Asset Tracking on the International Space Station Using Global SAW Tag RFID Technology

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***Abstract*—Final preparations are underway to test Global SAW Tag (GST) RFID technology [1, 2] for tracking assets aboard the International Space Station (ISS) [3]. This will be the first test of RFID technology on ISS. It is planned for early 2008 by the Expedition 16 crew. It will evaluate the ability of SAW RFID to track consumable items while packed in standard crew bags. The GST system was selected based on its signal penetration ability and its anti-collision capabilities that allow reliable detection of tags even when placed on, behind, and between items with high liquid and metal content in randomly packed crew bags. Substantial savings of highly-valuable crew time is projected with corresponding improvements in ISS crew productivity.**

Keywords- SAW RFID; Global SAW Tag; GST; International Space Station; asset tracking

I. INTRODUCTION

The International Space Station (ISS) is a joint project between the space agencies of USA (NASA), Russia (RKA), Canada (CSA), Japan (JAXA), and several European countries through the European Space Agency (ESA). In addition, the Brazilian Space Agency (AEB) and the Italian Space Agency participate through separate contracts with NASA. (Italy also participates fully under the framework of ESA's ISS work.)

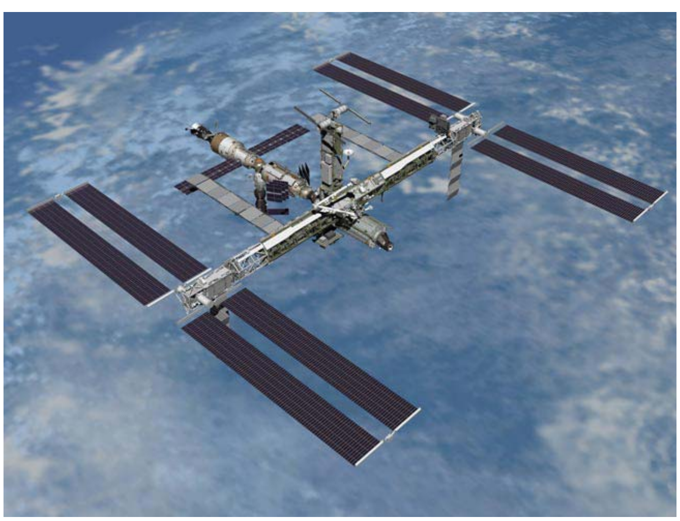

Figure 1: The International Space Station

A major goal of operating ISS is to develop the technology necessary for human-based space and planetary exploration and colonization (including life support systems, safety precautions, environmental monitoring in space, etc.) [3]. RFID technology will be essential for efficient logistic support for future lunar and Mars base operations. However, as described below, RFID is expected to dramatically improve operations on the ISS by enabling significantly more efficient tracking of consumables and critical hardware.

II. ISS ASSET TRACKING PROBLEMS

Due to the weightless conditions aboard the ISS, all items must be stowed and tied down. If not, they will drift from their assigned places and obstruct station operations. As illustrated in Figure 2, most items are kept inside flight bags which are secured to the walls of the station, stacked several deep.

Figure2: ISS assets stowed in flight bags and secured to walls

Finding needed items often presents a major challenge because items are hidden from view inside the flight bags. In zero gravity condition, care must be used when opening a bag to search for a needed item since all items inside the bag can easily float away.

To aid in solving this problem, the ISS uses a barcode-enabled Inventory Management System (IMS) Database to track almost 10,000 stowed and loose U.S. hardware items. The ISS crew and ground team access the IMS to locate needed items. The IMS is updated by the ISS crew and ground team daily. The ISS and ground versions of the IMS databases are synchronized by uplinking and downlinking "Delta Files". Each crewmember is scheduled 20 minutes per day to update the IMS database.

If the crew moves an item and does not notify the ground or spend sufficient time to update the database, then the item may not be easily found by the next crew. As a result, the accuracy of the IMS database is compromised (approximately 3% of the tracked items in IMS are currently considered "lost"). These problems will multiply as the number of on-orbit items grows.

Another serious weakness in current ISS inventory management is caused by the line of sight operation of barcode technology. Many items (including crew consumables) can only be tracked at the flight bag level with barcodes, because barcode readers cannot "see" inside the bags. Thus the IMS is not able to directly track remaining stock of items as they are consumed.

To overcome this weakness, periodic, manually-intensive audits are conducted by the crew to ensure that the on-orbit supply of food, clothing, and other consumables is adequate. Also, since "up mass" and on-orbit stowage are critical limited assets, the ISS program cannot afford to oversupply such items. These audits are very expensive measured in crew time. For example, the April 2007 audit consumed over 3 hours for the entire ISS crew.

III. Potential Paybacks From RFID Solution

Numerous potential paybacks have been identified from using RFID technology to extend the scope and accuracy of the information contained in the IMS database as follows:

- Reduce the currently scheduled 20 minutes per crew member per day used to update IMS using the barcode technology
- Eliminate the periodic, manually-intensive audits by the ISS crew to ensure the supply of consumables
- Minimize "up-mass" and on-orbit stowage
- Eliminate time spent searching for lost items
- Allow more time for science and critical maintenance
- Improve safety
    - Knowing locations of key items in emergency
    - Timely resupply of critical items

Based on publicly-available information [3, 4], RF SAW, Inc. has estimated the operating cost for ISS as approximately $8.8 million per day. This estimate excludes the costs of building the space station but it does include NASA's published ISS operating costs, plus a portion of the published cost of operating the space Shuttle (since the vast majority of all Shuttle use is for ISS flights), and the estimated share of ISS operations costs paid by other ISS partners. (It should be noted that the Shuttle program costs are not considered part of the overall ISS costs by NASA, because the Shuttle program is considered an independent program aside from the ISS.) While this estimated cost is uncertain, it is useful for estimating benefits of deploying RFID for asset tracking on ISS.

For example, if RFID-based automation could reduce the currently scheduled inventory update time from 20 minutes to 4 minutes per crew member per day, the estimated saving is $100,000 per day. A second example is that approximately $1 million in savings would be achieved by eliminating but one of the 3-hour periodic, manually-intensive audits conducted by the ISS crew to ensure supplies of consumables.

IV. Developing RFID For ISS Asset Tracking

NASA has been well aware of the need for and potential paybacks from a fully automated asset tracking system for space operations. NASA has internally studied RFID for years as the best hope for solving the asset tracking problem.

In addition, the NASA Johnson Space Center has previously funded two external programs aimed at using RFID for this purpose. Both of those program used IC-based RFID technology and in both cases the RFID reading reliability results did not warrant proceeding to an on-orbit test or SDTO (Station Detailed Test Objective).

In 2006, NASA began evaluation of SAW RFID technology due to enhanced performance around metals and liquids. The system from RF SAW was chosen for evaluation due to its unique capability (among SAW RFID systems) for providing the anti-collision performance needed to read tightly packed items inside crew flight bags. The initial ground testing exceeded the greater than 98% accuracy level that NASA had set as the minimum performance needed when scanning crew provisioning items. The SAW technology could provide a complete inventory of a bag in well under 1 minute as compared to the approximately 30 minutes that are currently required to manually inventory a bag while on-orbit.

Subsequently, a contract was issued to RF SAW to supply a flight-ready system to perform an SDTO test to validate the benefits of tracking consumable items aboard ISS. RF SAW developed a small flexible RFID tag that was suitable for attachment to clothing and for use on other consumable items. Figure 3 shows a close-up view of the tags and a typical crew flight bag used for consumable items. Note that the bag itself is also tagged as evident in the clear pocket in the bag's lid.

Figure 3: Flexible antenna RFID tags and crew bag with tagged items inside

RF SAW also developed a NASA version of the Model 704 portable reader. It was adapted to function with batteries that are already used on the ISS and to interface with a PDA device that is already on-orbit. The key requirements for this reader included the following:

- Read 15 to 30 tags in a small volume (anti-collision)
- Accommodate a wide variety of items in the read field including both RF opaque and RF transparent materials
- Achieve reliable signal penetration into the bag even with metal and liquid items
- Use very low RF radiated power levels

The entire system solution was based on an 80-bit GST tag that supports a 40-bit user ID number space. (A 40-bit space can theoretically accommodate 10^{12} unique ID numbers.) A photo of the NASA model 704 reader is shown in Figure 4.

Figure 4: NASA version of RF SAW Model 704 Reader (shown with PDA)

In use aboard the ISS, the reader and attached PDA will be placed at a convenient location near crew bags that are to be inventoried. The various sides of a bag will then be passed in front of the reader which will automatically record both the ID tag that identifies the bag and also record all tagged items inside that bag. The crew can directly view a list of bag contents on the PDA display, but more importantly, that updated inventory list will be automatically loaded into the IMS database when the PDA is placed in its recharging stand after use. Thus the system will both create the expanded inventory inside the IMS automatically and/or allow the crew to use the system to expedite searching for desired items.

V. Current Status of SDTO On-Orbit Testing

Flight ready readers and tags were delivered to NASA in late summer 2007. Subsequently, after testing the hardware for satisfactory operation, NASA has now packed flight bags with RFID-tagged consumables that are scheduled to be launched from Russia in December 2007. The reader is scheduled to be launched to the ISS aboard the space Shuttle in approximately the same time frame.

The target date for on-orbit testing is early 2008. The plan calls for RFID scans to be done in parallel with manual audits by the flight crew. By comparing results, the success of the SDTO can be analyzed.

VI. Future Plans Assuming SDTO Success

If the initial testing is successful, the next likely step would be full implementation of consumables tracking using the GST RFID system. NASA has already ordered and received a number of RFID tags that should be sufficient for several more supply ship cycles. Several other extensions for using this technology in space operations have been discussed with both near and longer term implementation as follows:

- Extend RFID tracking to all critical items
- Deploy readers at hatches – particularly with docked supply vehicles. Substantial time savings are possible in tracking both resupply and returning items.
- Integration into the design of future space vehicles
- Research of fully autonomous asset tracking

VII. Conclusions

SAW-based GST RFID technology was evaluated by NASA for solving serious asset tracking problems aboard the International Space Station. Ground-based preliminary testing showed excellent performance and the decision has been made to test the system on-orbit in early 2008.

A more severe version of these same problems will exist for future human-based space and planetary exploration and colonization. Thus finding an acceptable solution to these asset management problems directly supports a major ISS research goal to develop critical technology for such future missions.

However, solving the asset tracking problem also provides major benefits for near term operation of the ISS that directly enhances its ability to achieve its many other research objectives. While the savings can be expressed in monetary terms that reach many millions of dollars, the most important practical benefit will be that time saved by the ISS crew can now be applied to science.

This project also illustrates the sustainable advantages of the Global SAW Tag system versus IC-based RFID tag systems. The GST system succeeded for this application where multiple previous attempts to solve problem using IC-based RFID had failed. The key items in that success included the following:

- Robust anti-collision capability
- Signal penetration in and around liquids and metals
- Large user ID number space
- Small physical size of SAW tags
- Low, safe radiated RF reader power

While this project was a space-based application, the same factors that created a successful implementation in this system are expected to result in many large terrestrial applications as well.

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