Livingstone on Earth Observing One (EO-1)

Software that can automatically detect errors in a space vehicle's systems and subsystems before complex problems become critical could significantly reduce mission operations costs, boost mission efficiency and could one day save a rover, a spacecraft or even a human life. In a test of autonomous diagnostics this summer, NASA computer scientists at Ames Research Center at Moffett Field, Calif., will flight-test the Livingstone diagnostic software on-board the EO-1 spacecraft.

Diagnosis of Spacecraft

Cutting edge space technologies are growing in complexity and sophistication as we embark on more ambitious space ventures. That's why it is critical to make sure these systems behave as their designers intended, and to diagnose accurately when things go wrong. This gives us a chance to recover from errors, protect our investments in space, and continue on to achieve our mission goals. Model-based diagnosis is a means to that end. Ames will deploy the Livingstone Version 2 (L2) software, which will automatically identify and diagnose a number of simulated failures scheduled to occur by software controlling the instruments of an Earth observing satellite.

The Earth Observing One (EO-1) satellite is a platform for testing new technologies and strategies for improving missions while reducing cost and development time. NASA's Goddard Space Flight Center manages the satellite. Livingstone will run at times when NASA JPL's autonomy software, the Autonomous Sciencecraft Experiment (ASE), is in control of the spacecraft.

In this first flight, L2 will watch for things to go wrong with the spacecraft as the autonomy software executes the satellite's imaging process, and will automatically diagnose the errors and send the diagnosis to Goddard. In follow-up flights, the autonomy software will use the information to determine the best way to continue and achieve its goal.

L2 on EO-1 is Ames' first ISHM demonstration in space since 1999, when the first version of Livingstone flew on the Deep Space One spacecraft with the Remote Agent Experiment, an autonomy demonstration named one of the 10 greatest achievements in Artificial Intelligence.

Research Overview

Livingstone uses a model of the system to predict its behavior. If actual behavior diverges from the model's predictions, a diagnosis is made to isolate the cause of the discrepancy to a fault. The first version of Livingstone could give mission operators only a single candidate for an error. L2 provides several hypotheses of what went wrong. L2 updates a diagnosis based on the histories of the sensor data and the commands that have been sent to the spacecraft. L2 continually monitors a spacecraft's state and history, providing the most accurate, up-to-date diagnosis in real-time.

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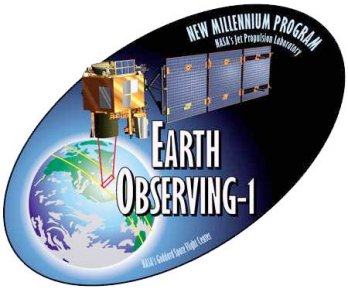
Researchers at Ames built models of the EO-1 spacecraft, its instruments, its cameras and one of its processors. L2's model-based diagnosis approach is more technically advanced than traditional approaches. The Livingstone reasoner is given a model of the system that it is to watch over. This separation between the reasoner and the object of the diagnosis means that Livingstone can with less effort be applied to diagnose new systems. The diagnostic reasoner does not need to change, only a new model has to be developed for the system to be diagnosed.

Many systems have the same parts, such as valves, switches and sensors, so a model can be built more quickly by reusing these common parts. In this fast-paced experiment, the development of the models, and the integration of L2 with the autonomy software on-board EO-1, has all been done within the last year. L2 can also use the same model for simulation as well as diagnosis. In future, models might be developed that can be used both for planning and diagnosis.

Another planned extension is for L2 to address software failures. Current mission protocol for preventing failures is manual software testing. However, bugs inevitably slip through. Meanwhile, software code is growing in size as vehicles become more complex, introducing more likelihood for errors. This is a prime opportunity for L2 to add value.

Livingstone has proven valuable as a research tool in academia and as a diagnostic application at several NASA centers. The tool has been used in several NASA technology demonstrations. Livingstone developed a strong following in the aerospace industry through NASA's Space Launch Initiative, an effort to define, develop and test technologies for a reusable launch vehicle.

The continued research and development of tools like L2 will make future NASA missions safer, more affordable, and more effective.



Relevance to Exploration Systems
In future long-duration missions to Mars or elsewhere in the solar system, frequent and extensive spacecraft maintenance operations or overhauls will not be an option. Before humans are able to travel to Mars, where Earth-based crews cannot monitor what is happening in real-time, better automatic diagnostic tools for spacecraft and robots are needed. When people start traveling deeper into space, automatic diagnostic tools can tell crew and controllers about a potential problem in sufficient time to make repairs.

H&RT Program Elements:

This research capability supports the following H&RT program /elements:

ASTP/Software, Intelligent Systems & Modeling

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