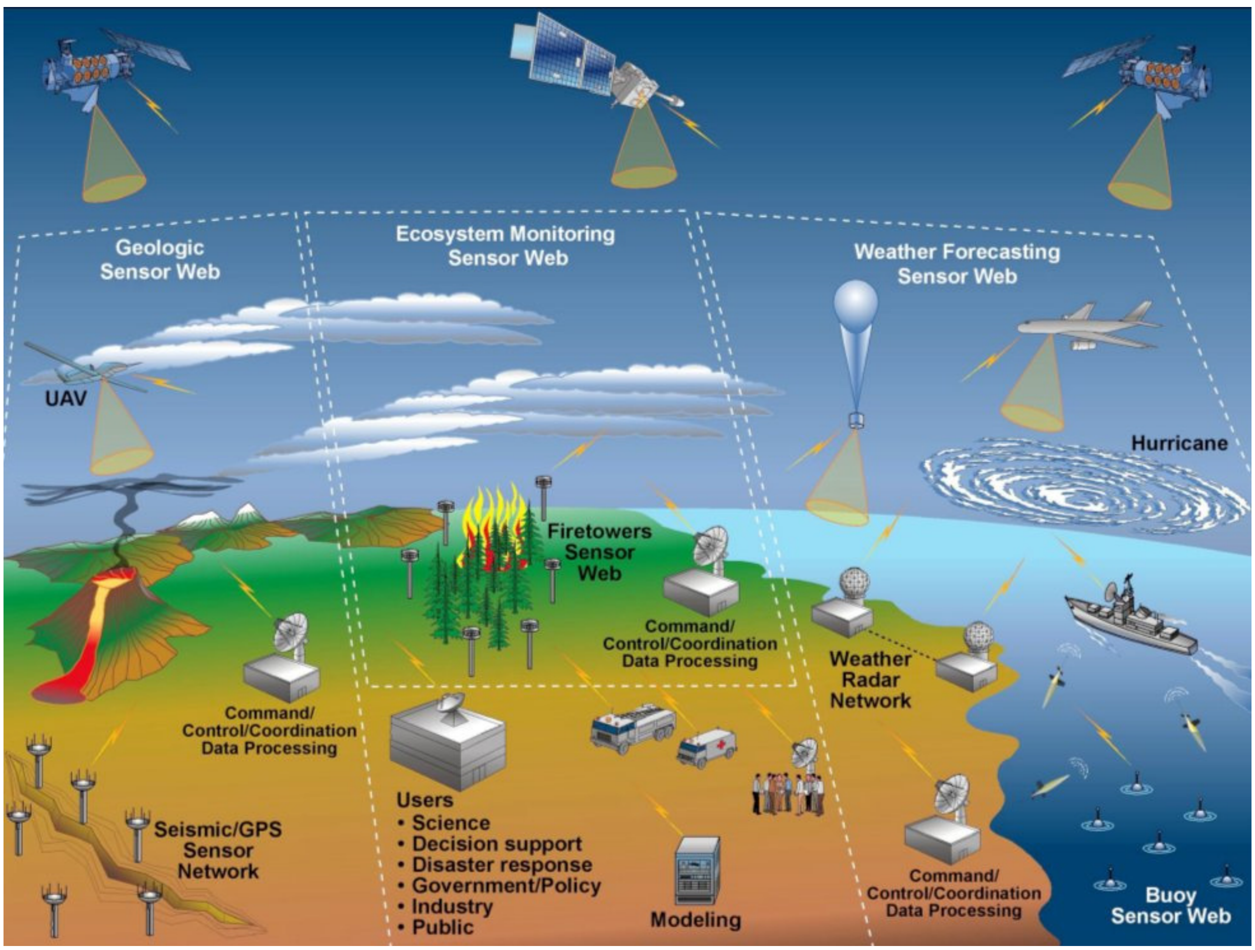
2008 Report from the Earth Science Technology Office (ESTO) Advanced Information Systems Technology (AIST) Sensor Web Technology Meeting

April 2-3, 2008



1 Executive Summary

This report documents the proceedings of the second NASA Earth Science Technology Office sponsored sensor web meeting, which took place on April 2 - 3, 2008. The primary objectives of this meeting were to:

- Increase the awareness and understanding of Earth science sensor web features and benefits within the investigator teams, for the Earth science community, and for NASA managers;
- Interactively explore and document sensor web use case scenarios for Earth science applications, including the Global Earth Observation System-of-System (GEOSS);
- Relate these use cases to the National Research Council's Decadal Survey [DEC 07]; and
- Provide a forum for collaboration and furthering the technology infusion goals of the AIST program, including plans for demonstrating use cases using prototype technology developed by the investigator teams.

Developing use cases as a means of capturing system requirements and processes is a leading edge application of modeling techniques to non-software systems. Traditionally, use cases capture system requirements prior to software development [BITTNER 02]. This technique is uniquely suited to describing the capabilities of the sensor web approach to Earth observation goals. The resulting use cases will serve ESTO's need to describe the benefits that the sensor web concepts bring to NASA's Earth science challenges. All seven (7) thematic focus areas identified in the Decadal Survey were addressed in the use cases developed during this conference, as indicated in Table 1.

Table 1. Decadal Survey Theme Coverage

Decadal Survey Theme	Use Cases
Earth-science applications and societal needs	28
Land-use change, ecosystem dynamics, and biodiversity	17
Weather (including space and chemical weather)	16
Climate variability & change	12
Water resources and the global hydrologic cycle	12
Human health and security	11
Solid-Earth hazards, resources, and dynamics	7

In all, 46 investigators from academia, NASA, and industry were in attendance, representing a broad cross-section of the research being conducted in science, sensor web technologies, and applications. During the meeting, the investigators were divided into three separate groups, each of which focused on a different technology area. These areas were:

1. Middleware 1 – Model Interoperability;
2. Middleware 2 – Systems Management; and
3. Smart Sensors.

While in the breakout groups, investigators presented their works-in-progress, depicting current use cases, from which lively discussions ensued. These use case scenarios were further refined by the investigators in real-time during the conference. After significant discussion and collaboration, several representative use cases were selected from each breakout session for presentation to the conference as a whole. The groups were asked to provide feedback on lessons learned and recommendations for promoting sensor web technologies.

This report describes the proceedings of the conference and also contains a compilation of all 41 sensor web use cases presented and developed during the conference. Key terms, features, architectures, and applications are documented throughout the use cases, which were grouped according to earth science theme, including Atmospheric Composition, Earth Surface & Interior, Climate Variability & Change, Carbon Cycle & Ecosystems, Weather, and Water and Energy Cycle. In addition, the patterns, themes, and technology gaps identified during the conference are documented.

The resulting use case scenarios developed during the conference represent fundamental and practical applications of sensor web technologies to Earth science challenges. Starting from the sensor web concepts, which were clarified and described at the first meeting in 2007, these 2008 use case scenarios were developed to:

- Describe how a distributed collection of resources (e.g., sensors, satellites, forecast models, and supporting systems) can collectively behave as a single, autonomous, task-able, dynamically adaptive and reconfigurable observing system; and
- Describe how raw and processed data, along with associated meta-data, can be collected via a set of standards-based service-oriented interfaces.

The use case scenarios were developed to communicate key sensor web features, including the following:

- The ability to obtain targeted observations through dynamic tasking requests;
- The ability to incorporate feedback to adapt via autonomous operations and dynamic reconfiguration; and
- Improved ease of access to data and information.

Finally, scenarios were developed to highlight key sensor web benefits, such as the following:

- Improved resource usage where selected sensors are reconfigured to support new science questions;
- Improved ability to respond to rapidly evolving, transient phenomena via autonomous rapid reconfiguration, contributing to improved tracking accuracy;
- Demonstrate cost effectiveness, derived from the ability to assemble separate but collaborating sensors and data forecasting systems to meet a broad range of research and application needs; and
- Improved data accuracy, through the ability to calibrate and compare distinct sensor results when viewing the same event.

The NRC Decadal Survey provided the backdrop to the sensor web deliberations. In addition to recommending new Earth observation missions to NASA, the Decadal Survey panels highlighted the significance of the societal benefits resulting from an integrated strategy for science and applications from space. By projecting existing and near-term use cases into the future decade, the use case scenarios developed at this conference are an attempt to illustrate how the capabilities envisioned by the Decadal Survey might be employed.

The conference was successful in addressing all of the above features and benefits of sensor webs to future NASA Earth science goals. During the meeting discussions, additional capabilities were identified and some common themes emerged such as autonomous sensor operations, autonomous data productions, and user support (i.e., tools to support the design and management of sensor webs). The following list highlights the sensor web capabilities that the participants discussed in the use cases detailed in this report.

- Sensor webs, being system-of-systems, are scalable, and supporting technologies allow systems to interoperate, supporting disparate data content and interfaces.
- Sensor webs detect events and respond by autonomously tasking sensor resources and feeding results into models in near real-time.
- Sensor webs have been successfully used to support autonomous flight plans for unmanned aircraft.
- Sensor webs can support calibration and validation of future Decadal missions.
- Sensor web approaches enable autonomous management of sensor resources, notably power and communications for in situ sensors.
- Sensor observations can influence models to improve forecasts and how model predictions can influence sensor observations to collect the most relevant observations at the time they are most needed.

- Sensor webs can improve the accuracy of predictions and the handling of uncertainty in forecast models.
- Sensor webs can also validate model results and design field campaigns to optimize resource use and science results. This involves methods to enable smooth assimilation of in situ and satellite data into models.
- Sensor webs can be implemented using repeatable patterns of assembling sensors and data processing systems, reusing the same middleware systems for different application domains, such as monitoring and responding to a fire or a volcano or a flood.

The set of use case scenarios documented in this report exemplifies a full suite of capabilities to transform sensor data and model outputs into Earth observation information as recommended in the Decadal Survey.