A Modular Instrumentation System for NASA's Habitat Demonstration Unit

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Abstract

NASA's human spaceflight program is focused on developing technologies to expand the reaches of human exploration and science activities beyond low earth orbit. A critical aspect of living in space or on planetary surfaces is habitation, which provides a safe and comfortable space in which humans can live and work. NASA is seeking out the best option for habitation by exploring several different concepts through the Habitat Demonstration Unit (HDU) project. The purpose of this HDU is to develop a fully autonomous habitation system that enables human exploration of space. One critical feature of the HDU project that helps to accomplish its mission of autonomy is the instrumentation system that monitors key subsystems operating within a Habitat configuration. The following paper will discuss previous instrumentation systems used in analog habitat concepts and how the current instrumentation system being implemented on the HDU1-PEM, or pressurized excursion module, is building upon the lessons learned of those previous systems. Additionally, this paper will discuss the benefits and the limitations of implementing a wireless sensor network (WSN) as the basis for data transport in the instrumentation system. Finally, this paper will address the experiences and lessons learned with integration, testing prior to deployment, and field testing at the JSC rock yard.

NASA is developing the HDU1-PEM as a step towards a fully autonomous habitation system that enables human exploration of space. To accomplish this purpose, the HDU project is focusing on development, integration, testing, and evaluation of habitation systems. The HDU will be used as a technology pull, testbed, and integration environment in which to advance NASA's understanding of alternative mission architectures, requirements, and operations concepts definition and validation. This project is a multi-year effort. In 2010, the HDU1-PEM will be in a pressurized excursion module configuration, and in 2011 the module will be reconfigured for a pressurized core module configuration. Each year the HDU configurations will undergo testing at NASA's Desert Research and Technology Studies (D-RaTS) in Arizona [1].

As part of this project, a modular instrumentation system is developed to meet the monitoring needs of the HDU subsystems and to integrate with the current command and data handling infrastructure that has been developed for the project. The main objective of this study is to provide for the monitoring needs of the HDU. The requirements necessary to meet this objective are developed by working with the subsystem managers of the HDU to understand their monitoring needs. Additionally, the instrumentation system design leverages knowledge and lessons learned from previous studies, such as the inflatable habitat health monitoring system that was deployed in Antarctica [2], the integrated health monitoring system developed for NASA's Microhab [3], and the JSC Lunar Habitat Wireless Testbed to demonstrate a "standards-based" approach to a wireless instrumentation system [4]. The HDU also requires flexibility in reconfiguration options, and it is necessary to demonstrate and evaluate a modular approach to an instrumentation system. Thus, the instrumentation system is designed in two parts: the primary system employs a standard WSN configuration, and the secondary system employs a wired USB hub. The WSN design provides for reconfiguration or replacement of sensors due to malfunctions or upgrades by using a wireless node that accepts ten instrument inputs and wirelessly transmits the data to the command and data handling system. The USB hub is necessary for those instruments that operate using a wired USB connection, although the design attempts to limit the amount of sensors that need to be wired connections.

Prior to field testing of the integrated HDU1-PEM, it is necessary to undergo rigorous integration and testing of the instrumentation system to ensure functionality of the system and successful integration with the other subsystems. This integration and testing is completed in several steps which increase in complexity with each step. This process starts with laboratory testing of each instrument as it is acquired. The wireless sensor nodes are tested separately, prior to installation of sensors on the nodes. Then, the fully integrated nodes are tested in the Habitat Testbed (HaT), which essentially replicates the command and data handling (CDH) infrastructure for testing purposes prior to installation in the HDU1-PEM. This allows for investigation of the instrumentation system's functionality while integrated with the CDH infrastructure and other subsystems of the HDU1-PEM. Finally, the instruments and wireless sensor nodes are integrated into the HDU1-PEM and a fully integrated checkout of the entire HDU1-PEM is completed.

This work culminates in field testing at the JSC Rockyard and will continue with field testing at the 2010 D-RaTS in Arizona, where the HDU1-PEM will undergo operations scenarios with other prototype lunar elements. The data used and collected during these studies will prove invaluable in understanding the strengths and weaknesses of this modular instrumentation system. The lessons learned from this project will lead to improved instrumentation systems in the future, allowing for more autonomous, integrated, and flight-like systems that could be used in a habitation element in space or on a planetary surface.

The instrumentation system discussed in this paper is built upon previous instrumentation systems and the recommendations from those experiences. This system employs a standards-based approach by implementing wireless networking protocols developed for the industrial process control industry and derived from the IEEE 802.15.4 WSN standard. Additionally, it provides flexibility in reconfiguration through modularity. The development of this system and the data resulting from field tests provides invaluable lessons learned which will lead to more refined instrumentation systems in the future.

References

[1] K.J. Kennedy, T.O. Tri, T.R. Gill, A.S. Howe, "The Habitat Demonstration Unit Project Overview," Proceedings of the *Twelfth Biennial ASCE Aerospace Division International Conference on Engineering, Science, Construction, and Operations in Challenging Environments* (Earth & Space 2010), Honolulu Hawaii, 14-17 March 2010.

[2] K. Rojdev, T. Hong, D.S. Hafermalz, R. Hunkins, G. Valle, L. Toups, "Inflatable Habitat Health Monitoring: Implementation, Lessons Learned, and Application to Lunar or Martian Habitat Health Monitoring," Proceedings of the *AIAA Space 2009 Conference and Exposition*, Pasadena, CA, 14-17 September 2009.

[3] A.S. Howe, T. Hong, B. Hunkins, D.S. Hafermalz, K.J. Kennedy, L. Toups, "Mobile Field Analog for Lunar Habitat Integrated System Health Monitoring," Proceedings of the *Twelfth Biennial ASCE Aerospace Division International Conference on Engineering, Science, Construction, and Operations in Challenging Environments* (Earth & Space 2010), Honolulu Hawaii, 14-17 March 2010.

[4] R.S. Wagner, "Standards-Based Wireless Sensor Networking Protocols for Spaceflight Applications," Proceedings of the *IEEE Aerospace Conference*, Big Sky, MT, 6-13 March 2010.

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