI) is a world class expert in commercial space analysis products and services, with significant experience and heritage in space situational awareness (SSA). Some examples of these products and services include:

- Orbit determination
- Conjunction screening
- Maneuver detection
- Rendezvous and proximity operations (RPO) analysis

- New foreign launch (NFL)
- Co-orbital and direct ascent anti-satellite (ASAT)
- Geolocation
- Radio frequency interference (RFI) analysis

These products and services are available and provided via three proven solutions: the Commercial Space Operations Center (ComSpOC™), the Space Data Center (SDC) and the AGI SSA Software Suite, which is currently in use for the USAF JSpOC Mission System.

Commercial Space Operations Center (ComSpOC)

The ComSpOC is a state-of-the-art data processing facility established and operated by AGI that fuses satellite tracking measurements from a network of commercial sensors to generate highly accurate SSA data products for resident space object (RSO) characterization. Commercial satellite owner/operators and government space operations centers can leverage ComSpOC data products by subscribing to SpaceBook, an SOA-based SSA service that provides position, health, status, event and trending information for all tracked objects.

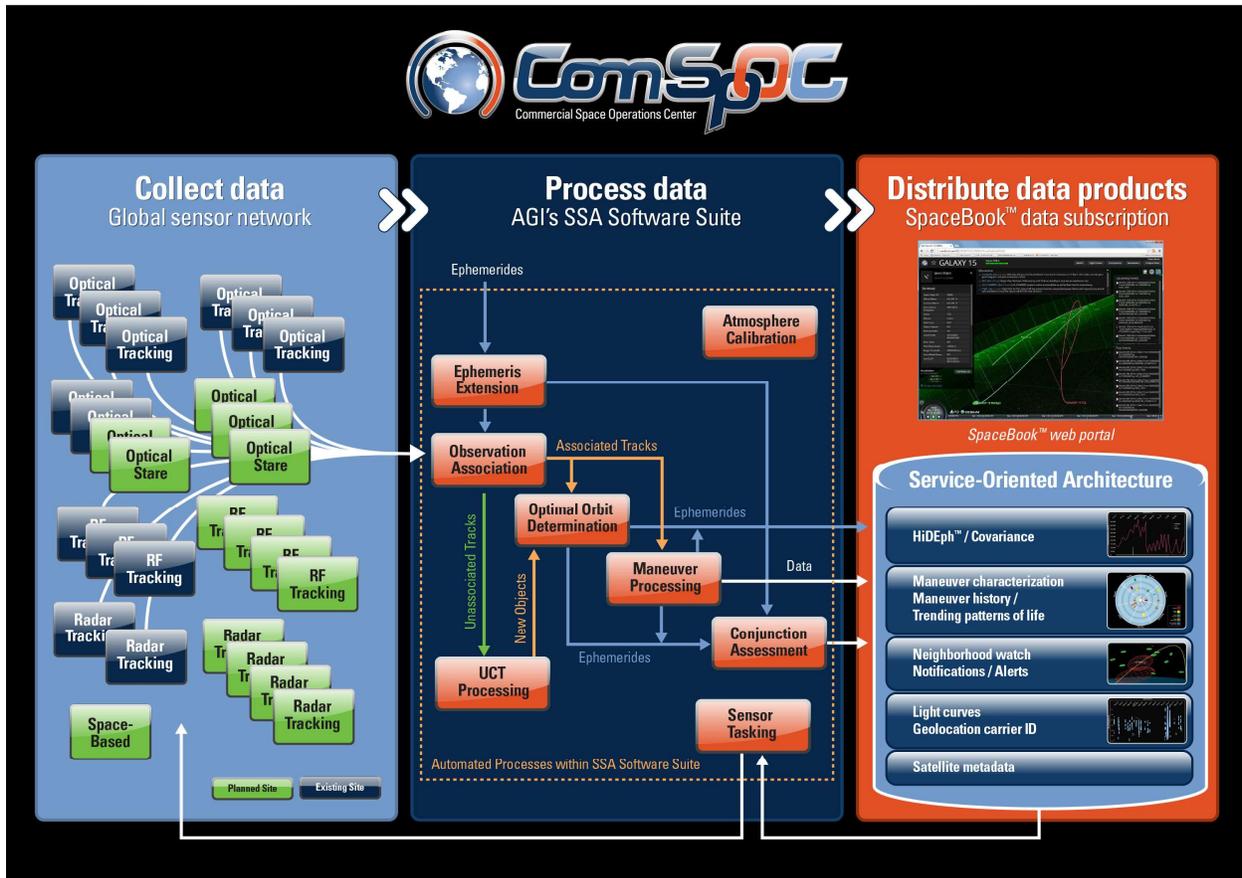


Figure 2. ComSpOC Operational Architecture Diagram

Since being launched in March 2014, the ComSpOC system is running daily operations from a global network of optical, Radio Frequency (RF) interferometry and radar sensors with observations contributed by commercial and sensor operators. The ComSpOC-published SpaceBook web interface provides a current status and history of all space objects and their activity, including relevant metadata. The ComSpOC allows SpaceBook subscribers to quickly stand up an SSA capability by leveraging existing

commercial data sources for SSA data processing and to generate relevant SSA results. This brings subscribers persistent tracking and timely characterization of RSOs.

The benefits of heavily leveraging commercial hardware and software are apparent from the number of milestones since ComSpOC's launch:

- Daily observation processing from over 20 optical sensor sites, three passive RF interferometry sites and one radar site
- Closed-loop tracking provided back to sites
- Successfully tracked a space launch
- Real-time maneuver characterization
- Active maintenance of a catalog of over 1,000 RSOs
- Tracking 73% of all active geostationary satellites

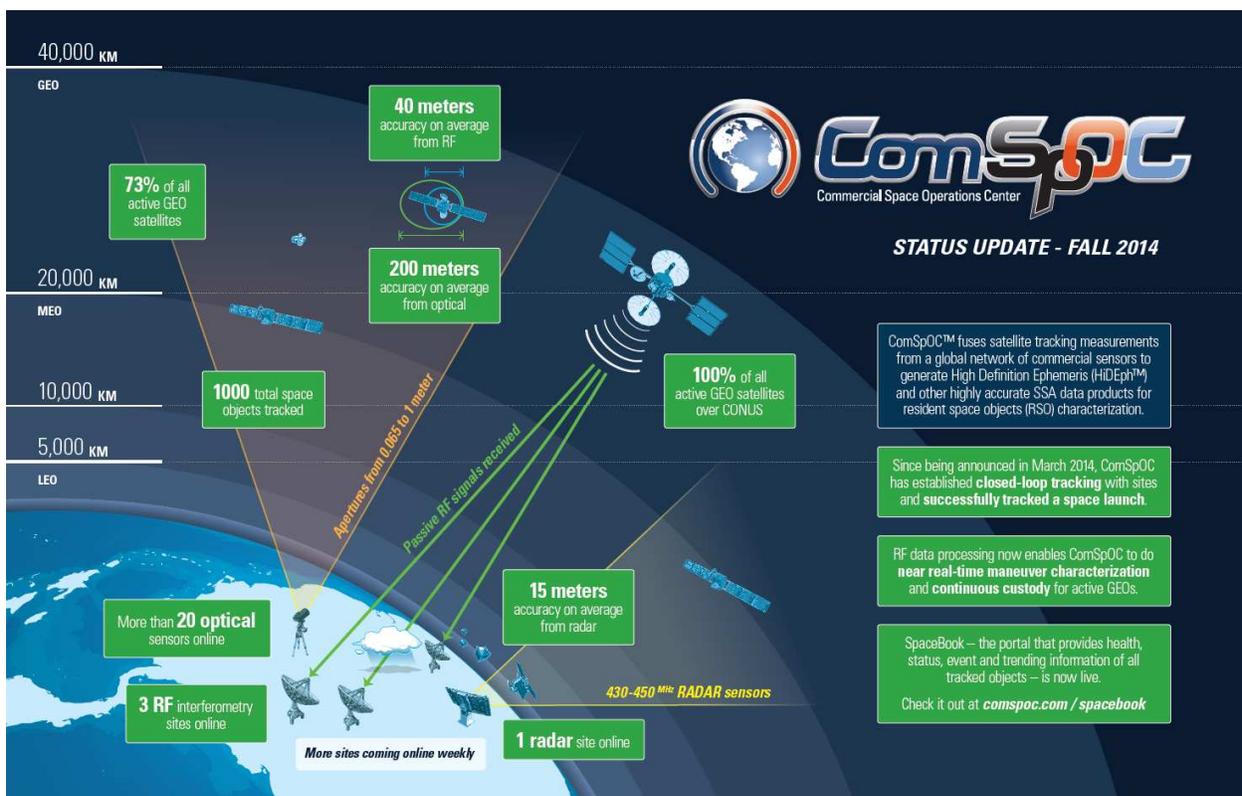


Figure 3. ComSpOC Status Update - Fall 2014 Infographic

AGI's strong experience with a Web-hosted SSA domain enables strong data security for subscribers. Combining commercially available low-cost optical and RF sensors with advanced commercial off-the-shelf (COTS) software solutions allows AGI to deliver the SpaceBook at a lower cost and with greater accuracy than current capabilities or developing a new SSA system. The public can get a sneak peak of the SpaceBook at www.comspoc.com/spacebook.

Space Data Center

The Space Data Association (SDA), AGI's first operational SSA system, is a nonprofit association that brings together satellite operators who value controlled, reliable and efficient data sharing critical to the safety and integrity of the space environment and RF spectrum. The SDA was founded by Inmarsat, Intelsat and SES, three of the leading global satellite companies. SDA's mission is implemented by the

Space Data Center, an automated SSA system developed and operated by AGI that provides SDA member organizations with:

- Increased safety of flight through automatic conjunction assessments and warnings
- RF interference and geolocation support
- Authoritative contact information to support timely resolution of operational issues

AGI has designed and operated the SDC, a high-availability 24/7 operational system, since 2010. The SDC system converts disparate operator data to a common “normalized” reference frame and performs integrity checks on contributed ephemerides for 240 satellites. By using this authoritative operator data, the system provides SDA members with the most up-to-date SSA reports available for their assets. The SDC currently provides CA processing for more than 57% of all operational satellites in GEO. Through the SDC, AGI software is trusted by the leading global satellite operators for operational situational awareness.

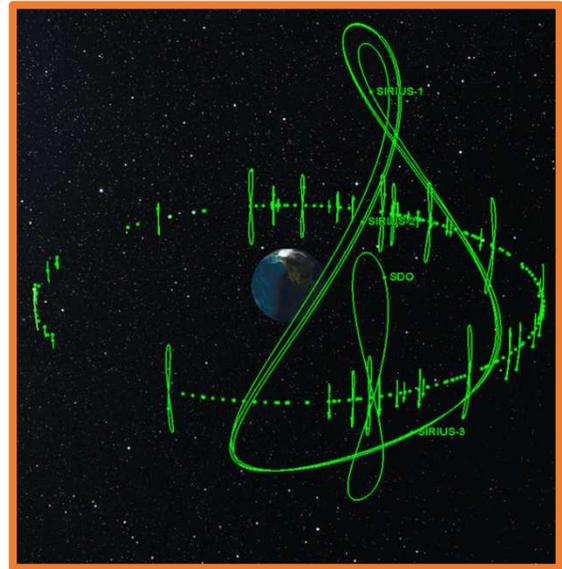


Figure 4. SDC Participants (240)

SSA Software Suite

The heart of AGI’s SSA solution deliveries is the commercial SSA Software Suite which delivers SSA capabilities in an SOA designed for scalability, reliable performance, full-database integration, secure operations and web-based user interactions in an integrated, off-the-shelf package.

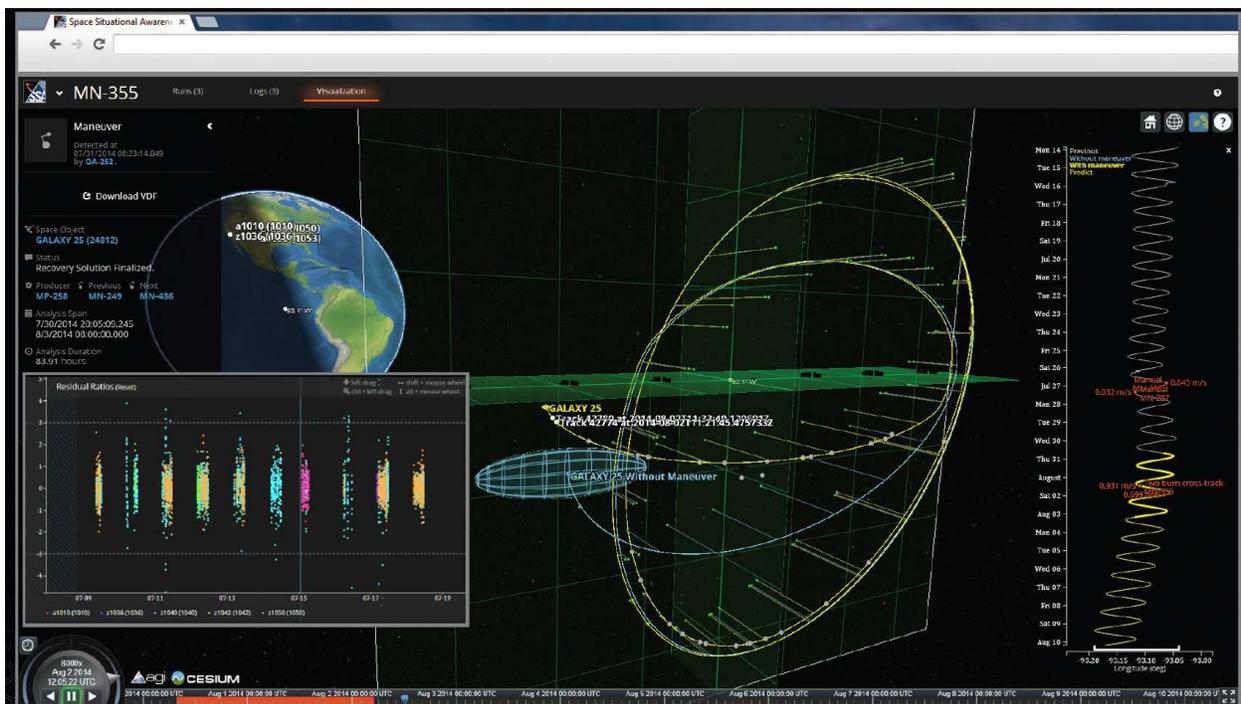


Figure 5. Screen shot from AGI’s SSA Software Suite showing characterization and residual ratios through a maneuver of a geostationary satellite

The open architecture of the system allows for additional applications to be integrated into the system, and the AGI SSA Software Suite includes analytical capabilities that are not included in the AGI legacy desktop products for near real-time, continuous performance for catalog generation, conjunction analysis and maneuver processing and detecting.

The entire AGI SSA Software Suite includes the application services:

- **Catalog Maintenance and Observation Processing** – Process sensor observations and perform observation association and orbit determination to generate precision state vectors and produce a High Definition Ephemeris (HiDEph™) catalog.
- **Maneuver Processing** – Monitor observation data to identify deviations from anticipated trajectories and evaluate potential maneuver profiles.
- **Sensor Tasking** – Develop sensor tasking plans to optimize observations for high-priority activities.
- **Conjunction Assessment** – Use all sources of ephemeris data to determine potential conjunctions for the entire space catalog.
- **Mission Analysis Application** – Integrate SSA capabilities in a Web-based, network centric infrastructure with integrated visualization.

Below is a functional architecture diagram of the SSA Software Suite which performs the ComSpOC data processing.

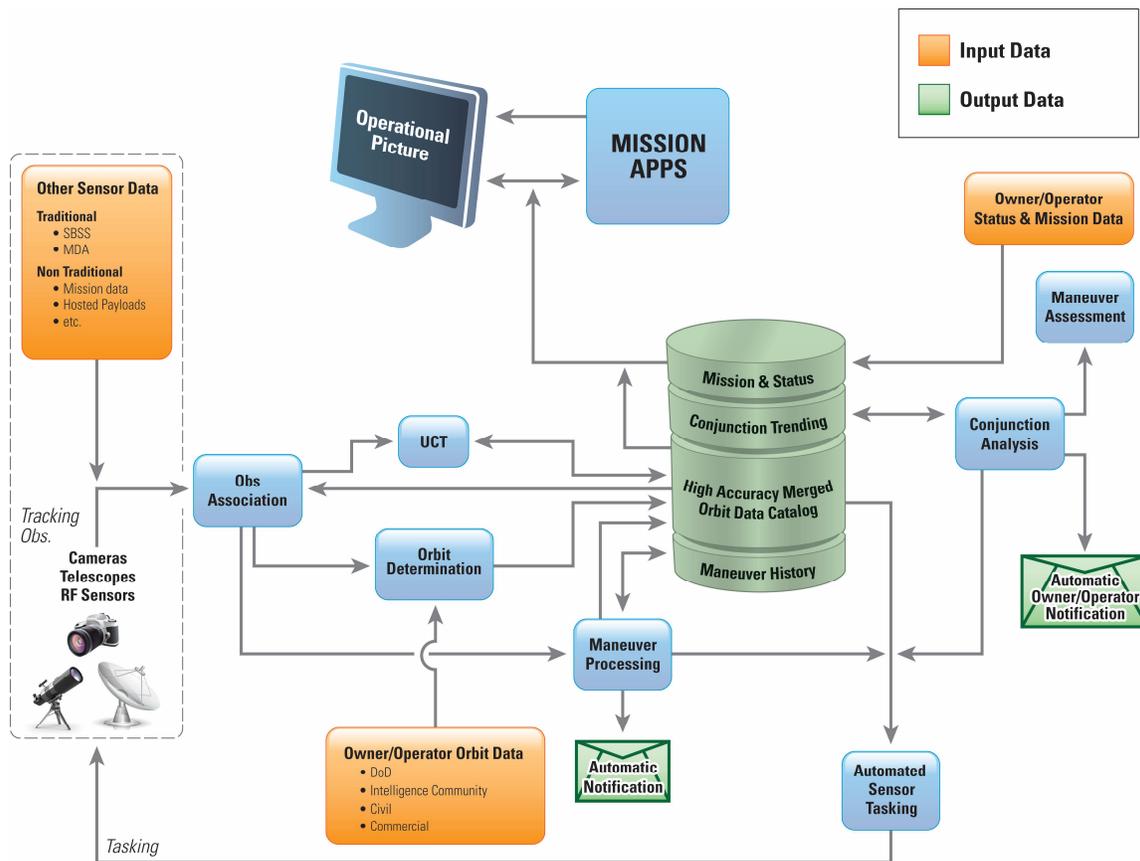


Figure 6. AGI SSA Software Suite Functional Block Diagram

The SSA Software Suite includes:

- Application software
- Scalable, server-based processing
- Integrated database and schema
- Web-based user interfaces
 - Client/server interfaces needed to implement the system in an SOA

The strength of this solution is in the ability to process all observation types from any observer (ground or space), traditional and non-traditional sources, as well as the unique third-party algorithms used in the data processing (See Figure 7 below). Supported formats include standard metric measurement formats such as range, azimuth, elevation, Doppler, Right Ascension, Declination as well as other less traditional measurements such as space-based angles-only measurements, time and frequency difference of arrival (TDOA/FDOA), OPIR data and others. AGI software is designed to process all of these sources together simultaneously to provide the most accurate representation of the behavior of a given RSO. Below is a summary of the various sensor sources, measurements and formats that can be processed with AGI software in support of the protection and characterization mission.

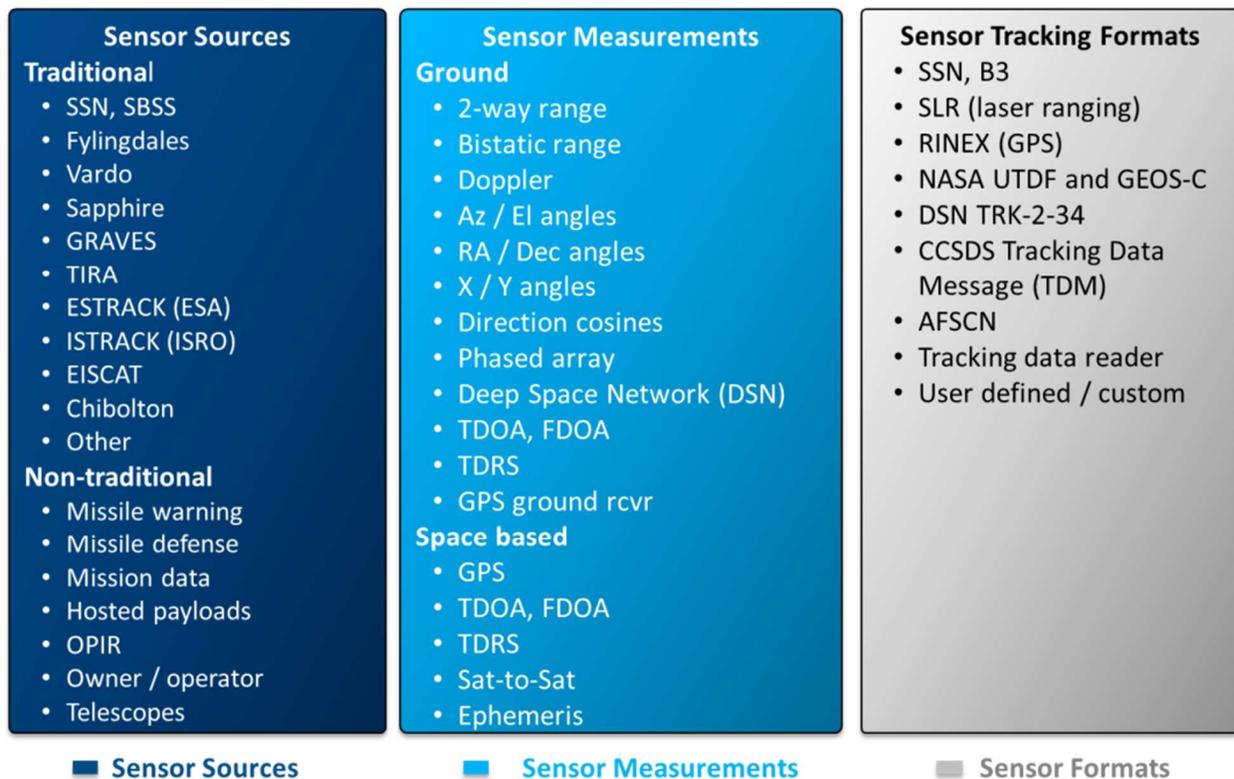


Figure 7. AGI SSA Software suite observation sources and measurement types

AGI can implement the software capabilities in an organization’s own infrastructure, including its own databases and security services. Turnkey SSA solutions are also available, including integration and engineering services, prototyping, testing and system training for full-system integration and delivery.

The SSA Software Suite leverages tenth generation pedigree commercial products that have been independently validated and verified. The SSA Software Suite has been deployed into operational environments processing real data for the U.S. intelligence community and DoD missions and events,

and was selected by the U.S. Air Force's Joint Space Operations Center (JSpOC) to implement a high-accuracy catalog for its JSpOC Mission System (JMS) program.

AGI's SSA Software also undergoes a significant amount of regression testing leveraging the 25-year history of AGI software development practices.

Summary

AGI has a long legacy providing world-class SSA solutions to industry, with operationally proven implementations within both commercial, defense and intelligence environments. 2014 has seen explosive growth of these capabilities with the expanding operations of the ComSpOC. As outlined in this paper, AGI offers multiple paths for organizations interested in achieving rapid SSA capabilities with limited risk:

- Participate in the Space Data Association/Space Data Center
- Subscribe to AGI's ComSpOC SpaceBook
- Acquire the AGI SSA software suite

To learn more, visit www.agi.com/ssa or contact AGI at ssa@agi.com.

Reported Benefits of AGI Software	
Customer Benefit	Result
Time to market	Up to 4x faster
Productivity	Up to 69.8x more productive
Reduced cost	Up to 99.9% savings
Return on Investment	Up to 500%

Figure 8. Results from the 2008 Frost & Sullivan Report: "An Assessment of the Benefits Associated with Software by Analytical Graphics, Inc. (AGI)"

Moreover, AGI commercial software solutions have time and again proven to deliver capability faster, with less risk and lower cost than custom-built alternatives for a specific program. The September 14, 2010 memorandum, "Betting Buying Power: Guidance for Obtaining Greater Efficiency and Productivity in Defense Spending," issued by Ashton Carter, U.S. Under Secretary of Defense for Acquisition, Technology and Logistics (ATL), includes specific guidance for "doing more without more." It is well-recognized that, where commercially available software meets a program need, it is significantly less costly than custom-built and maintained code. Furthermore, the Defense Science Board noted that the maintenance cost for commercial software can be as much as ten times lower than that for free and open source software.

Finally, Figure 8 depicts how independent reviews of performance of AGI software solution deliveries have uncovered significant cost, time and risk reductions as well as significant productivity enhancements over legacy solutions. For a number of studies on the cost benefit associated with AGI software, please visit www.agi.com/efficiency.