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Automation of Space and Ground Inventory Management Systems

Consultative Committee for Space Data Systems
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Overview

- **Update on ISS handheld readers for inventory audits**
- **Integrated RFID over a Delay/Disruption Tolerant Network (DTN)**
  - Handheld RFID readers
  - RFID portal
  - RFID "Smart" Shelf
  - RFID Trash Receptacle
  - RFID Soft Stowage
  - RFID Application
- **RFID for Center Operations - Pilot Projects**
  - Space Vehicle Mockup Facility
  - Neutral Buoyancy Laboratory (NBL)
- **RFID Enclosures**

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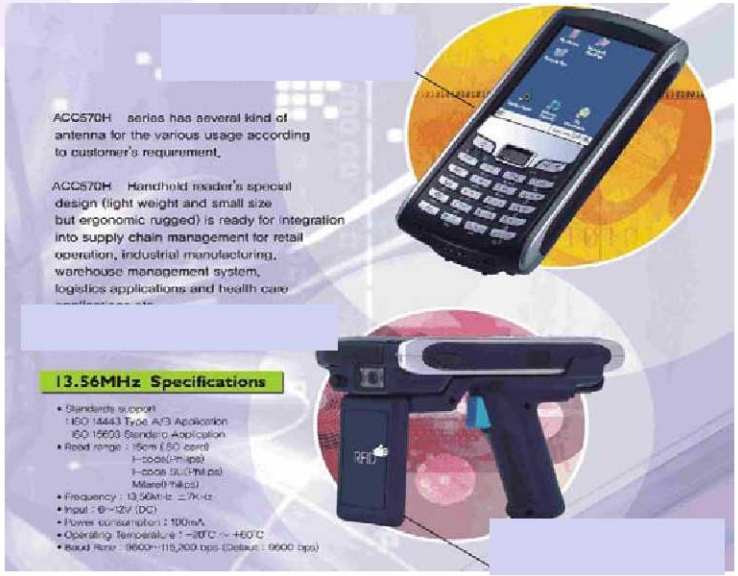
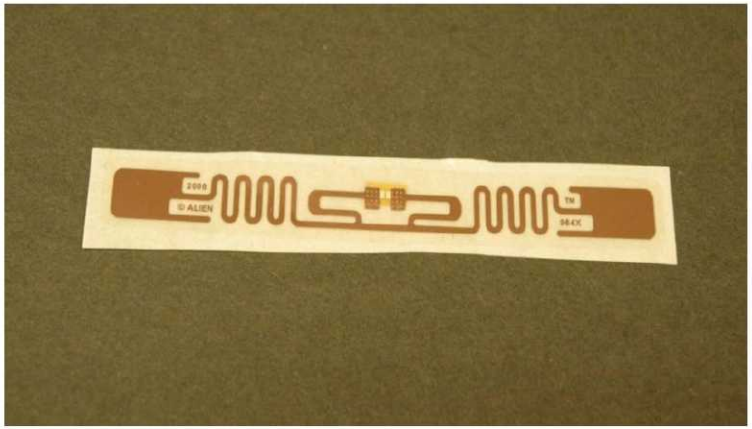
BCR/RFID System Hardware

- **READER: ACC 570u**
- **Completed testing and assessments**
- **System 570 is the primary candidate reader based on the following considerations:**
  - Crew comments (form factor, display size)
  - Barcode reading accuracy
  - RFID reading accuracy
  - Functions and capabilities (power setting, user-friendliness, software platform (Windows CE 5.0))
  - Battery and battery charger (offers a multi-battery charger)
  - Successfully operated during parabolic flights



BCR/RFID System Hardware

- **TAGS:**
- **Following types of tags have been selected as primary candidates:**
  - OMNI-ID 2-part Prox Tags (for metal, items with liquid)
  - Alien Technology Squiggle Tags in form factor 4” x 1” and 4” x 6” (for general uses such as zip-lock bags, CTBs, etc.)
  - All 3 of these tags uses the Alien Technology Higgs 3 integrated circuit.
  - Tags performed well in zero-g parabolic flight tests



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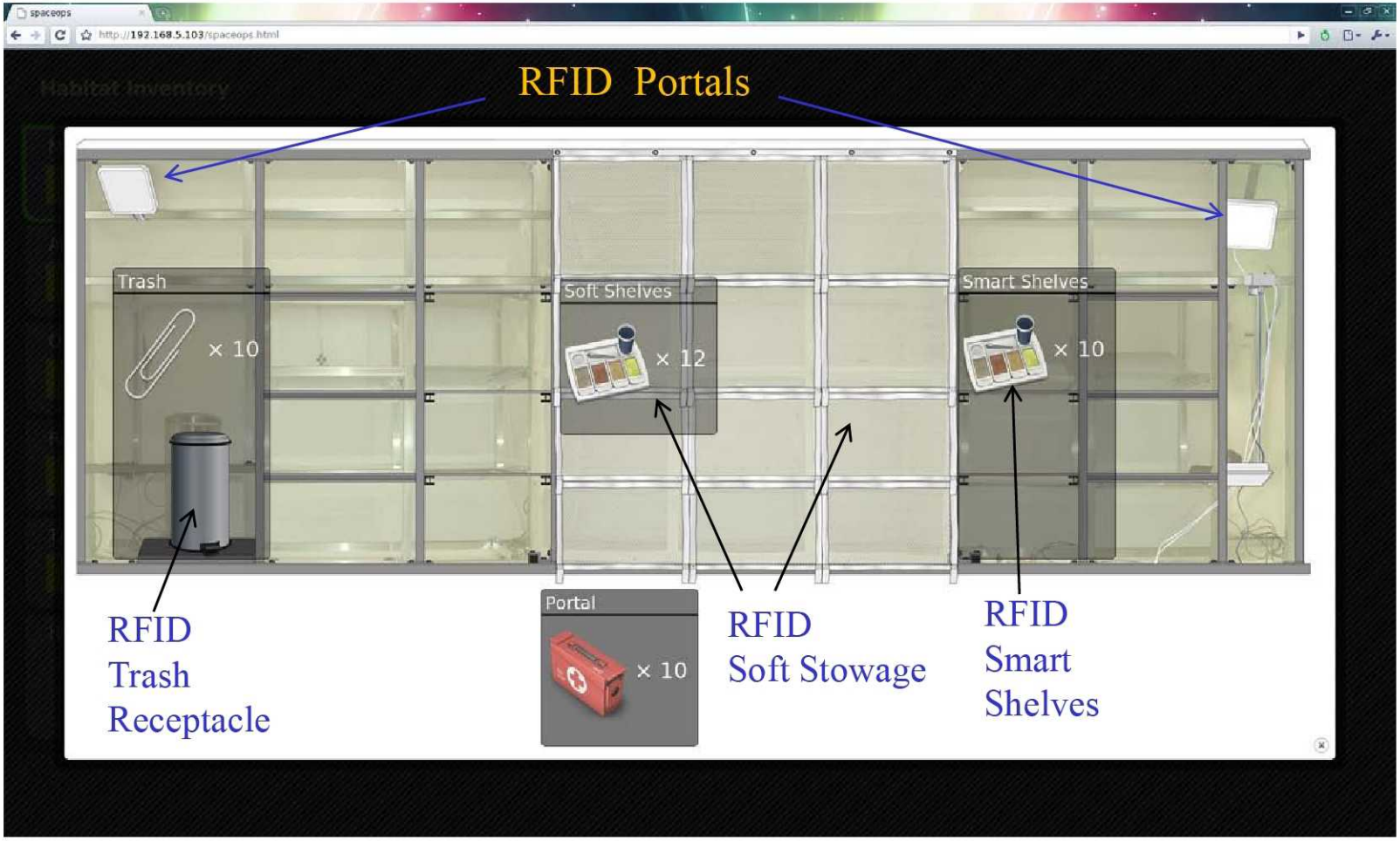
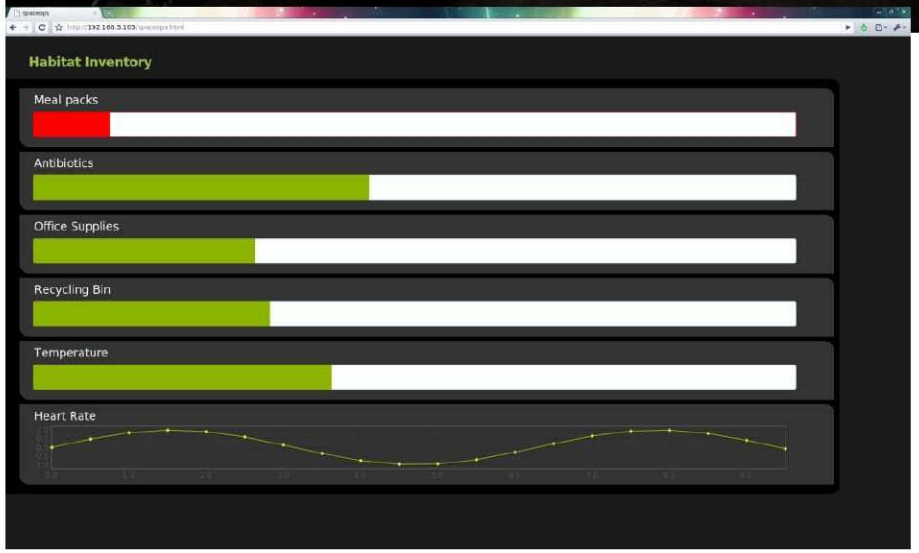
Integrated RFID over a Delay/Disruption Tolerant Network (DTN)

Integrated RFID Systems



Efficient and Autonomous Merging of Networks

- As the LER arrives to re-stock the habitat…
- LER WLAN network is discovered, and…
- Habitat and LER inventories are displayed



Inventory Transfer Test

Inventory is transferred from the LER to the Habitat.

LER portal and Habitat RFID systems capture transfer.

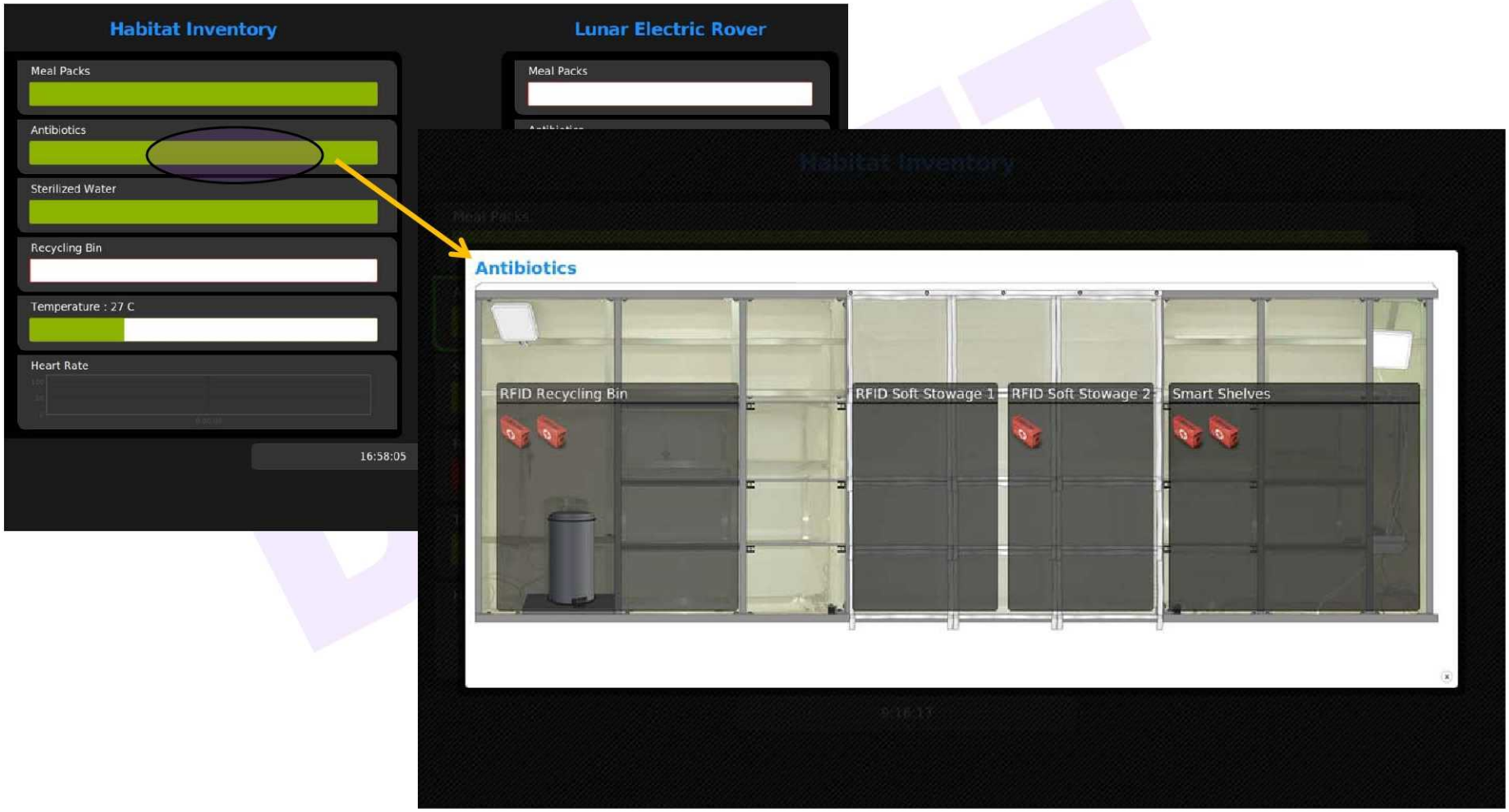
Inventory management screens are updated.

Before

After

Inventory "Drill-Down"

Clicking on any inventory bar brings up quantities and known locations.



Showing Contents of Locations

The application can also show contents of all storage locations.

Inventory Management Applications over DTN Network

Control Center Inventories Automatically Refreshed Following Disruption

Habitat Display

Databases synchronized

Link disrupted,
MCC display becomes "stale"

Link restored,
MCC display updates automatically

MCC Display

RFID for Center Operations - Pilot Projects

RFID Pilot: Targeted Area #1 - SVMF

- **Description**
  - Track movement of items from 3 classes (EVA prep/post, Emergency, Habitation Procedures) as tagged items enter or exit the loose equipment stowage room and Lab/Node 1/Airlock modules

- **Benefits**
  - Particularly relevant as an ISS RFID inventory management test bed
  - Easy to modularize for reduced-scope study; i.e., limited entry/exit
  - Easy to scale for full operational deployment
  - University partner running concurrent RFID experiments in SVMF (University of Nebraska-Lincoln)

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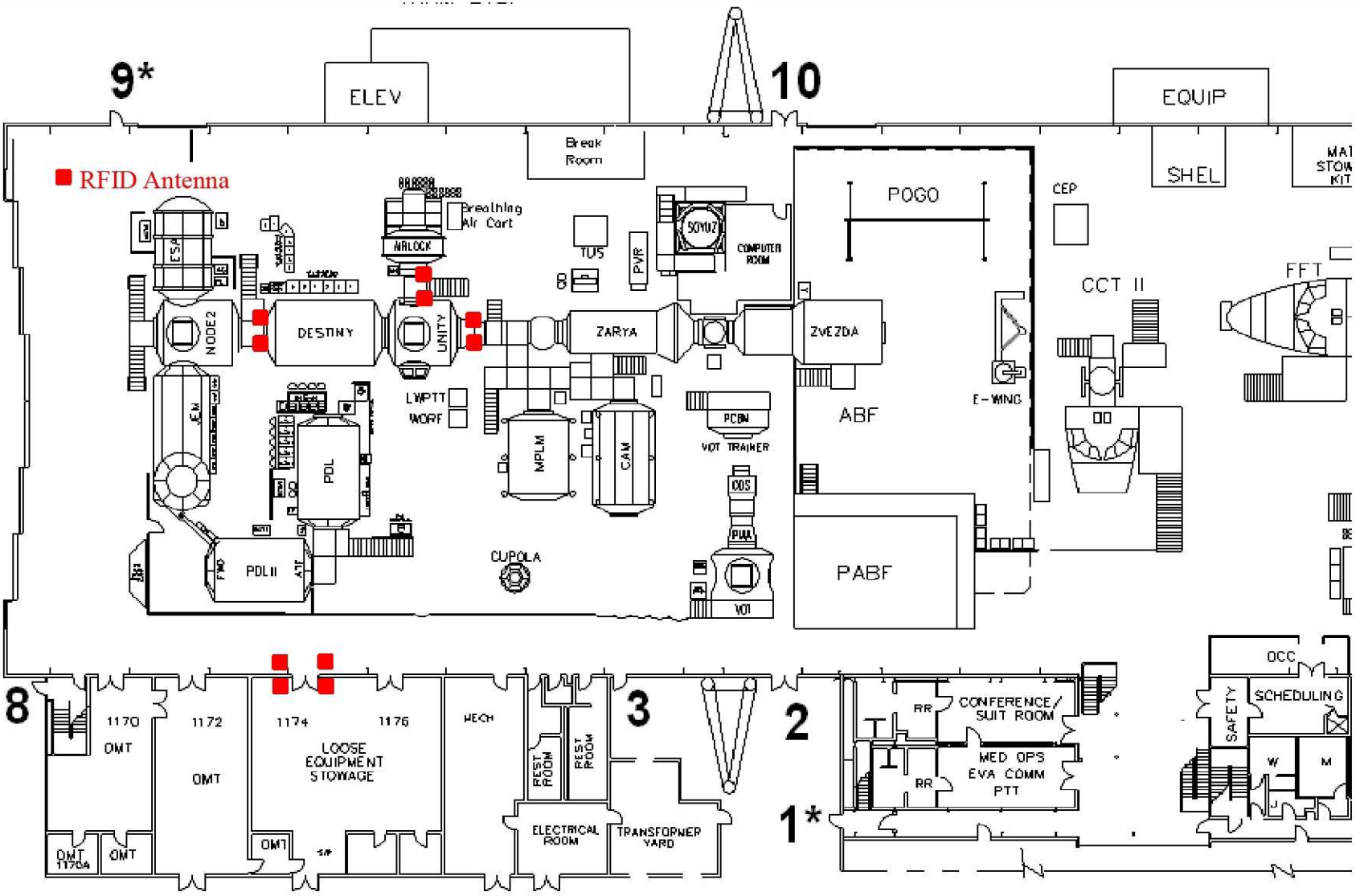
RFID Pilot: Targeted Area #1 - SVMF



RFID Pilot: Targeted Area #2 – Neutral Buoyancy Lab (NBL)

- **Description**
  - Track 1000's of tools, parts, and mockups into and out of the NBL pool
  - Multi-warehouse environment, complex scattering environment
  - Many entries and exits with large high-bay doors
  - Focus for pilot: track scuba tanks as they come in and out of elevator at 1st and 2nd floors

- **Benefits**
  - Even limited scope of scuba tanks will provide inventory management time savings
  - Scuba tanks traverse the same path with limited entry/exit points
    - Easy to track with two portals

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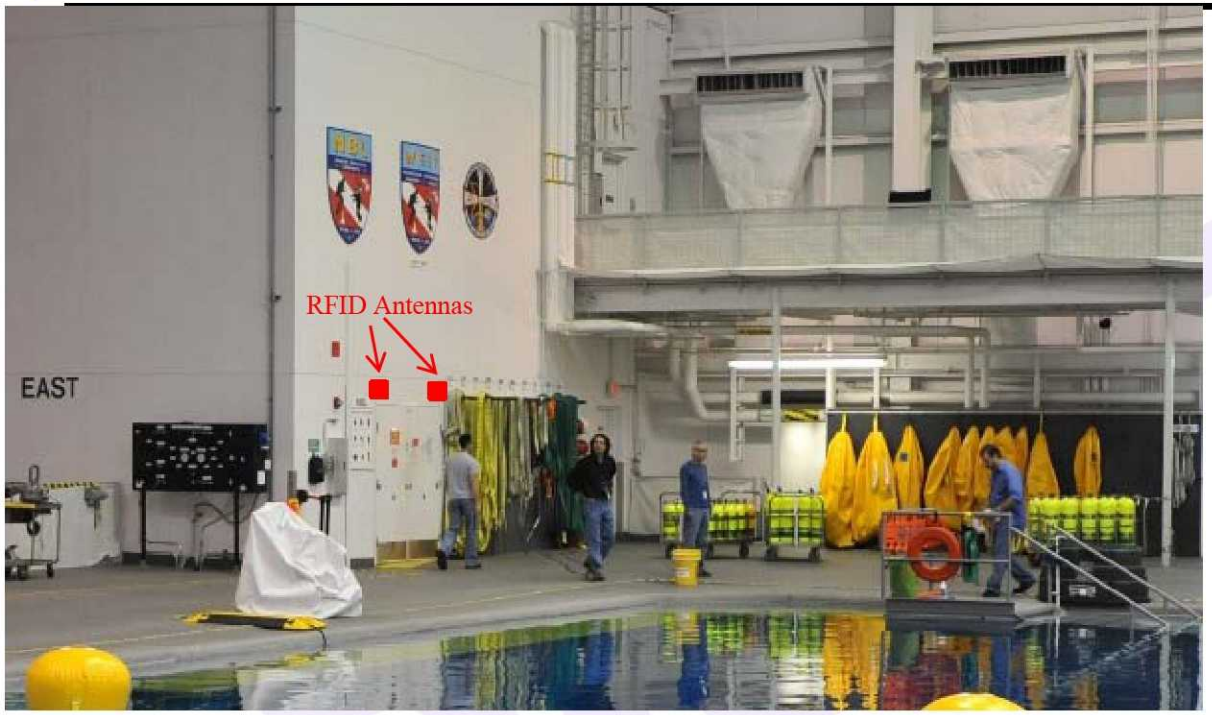
RFID Pilot: Targeted Area #2 - NBL



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RFID Enclosures

- Tested in various forms: trash receptacles, soft stowage, CTB carriers
- Read accuracies typically are > 95%, and are often near 100%
- Additional advantage compared to handheld interrogators: less likely to read tags in the surrounding environment; e.g., tags in other CTBs

CTB in RFID Enclosure

RFID Trash Container

Conclusion/Forward Work

- **ISS is moving forward with first operational RFID system for inventory audits**
  - Optical barcode scanning functionality is still retained
- **Integrated RFID system used to track transfers of tagged items over DTN network**
  - Control center displays are updated automatically upon restoration of a disrupted communication link
- **Several pilot programs underway for Center ground operations**
- **RFID Enclosure found to be highly accurate**
  - Benefits:
    - confines reads to interior tagged items
    - Less likely to cause interference to other systems

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Backup

ISS Inventory Management Present State

- ~ 10,000 items are tracked with the Inventory Management System (IMS) software application
- Hand-held optical barcode reader used for inventory audits
- Crew/Cargo Transfer Bags must have Ziploc bag contents removed, audited, replaced:
  - ~ 20 mins crew time,
  - 1 CTB/crew/day
- ~ 500 CTBs on ISS at any given time (2008)

Cargo Transfer Bags (CTBs)

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RFID Space Inventory Introduction: Handheld Readers

- **Handheld RFID readers are likely to be the first operational RFID system on ISS**
  - Will have dual barcode capability, also, to facilitate transition
- **Read accuracies < 100% for single CTB read, but fairly effective when reader scanned or "painted" around CTB exterior**
- **Requires 20s/CTB read and little vehicle infrastructure (battery powered with 802.11 capability)**
- **Tested on CTBs (10in. x 17in. x 9.5in) containing tagged Ziplock bags filled with tagged personal items (52 tags total)**
- **Tested on Ambulatory Medical Packs (AMPs - 12.5in. x 24.5in. x 8in.) with sub-kits filled with tagged pharmaceutical items (330 tags total)**

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Handheld RFID Reader Evaluation

Four commercially available readers tested by five different individuals (I1-I5):

CTB tags
(52 tags total)

	I1	I2	I3	I4	I5	average	%
Reader 1 30 dBm	48	48	49	48	48	48.2	92.7%
Reader 2 28 dBm	48	48	47	48	47	47.6	91.5%
Reader 3 30 dBm	42	42	44	45	43	43.2	83.1%
Reader 4 30 dBm	48	48	48	49	48	48.2	92.7%

AMP tags
(330 tags total)

	I1	I2	I3	I4	average	%
Reader 2 28 dBm	267	264	266	263	265	80.3%
Reader 3 30 dBm	122	125	130	120	124.3	37.7%
Reader 1 30 dBm	281	276	282	280	279.8	84.8%
Reader 4 30 dBm	245	239	238	226	237	71.8%

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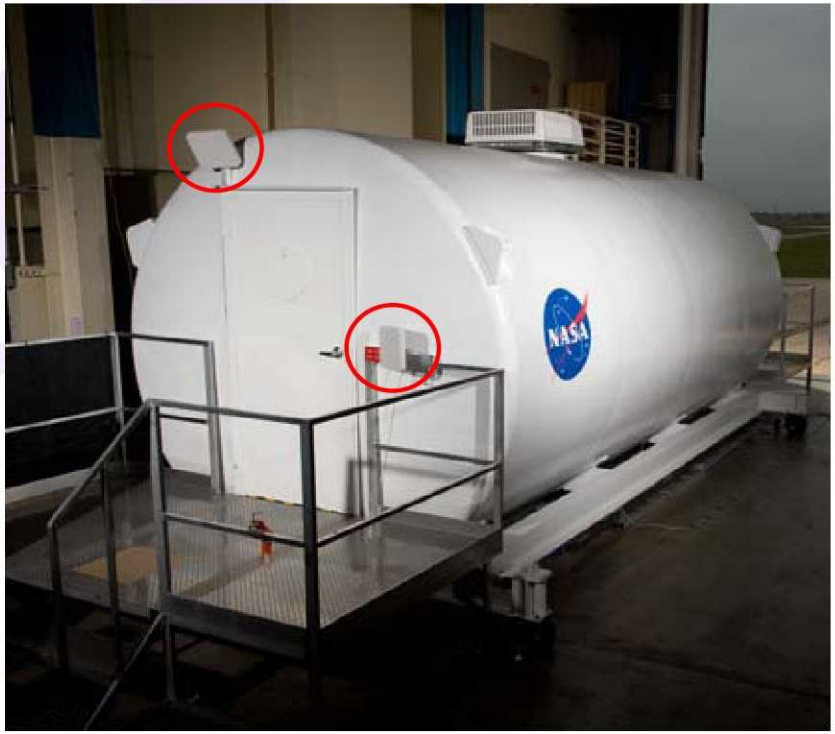
Portal-based RFID Inventory Management

- **More automation desired for viable RFID inventory system**
- **Portal-based interrogator reads CTBs entering/exiting habitat**
- **Requirements:**
  - High read accuracy
  - Low power (→ triggered operation)
  - Tag directionality determined
- **Four antenna system (two external, two internal) implemented in habitat mockup**
- **Pressure pad on porch used to trigger tag reads**



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RFID Portal Evaluation

- **CTB (52 tagged items) carried on left, right, and in front of test subject**
- **Reader tested in "continuously on" and "triggered" modes**
- **Transmit power of 30 dBm used for all tests**
- **CTB carried starting 40 feet out, pressure mat mounted five feet out**
- **Results averaged over five trials**

accuracy vs. position

	Avg. front	Avg. right	Avg. left
Item level	75.5%	75.3%	75.7%
Ziplock level	95.1%	94.7%	93.7%

accuracy vs. operation mode

	Avg. (triggered)	Avg. (continuous)
Item level	76%	75%
Ziplock level	95%	94%

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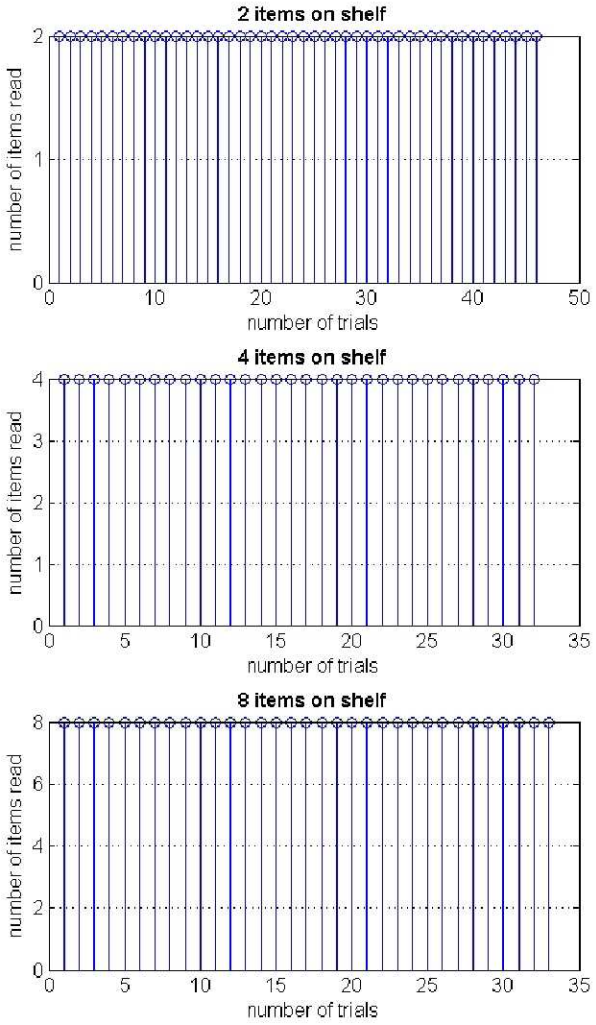
RFID “Smart” Shelves and Receptacles



RFID "Smart" Shelves and Receptacles

- **RFID reads on densely packed containers difficult**
  - high metal /liquid content esp. challenging
- **RFID smart containers can provide supplemental inventory data**
  - smart shelve: additive (log items into database as added)
  - smart trash can: reductive (remove items from database as containers discarded)
- **Testing of RFID trash can indicates near-100% read accuracy**
  - Ziploc bags, food vacuum packs, conductive drink pouches, battery packs, pharmaceuticals, etc.
- **Work on zero-g RFID trash can in progress**

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