NASA SBIR 2010 Phase I Solicitation

O3.01 Mission Operations

Lead Center: ARC

Participating Center(s): JPL

The objective is to develop advanced capability software systems for mission operations in support of NASA’s Space Communications Infrastructure. The current infrastructure for NASA Space Communications provides services for near-Earth spacecraft and deep space planetary missions. The infrastructure assets include the Deep Space Network (DSN), the Ground Network (GN), and the Space Network (SN).

NASA seeks automation technologies that will facilitate scheduling of oversubscribed communications resources. These capabilities should focus on the development of user interfaces and algorithms for the integration of diagnostic and situational awareness tools; and planning, scheduling, and resource optimization tools supporting:

- Increased numbers of missions and customers
- Increased number and complexity of constraints
- Decreased operations budgets
- Scheduling algorithms should be fault-tolerant

Current State-of-the-Art: Diagnosis software tools and resource optimization tools are mature independent software technologies, however the integration of the two is less mature. The challenge is to develop integrated software tools that can leverage the strengths of each class of tool. Diagnosis tools must inform the resource optimization algorithms of the active portions of the system, while the resource optimization tools must inform the diagnosis tools of the current plan in order to facilitate tracking of system state.

User Interfaces: Diagnosis software user interfaces rely on displaying diagnostic information either in fault tree form or spatially highlighting portions of schematics, which are suspect. On the other hand, planning/scheduling/resource optimization tools rely on the display of temporal information in Gantt charts, and other timeline-based methods. An integrated user interface would require the integration of the spatial and temporal information into a single display to facilitate the ease of use and understanding of the integrated tools.

Diagnosis and Situational Awareness: Space Communication Networks are complex systems made up of both
physical and wireless connections. When faults occur in the network, isolating the faults in real-time is critical in order to maintain network capability. Model-based diagnostic systems are capable of modeling the connectivity of the system as well as propagating both nominal and off-nominal flow of information in the network. These systems can accurately characterize the state of the system in order to provide situational awareness for both humans as well as intelligent assistant and resource optimization tools. The utilization of the current state of the network is critical to reschedule resources that have failed or degraded.

Planning and Scheduling Tools for Resource Optimization: The goal of schedule optimization is to produce allocations that yield the best objectives. These may include maximizing DSN utilization, minimizing loss of desired tracking time, and optimizing project satisfaction. Each project may have its own definition of satisfaction such as maximal science data returned, maximal tracking time, best allocation of the day/week, etc. The difficulty is that we may not satisfy all of these objectives during the optimization process. Obviously, optimal solution for one objective may produce worse results for the other objectives. One possible solution is to map all of these objectives to an overall system goal. This mapping is normally non-linear. Technology needs to be developed for this non-linear mapping for scoring in addition to regular optimization approaches.

Areas of Interest: Integrated diagnosis and resource optimization tools are useful in different phases in the design and development of space communication networks. In early pre-planning phases of mission operations such tools are useful for: procedure development, contingency development, and other preparatory tasks. During the operations phase, such tools are useful for telemetry analysis; fault diagnosis, state determination and situational assessment; plan, procedure, and rules revisions and execution; decision-making; commanding; fault responses; and data management among others.

NASA seeks proposals to develop the following capabilities in support of human situational awareness:

- Methods for acquiring, evaluating, and displaying telemetric information, so as to provide users with flexibility and easy access to desired information in desired format.
- Methods to determine situational information from multiple data sources, possibly noisy and incomplete, and present those to the user;
- Methods to track actions of other users or systems, including automated systems, and keep user aware of the situation.
- Methods to track user intent and provide the appropriate situational information;
- Methods for controlling the degree of automated/manual control, and tools for transitioning control between user and automation with minimal loss of context and situational awareness.
- Methods for creating, validating, evaluating, and revising model-based diagnostics models, taking into account collaborative aspects and reference materials required to build models (architecture diagrams/schematics, sensor definitions, fault modes, configurations and other reference materials).
- Techniques for checking or simulating model-based diagnostic models, in order to acquire a level of trust or assurance that the model is correct with respect to the configuration of the network.
- Methods for creating, validating, evaluating, and revising operations plans, taking into account collaborative aspects, complex flight rules, resource limitations and need for one-time constraints and exceptions.
- Techniques for checking or simulating plans, procedures, sequences and other combinations of commands and actions, in order to acquire a level of trust or assurance that the combination is correct and will satisfy desired safety and operations properties in actual execution.
- Methods to change the planning/scheduling optimization functions to incorporate high priority requests.

Performance metrics: Measures of performance will compare human generated results vs. human/computer results for nominal and off-nominal network conditions. Experiments should be run on simulated communications testbed(s), which can seed failures of different classes at different points in time.
Schedule quality will be determined by a number of factors including: (1) level of up time on the network, (2) degree of priority allocation (higher priority items scheduled first), (3) degree of contiguity allocation (items are scheduled as a group) and (4) other factors.

For the proposed technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II hardware demonstration and testing. Delivery of a demonstration unit for NASA testing at the completion of the Phase II contract is also required.

Phase I Deliverables: Propose demonstration of integrated fault diagnosis/resource optimization tool on a number of communication asset allocation problem sets (involving dozens of missions, communications assets, and operational constraints). End Phase deliverable (TRL 4-5) would include a detailed rationale for technology return-on-investment (ROI) based on knowledge of current and future operations flows.

Phase II Deliverables: A demonstration of the integrated fault diagnosis/resource optimization tool with fault diagnosis/situational awareness system on actual or surrogate communication asset scheduling datasets. Deliverables (TRL 6) would include software system, use cases and evidence of utility of deployment of developed technology.