Avionic Systems Division
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Automation of Space Inventory Management

Consultative Committee for Space Data Systems
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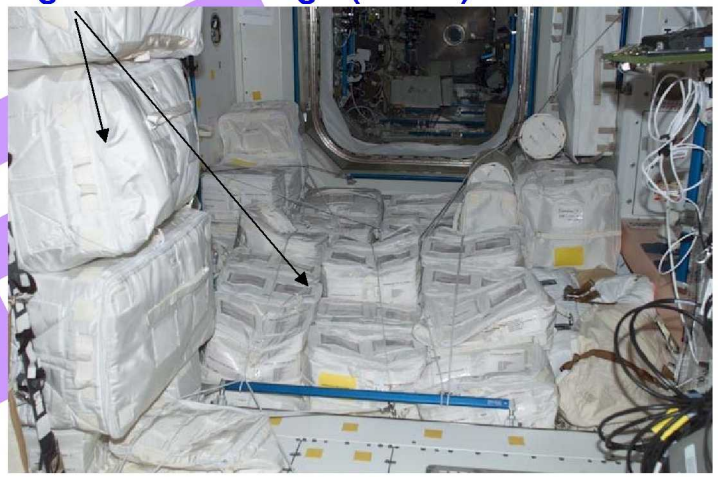
Overview

- **Space-Based Inventory Management**
  - Current state
  - Handheld RFID readers
  - RFID portal
  - RFID "Smart" Shelf
- **Real-Time RFID Location and Tracking**
  - Ultra-Wideband (UWB)
- **Surface Acoustic Wave (SAW) RFID**
- **Bionet Middleware**

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)



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)**

Handheld RFID Reader Evaluation

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

CTB tags
(52 tags total)

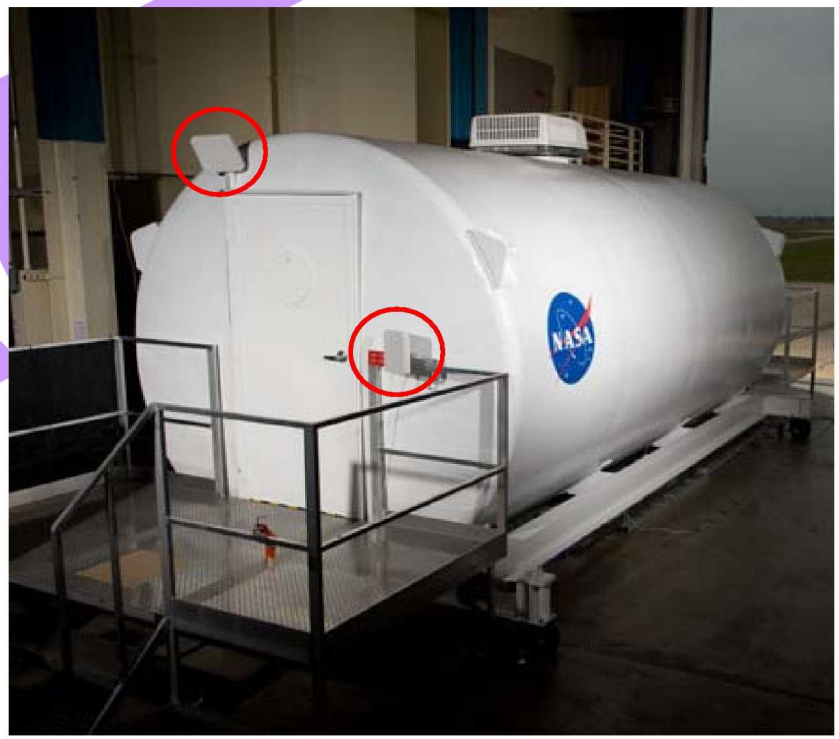
	I1	I2	I3	I4	I5	average	%
Reader 1 30 dBm	48	48	49	48	48	48.2	92.7%
Reader 2 28 dBm	48	48	47	48	47	47.6	91.5%
Reader 3 30 dBm	42	42	44	45	43	43.2	83.1%
Reader 4 30 dBm	48	48	48	49	48	48.2	92.7%

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%

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**



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

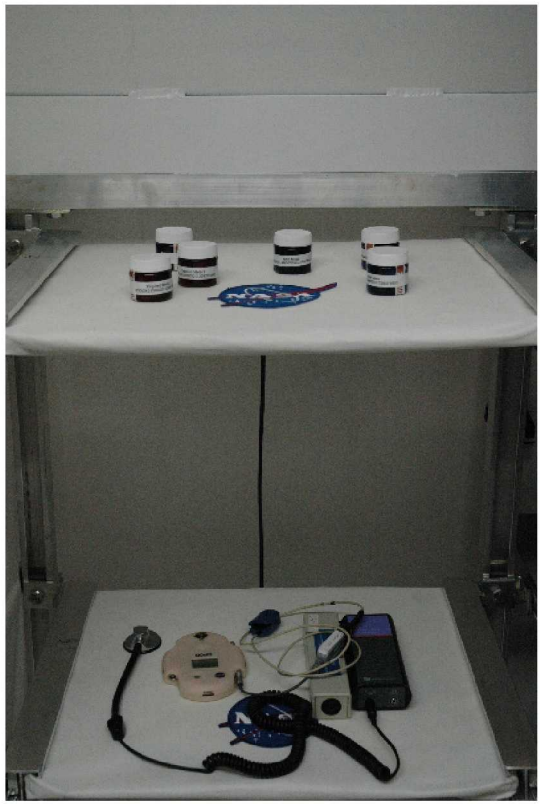
accuracy vs. position

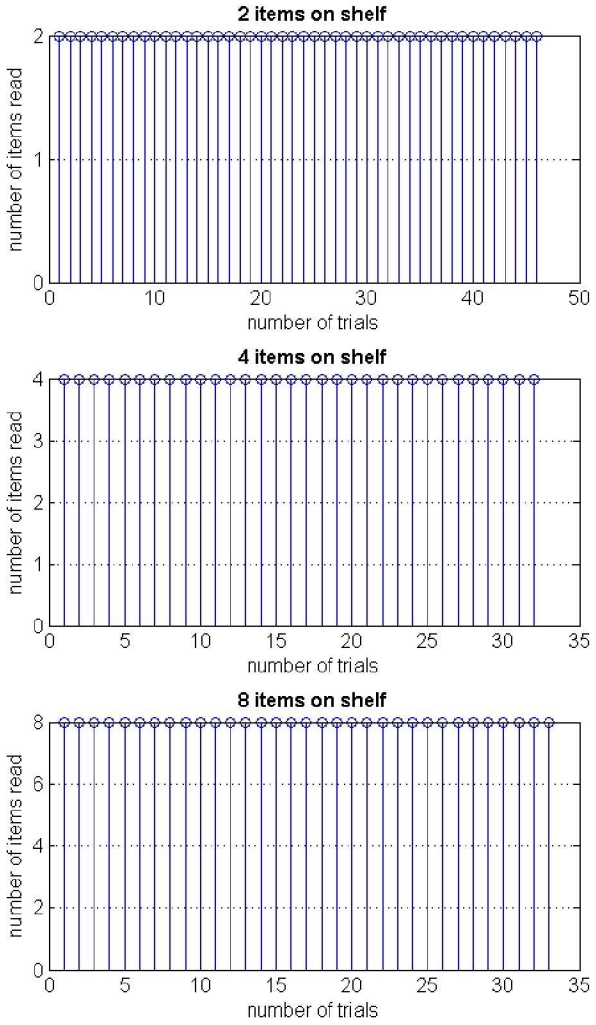
	Avg. front	Avg. right	Avg. left
Item level	75.5%	75.3%	75.7%
Ziplock level	95.1%	94.7%	93.7%

accuracy vs. operation mode

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

RFID "Smart" Shelves and Receptacles



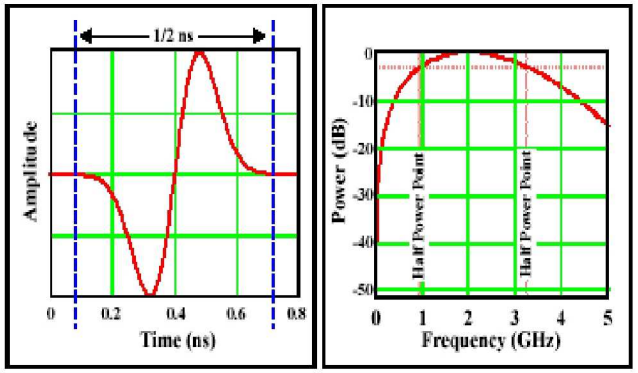


RFID "Smart" Shelves and Receptacles

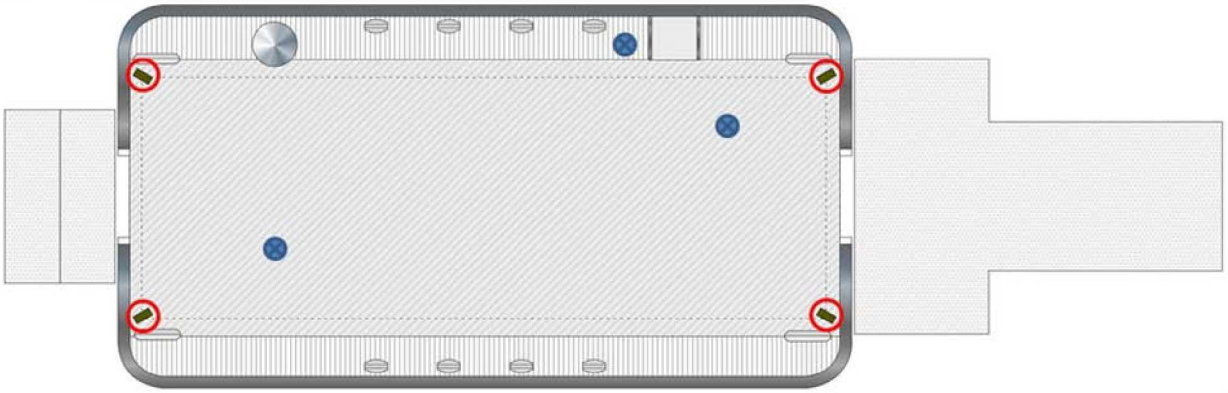
- **RFID reads on densely packed containers difficult**
  - high metal /liquid content esp. challenging
- **RFID smart containers can provide supplemental inventory data**
  - smart shelve: additive (log items into database as added)
  - smart trash can: reductive (remove items from database as containers 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**

RFID for Real-Time Location and Tracking

- **Ultra-Wideband (UWB) active-tag RFID technology**
  - Transmits sub-nanosecond, high bandwidth impulses (~GHz)
  - low power spectral density make system non-interfering
  - short pulses reduce fading and multipath effects
- **Tested UWB real-time location system (Sapphire DART by Multispectral Solutions)**
- **UWB tags are transmit-only devices**
  - each sends unique pulse-train ID (one pulse/second)
  - 30cm (1 ft.) tracking accuracy
  - read ranges up to 90 m
  - tag battery life > 7 yrs



UWB impulse signal (time and freq.)



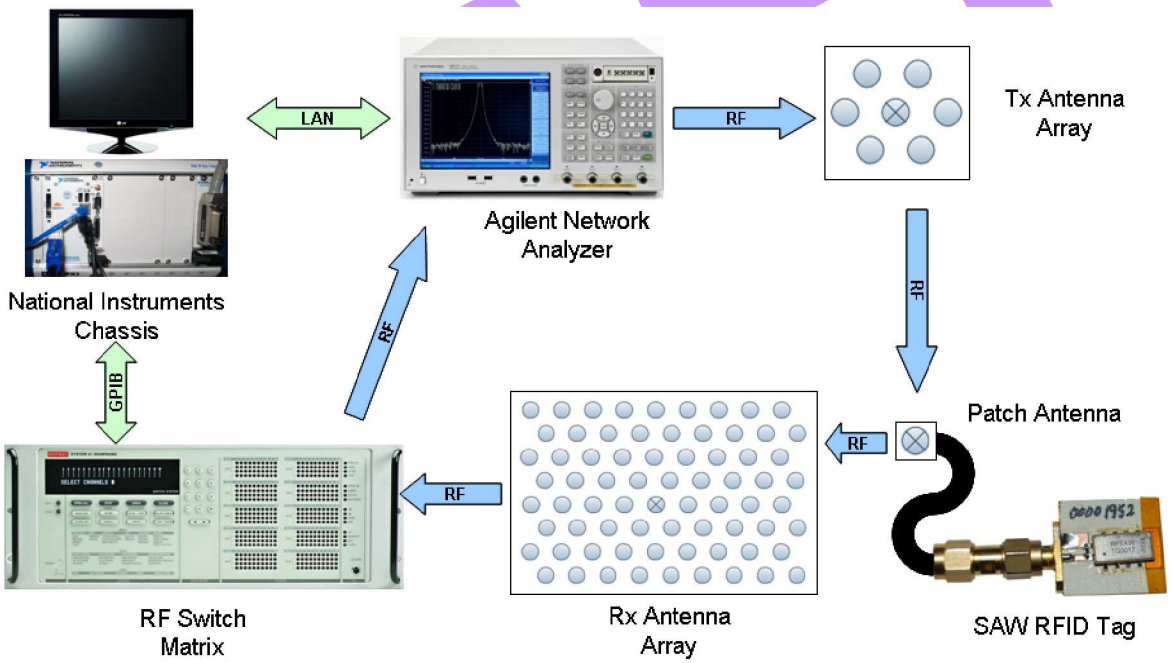
Surface Acoustic Wave (SAW) RFID

- **SAW RFID tags do not rectify incident electromagnetic power**
  - modulate , re-radiate interrogation signal using series of reflectors
  - operate at much lower interrogator transmit power, much longer range (compared to IC tags)
  - can incorporate telemetry readings (e.g., temperature)
  - tolerate temperature, radiation, shock better than IC tags

- **SAW tags being investigated for planetary ops support (Passive Adaptive RFID Sensor Equipment - PARSEQ)**
  - sensing surface of habitation module remotely
  - interrogating lunar road signs, dropping "breadcrumbs" for navigation
  - locating expended equipment in salvage yards
  - tracking crew/vehicles in habitat proximity
  - providing navigation aids to landers

Custom SAW Tag Interrogator

- Ranges over 100 feet achieved with 100 mW transmit power
- Digital adaptive beamforming to enable multi-cluster interrogation
- Over 10 tags read per cluster
- Angle-of-arrival, range, and temperature returned from SAW tag



BioNet Middleware

- **Long-term habitat operations likely will entail:**
  1. both wired and wireless data-producing hardware
  2. all hardware requirements **not** known a priori

- **NASA Command, Control, Communications, and Information (C3I) Interoperability specification proposes an architecture to co-ordinate operations among subsystems developed by many different sources**

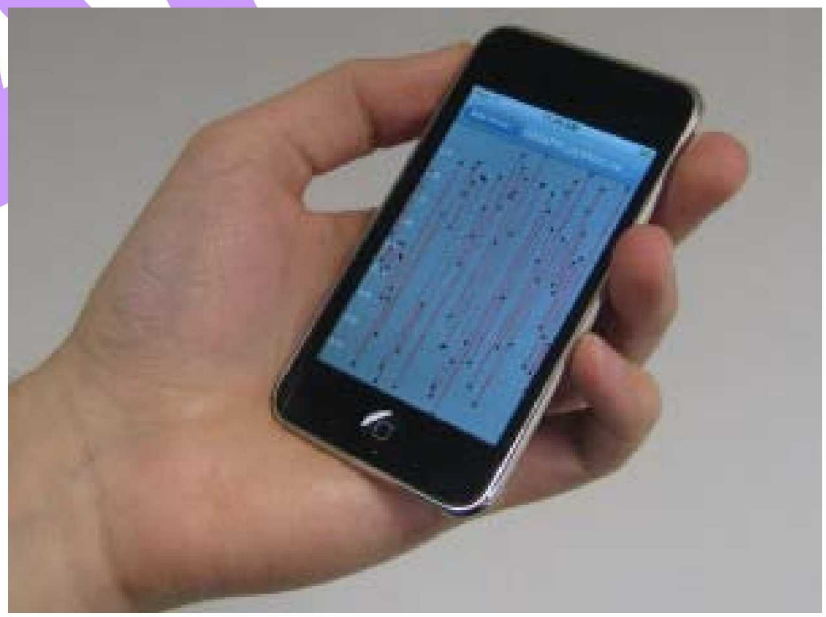
- **BioNet middleware is preliminary C3I instantiation used in NASA-JSC lunar habitat wireless test bed:**
  - integrates wired/wireless data-producing hardware
  - provides application development framework to separate design of data production and data consumption subsystems

BioNet Middleware

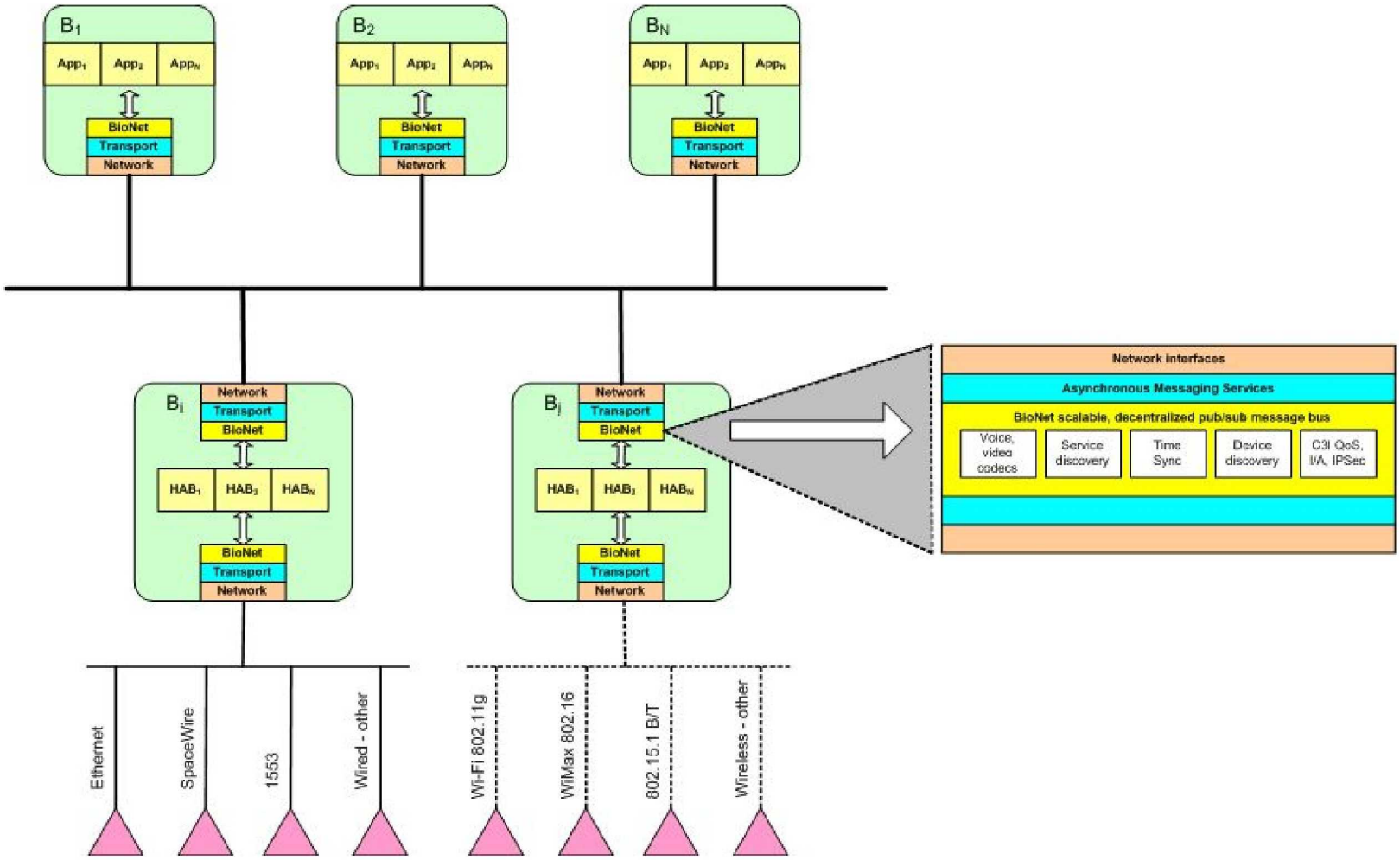
- BioNet focuses on enabling a "system of systems"
- Provides publish/subscribe asynchronous messaging between distributed applications and distributed data-generating endpoint sensors/systems
- Facilitates incorporation of heterogeneous wired and wireless sensing/control devices into unified data system with standardized application interface

BioNet Middleware

- **Provides software development framework, standard services, and network communications for distributed applications**
- **Hides complexity of (heterogeneous) network communication from developers who want read/write without regards to lower-layer communications specifics**
- **Provides critical integrated system services:**
  - naming
  - device discovery
  - service discovery
  - security
  - data compression
  - data grouping



BioNet Middleware



Conclusion/Forward Work

- **Desire to have as much functionality as possible with as few RFID protocols/interrogators required**
  - On-going work for real-time location using EPCglobal Class 1, Gen 2 (UHF)
- **Handheld RFID technology provides acceptable accuracy when "painted" over CTB**
- **RFID trash receptacle appears promising for wrapper tracking**
  - Near 100% accuracy
- **Battery-power UWB RFID tags and system provides 12 inch accuracy**
  - Possible use for larger, critical items
- **SAW-based RFID could find niche applications for NASA**
  - Longer range and extreme environments (e.g., lunar surface, ground facilities)
  - Capability to provide sensor telemetry
- **BioNet middleware has proven highly effective for integration of a large number of disparate devices and networks**