Advanced Modeling, Simulation, and Analysis for Science

Modeling and simulation are being used more pervasively and more effectively throughout the space program for both engineering and science pursuits. These are tools that allow high fidelity simulations of systems in environments that are difficult or impossible to create on Earth, allow removal of humans from experiments in dangerous situations, and provide visualizations of datasets that are extremely large and complicated. Examples of past simulation successes include simulations of entry conditions for man-rated space flight vehicles, visualizations of distant planet topography via simulated fly-over, and three-dimensional visualizations of coupled ocean and weather systems. In many of these situations, assimilation of real data into a highly sophisticated physics model is needed. Also use NASA missions and other activities to inspire and motivate the nation's students and teachers, to engage and educate the public, and to advance the scientific and technological capabilities of the nation.

Subtopics

S9.01 Automation and Planning

Lead Center: ARC
Participating Center(s): GSFC

The Automation and Planning subtopic solicits proposals that allow either spacecraft or ground systems to robustly perform complex tasks given high-level goals with minimal human direction. Areas of interest include all aspects of data collection, processing analysis, and decision making. NASA wants to go from specifying “how” something is done to specifying “what” is needed and letting the system figure what data and resources best meet the high-level goals under a set of constraints (e.g., cost, time, etc.).

Technology innovations include, but are not limited to: 1) automation and autonomous systems that support high-level command abstraction; 2) efficient and effective techniques for assembling and processing large volumes of data (commonly available on the Internet) into useful information; 3) intelligent searches of large, distributed data archives, and data discovery through searches of heterogeneous data sets and architecture; and 4) automation of routine, labor intensive tasks that either increase reliability or throughput of current process. Specific areas of interest include the following:

Search agents that support applications involving the use of NASA data; The Automation and Planning subtopic
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- Search agents that support applications involving the use of NASA data;
- Methods that support the robust production of data products given a set of high-level goals and constraints;
- Autonomous data collection including the coordination of space or airborne platforms while adhering to a set of data collection goals and resource constraints;
- Autonomous data logging devices (software, or hardware and software) supporting a variety of weather and climate sensors, capable of ground-based operation in a wide variety of environmental conditions; such systems would probably be solar powered with accurate time stamping;
- Planning and scheduling methods related to Earth Science Mission objectives;
- System and subsystem health and maintenance, both space- and ground-based;
- Distributed decision making, using multiple agents, and/or mixed autonomous systems;
- Automated software testing;
- Verification and validation of automated systems;
- Automatic software generation and processing algorithms; and
- Control of Field Programmable Gate-Arrays (FPGA) to provide real-time products.

Problems address must be relevant to Earth and Solar Sciences including space weather.
This subtopic seeks advances in tools, techniques, and technologies for distributed information systems and large-scale numerical simulation. The goal of this work is to create an autonomous information and computing environment that enables NASA scientists to work naturally with distributed teams and resources to dramatically reduce total time-to-solution (i.e., time to discovery, understanding, or prediction), vastly increase the feasible scale and complexity of analysis and data assimilation, and greatly accelerate model advancement cycles. Areas of interest follow below.

**Distributed Information Systems**

- Core services (autonomous software systems) for automated, scalable, and reliable management of distributed, dynamic, and heterogeneous computing, data, and instrument resources. Services of interest include those for authentication and security, resource and service discovery, resource scheduling, event monitoring, uniform access to compute and data resources, and efficient and reliable data transfer;

- Services for management of distributed, heterogeneous information, including replica management, intuitive interfaces, and instantiation on demand or "virtualized data." These services would be used, for example, to access and manipulate NASA's wealth of geospatial and remote sensing data;

- Science portals for cross-disciplinary discovery, understanding, and prediction, encapsulating services for single sign-on access, semantic resource and service discovery, workflow composition and management, remote collaboration, and results analysis and visualization; and

- Tools for rapidly porting and hosting science applications in a distributed environment. These applications should be written for an integrated, or workstation, environment using standard programming languages or tools such as Matlab, Interactive Data Language (IDL), or Mathematica.

**Large-Scale Numerical Simulation**

- Tools for automating large-scale modeling, simulation, and analysis, including those for managing computational ensembles, performing model-optimization studies, interactive computational steering, and maintaining progress in long-running computations in spite of unreliable computing, data, and network resources;

- Tools for computer system performance modeling, prediction, and optimization for real applications;

- Techniques and tools for application parallelization and performance analysis;

- Tools for effective load balancing, and high reliability, availability, and serviceability (RAS) in commodity clusters and other large-scale computing systems; and

- Novel supercomputing approaches using FPGAs, graphics processors, and other novel architectures and technologies.

**S9.03 Data Management and Visualization**
This subtopic focuses on supporting science analysis through innovative approaches to managing and visualizing large collections of science data. These data sets are extremely large and complicated and are highly distributed in a networked environment that encompasses large geographic areas. There are specific areas for which proposals are being sought.

3D Virtual Reality Environments

- 3D virtual reality environments for scientific data visualization that make use of novel 3D presentation techniques that minimize or eliminate the need for special user devices such as goggles or helmets; and
- Software tools that will enable users to 'fly' through the data space to locate specific areas of interest.

Distributed Scientific Collaboration

- Tools that enable high bandwidth scientific collaboration in a wide area distributed environment; and
- Novel tools for data viewing, real-time data browsing, and general purpose rendering of multivariate geospatial scientific data sets that use geo-rectification, data overlays, data reduction, and data encoding across widely differing data types and formats.

Distributed Data Management

- Metadata catalog environments to locate very large and diverse science data sets that are distributed over large geographic areas; and
- Object based storage systems, file systems, and data management systems that promote the long-term preservation of data in a distributed, online (i.e., disk based) storage environment, and provide for recovery from system and user errors.

Distributed Data Access

- Dynamically configurable, high-speed access to data stored in Storage Area Networks (SAN) distributed over wide area environments; and
- Technologies for sharing data over newly developed, high-speed, wide area networks such as the National Lambda Rail (NLR).
S9.04 On-Board Science for Decisions and Actions

Lead Center: ARC

Current sensors are stove-piped systems, which can collect more data than is possible to transmit to the ground. Intelligence in the sensor or platform can prioritize or summarize the data and send down high priority or synoptic science data. In the future, a sensor-web capability will demand this remote onboard autonomy and intelligence about the kind and content of data being collected to support rapid decision making and tasking. This subtopic is interested in developing new methods to autonomously understand ES data in support of making rapid decisions and taking actions under three themes:

**Onboard Satellite Data Processing and Intelligent Sensor Control**

Software technologies that support the configuration of sensors, satellites, and sensor webs of space-based resources. Examples include capabilities that allow the reconfiguration or re-targeting of sensors in response to user demand or in significant events seen in other sensors. Included are software that supports the reasoning and modeling of such capabilities for demonstration and mission simulation. Also included in this category is onboard analysis of sensor data that could run on reconfigurable computing environments as well as technologies that support or enable the generation of data products for direct distribution to users.

**Onboard Satellite Data Organization, Analysis, and Storage**

Software technologies that support the storage, handling, analysis, and interpretation of data. Examples include innovations in the enhancement, classification, or feature extraction processes. Also included are data mining, intelligent agent applications for tracking data, distributed heterogeneous frameworks (including open system interfaces and protocols), and data and/or metadata structures to support autonomous data handling, as well as compaction (lossless) or compression of data for storage and transmission.

**Simulation and Analysis of Sensor Webs**

Software that allows for the simulation of a sensor web of varying platform types producing a variety of data streams. These platforms could be in various orbits (L1, L2, NEO, LEO, etc.) and suborbital (UAV) that are automatically assigned different temporal and spatial coverages. Data streams would be assigned to these platforms and the system computes how the sensor web would cover of events (e.g., volcanic eruption, fires, and crop monitoring) at user designated, particular, geospatial locations (or areas).