Automating ISS File Management Using Agent-Based Systems Integration

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The crew of the International Space Station (ISS) is supported around the clock by a variety of specialists including flight controllers, physicians, planners, and engineers. Besides verbal communications and direct control of ISS systems, the most important means of communication between the crew and the ground team is through files, in over 30 types, including crew timeline updates, crew email, photographs, and exercise logs. A dedicated flight control position in the Mission Control Center of Johnson Space Center has served as the "switchboard operator" for transferring files between the Space Station Computers (SSCs) and ground support teams, using folder drop boxes, email, and electronic flight notes to receive and forward files. Much of this work has become routine and can now be automated using intelligent software "agents" that integrate a variety of applications on different networks.

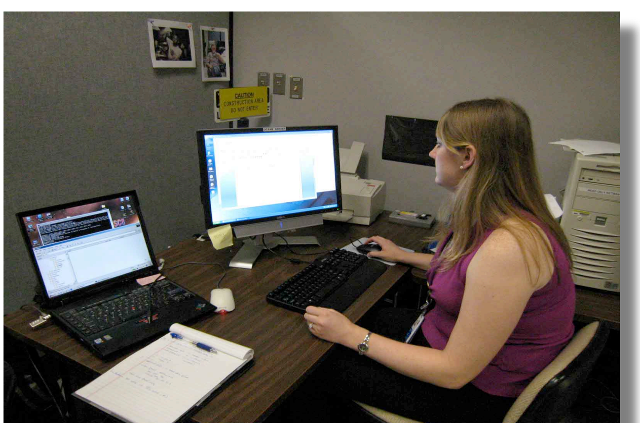

Fig. 1. *Orbital Communications Adapter (OCA) Officer using OCAMS in Mission Control Center (MCC) Multi Purpose Support Room MPSR or "backroom"*

The OCA Mirroring System (OCAMS) was deployed into MCC operations in July 2008 to assist the OCA Officer by automating the maintenance of a ground virtual copy (or "mirror") of the folders and files found on the SSCs. OCAMS reads the log of the OCA Officer's actions when transmitting files between the ISS on orbit and the MCC, including moving and deleting files. Then OCAMS uses this data to mimic the OCA Officer's actions on the "Mirror LAN" computers. OCAMS agent rules also define how file types are handled for privacy and practical reasons; for example, medical files and photographs are not mirrored because they require special handling on the ground first.

The "simulation-to-implementation" methodology for developing the OCAMS software is a novel demonstration of using simulation to design the system and quantitatively evaluate and test its performance on actual data, prior to implementation. This method (simulation-to-implementation) began with a partnership between the OCA Officer team and artificial intelligence experts in the Intelligent Systems Division of Ames Research Center. Ames researchers observed OCA operations in the MCC backroom and then collaboratively simulated the manual mirroring operations in a tool called Brahms. Brahms models describe how people do their work, chronologically, including a model of the office environment, as well as the workflow tools they use, and how they communicate (e.g., telephone, voice loop, email).

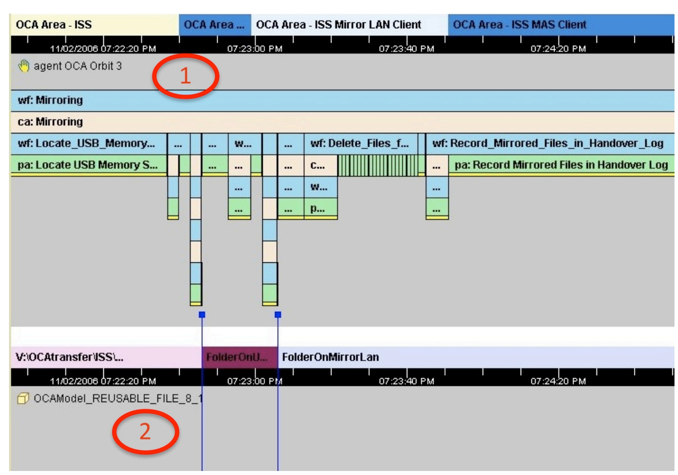

Fig. 2. *Simulation of OCA Officer's manual mirroring activity—using USB "sneaker net" method—during Orbit 3.*

Using Brahms' "activity-based modeling" the joint JSC-ARC team was able to quantify the "cost" or effort involved in the manual mirroring process. Subsequently, this "current operations" simulation was directly edited to create a “future operations” simulation, in which the model of what the OCA Officer did manually was converted into automated software agents. The future operations simulation included a prototype graphical interface, with which the OCA officers could interact with in the simulation, effectively controlling the prototype software. Another advantage was the future operations simulation already integrated the software agents with actual systems to be used in the future tool (e.g., Microsoft Excel and Word, email, and FTP programs). A validation of the future operations simulation was performed against historical logs of the OCA Officer file handling actions and produced metrics on the “cost” or effort savings to be expected. The agents and GUI were then extracted from the simulation and converted into a standalone software package called OCAMS. This agent implementation also integrated, for the first time in MCC, new higher standards for security in communication across multiple networks of varying security levels.

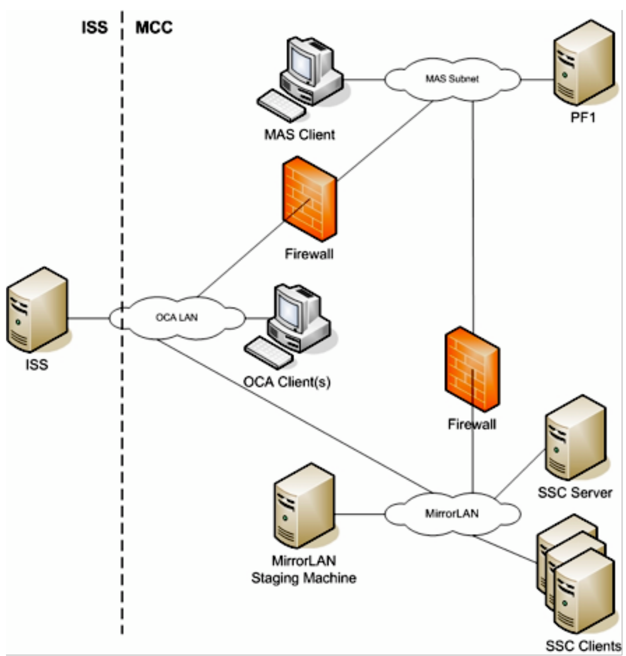

Fig. 3. *OCAMS initial implementation runs on the Mirror LAN staging machine, transferring files between the OCA client computers and SSC server that replicates a subset of the ISS file system.*

By September 2008, OCAMS was used by all OCA officers and estimated to save about 5-10% of each total shift time. This allowed the backroom flight controllers to focus on more complex priority tasks. The automated logging feature alone was especially welcome for eliminating a tedious process of recording the mirroring process, which itself already duplicated the work they had performed while onboard the ISS computers.
By early 2009, the OCAMS package included an editor for modifying file handling rules, enabling OCA officers to modify OCAMS operations without engaging developers to reprogram the software agents (e.g., to change naming conventions or where files are stored). During 2009 archiving and delivering files (e.g., providing exercise logs to the Biomedical engineers) will also be automated, further reducing the OCA Officer’s workload by approximately 25-30%, enabling the position to be combined with another backroom flight control position. Following an OCA equipment upgrade scheduled for late 2009, OCAMS “Revision 3” agents will be distributed, allowing for the file handling process to be monitored and controlled when necessary from remote console locations, like the OpsPlan flight controller position in the main MCC Flight Control Room (FCR), or “front room”.

The final stage of automation planned for 2010 will automate most uplink and downlink operations to ISS, reducing the OCA Officers workload by 90%, essentially eliminating the need for a dedicated OCA officer position in the MCC. The remaining 10% OCA work will focus on special file transfer requests that require supervisory approval or manual overrides to the rules that will be managed with available bandwidth from other positions.

In summary, the OCAMS simulation-to-implementation development methodology combines ethnography, participatory design, multi-agent simulation, and agent-based systems integration to accurately model, simulate then automate tasks. OCAMS success can be used leveraged to reduce future costs of other NASA programs and operations. Models of existing operations and systems can be reused for designing extensions to OCAMS software. Agent components and application interfaces can be reused for automating operations for other backroom and flight control room positions throughout the MCC for ISS as well as future Constellation flight control positions. Time savings predicted by the work practice simulation can be validated by subsequent observation, improving our understanding of spaceflight operations. The methodology yielded a hybrid simulation that combined actual and simulated systems (e.g., mail) and objects (e.g., files) with simulated people. Actual flight operations data was used to validate the simulations and the prototype workflow tool.

More generally, the project demonstrates a systems-integration architecture in which software agents are used to link arbitrary hardware and software systems to distributed teams of people on earth and in space- a solution that will be needed throughout the future of human space flight.

OCAMS may be the first step in developing an ***Interplanetary Multi-Agent System***!