Motion Imagery and Robotics Application Project: Standards Based Protocol

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The current Mission Control Center (MCC) is dedicated to the execution of human space flight missions. As the future of NASA and human space flight evolves, it is clear that robotic artifacts will ultimately be integrated and immersed into the human mission as tools and even as assistants. To make the evolution and integration as technically capable at a constrained risk level and with reasonable cost, the robotic elements must adhere to standards that allow not only reuse of previous work, but that keep the interfaces stable and reusable. This experience has been seen already on the International Space Station (ISS) experiment packages and with the Robonaut robot.

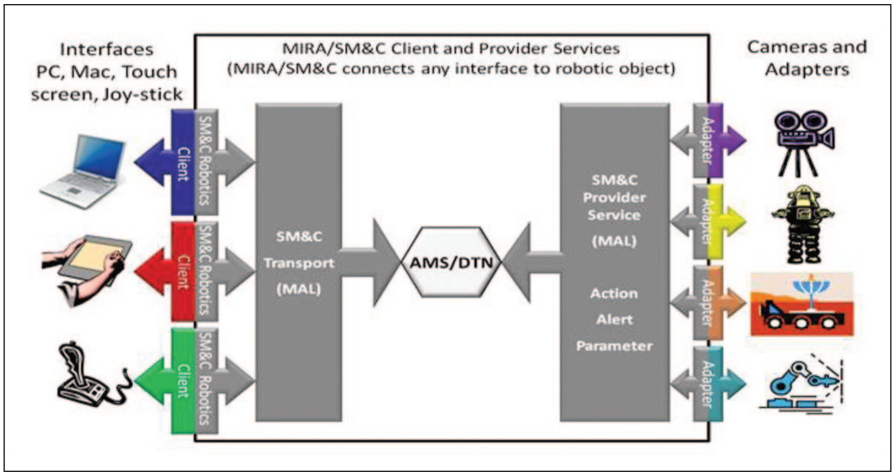

Fig. 1. *Spacecraft Monitor and Control architecture.*

The Motion Imagery and Robotics Application (MIRA) project—a collaborative effort among several NASA centers including Jet Propulsion Laboratory, Marshall Space Flight Center, and Johnson Space Center's (JSC's) Engineering and Mission Operations Directorates, as well as with the University of Colorado—was built to Consultative Committee for Space Data Standards (CCSDS) Spacecraft Monitor and Control (SM&C) and Asynchronous Message Service (AMS) and Delay Tolerant Networking (DTN) specifications. The "stacked protocol" provides standard-based methodology to control and status tele-robotic devices (figure 1), starting with a space-based robotic camera application. Largely developed with JSC inputs, SM&C is an application service that isolates many lower layer services by providing a consistent set of interfaces to mission development and operations teams.

The MIRA project integrates several tele-robotic functions into a powerful international standards-based tele-robotic service capable of running in an ISS payload computer. The MIRA goal is to mature, integrate, and demonstrate the MIRA, SM&C, AMS, and DTN approaches into an integrated system.

The ultimate goal of the MIRA project is to develop the application stack in figure 2 for all robotics—even complex ones. MIRA Phase 1 developed a new CCSDS state-based camera control service standard, with code, capable of controlling a robotic camera system remotely. MIRA Phase 2 will be capable of status and control of three different cameras on the exposed facility (the "porch") of the ISS Japanese Experiment Module, from MCC. Each successive phase will add incremental capabilities such as handling human factors and performance, automatic/semiautomatic change detection from imagery of space flight vehicles and equipment. In later project phases, ground control of robotic assets over Earth-moon-Mars time delays and remote sensing of planetary surfaces and surface navigation will be possible. Additional phases will add functionality to the robotic service until project completion with a demonstration of the Common Communication for Visiting Vehicle (C^2V^2) protocol using MIRA and SM&C services. The MIRA approach to robotic control is therefore applicable near Earth or to distant applications where the DTN provides the bridge across the time delay impacts.

Currently, there is no consensus between the MCC and international partners with respect to the use of standard protocols, ease of access, and robotic system control applications. For the MCC to continue to lead human space missions, it must not only support human missions, but integrate with robotic and human precursor mission

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continued

requirements. The state of the art for interoperability, via standards, is well established in the international partner community. This project seeks to develop a new standard for robotics such that interoperability with crewed as well as non-crewed elements is provided, assuring that cost-effective collaboration between NASA and the international space community is possible. In addition, the standard that is proposed to be developed will be extensible to support technology insertion into both crewed and non-crewed elements. The evolution of the proposed standard will be coordinated through the CCSDS international standards community. The confluence of the MIRA, SM&C/AMS /DTN standards, the robustness of DTN capability, and remote connectivity to ISS and ground assets (interoperability) will assure that JSC/MCC will be the hub of human, human precursor, and robotic missions where the mission components can be seamlessly integrated with other locations without excessive reconfiguration and integration costs that would render the MCC noncompetitive.

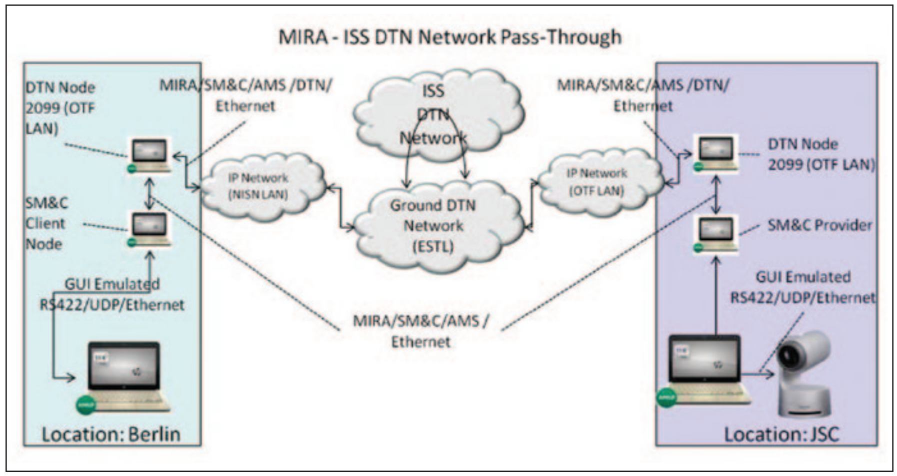

***Fig. 2.** Motion Imagery and Robotics Application architecture.*

The results of the MIRA Phase 1 camera demonstration, referred to as Phase I, have demonstrated robotic camera control that is applicable near Earth or to distant applications where the DTN provides the bridge across the time delay impacts. The MIRA, SM&C/AMS/DTN standards-based status and control system software and protocol could be hardened, and expanded into the next-generation MCC protocol supporting human, robotic, and human-robotic missions. As such, this simple robotic camera prototype is a significant first step in the integration of robotic and human missions into true distant independent building blocks for future missions—the scope of which will dwarf the mission complexity of the last 50 years of human exploration.