Terra Harvest: an open, integrated battlefield unattended ground sensors architecture

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ABSTRACT

The Defense Intelligence Agency (DIA) is developing Terra Harvest, an open, integrated battlefield unattended ground sensors (UGS) architecture that will employ multiple, flexible sensors via standards-based integration. The Terra Harvest open architecture separates the UGS system into fundamental components and standardizes internal and external interfaces to optimize interoperability. Other acquisition programs can take advantage of this open architecture to meet challenging mission requirements.

Keywords: acquisition, battlefield architecture, DIA, interoperability, plug-and-play, reference implementation, Terra Harvest, unattended ground sensor, UGS SWG

1. INTRODUCTION

The DIA Deputy Director for Technical Collection identifies operational requirements and develops collection systems and architectures via research, development, testing, and evaluation. One such collection system includes the family of unattended ground sensors (UGS). Although widely fielded, UGS are nonetheless encumbered by proprietary designs, incompatible components, and unique interfaces. At an acquisition level, this lack of flexibility has adversely affected cost, development cycles, and deployment times. At an operational level, warfighters and operational users have been unable to benefit fully from UGS systems because UGS cannot share, process, exploit, or disseminate data in a standard or timely manner.

The Defense Intelligence Agency (DIA) started the Terra Harvest program to examine current UGS designs, develop open architecture components, and ensure that these components are both reproducible and interoperable. Accordingly, Terra Harvest is developing an open UGS architecture, reference implementations of an UGS controller, asset plug-ins, and graphical user interfaces (GUIs) to support DIA's persistent surveillance collection missions. The key to success in these development efforts is Terra Harvest's focus on an open, plug-and-play approach that enhances flexibility and interoperability for both future and legacy UGS systems.

The Deputy Under Secretary of Defense (DUSD) for Technical Collection and Analysis (TC&A) Office of the Secretary of Defense (OSD) created an UGS Standards Working Group (SWG) within the defense community, to support Terra Harvest and bring together the principal stakeholders in the UGS community of interest.[1] The resulting UGS SWG charter highlights the ways in which Terra Harvest and the SWG complement each other. Together, they coordinate policy, security, standards, and training that benefit the UGS acquisition and operational communities. They also encourage industry's embrace of interoperable interfaces, enabling warfighters to execute their missions by ensuring that sensor data can be used and shared in an operational environment.[2]

2. OPERATIONAL ISSUES AND REQUIREMENTS

The Terra Harvest concept originated to address the following operational issues.

Stovepiped architectures drive operators to field too much equipment. UGS systems have been stovepiped, each with its own training plan, communications path, mission planning tools, and graphical user interface (GUI) work stations. Compelled to deploy multiple sensor systems, often from different vendors, overburdened operators thus

developed a requirement to mix and match sensor components from different manufacturers to reduce the amount of equipment they have to carry into the field.

Proprietary components impede rapid integration. In 2006, one group of operational users needed to integrate a series of specific sensors into an existing UGS architecture. Only the original equipment manufacturer could perform the integration, but the company was already overwhelmed with a large UGS order and was thus unable to perform the small-quantity integration task. The users canceled integration and looked for alternative methods, which proved to be an expensive, time-consuming process.

Fielded equipment may not satisfy mission requirements or real-time constraints. Mission requirements are often not finalized until operators reach the field site. Necessary UGS field adjustments to optimize system operation may not be possible without interoperable components and compatible interfaces. Equipment may therefore be stored and never used.

With the above issues in mind, operators require—and have requested—a flexible UGS system architecture that addresses changing mission needs, incorporates plug-and-play sensor components, centralizes command and control, employs common training procedures, and minimizes deployment time. Through Terra Harvest and its efforts to develop reference implementations, DIA is identifying UGS collection requirements, assessing those requirements, documenting capability gaps, and developing funding recommendations to fill these gaps.

3. TERRA HARVEST REFERENCE ARCHITECTURE AND IMPLEMENTATIONS

Remote ground control systems must quickly exchange critical event and control data with one another. A dynamic exchange of such information may buckle a stovepiped communications architecture. In contrast, the Terra Harvest open architecture approach facilitates a rapid exchange of control and event data.[3] Mindful of this approach, the Army Research Laboratory (ARL) is leading the technical development for the Terra Harvest Reference Architecture.[4]

When fully developed, the Terra Harvest Reference Architecture will enable:

- Adding and replacing UGS capabilities seamlessly, with minimal integration costs
- Understanding the interoperability requirements of different application domains
- Defining an architecture profile
- Passing data and instructions among UGS systems built by different vendors
- Integrating disparate data models, formats, and coordinate systems

DIA is directing production of the Terra Harvest Reference Architecture implementations as part of a four-phase, open competition.[4,5]

In general, a *reference implementation*, or a working model derived from the architecture, has these attributes:

- It is developed along with technical specifications and the test suite.
- It enables independent verification and validation of the test suite.
- It helps clarify the intent of the specifications in the event that conformance tests fail.
- It serves as the standard against which other implementations can be measured.[6]

During Phase 1 of the Terra Harvest implementation development, DIA selected vendors to conduct technical market research, trade studies, and initial design activities for a notional UGS architecture. For Phase 2, DIA chose a single contractor, Honeywell Aerospace-Albuquerque. In this phase, Honeywell fabricated an operational prototype that was based on the Phase 1 architecture. Phase 2 ended in January 2010, with a demonstration of a prototype controller, Honeywell's Network Enabled Operator Station (NEOS) software system. Honeywell tested this controller with a limited set of sensors and communications components. Honeywell then progressed into Phase 3a, correcting any prototype testing deficiencies, completing the design work, and fabricating four additional production prototype controllers. In October 2010, at the end of Phase 3a, Honeywell demonstrated the next iteration of the controller with an expanded set of sensors and communications components.

Prior to beginning Phase 3a, DIA opted to validate Honeywell's NEOS architecture to establish that sensor, controller, and communications vendors could build to the Interface Control Document provided by Honeywell at the end of Phase 2. This validation phase, conducted in parallel with Honeywell's Phase 3 development, ends in April 2011. For this validation phase, DIA selected five contractors: Brimrose, Digital Force Technologies (DFT), Harris, L-3 Nova, and Quantum Technology Sciences Corporation (QTSI). DFT is hosting NEOS on their Muskrat controller. L-3 Nova/University of Dayton Research Institute (UDRI) is developing the Terra Harvest Open Source Environment (THOSE) operating system, which is comparable to NEOS. Harris is integrating a broadband global area network (BGAN) communications device. Brimrose and QTSI are integrating a long-wave infrared profiling sensor and seismic/acoustic sensor, respectively.

Honeywell developed NEOS in JAVA, and L-3 Nova also developed THOSE in JAVA, with a Linux-based operating system in mind. DIA will complete the THOSE development and use it in controllers that are based on system-on-module technology. THOSE development is fully funded, and the government will have unlimited rights to the software and documentation. THOSE will become the reference architecture for Terra Harvest. Honeywell's NEOS will remain an alternative, under a separate agreement between any interested hardware vendor and Honeywell. Both Honeywell and any hardware vendor must ensure that their hardware and software systems remain Terra Harvest compliant.

Ensuring open participation, Phase 3b began with Government Industry Day on 4 February 2010. Twenty-one companies participated either onsite or virtually to understand Terra Harvest and the scope of its architecture validation efforts. In Phase 3b, the government will validate the Terra Harvest architecture by selecting vendors to develop, build, and demonstrate plug-in UGS components based on the current reference architecture.

In December 2010, one vendor, QTSI, completed their architecture validation and plug-in development tasks. They determined that the Terra Harvest architecture was not yet fully mature due to incomplete documentation and specifications. QTSI observed that the Terra Harvest concept is promising, potentially offering a great advantage to the government, users, and industry. However, QTSI further observed that a significant amount of work is required to realize fully the promise of the concept.[7]

In that vein, Phase 4 of Terra Harvest will continue UGS component development and identify key technologies of interest.

4. INTERFACE, OR PLUG-IN, TECHNOLOGIES

As it works to bring together the principal stakeholders in the UGS community of interest, the UGS SWG encourages industry's embrace of interoperable interfaces because they help ensure that sensor data can be used and shared in an operational environment. Ultimately, the purpose of developing tailorable sensor systems is threefold. Such systems:

- Minimize acquisition and system integration costs
- Maximize flexibility and adaptability for capability delivery and technology insertion
- Support dynamic mission environments

By building incrementally with best-of-breed components, and by enabling operators to swap out components as they become obsolete, Terra Harvest will use standardized plug-in interfaces that facilitate interoperability and avoid obsolescence. Terra Harvest plug-ins encompass hardware, software, and communications. For the purposes of Terra Harvest, *plug-in technology* refers to the logical connections of hardware with software.

4.1 Hardware

Hardware interfaces. Hardware interfaces comprise the mechanical and electrical connections between components of an UGS and any external devices. Generally, harsh environmental conditions, anti-tamper features, and concealment goals drive UGS hardware requirements, complexity, and costs.

Physical interfaces. Terra Harvest conducted a trade study to determine which interfaces would satisfy most anticipated UGS assets. Although not requiring that a controller include all physical interfaces, Terra Harvest documents will specify how each interface would be used by compliant assets.

Terra Harvest specifies which interfaces will be supported, but it does not specify connectors and pin assignments. DIA's follow-up to the original interface trade study, addressing other evaluation considerations (e.g., night-time operation, cable thickness, and connector size), will include a Request for Information (RFI) to solicit vendor feedback. A subsequent industry day discussion group will define further the interfaces.

Power management. As with any battery-powered system, trade-offs must occur between power consumption, size, heat, and performance. Nonetheless, Terra Harvest power conservation is particularly important because it extends the operational life of the UGS system.

Terra Harvest assets will have detailed power needs and related capabilities (e.g., imaging, motion detection, and effective range). Embarking on a data call to list power resources and asset capabilities, ARL will consolidate its findings into a common lexicon that will be published on the UGS SWG portal upon its completion.

Terra Harvest asset capabilities describe the required power management (e.g., number of power states, power consumption, duty cycles, and transition time between states). Assets will inform the controller of power requirements for sensing conditions, such as wake on event, wake on schedule, and wake after delay.

In a related vein, controllers will shut down and start up assets, while monitoring and reporting power consumption, when applicable. With these controller capabilities in mind, Terra Harvest will have a common Application Program Interface (API) for power management.

4.2 Software

Plug-in framework. As an alternative to the NEOS plug-in, Terra Harvest will use the Open Services Gateway initiative (OSGi) framework for plug-ins because the OSGi architecture simplifies building, maintaining, and deploying applications. In addition, OSGi makes it possible to use a given device to change network composition in real time, without requiring a restart. To minimize and manage component couplings, OSGi "enables these components to dynamically discover each other for collaboration" via standard interfaces for common functions, such as Hypertext Transfer Protocol (HTTP) servers, configuration, logging, security, user administration, eXtensible Markup Language (XML), and others.[8]

Data formats. Merging data products from disparate sensors dramatically improves the effectiveness of tactical UGS systems.[9] Correlating dissimilar data saves time and money when compared to stovepiping data in sensor exploitation systems. Similarly, because data abstraction works best with clearly defined, standard data types, Terra Harvest will require the following formats:

- Javadoc
- Portable Document Format (PDF), with text descriptions of components and interactions, along with embedded programming architecture drawings (including Unified Modeling Language class diagrams, sequence diagrams, and use-case diagrams)

Mission logic and SensorML. Terra Harvest will employ a SensorML-based representation for mission logic and controller format-storage, superseding a previous decision to use Cursor on Target extensions. Combining Sensor Model Language (SensorML) with an open architecture allows a UGS controller to accept and interpret data from disparate sensors, thus enhancing sensor interoperability. In addition, a SensorML-enabled controller will permit soldiers to choose "the best sensors to accomplish their missions, while ensuring that the data from these sensors can be used and disseminated effectively."[10]

Under the aegis of the UGS SWG, ARL is developing a standard lexicon for UGS data attributes and a configuration management procedure. ARL will synthesize vendor responses for this lexicon, and they will map lexicon entries to appropriate data types and values within a controlled identifier name space. ARL will also define the subset of allowed SensorML for the persistent store. Plug-ins shall list, query, and set data attributes through an API. With these plug-ins in mind, L-3/UDRI is investigating optimizations (e.g., caching of parsed data) to avoid complex parsing of SensorML by all plug-ins.

Security, accreditation, and encryption. The DoD is moving toward full accreditation of data devices, such as sensor controllers. Historically, DoD has only applied this level of scrutiny to back-end systems connected to production network enterprises. Terra Harvest is investigating how best to address relevant information assurance regulations, such

as Certification and Accreditation (C&A), DoD Information Assurance Certification and Accreditation Process (DIACAP), and Certificate of Networthiness.

Passing information in an open format presents advantages, such as the use of commercial exploitation software and reduced processing requirements. However, with deployed UGS numbers increasing, maintaining this open format could compromise operational security and data integrity.[11] For example, an astute enemy could intercept unencrypted information being transmitted.[12] For these reasons—and to prevent a proliferation of numerous encryption standards from multiple vendors—Terra Harvest is exploring encryption and authentication methods.[13]

4.3 Communications

The Terra Harvest architecture requires means for internal communications between the sensors and controllers, as well as communications for data exfiltration. Data exfiltration examples include Common Sensor Radio (CSR), Broadband Global Area Network (BGAN), and Iridium.

Common Sensor Radio. As a major component needed for Terra Harvest interoperability, the CSR is funded by the Marine Corps' Tactical Remote Sensor Systems (TRSS) program.[14] Terra Harvest developers are discussing preferred modes and policies for CSR operation with Terra Harvest controllers. Issues of note include power-on policy, sub-address assignment to protocols, segmentation, and transport protocols.

Broadband Global Area Network. Terra Harvest UGS controllers will have a plug-in to support the Broadband Global Area Network (BGAN) data exfil option. BGAN terminals use the Inmarsat satellite constellation, which precludes polar coverage.[15] However, this limitation should have no impact on Terra Harvest.

Iridium. Iridium fields a constellation of 66 Low Earth Orbiting cross-linked satellites that route communications traffic around the world.[16] The Terra Harvest architecture supports an Iridium plug-in for a data exfil option. However, the data rates will not be as robust as those for the BGAN terminal option.[15]

5. CONCLUSION

DIA has been developing the Terra Harvest reference architecture and its implementations for more than 2 years, with active involvement from industry. Performance measures for Terra Harvest include improving acquisition, making UGS components and systems interoperable, and reducing integration time and costs. Other acquisition programs can take advantage of Terra Harvest's open architecture to meet their own challenging mission requirements.

Seven vendors are currently building reference implementations—wider industry has the opportunity to participate, to define standards, and to make the work of government more efficient, while making defense of the nation more effective. DIA needs industry's full engagement to ensure Terra Harvest's success.

6. REFERENCES

[1] Salvatori, J. B., Deputy Under Secretary of Defense for Technical Collection and Analysis, Memorandum for See Distribution: Establishment of Unattended Ground Sensors Working Group, 5 January 2009.

[2] Chambers, J. and Fairgreve, S. "Interoperabililty of Unattended Ground Sensors with an open architecture controller using Sensor ML," Proc. SPIE 7694, 76940O, 1-11 (2010).

[3] Heathcock, R. and Brasch, C. "Unattended ground sensors standards working group," Proc. SPIE 7694, 76940L (2010).

[4] Houser, J. Terra Harvest Architecture. Proc. SPIE (in press).

[5] Cross, C. Terra Harvest Program. Terra Harvest Offsite, 6-7 December 2010, Charlottesville, VA.

[6] Curran, P. Conformance Testing: An Industry Perspective. Sun Microsystems. Available: http://www.nist.gov/itl/vote/upload/6-Curran.pdf (2003).

[7] Fussell, R. Terra Harvest Architecture Validation & Capability Expansion. Cocoa Beach, FL: Quantum Technology Sciences, Inc. (QTSI) (15 November 2010).

[8] OSGi Alliance. "What is the OSGi technology in a nutshell?" Available: http://www.osgi.org/About/FAQ#q6.

[9] SITIS Archives-Topic Details. Target Detection Using Disparate Sensor Systems. Available: http://www.dodsbir.net/Sitis/archives_display_topic.asp?Bookmark=28092

[10] Chambers, J. and Fairgreve, S. “Interoperabililty of Unattended Ground Sensors with an open architecture controller using Sensor ML,” Proc. SPIE 7694, 76940O, 1-11 (2010).
[11] Bobier, K., Wells, J., and Dapper, M., “Enhanced unattended ground sensor system communications,” Proc. IEEE Military Communications Conference (MILCOM-02) IEEE vol 1, 282-289 (2002).
[12] Gorman, S., Dreazen, Y., and Cole, A. Insurgents Hack U.S. Drones. The Wall Street Journal. Available: http://online.wsj.com/article/SB126102247889095011
[13] Heathcock, R., Linnebur, K., and Brasch, C. “Unattended ground sensors standards working group,” Proc. SPIE 7694, 76940L (2010). Available: http://spie.org/x648.html?product_id=851872
[14] US Marine Corps. Tactical Remote Sensor Systems System-of-Systems (TRSS SoS). Available: http://www.marcorsyscom.usmc.mil/sites/cins/Fact%20Books/All_Source/TRSS_SoS.pdf.
[15] Brasch, C. Broadband Global Area Network Terminals Report. The MITRE Corporation. (26 January 2007).
[16] Iridium. Available: http://iridium.com