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NASA's Mars Pathfinder Mission: Planning System

Did you know that NASA's Mars Pathfinder spacecraft mission was planned before and during operation by a software system developed using Allegro CL? The Planner system helped Pathfinder scientists account for new data as it was transmitted from Mars by the Pathfinder spacecraft, and to evolve their mission plans in real-time to optimize spacecraft operations.

"This was incredibly important with such a complex, pioneering mission," says David Mittman, a Flight Engineer on the Mars Pathfinder team and key developer for the planning system adaptation used on this mission.

"We were actually able to respond to new information about the status of the spacecraft during operation, and then redesign our operational strategies right away." This real-time capability ended up playing an important role in the overall success of this mission, enabling the spacecraft to operate well beyond their expected lifetimes and send back more data than ever thought possible.

Real-Time Plan Evolution

The Pathfinder mission, managed by the Jet Propulsion Laboratory (Pasadena, CA) for NASA's Office of Space Science, used a software system called *MPF Plan-IT-II*, to plan and re-plan operations. This system was developed and adapted for this mission using Allegro CL.

"The Planner essentially performs activity and resource modeling for things like solar panel power generation, data storage capacities, environmental conditions and other resources. It places all planned activities on a time-line, and shows us the condition of the spacecraft at any point in time. For example, it can show us how much power is being used and how much data has been collected."

Mittman continues: "With the Planner, we are able to model highly complex operational scenarios before the launch and plan for various contingencies. For example, what if the

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Flight Engineer, Mars Pathfinder Mission

temperature ends up being much higher than what we expect? What if there are dust storms?"

Not only was the system used pre-launch to plan out the activities of the spacecraft, but it was also used during mission operations, on each and every day of the Pathfinder mission. "Every day, we would plug in the activities planned for that day. Then, we would take the information we'd gathered on the previous day, input this data into the Planner, and see how the activities were affected. We'd make any necessary modifications, then spit out the new plan."

Changing the Operations Strategy

Sometimes this capability to change plans in real-time resulted in significant optimizations that ultimately played an important role in the Pathfinder mission's success.

For example, new data rate and temperature information were taken into account. "We discovered that we could operate the spacecraft's transmitter for more hours during the day because it wasn't getting as hot as we had predicted. We were also expecting 1185 bits per second and we were actually getting closer to 8300 bits per second! It was because we got such a great direct signal that we were able to boost the data rates, and then redesign our operations strategy as a result," explains Mittman.

The significance of this redesign was that it enabled the battery life of the spacecraft to be extended far beyond what had initially been planned. The mission was expected to have lasted for 30 days, based on the projected energy requirements. In actuality, the Pathfinder spacecraft were still sending data back to Earth after 83 days on Mars.

Planning System Used for Multiple Missions

The Planner is an adaptation of the *Plan-IT-II* planning and scheduling program developed with Allegro CL and used by NASA for other spacecraft missions.

"The Planner is what we call a 'multi-mission tool,'" says David Mittman. "It can be adapted to different spacecraft projects." The adaptation of the system to different projects is facilitated by the Plan-IT-II Adaptation Language, a domain-specific extension to Common Lisp which was built on top of Allegro CL. This language, designed for resource-modeling, makes it easier to efficiently customize the base Plan-IT-II system to particular spacecraft.

Allegro CL Best Tool for the Job

"One of the important things you need to realize about this system," says Mittman, "is that it uses data from many other different systems. These other systems were written in C, Ada, Tcl, Perl, and then there are a couple of commercial packaged systems. The only thing that ties these systems together is that they're all Unix-based."

The Allegro CL system was able to integrate with all of these systems. "Because of the O/S hooks in Allegro CL, it is an open system. We could use the data generated in all of our existing systems as inputs to the Planner."

Other features of Common Lisp important to this particular system included the macro expansion capability used in the development of the Adaptation Language, the incremental compilation and runtime patching features ("a definite win in development as well as in operation" according to Mittman), and dynamic typing, which gives Allegro CL the ability to support very rapid, interactive development.

"This was definitely important for us," comments Mittman. "I didn't have to worry about the changes we were making to the system on an ongoing basis. I knew they weren't likely to cause the system to break. And sure, that was important. We were operating in a 'flight environment' here! To bring a complex, evolving piece of code like this into a flight environment is a feat in and of itself!"

"We were using what's known as 'concurrent engineering'," he adds. "We were actually building the Planner at the same time as we were designing the spacecraft and figuring out how it works. *We were using the Planner and developing it at the same time!* We couldn't have done this if we were not working with Common Lisp."

For more information on the Pathfinder Mars mission, please visit http://www.jpl.nasa.gov.