Sensor Webs for Modeling and Analysis

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NASA envisions a sensor web as an intelligent and integrated observation network comprised of sensors deployed to vantage points from the Earth's subsurface to deep space that provides timely, on-demand data and analysis to users. [1] The observations from sensor webs are used in supporting a variety of decision making contexts.

Sensor webs provide a new type of dynamic and real-time resource for earth science data analysis and modeling. Sensor webs are distributed, organized systems of sensor, computing and storage nodes, interconnected by a communications fabric that behaves as a single, coherent system. [2] Future earth observing systems will blend dynamic sensors with traditional, "fixed mode" sensors to create sensor webs that provide a more comprehensive picture of the state of the environment. Sensor webs are characterized by their real-time dissemination and adaptive configurations and present an opportunity for more active, two-way communication among data collection systems and model and analysis tools.

Figure 1 is taken from the ROSES AIST NRA and depicts a sensor web as a system of systems. The figure defines two major systems within the sensor web including, 1) sensors, which perform the data acquisition, system control and processing and 2) communications components needed for connectivity among sensors and between sensors and processing and control. Models, analysis tools, decision support, and other sensor webs are depicted as external systems with which the sensor web interacts.

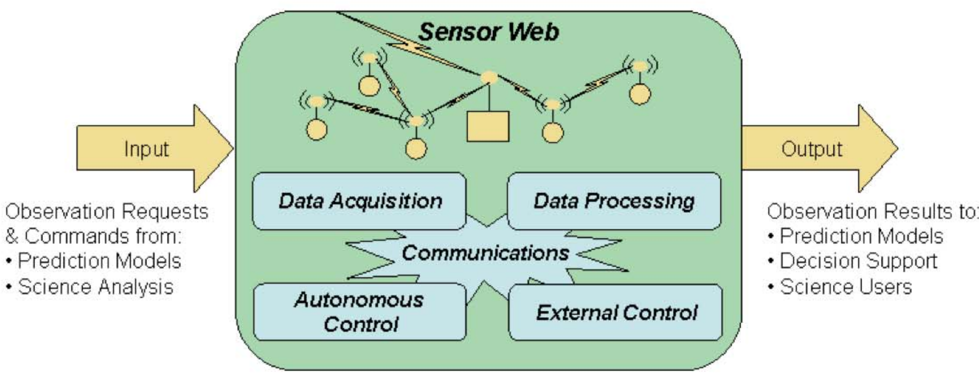

Figure 1. Sensor Web as a System of Systems

The value of sensor webs comes within the context of how their observations are used (the output and input in Figure 1). The definition of the sensor web becomes more complete with the explicit inclusion of the communications between the sensor web and the external systems (Figure 2). The interfaces foster interoperable information exchange into and out of the sensor web. Examples include tasking/planning instructions for sensors and observation data for input into models. The Figure also adds a feedback arrow to indicate that the receiving system of the sensor web output might also subsequently serve as the provider of sensor web input.

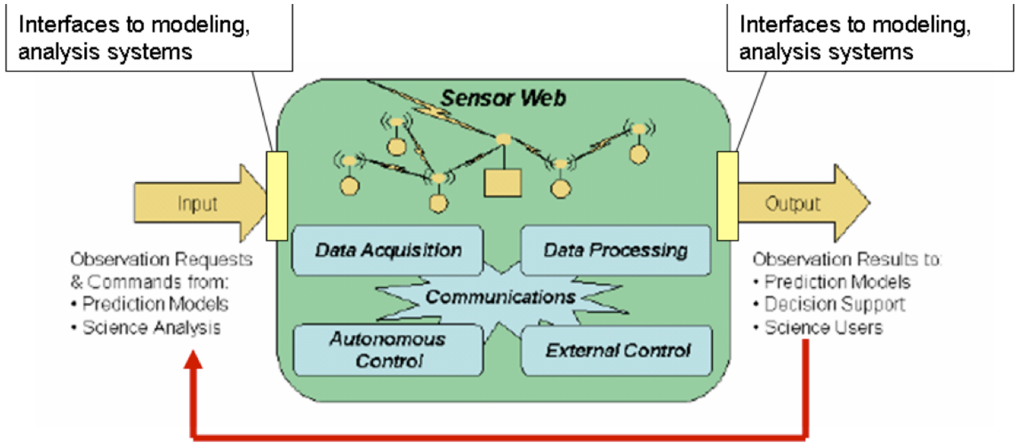

Figure 2. Inclusion of interfaces to external systems within the Sensor Web

The System of Systems perspective is useful in defining sensor web concepts. One description of Systems-of-Systems is that they are characterized by

- operational independence of the individual systems
- managerial independence of the systems
- evolutionary development
- geographical distribution
- emergent behavior [3]

These qualities seem appropriate in describing a sensor web as each of the components included in the sensor web is an individual, independent entity that operates on its own and has its internal management system in its own physical locations. However, when the individual components are connected in a sensor web, their integration results in new capabilities and the value generated is greater than the sum of the individual components.

A key to the success of sensor webs, and systems of systems in general, is the "glueware" or "middleware" that connects the systems. This includes standards for data and information exchange and service oriented components. In defining sensor webs and their infrastructure, it is useful to place them in the context of two related concepts; the Global Earth Observation System of Systems (GEOSS) and Cyberinfrastructure.

GEOSS

GEOSS is an international effort to coordinate and share earth observations among countries. Its plan is to become a distributed system of systems, building step-by-step on current cooperation efforts among existing observing and processing systems while accommodating new components. [4] It is formed through the integration and interoperability of observations, processing, and data exchange components. The GEOSS architecture is commonly described in terms of NASA's Integrated Systems Solutions diagram (Figure 3).

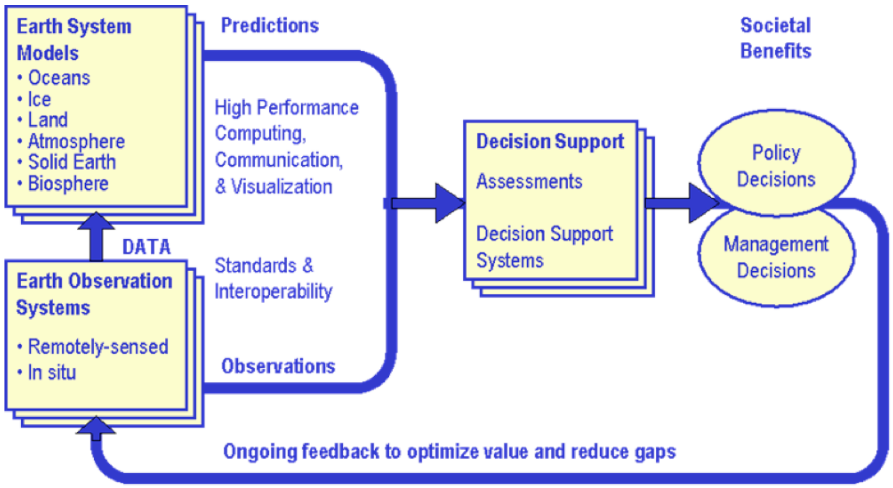

Figure 3. NASA Integrated Systems Solution diagram and basis for GEOSS architecture

Figure 4 modifies the GEOSS architecture from the perspective of sensor webs. The earth observations are generated through sensor webs. The observations interface with models, analysis tools, catalogs, and decision support tools. An important characteristic is that the sensor web system of systems is itself a system within a larger system of systems (system of systems have a fractal behavior).

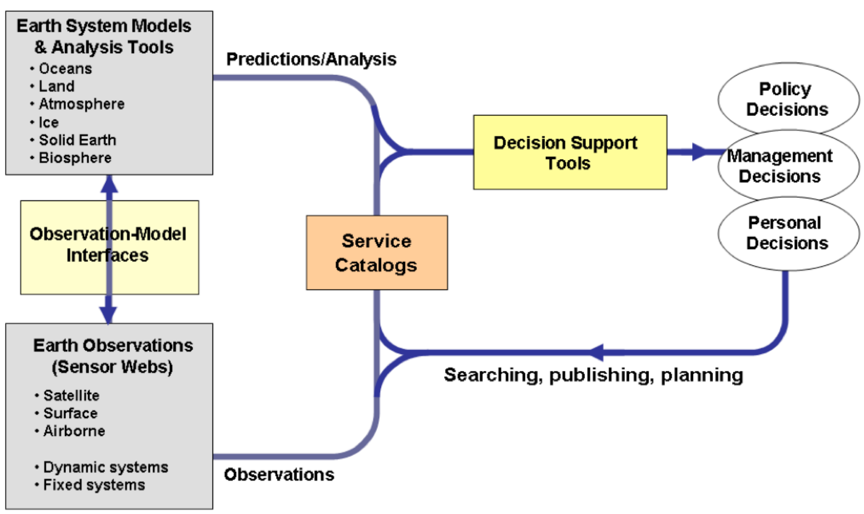

Figure 4. Sensor webs within the GEOSS architecture

Cyberinfrastructure

Cyberinfrastructure is a term coined through NSF to define the set of reliable, well-specified, and interoperable connections of electronic hardware and software that allows people to discover, learn, teach, collaborate, disseminate, access, and preserve knowledge in their domain. Cyberinfrastructure extends from the scientific instrument to the desktop of the working scientist and encompasses networks, models, data sets, metadata, data archives, data analysis and manipulation tools, as well as communication and collaboration tools and environments [5, 6].

Cyberinfrastructure efforts are characterized by:

- open systems and open exchange of data, software, and results
- a marriage of existing and new technologies
- constant balancing of top-down guidance and bottom-up self-direction, innovation and reliability, and disciplinary and interdisciplinary priorities.
- collaborations, linkages, and portals to the broader community that involve a new level of cooperation among agencies, domain scientists, computer scientists

The aspects of NFS's Cyberinfrastructure program are shown in Figure 6a including computing resources, analysis tools to handle increased amounts of data, collaboratories to foster interaction among diverse groups, and applying results in education and workforce environments. [7] Sensor webs are placed within the context of the cyberinfrastructure components, including computing and data analysis, in Figure 6b.

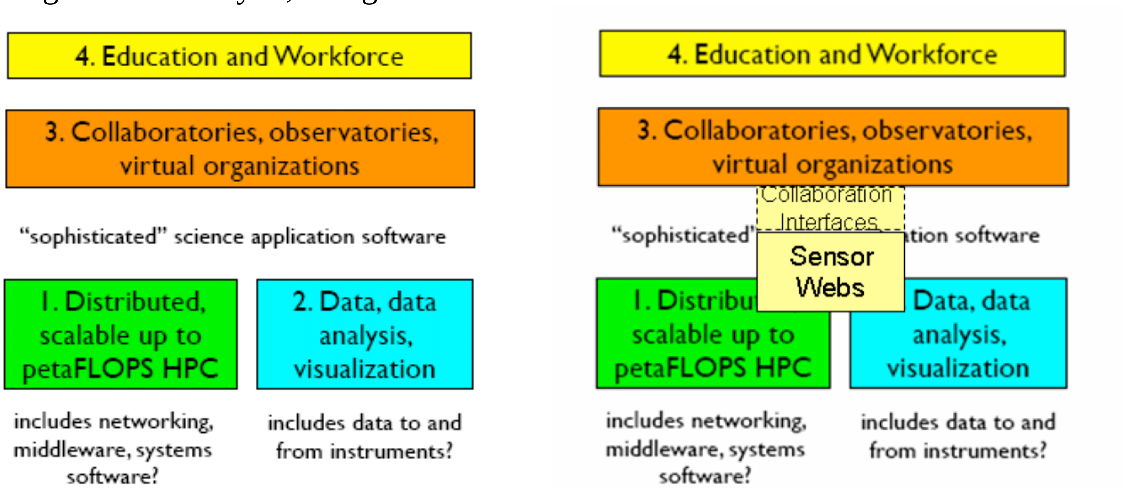

Figure 6. a) NSF Cyberinfrastructure components (Atkins, 2005), b) Sensor webs within the context of cyberinfrastructure.

Sensor Web Characteristics

Based on current descriptions of sensor webs, systems of systems, GEOSS, and cyberinfrastructure, sensor webs for our consideration could be characterized by:

- dynamic and fixed mode sensors (satellite, aerial, surface, in-situ)
- distributed, self-maintained components (sensors, processing, communications, infrastructure, models)
- real-time sensor-to-sensor communication
- sensor-to-sensor web interoperability
- sensor-to-model/analysis/processing interoperability
- a system of systems
- a system within broader system of systems
- a combination of new and existing technologies
- open systems and exchange of information
- collaborative environment
- emergent behavior

References

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