RFID-Based Asset Management for Space Habitats

Patrick W. Fink, Ph.D.
NASA JSC
Deputy Chief, Antenna and Wireless Systems Branch
2101 NASA Parkway
Houston, TX 77058 USA
(+1) 281-483-0973
patrick.w.fink@nasa.gov

Acknowledgements

- **John B. Bacon, ISS Program Integration Office**
- **William Hartwell, ISS Mission Integration and Operations Office**
- **Robert Stonestreet, ISS Mission Integration and Operations Office**
- **Phong Ngo, Antenna and Wireless Systems Branch**
- **Richard Barton, Ph.D., Antenna and Wireless Systems Branch**
- **Andrew Chu, Antenna and Wireless Systems Branch**
- **Greg Lin, Antenna and Wireless Systems Branch**
- **Timothy Kennedy, Ph.D., Antenna and Wireless Systems Branch**

Outline

- Background – the need for inventory automation
- Current RFID infrastructure on International Space Station (ISS)
- Toward an automated inventory management
- Real-time location system

The ISS is Huge

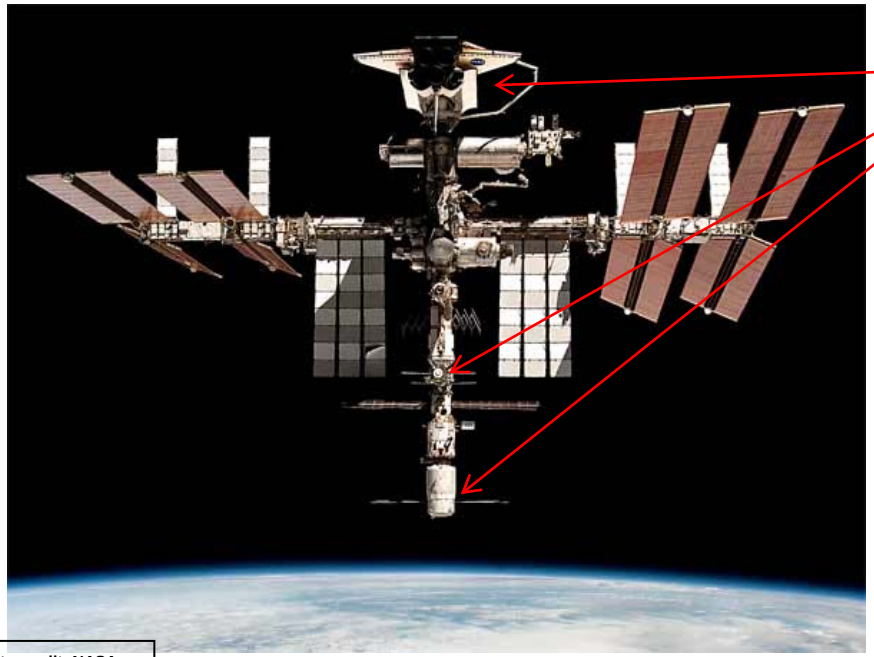


Photo credit: NASA

- (Cargo ships the size of freight cars)
- 440,000 kg core station
  - 100m x70 m
  - 4-m diameter tubular living areas
- Six “permanent” crew
  - in 6-month overlapped shifts
- 6 partner agencies
- 30-year station life possible

The ISS 400 km in space is resolvable to the human eye (seen here silhouetted against the sun (Photo credit: Thierry Legault)

- The inventory onboard is:
  - vast
  - densely-packed
  - packed by other people
  - often behind metal
  - mobile
  - diverse
  - and often small, unique, and irreplaceable

…and it costs ~$30 USD per gram to launch


Photo credit: NASA

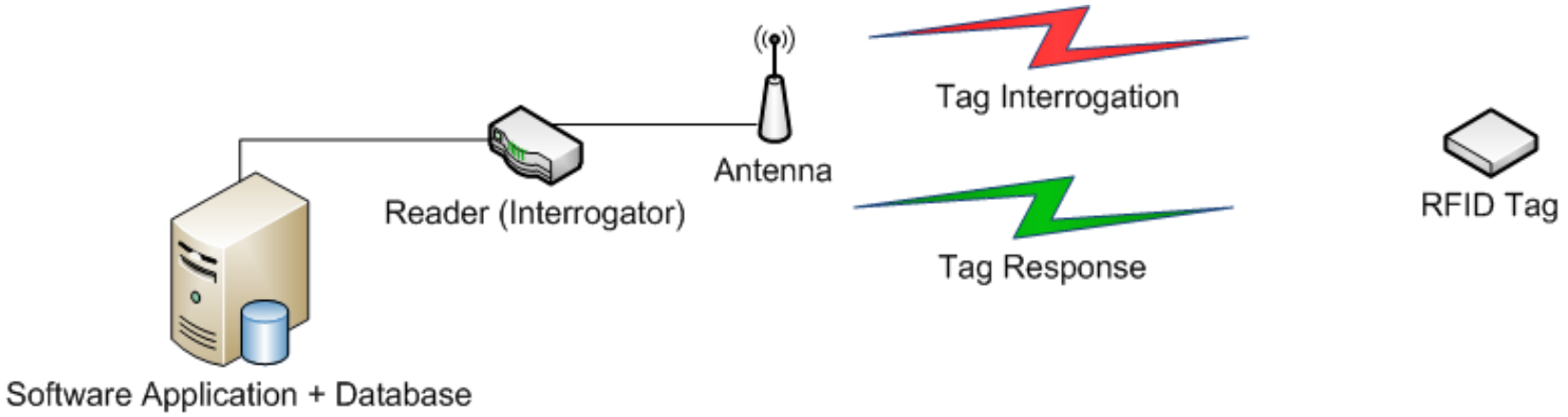
Photo credit: NASA


SPEED
LIMIT
17500
28000
km/h
FGB

CURRENT RFID INFRASTRUCTURE ON INTERNATIONAL SPACE STATION (ISS)

Components of an RFID System

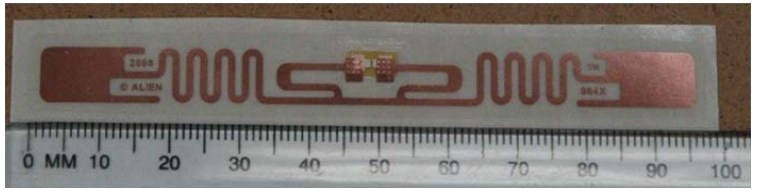
- Basic RFID system (IC-based):
  - An **interrogator** (reader) with antenna
  - A **transponder** (RF tag) containing an antenna and IC
- Consultative Committee for Space Data Standards recommended practice for RFID for Inventory Management: EPC Class 1, Generation 2 RFID Standard: UHF 860 – 960 MHz
  - Passive tag, interrogator-talks-first



Current ISS RFID Infrastructure

Omni-ID “Prox” tag for conductive items

Alien “Squiggle”Tag for non-conductive items



- Handheld RFID/barcode reader is current basis for on-board RFID technology
  - Two primary RFID functions:
    - Crew-assisted Cargo Transfer Bag (CTB) audits
      - 20 seconds compared to 20 minutes per CTB audit
      - Translation of CTB to isolated tag-free area for scan increases cost to several minutes per CTB
    - Search for missing items – audible rate increases with proximity

Certified RFID Tags

Omni-ID Tags for Metal / Liquid-Filled Items

RFID Label Drawing Numbers:

- **OMNI-ID RFID label:** SEG32111601
  SEG32111601-301,-302, -303

OMNI-ID 2-part RFID Labels

Assembled Product

Pros:

- Can be produced using RFID printer
  - Easy to print IMS barcode on top
  - Easy to encode RFID label
  - Allows high volume production
- Can be used on metal and fluid-filled items

Cons:

- Barcode label is a separate sticker from RFID label
- Not very durable
- Short read range. Not good for locating lost items
- Tag is thick

Thick structure which improves antenna's performance

RFID Tags

Current Tagging Techniques

Challenge:
Applying RFID labels to individual X-static shirts and pairs of socks, which contain metal (silver) fibers.

Solution:
An OMNI-ID tag is adhered to a bendable sheet of Lexan (OMNI-ID tag adheres well to Lexan). Each tag w/ Lexan is placed at end of each rolled-up shirt or pair of socks. Several shirts or socks are placed in a zip-lock bag. When these are packed into CTB's, the ends w/ tags are faced to outside of CTB to allow more reliable scanning.

Class III X-static Socks with flight-like tags
X-Static Clothing has metal (silver) fibers

SEG32111601-303
(OMNI-ID w/ Lexan)

RFID Tags

Current Tagging Techniques

Challenge:
Applying RFID labels to packages of batteries (metal items)

Solution:
4” x 1” “Squiggle” tag is placed on the outside of the zip-lock bag. The tag is placed on the “locking” edge of the zip-lock so that the tag does not rest on top of metal batteries.

4”x1” Squiggle tag SDG32111604

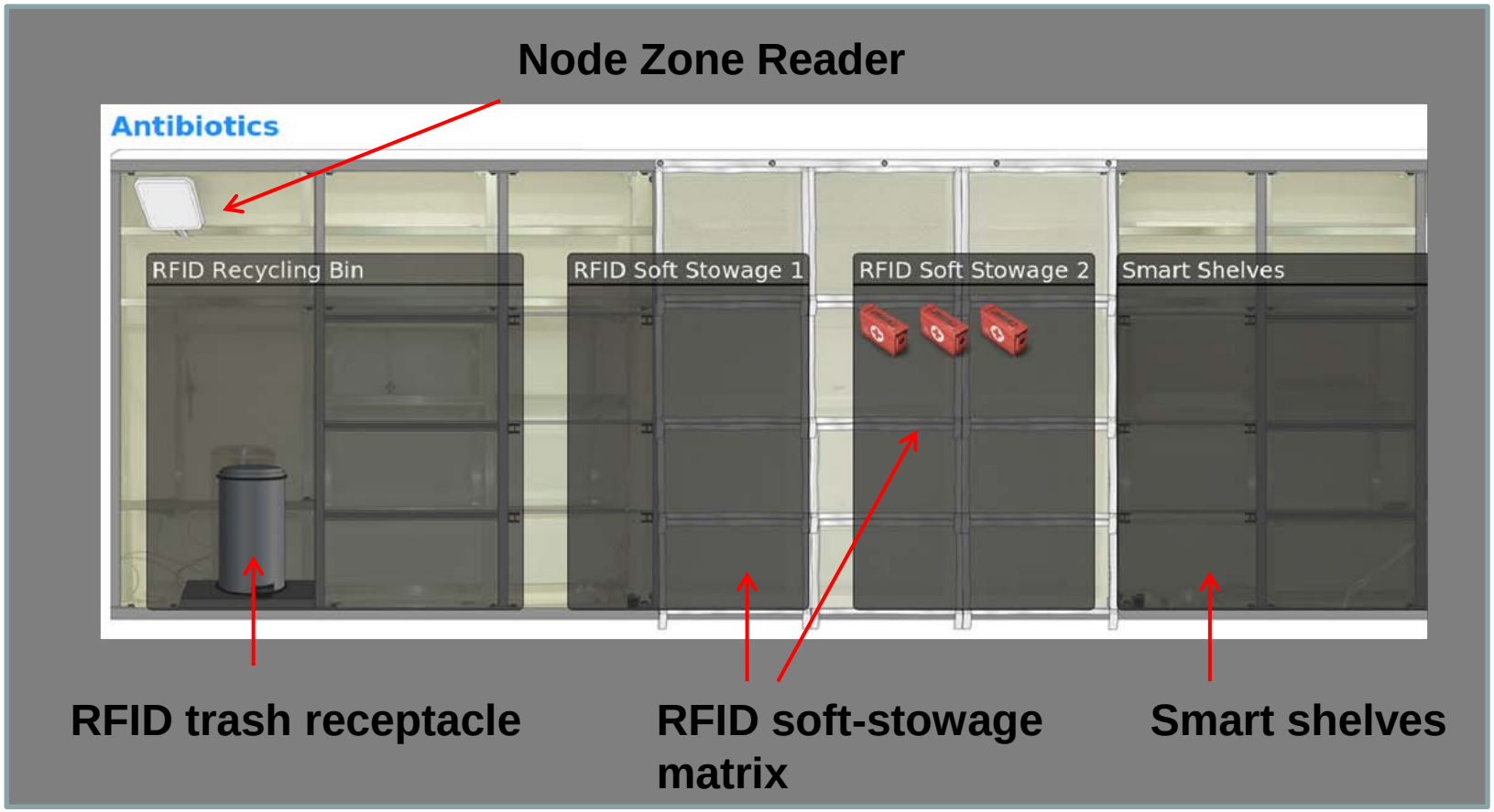
Class I Crew Provisions at 42P packing

TOWARD AN AUTOMATED INVENTORY MANAGEMENT SYSTEM

Wireless Habitat Test Bed

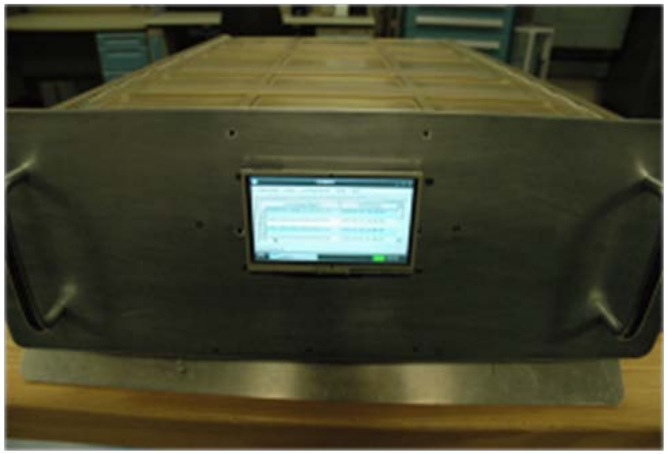
- 3m diameter x 6m length horizontal cylindrical architecture
- Used to demo RFID-based inventory tracking concepts

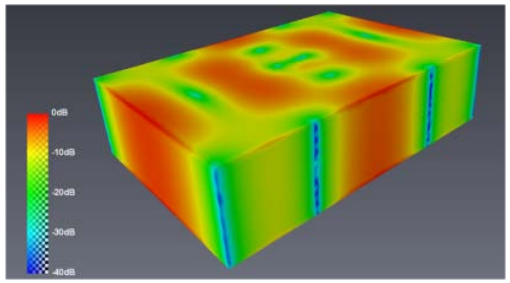
Wireless Habitat Test Bed – Cross Section



RFID-Enabled Enclosures

EMBER on ISIS Drawer





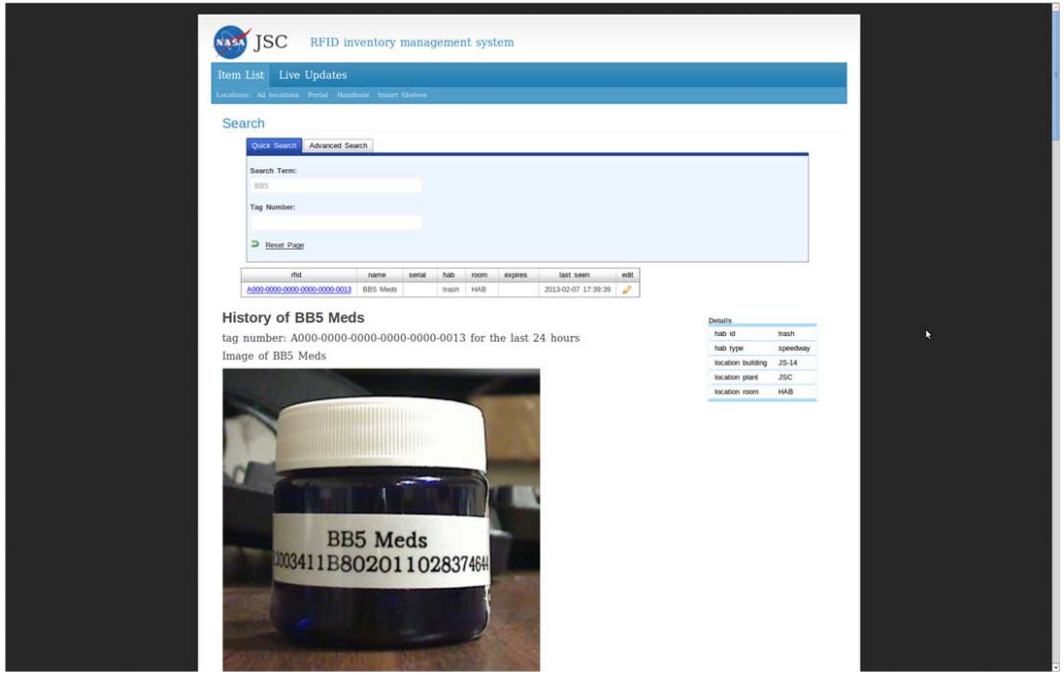
CEM Model for RFID Enclosure

RFID Enabled Waste Receptacle

Zero-g Stowage Rack (ZSR)

Web Asset Management Application

- Item search
  - meta data
  - thumbnails
  - location history



- Global or local analog inventory meters

Integrated RFID Environment

Middleware + Application

RFID Components

Products

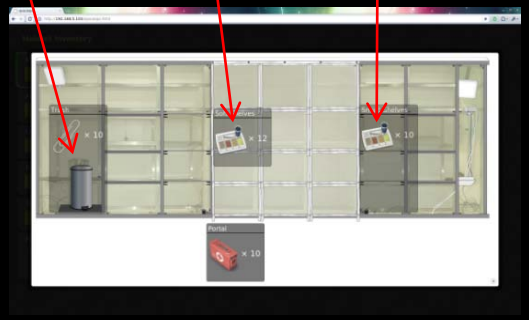
(ISIS) Embedded Reader (EMBER)

RFID Pill Tracking

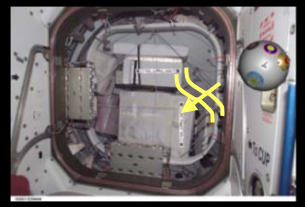
Smart Can

RFID Soft-Cells

Smart Shelves



Robotic Interrogators: DTN- EMBER Gen2 on Free-Flyer



ISS RFID Handhelds

Deployable RFID "Crush Can"

RFID Portals

Optical Barcode

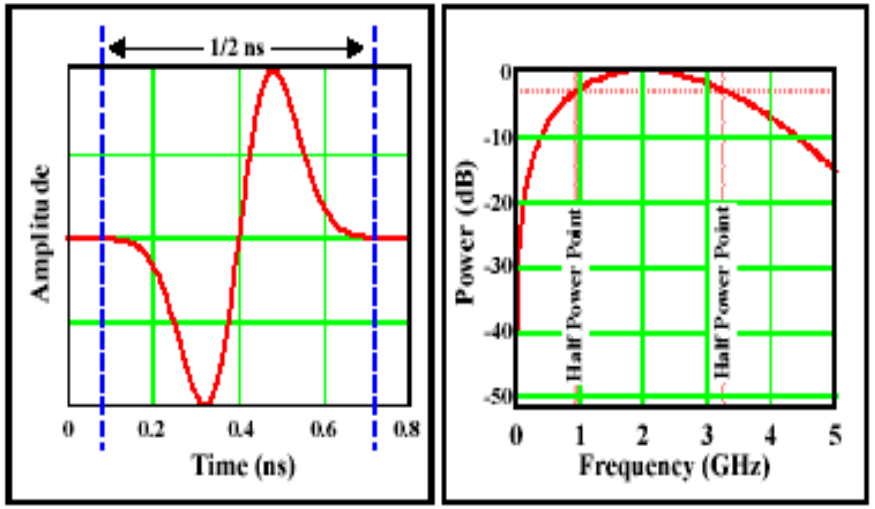
Notional timeline – cost driven

2010 2011 2012 2013 2014 2015

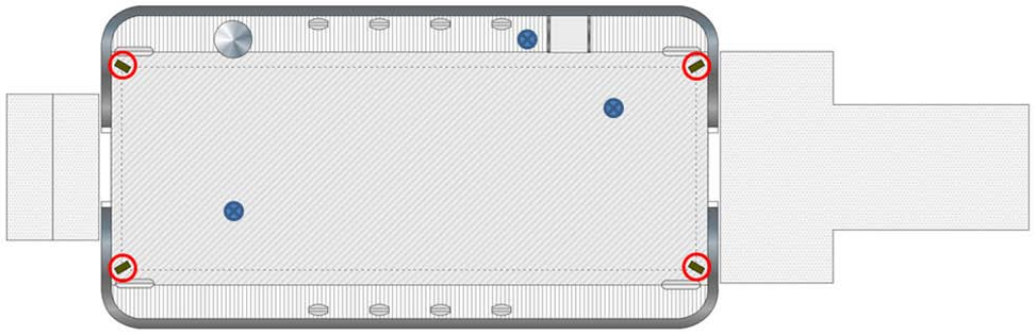
20 min/CTB 2 min/CTB 10 sec/CTB → **0 : no crew involvement in inventory management**

REAL-TIME LOCATION SYSTEMS

Active-Tag Ultra-Wideband (UWB) RFID System



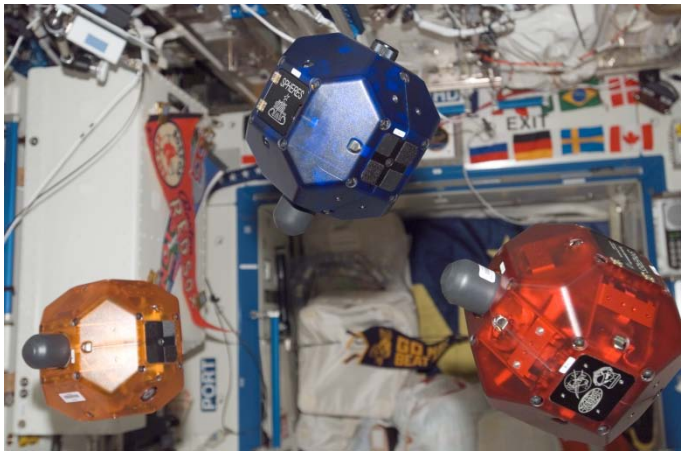
UWB impulsive signal in time- and frequency-domains.



UWB receiver locations and three tag locations being tracked.

Potential UWB RFID Applications

- **Key Features**
  - Immunity to interference from narrow band RF systems due to ultra-wide bandwidth
  - Low impact on other RF systems due to extremely low power spectral densities
  - Capable of precise tracking due to fine time resolution (picoseconds)
    - 3-D localization of EVA/IVA assets to aid in telerobotic operations i.e. SPHERES, R-2



Conclusion

- Remote habitats are often densely packed
  - items necessary to sustain life
  - items necessary to conduct work
- Inhabitant's time is often quite valuable, if not priceless
- Resupply shipments can be infrequent and expensive
- Inaccurate inventory knowledge can lead to unnecessary overstocking, which can lead to insufficient work and/or living volume
- Not being able to find items when they are needed can present:
  - safety issues
  - morale issues
- RFID technology has the potential solve a lot of these issues