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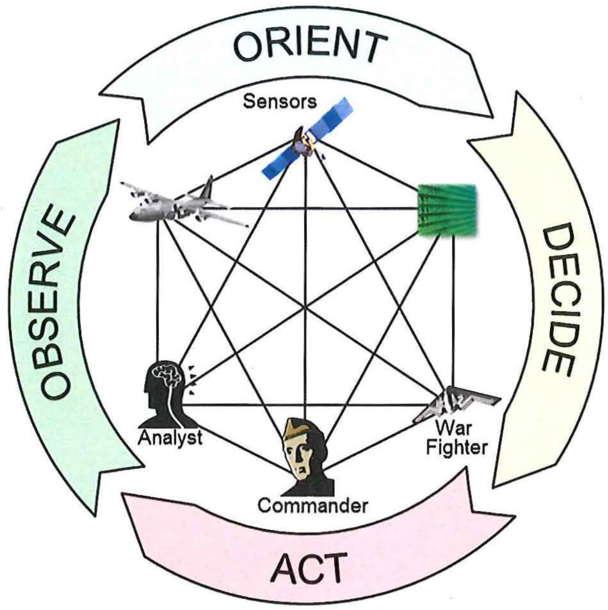
SENSING AS A SERVICE



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ISR HORIZONS FUTURE VISION

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This vision of *Sensing as a Service* **combines two very powerful concepts of "sensing" and "multi-user services"** to greatly increase integration of sensors with warfighters and decision systems across all echelons of operations. It aims to dramatically compress decision loops, support distributed mission teaming, and make relevant information discoverable by any authorized user who needs it. Integration of intelligence and command and control information improves tasking of air, space, and cyberspace assets and in turn improves mission effectiveness.

The term **"sensing" means *to become aware of; to perceive; to understand.*** It means that sensor developers should shift from a *sensor* paradigm (collect data now; analyze it later) to a *sensing* paradigm where sensors, embedded within a system of systems, directly provide meaningful information and automatically respond to need. While continuing to support essential post-mission analyses, sensing embraces a closed-loop concept of distributed computing and collaboration that optimizes the real-time mix of responsive sensing, automated exploitation and fusion, human analytical skill, and agile decision making. Sensing enables speed of command.

Presenting sensors as information services connected by robust battlespace networks **transforms the sensing paradigm to simultaneously serve the needs of many independent users.** Some of the modern sensing systems are quite well-suited for this. Platforms can rapidly relocate across the globe; many sensors can cover broad areas; and some new ISR capabilities are not bounded by geography at all. Future ISR systems should take advantage of improved on-board processing to manage multi-user collection requests (without disrupting the primary controller), automate and negotiate collection tasks with other sensors on the network, and fuse data from multiple sensors and sources into meaningful information. Enhanced battlespace networks are needed to securely connect this wealth of information to skilled human analysts, decision makers, and warfighters in their aircraft, ships, vehicles, and consoles.

Linkage to Air Force ISR Strategy

AF ISR 2023: Delivering Decision Advantage – a strategic vision for the Air Force ISR Enterprise – describes three core tenets and five priorities to shape the future. ***Sensing as a Service* enables the AF ISR 2023 visions of *Full-Spectrum Awareness* and *Delivering Decision Advantage*.** It supports the stated priorities of 1) rebalancing and optimizing integrated ISR capabilities; 2) strengthening integration, collaboration, and partnerships; and 3) revolutionizing analysis and exploitation. This document helps bridge the gap between the AF ISR 2023 vision and planning documents like Core Function Support Plans. It is intended to guide capability roadmaps across the ISR spectrum including the Air Force Targeting Enterprise and Distributed Common Ground System. It will also help coordinate needed modernization efforts across the broader intelligence community.

Tenets

Six tenets define the essential characteristics of sensing solutions beyond the development of novel platforms and sensors. They **ensure that new systems will be integrated across the ISR Enterprise and embedded within the command and control loop**. They provide for rapid analysis and fusion providing meaningful information to warfighters and decision makers who need it.

Embedding in Closed-Loop Decision Systems

"Sensors" make measurements and supply data. "Sensing" **embeds the sensor and its data into our analytical and decision making systems and processes.** It is tempting when developing new sensors to focus on the physics first and the integration later. However, new sensors must be designed from the start to integrate directly with our analysis and command architectures so as to compress and strengthen decision loops. The OODA (Observe Orient Decide and Act) loop must be extended to include embedded sensors in an automated closed-loop system-of-systems fashion. This allows computer-mediated workflow that can provide decision advantage in terms of speed and relevancy. To support this expedited workflow, data must cross operational and security domains without human intervention. Humans are certainly central to the analytical and decision processes, but they should work on the information *as it flows* rather than bridging gaps in the flow.

Tenets of *Sensing as a Service*

- Embedding in closed-loop decision systems
- Responsive sensing automation
- Streaming analytics and multi-modal fusion
- Accessible across domains
- Multi-user support
- Comprehensive assessment

Responsive Sensing Automation

Sensors must understand the purpose of the data they collect so they can feed useful information into the decision systems and intelligently respond to tasks. This concept is already employed extensively with sensors embedded in weapons systems. Fighter radars automatically detect and track targets. They intelligently discern and display amplifying information on radar responses they know will be of interest to the aircrew. Maverick missiles forego optimum image settings to enhance target detection and tracking. When ISR sensors **understand the needs of the users and are empowered with responsive automation, they can provide tailored products on demand for analysts and decision makers.**

Sensors must be responsive not only to tasking from the analysts and operators but to the quality of their own data and the needs of other sensors in the area to fill their tasking. They must be responsive to dynamically changing weather conditions, mission scenarios, user needs, and threat conditions. Sensors must evaluate the quality of data they collect and, when authorized, automatically re-task themselves to correct deficiencies or improve quality. They must be able to rapidly and automatically change modes, sensing bands, and field of view, and track moving targets. When they cannot fulfill their tasks alone, they should be able to request support from other sensors in the network. For example, in the Air Force Academy's cooperative sensing program, UAS sensors automatically collaborate with those on other UASs to localize and track targets with much more accuracy than a single sensor could provide.

Sensing systems should also strive to determine target intent—either natively or from external inputs—so as to predictively plan sensor operations and feed the operational commanders. Sensing is intelligent and dynamic not merely vacuuming up observables. Sensor owners must have a flexible range of control options to allow optimal use of sensor automation while ensuring primary mission goals are met. A sensor's actions can and must be responsive to dynamic analysis and operations.

Streaming Analytics and Multi-Modal Fusion

Streaming Analytics converts sensor data into valued information inside a closed-loop machine-to-machine decision system. Using data-centric principles, sensor information and meta data is maintained in a digital format (termed an information object) as it passes through multiple processing steps, some of which may be on-board the sensor platform and some which may be distributed through analysis sites and C2 sites. Some processing may be autonomous—much will deeply leverage human analytical skills. At each step, value is added to the existing information object rather than creating a new one. In contrast, the old wet-film systems replaced data objects with new ones at nearly every processing step (negative to print to annotation to report). Potentially useful information is lost at each step and numerous information artifacts are created. With streaming analytics, data is fluid, responsive to new observations, and rapidly available to the analyst and decision maker.

Upstream data fusion from multiple sensors in near real time will require improved intelligence mission data, advanced automation logic and interoperable data standards within a geospatially-enabled knowledge management structure. This structure is key to an enduring precision ID capability for targeting. For example, tracking a high-value individual through a busy city may combine detection from wide area motion imagery, signals intercepts, moving-target-indicator radars and cyber monitoring. Data structures and automation logic for each of the sensor types must be designed so they can cross correlate with each other. Information objects must be flexible to easily incorporate new sensor types as well as evolving human analysis and mission planning data.

Accessible Across Domains

Sensor tasks, status, and data must be accessible to analysts, warfighters, and decision makers across the extended battlespace in near real time. New sensors must be directly on an accessible network, not just coupled to a dedicated ground station through a stove-pipe data link. As part of a secure and distributed air, surface, and space network, communications packages for sensors must also act as routers for other sensors and users on the network. Thus the sensors not only provide data but also help to build and extend the battlespace network in a system-of-systems architecture. This network must work at high bandwidths in contested environments and minimize probability of enemy detection.

Sensing systems must expose their own data *and* the data from the rest of the networked sensors and users as a web service. Analysts and combatants both in human or machine form can then access the data from any sensor on the net through the battlespace internet. A good example is recent upgrades to the Litening and Sniper targeting pods which expose sensor imagery as a web service that ground combatants can access through their ROVER radios. Combatants can download imagery from fighter and bomber aircraft, annotate targets, and post the annotated image back up to the targeting pod for the aircrew to reference. They can also use the targeting pods as a communications relay with other ground combatants to collaborate on sensor data or for any other type of communications.

Sensors and users exist in many domains. These may be operational domains like air, space, and cyberspace; organizational domains like U.S. versus coalition networks; security domains like unclassified, secret, NATO secret; or specialty domains like SIGINT networks or tactical data links. The battlespace network must securely integrate these domains with automated guards to enable appropriate sensor access to any validated user who needs it. Information objects must specifically identify the cross domain releasability of information. Cross domain gateways must be distributed throughout the battlespace network for resilience and responsiveness.

Multi-User Support

New sensors should be designed from the start for multi-user support. Many legacy sensors can be adapted for multi-user access through the addition of software abstraction layers that present the sensor controls and outputs as a web-service.

Automated control of sensors is the key to multi-user support. This can be done while preserving the fine-grained control that professional sensor operators need to fully exercise their art. **Sensors must be designed to respond to multiple authorized requests without degrading support to the primary user**. They must be able to either recognize multiple targets simultaneously in a large field of view or rapidly jump from target to target with narrower fields of view. Current wide area sensors with embedded target recognition provide good example: moving-target-indicator radar, overhead persistent infrared satellites, and wide-area motion imagery. The DARPA VIVID program provided an excellent example of rapidly shifting narrow field of view sensors to simultaneously track multiple targets.

Sensor automation must be able to rapidly change modes and sensing bands with no requirement for manual intervention or lengthy delays for recalibration. They must be able to queue and sequence requests from users and other sensors as well as buffer recent collections for immediate response. For example, several ground-based radar systems and overhead infrared systems are specifically tuned to minimize the impact of weather. By changing modes, they can help detect and characterize weather phenomena that can impact operations. Automating these mode changes and vectoring the data to specific users can provide great value without impacting primary operations.

Comprehensive Assessment

Sensors are typically assessed by how well they measure the environment—their image resolution or minimum detection velocity for example. These measures are necessary but not sufficient. *Sensing systems* must also be assessed on how they impact the decisions they support. This means not only the sensor quality, but the responsiveness of the sensor automation, the connectivity of the data services, the effectiveness of fusion, and the timeliness of delivering decision advantage. Whenever possible, feedback should be built into the decision loop so the sensing system can react and adapt in real time to the needs of the users. The quality of the sensing solution is driven by the situational awareness it offers and measured by the improvement in decision making ability and the effectiveness of operations.

Summary

One of the key challenges identified in AF ISR 2023 is how to break the linear relationship that currently exists between the growing ability to collect large amounts of data, and the manpower needed to analyze the data and produce actionable intelligence. Another challenge, delivering decision advantage, requires data and refined intelligence to be made accessible, timely, and relevant for operational users. The six tenets of *Sensing as a Service* define the essential characteristics of networked sensing solutions to address these challenges.

Embedding sensors within closed-loop decision systems and making them responsive to provide tailored products on demand for a range of decision makers are the first two key principles. Combining the concepts of processing while collecting, streaming analytics, and upstream data fusion (made possible by cross-domain access) changes the current production-focused paradigm to a mission-focused one. The tenets of Multi-User Support and Comprehensive Assessment expand the ideas of AF ISR 2023 to include the realization that a service-based model could dramatically expand the number of decision-makers whose choices would be impacted, while providing them a richer source of relevant information to act on. Optimizing sensor resources and mission-tailored products can happen only with a robust and automated feedback of functional and user assessment of mission impact.

Sensing as a Service defines the essential characteristics of networked sensing solutions beyond the development of novel platforms and sensors. Our aim is to achieve effects that can only be reached by coordinating and collaborating on the ISR and C2 processes from end to end. Consistent with AF ISR 2023 tenets, this vision supports and integrates the analyst, warfighter and decision maker. **A paradigm shift is critical to transform the focus from sensors to sensing, from data to decisions, from stove-pipe to network.**