ISAAC: An Integrated System for Autonomous and Adaptive Caretaking

Authors: Trey Smith[1], Maria Bualat[1], Abiola Akanni[1], Oleg Alexandrov[1,3], Laura Barron[2], J Benton[1], Gabriel Chuang[1], Brian Coltin[1,3], Terry Fong[1], Janette Garcia[2], Kathryn Hamilton[1], Lewis Hill[2,4], Marina Moreira[1,3], Robert Morris[1], Nicole Ortega[2,4], Joseph Pea[1,3], Jonathan Rogers[2], Misha Savchenko[2,5], Khaled Sharif [1,3], Ryan Soussan[1,3]

[1]NASA Ames Research Center, Moffett Field, CA [2]NASA Johnson Space Center, Houston, TX
[3]KBR Wyle Services, LLC [4]Jacobs Technology, Inc. [5]METECS

ABSTRACT

The Integrated System for Autonomous and Adaptive Caretaking (ISAAC) project is developing technology for autonomous caretaking of spacecraft, primarily during uncrewed mission phases. ISAAC aims to integrate autonomous intra-vehicular robots (IVR) with spacecraft infrastructure (power, life support, etc.) and ground control. It focuses on capabilities required for NASA's Gateway cis-lunar outpost that also apply to human missions to Mars and beyond. Its development strategy is to test using existing IVR on the ISS (the Astrobee free-flyer and Robonaut dextrous manipulator) as an analog for future IVR on Gateway.

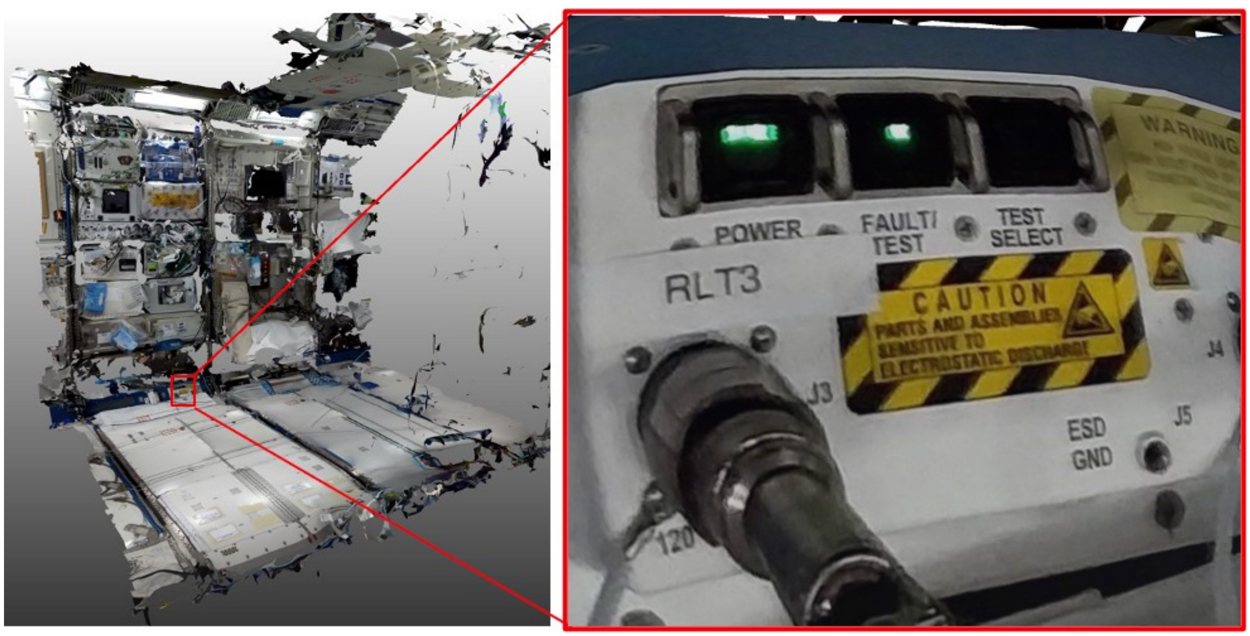

Figure 1 (left) Part of a 3D map built from Astrobee imagery (right) Detail showing texture captured by Astrobee's SciCam, resolution ~0.3 mm.

ISAAC's objectives are important because future human missions are expected to be uncrewed for extended periods. For example, the Gateway may initially be crewed only six weeks per year. During uncrewed periods, NASA needs autonomous systems to perform fault detection, isolation and recovery (FDIR), routine maintenance, and logistics operations, all under the constraint of limited communication with ground controllers (high latency, intermittent availability). Autonomous systems can also free crew from routine tasks. For example, the Gateway Ground

Rules & Assumptions anticipate crew spending 3.5 h/day on non-utilization, non-exercise tasks. Completing some of these tasks before crew arrival will allow more crew time for science utilization. ISAAC's Memorandum of Understanding with the Gateway program describes its technology infusion plan, which calls for interfacing through the Gateway IVR and Vehicle System Manager (VSM) Working Groups.

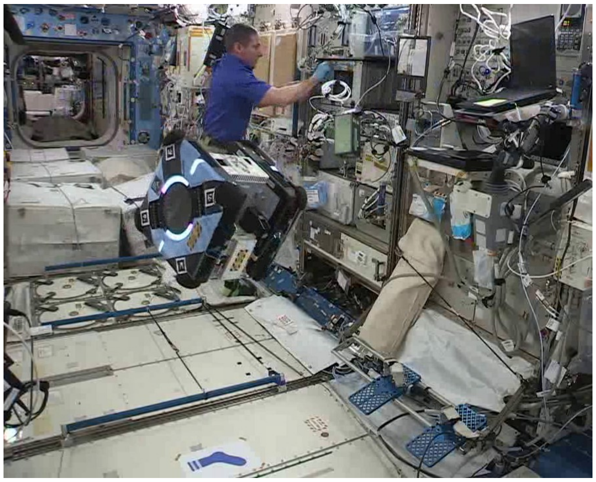

Figure 2 Bumble moves into position for its targeted inspection during the fault management scenario. Astronaut Mike Hopkins is seen working in the background.

ISAAC's research plan is organized into three phases of roughly one year each (2020-2022). In phase 1, ISAAC developed technology for integrated data analysis across vehicle and IVR systems and demonstrated an autonomous state assessment capability through a campaign of three Astrobee activities on the ISS, which included two main scenarios: (1) Multi-sensor survey: Astrobee built a multi-sensor 3D map of a section of the ISS Kibo module, including mesh geometry from Astrobee's HazCam LIDAR and high-resolution texture from Astrobee's SciCam camera. The survey was repeated later to provide data for change detection. (2) Fault management scenario: A high-CO_2 anomaly was injected into simulated vehicle life support telemetry, triggering Astrobee to perform an autonomous targeted inspection; automated image analysis then detected an unexpected object blocking a vent.

In order to enable its multi-sensor survey, ISAAC needed more robust Astrobee navigation than the Astrobee baseline flight software could provide. ISAAC therefore collaborated with the Astrobee Facility to develop new visual/inertial odometry (VIO) software, significantly reducing the rate of lost-robot faults. For example, in ISAAC's third ISS activity, Astrobee was able to collect multi-sensor imagery from 145 viewpoints while flying for about 2.5 hours without needing crew assistance. This new VIO component has been integrated into Astrobee's baseline flight software, making it available for all Astrobee users.

During phase 2, currently in progress, ISAAC is developing technology for an integrated operator control interface and demonstrating autonomous logistics management capability. In phase 3, ISAAC will develop technology for coordinated execution and demonstrate an integrated fault management capability.

Acknowledgments: ISAAC is funded by NASA's Space Technology Mission Directorate, Game Changing Development Program. Many thanks to the ISS Astrobee Facility for supporting ISAAC activities.