"Fly-by-Wireless" and Wireless Sensors Update
JANNAF Wireless Sensors Workshop
Apr 16-17, 2009

Example Shown:
Orbiter Wing Leading Edge
Impact Detection System

NASA/JSC/ES/George Studor
(763) 208-9283

- Vision/Problem
- Vehicle Architectures
- Add-on Instrumentation
- Common Ground

What Does the Aerospace Industry have in common?

Wires

Aviation	↔	Space
Aircraft	wires ↔	Manned Spacecraft
Helicopters	wires ↔	Launch/Landing Systems
Unmanned Aerial Vehicles	wires ↔	Unmanned Spacecraft
Internal/External Robots	wires ↔	Internal/External Robots
Balloons	wires ↔	Inflatable Habitats
Crew/Passenger/Logistics	wires ↔	Crew/Scientists/Logistics
Jet Engines	wires ↔	Rocket Engines
Airports/Heliports	wires ↔	Launch Sites
Engineering Validation	wires ↔	Engineering Validation
Ground Support	wires ↔	Ground Support

Petro-Chemical Plants, Transportation Vehicles & Infrastructure, Biomedical, Buildings, Item ID and Location tracking

What do these have in common?

1. **Data, Power, Grounding Wires and Connectors for: Avionics, Flt Control, Data Distribution, IVHM and Instrumentation.**
2. **Mobility & accessibility needs that restrict use of wires.**
3. **Performance issues that depend on weight.**
4. **Harsh environments.**
5. **Limited flexibility in the central avionics and data systems.**
6. **Limited accessibility**
7. **Design issues to place wires early and design avionics.**
8. **Manufacturing, grnd/flight test**
9. **Operations & Aging Problems**
10. **Civilian, Military, Academic & International Institutions.**
11. **Life-cycle costs due to wired infrastructure.**
12. **Need for Wireless Alternatives!!**

"Fly-by-Wireless"

(What is it?)

Vision:

To minimize cables and connectors and increase functionality across the aerospace industry by providing reliable, lower cost, modular, and higher performance alternatives to wired data connectivity to benefit the entire vehicle/program life-cycle.

Focus Areas:

1. **System Engineering and Integration to reduce cables and connectors.**

2. **Provisions for modularity and accessibility in the vehicle architecture.**

3. **Develop Alternatives to wired connectivity (the "tool box").**

“Fly-by-Wireless” Update

NASA/JSC “Fly-by-Wireless” Workshop	10/13/1999
USAF Reserve Report to AFRL	11/15/1999
DFRC Wireless F-18 flight control demo - Report	12/11/1999
ATWG “Wireless Aerospace Vehicle Roadmap”	2/12/2000
Office of naval Research	2/16/2000
NASA Space Launch Initiative Briefing	8/7/2001
World Space Congress, Houston	3/8/2002
International Telemetry Conference	4/6/2004
VHMS TIM at LaRC	5/11/2004
CANEUS 2004 “Wireless Structural Monitoring Sensor Systems for Reduced Vehicle Weight and Life Cycle Cost”	10/28/2004
Inflatable Habitat Wireless Hybrid Architecture & Technologies Project:	9/2006
CANEUS 2006 “Lessons Learned Micro-Wireless Instrumentation Systems on Space Shuttle and International Space Station”	9/2006
CANEUS “Fly-by-Wireless” Workshop to investigate the common interests (applications/end-users and technologies) and discuss future plans.	3/27/2007
NASA/AIAA Wireless and RFID Symposium for Spacecraft, Houston	May, 2007
AVSI/other intl. companies organize/address the spectrum issue at WRC07	Nov 2007
Antarctic Wireless Inflatable Habitat, AFRL-Garvey Space Launch Wireless	July 2008
RFIs in NASA Tech Briefs, Constellation Program Low Mass Modular Instr	May/Nov 2008
Gulfstream demonstrates “Fly-by-Wireless” Flight Control	Sep 2008
AFRL announces “Wireless Spacecraft” with Northrup-Grumman	Mar 2009
CANEUS “Fly-by-Wireless” Workshop – Canadian Sponsors in Montreal	June 2009

Working Together – We can't do it alone

- **Within Johnson Space Center**: Engineering Directorate, Mission Ops, Facilities

- **Within NASA**: Space Shuttle, International Space Station, EVA, Constellation, Safety and NESC, Aeronautical IVHM/Test, Science Mission – Spacecraft/Robotics, KSC and other Facilities, HQ Innovative Partnership Program (SBIR/STTR, etc).

- **External to NASA**:
  - CCSDS Wireless Working Group (international standards)
  - AVSI WAIC Project to obtain dedicated spectrum.
  - ISA100 – Industrial low power wireless standards
  - AF/DOD – Space Experiments – Plug-n-Play/Wireless Spacecraft
  - CANEUS – Montreal-based international consortium incubator
  - University Programs and Space Grant Offices
  - National Labs – Sandia, Oak Ridge, PNNL, etc.
  - Working Groups,Workshops, Conferences, Individual Corporation Visits, Telecons and partnership development.

Motivation: Cost of Wired Infrastructure

- **Expenses for Cabled Connectivity** begin in Preliminary Design Phase and continue for the entire life cycle.

- **Reducing the quantity and complexity** of the physical interconnects has a payback in many areas.

  1. **Failures of wires, connectors** and the safety and hazard provisions in avionics and vehicle design to control or mitigate the potential failures.

  2. **Direct Costs**: Measurement justification, design and implementation, structural provisions, inspection, test, retest after avionics r&r, logistics, vendor availability, etc.

  3. **Cost of Data not obtained:** Performance, analyses, safety, operations restrictions, environments and model validations, system modifications and upgrades, troubleshooting, end of life certification and extension.

  4. **Cost of Vehicle Resources:** needed to accommodate the connectivity or lack of measurements that come in the form of weight, volume, power, etc.

  5. **Reliability Design Limitations**: avionics boxes must build in high reliability to "make up for" low reliability cables, connectors, and sensors. Every sensor can talk to every data acquisition box, and every data acquisition box can talk to every relay box -backup flight control is easier.

Motivation: The Cost of Wired Infrastructure

6. **Physical Restrictions:** Cabled connectivity doesn't work for monitoring: structural barriers limit physical access and vehicle resources, the assembly of un-powered vehicle pieces (like the ISS), during deployments (like a solar array, cargo/payloads, or inflatable habitat), crew members, robotic operations, proximity monitoring at launch, landing or mission operations.

7. **Performance**: Weight is not just the weight of the cables, it is insulation, bundles, brackets, connectors, bulkheads, cable trays, structural attachment and reinforcement, and of course the resulting impact on payloads/operations. Upgrading various systems is more difficult with cabled systems. Adding sensors adds observability to the system controls such as an autopilot.

8. **Flexibility of Design:** Cabling connectivity has little design flexibility, you either run a cable or you don't get the connection. Robustness of wireless interconnects can match the need for functionality and level of criticality or hazard control appropriate for each application, including the provisions in structural design and use of materials.

9. **Cost of Change**: This cost grows enormously for as each flight grows closer, as the infrastructure grows more entrenched, as more flights are "lined-up" the cost of delays due to trouble-shooting and re-wiring cabling issues is huge.

1.Motivation: Cost of Change for Instrumentation

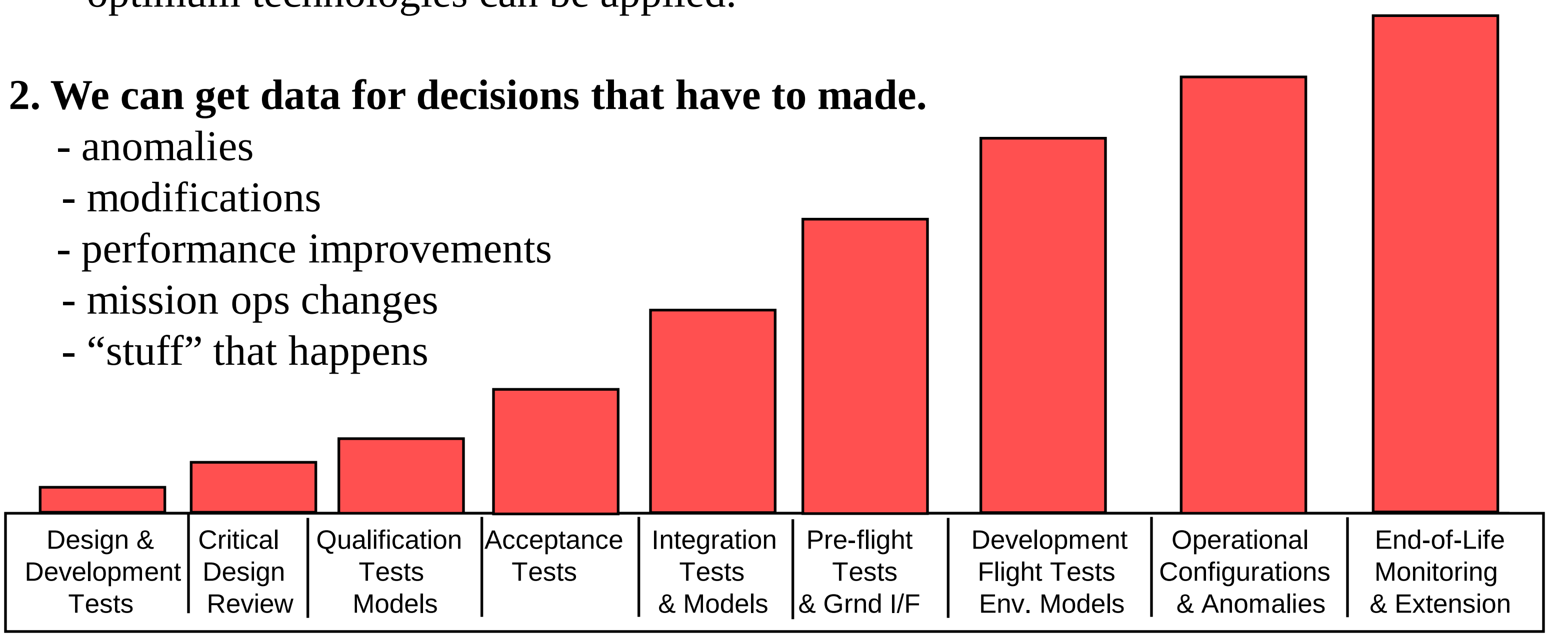
2.The earlier conventional instrumentation is fixed, the greater the cost of change.

- Different phases uncover and/or need to uncover new data and needs for change.
- Avionics and parts today go obsolete quickly - limited supportability, means big sustaining costs.
- The greater number of integration and resources that are involved, the greater the cost of change.
- Without developed/test systems and environments, many costly decisions result.

We need to design in modularity and accessibility so that:

1. We can put off some decisions until:
- sufficient design, tests/analysis can be made.
- optimum technologies can be applied.

2. We can get data for decisions that have to made.
- anomalies
- modifications
- performance improvements
- mission ops changes
- "stuff" that happens



Motivation: Reliability

Vehicle Reliability Analyses must include: the End to End system, including man-in-the-loop operations, and the ability to do effective troubleshooting, corrective action and recurrence control.

With Wireless Interconnects, the overall Vehicle Reliability is Increased:

Through Redundancy: All controllers, sensors, actuators, data storage and processing devices can be linked with greater redundancy. A completely separate failure path provides greater safety and reliability against common mode failures.

Through Structural and System Simplicity: Greatly reduced cables/connectors that get broken in maintenance, must be trouble-shot electronics problems, sources of noisy data and require structural penetrations and supports.

Through Less Hardware: Fewer Cables/Connectors to keep up with

Through Modular Standalone Robust Wireless Measurement Systems: These can be better focused on the system needs and replaced/upgraded/reconfigured easily to newer and better technologies. Smart wireless DAQs reduce total data needed to be transferred.

Through Vehicle Life-Cycle Efficiency: Critical and non-critical sensors can be temporarily installed for all kinds of reasons during the entire life cycle.

Through the Optimum Use of Vehicle and Human Resources: With the option of distributed instrumentation and control managed with much less integration needed with the vehicle central system, both system experts, hardware and software can concentrate on their system performance, instead of integration issues.

Motivation: Safety

- Reduced time to respond to unsafe conditions where wiring is involved or where monitoring is needed.
- Increased options for Sensing, Inspection, Display and Control.
- Fewer penetrations, wiring and operations support hazards.
- Better upgrade opportunities correct for safety deficiencies.

"Fly-by-Wireless" Focus Areas

(1) System Engineering and Integration to reduce cables and connectors,

- Capture the true program affects for cabling from launch & manned vehicles
- Requirements that enable and integrate alternatives to wires
- Metrics that best monitor progress or lack of progress toward goals.
(# cables, Length, # of connectors, # penetrations, overall weight/connectivity)
- Design Approach that baselines cables only when proven alternatives are shown not practical - use weight and cg until cabling can be proven needed.

(2) Provisions for modularity and accessibility in the vehicle architecture.

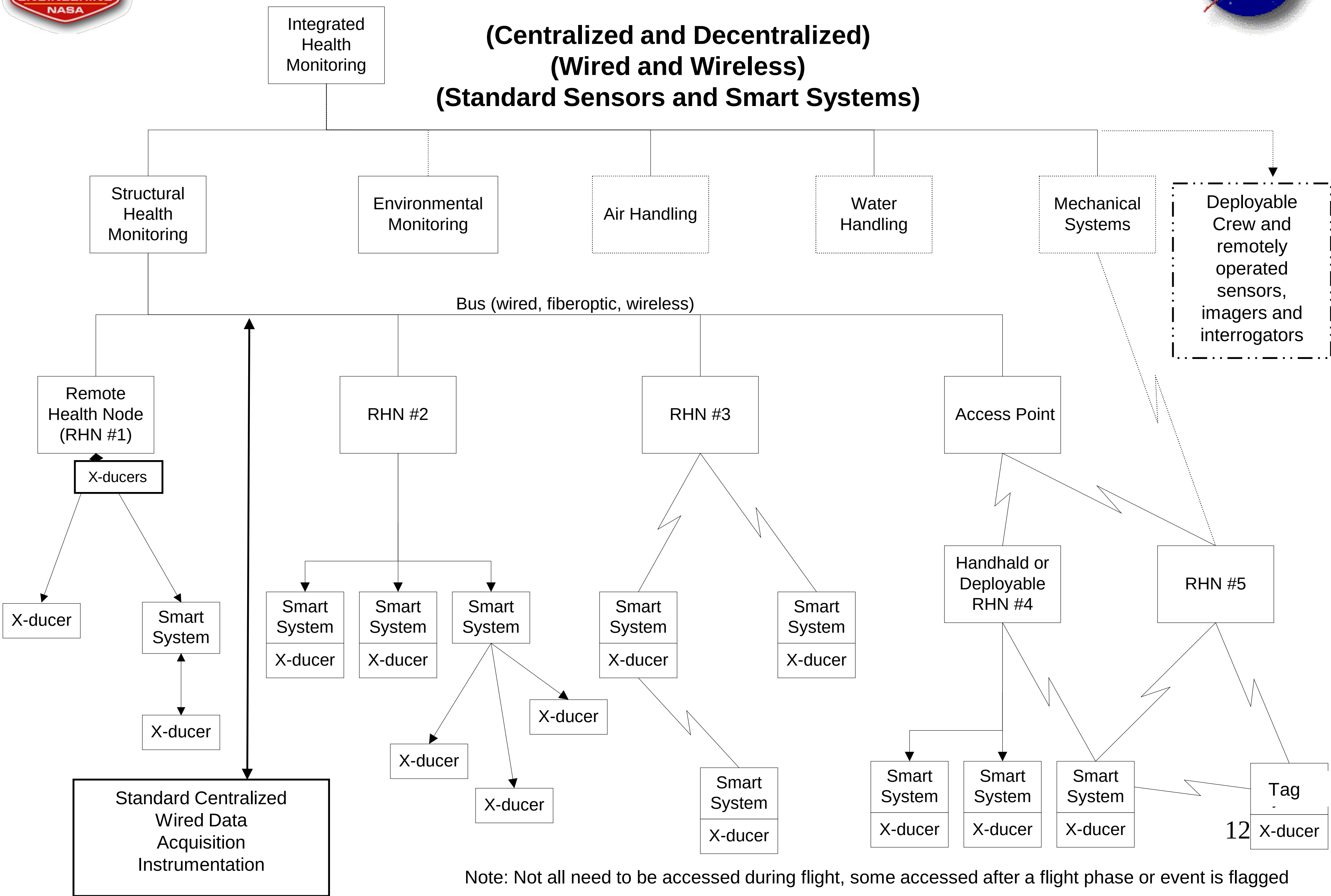
- **Vehicle Zones** need to be assessed for accessibility – driven by structural inspections, system assembly, failure modes and inspections, and system and environment monitoring and potential component trouble-shooting, remove & repair.
- **Vehicle Zones** need to be assessed for resource plug in points to access basic vehicle power, two-way data/commands, grounding and time (not all zones get it).
- **Centralized & De-centralized approaches** are available for measurement & control.
- **Entire life-cycle** needs to be considered in addition to schedule, performance, weight.

(3) Develop Alternatives to wired connectivity for the system designers and operators.

- Multi-drop bus-based systems
- Wireless no-power sensors/sensor-tags
- Standalone robust wireless data acquisition
- Standard interfaces & operability
- Wireless controls – back-up or low criticality
- Robust high speed wireless avionics comm.
- Data on power lines
- No connectors for avionics power
- Robust Programmable wireless radios
- Light wt coatings, shielding, connectors
- RFID for ID, position, data, & sensing.
- Inductive coupling for rechargeables

Challenge: Why Can't Wireless connectivity be made to be as reliable as a wire??

Conceptual Hybrid SMS Architecture for Future Space Habitats



Note: Not all need to be accessed during flight, some accessed after a flight phase or event is flagged

Current Fly-by-Wireless Technology Development at NASA JSC

- Wing Leading Edger Impact Detection System
- Distributed Impact Detection System
- Distributed Leak Detection System
- Crew Seat Vibration Monitoring System
- Short Range RFID Tags for ISS Inventory Systems
- Long Range Passive Sensor Tags: Temp, Pressure, Acceleration, Acoustic Emission, Position
- Plug-in-Play for Wireless systems (Standards based, Non-standards based)
- Scavenge Power, Rechargeable Systems and safe/high density Primary Batteries
- Test/Evaluation of various off-the-shelf standalone/networked wireless DAQs
- Wireless Position Determination
- Wireless Video and Evaluation of 60 GHz – HD Video
- Software Defined Radio
- Development of MIMO Networks based on evolving industry standards(ISA100, Zigbee).
- Networking/Building Teams in Industry/Other Government - Discussing Vision, Stimulating Partnering, Working on Standards and Developing and Evaluating Specific Technologies.

Current Manned Spaceflight Challenges

- <u>Space Shuttle</u>: monitoring for safety of flight thru end of program

- <u>ISS</u>: drag-thru cables that impeded rapid hatch closures, increased scope of on-orbit structural validation, rapid module leak location system, long term maintainability.

- <u>Constellation:</u> program cost/schedule, ground test instrumentation, development flight test instrumentation, operational instrumentation, weight reduction, lunar site maintainability and tools, lunar dust effects on connectors, standardization of wireless interfaces and systems.

NASA Human Space-flight Programs

Fly-by-Wireless Technology Development/Application Thrusts

1/2009 1/2012 1/2015 1/2018

Space Shuttle

Wireless LAN, EVA,GPS etc,
Add-on Instrumentation

ISS

Add-on Int/Ext Instrumentation, Wireless LAN/Services, Inventory, Flt Tests

Cxp Test

Add-on DFI, Wireless Standards & Interoperability, Passive Sensor-Tags, Facilities

Orion **Orion Block 2?**

Add-on Instrumentation, Wireless LAN, Inspection, Modular Instr back-bone

Ares 1 **Ares V**

Add-on Instrumentation Modular Instrumentation

Altair Lander

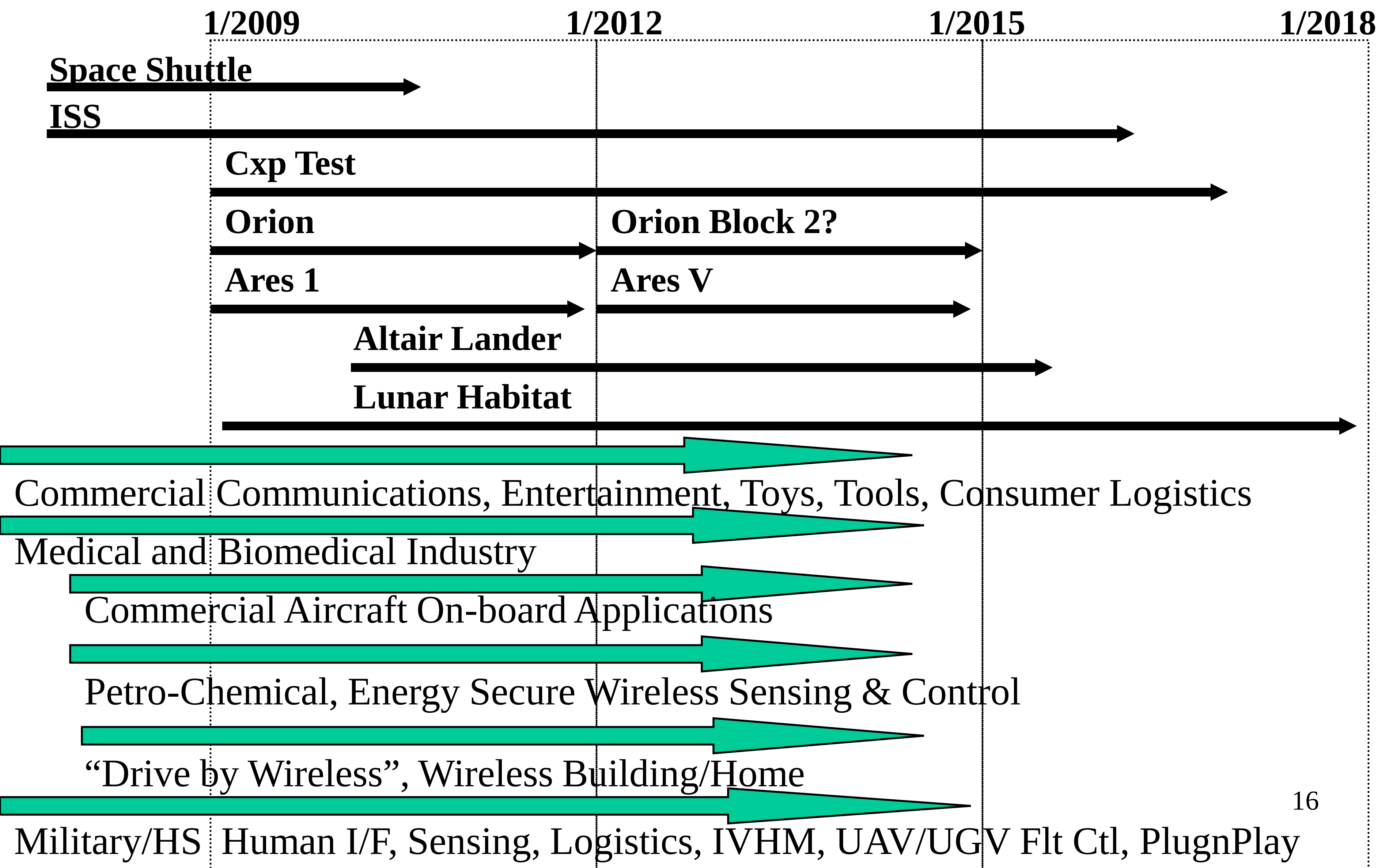
Add-on/Modular Instr, Wireless back-up controls for non-critical systems

Lunar Habitat

Modular Instrumentation and displays, sensor feeds to non-critical systems, back-up safety-related sensing, some primary controls for non-critical systems, robotic controls, Extensive Lunar Surface System EVA/Robotic/Sensor network

NASA Fly-by-Wireless Technology Development

Must Leverage Work with Major Industry Sectors



Constellation Program
Low Mass Modular
Add-On Instrumentation

RFI

16--LOW MASS MODULAR DEVELOPMENT FLIGHT INSTRUMENTATION SYSTEMS
Solicitation Number: FL-1
Agency: National Aeronautics and Space Administration
Office: Dryden Flight Research Center
Location: Office of Procurement

POC: Mauricio Rivas, George Studor

CxP Low Mass Modular Instrumentation

Problem: The measurements we want are hard to get when we need them. They aren't in the contracts, so they cost time & money to get, and impact performance, cost, maybe safety if we don't.

Why?

• If it is off-vehicle, we usually have to use a lot of wires and there is a lot of overhead with wiring.

• If it is on-vehicle or interfaces with the vehicle on the ground, we have to integrate the system into the vehicle and operate it remotely.

• If it needs to be a part of the vehicle systems, we have to develop the measurement systems in parallel with the basic vehicle.

• That means we don't know all we will need to measure when we specify the measurement systems.

Solution: Standalone Add-on Measurement Systems/Team

Low Mass Modular Instrumentation Forward Plan

1. Capture what we have done, what we are doing, what we know.
2. Define what we think we are looking for.
3. Look for/at what is out there.
4. Build the database.
5. Build the in house inventory – or know where it is.
6. Test the systems or have them demonstrated to/for us on site.
7. "Kit-up" the system as is & define what it is ready to do/where.
8. Field test selected systems that hold more promise of near term applications in ground or flight vehicle tests.

Low Mass Modular Instrumentation – CxP RFI

What are some our Goals?

• Maximize total useable data return for validation of vehicle, environment & ops.
• Minimize total mass and size required to make non-critical measurements.
• Minimize need for power, active cooling, comm or other vehicle resources.
• Minimize integration and operations, unique mods. installation and checkout..
• Minimize ground installation/servicing and mission operations required.
• Minimize life-cycle costs compared to conventional measurement systems.
• Maximize measurement system responsiveness, modularity, interoperability.
• Minimize effort to establish RF, EMI and EMC certification for flight.
• Minimize reliance on single vendors by the use of common standards.
• Minimize need for data transfer and vehicle data storage provisions.
• Maximize reliability/probability of obtaining the desired data.
• Minimize impact to vehicle/crew safety, reliability and mission success.

Low Mass Modular Instrumentation – CxP RFI

What are some Technology Objectives to help us reduce mass and life cycle costs?:

(1) Micro-size and minimum weight, including connectivity.
(2) Very low power, low maintenance, long-life between servicing.
(3) Least number of wires/connectors required, including wireless or no connectivity.
(4) Minimum integration and operations to achieve for modularity.
(5) Smart DAQs with User Specifiable calibration, scheduled and even-triggered modes.
(6) Smart DAQs with Processing/Storage allowing reduction of total data transfer.
(7) Robust/Secure Wireless networking and synchronization between DAQs and even between sensor and DAQ.
(8) Plug-and-play wireless interoperability.
(9) Plug-and-play DAQ to avionics integration.
(10) Open architecture standards to promote multiple vendors with competitive solutions.
(11) Wide variety of data acquisition rates – 1 sample per hour to 1 megasample/sec
(12) Robustness with respect to projected environments.
(13) Wide variety of sensor types such as: temperature, dynamic and quasi-static acceleration, dynamic and static strain, absolute and dynamic pressure, high rate acoustic pressure, calorimeters, dosimeters, radiometers, shock, air flow, various hand-held sensors etc.

Low Mass Modular Instrumentation Forward Plan

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Add-on Measurement Systems
Solving Real-World Problems for Shuttle & Space Station

• **ISS Assembly** – Thermal limits too close for some avionics boxes during assembly and prior to hook-up… No power/data path available. External temperatures were needed for boxes in near real time.
Result: Wireless Data Acquisition System DTO leading to **Shuttle-based WIS(SWIS) for P6 & Z1.**

• **ISS Structural Loads/Dynamics i**s different at every assembly step, so relocatable stand-alone accelerometer data acquisition units were needed to be RF time-synchronized, Micro-G sensitive.
Result: Internal WIS(IWIS) was first flown on STS-97 and is still in use today.

• **Shuttle Temp Monitoring** – Validation of thermal models became important for design of modifications and operations, but the cost of conventional wire/data acquisition was prohibitive.
Result: Micro-WIS was developed by SBIR, first flown in a non-RF configuration.

• **Shuttle Structural Loads and Dynamics Concerns** – SSME support strut strain data needed to refine certification life predictions for related parts.
Result: Micro Strain Gauge Unit (Micro-SGU). **and Micro-Tri Axial Accelerometer Units (Micro-TAU**) for Cargo to Orbiter Trunion Dynamics/Loads.

• **Shuttle SSME Feed-line Crack Investigation:** High data rates, RF synchronization and more storage needed to see how Main Propulsion System flow-liner dynamics affect SSME Feed-line Cracks. **Result: Wide-band Micro-TAU (WBMicro-TAU).**

• **Shuttle Impact Sensors** were needed to determine if and where the Orbiter Wing Leading Edge has been impacted by debris. **Result: Enhanced Wideband Micro-TAU (EWB Micro-TAU**).

• **SRMS On-Orbit Loads were increased** because of contingency crew EVA repairs at the end of the boom - extension of the SRMS arm. **Result: Wireless Strain Gauge Instrumentation System (WSGIS) and Instrumented Worksite Interface Fixture (IWIF)** – EWBMTAU/Triax MEMS Accels (DC to 200hz)

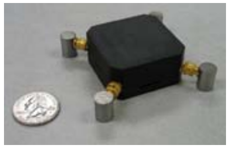
  • **Also used for measuring Shuttle Forward Nose area dynamics during roll-out (10 hours)**

• **ISS MMOD Impact/Leak Monitoring** is needed for high risk modules to reduce time necessary to locate a leak to vacuum so that it can be repaired. **Ultrasonic WIS (UltraWIS), DIDS, & DLDS SBIRs**

Standalone Wireless Instrumentation for Shuttle/ISS

Evolution of Micro-WIS Systems (page 1)

Micro-WIS XG



System	MicroWIS (SBIR)	Extended Life MicroWIS	MicroSGU / MicroTAU	Wideband MicroTAU	Enhanced WB MicroTAU	Ultra-sonic WIS (SBIR)	DIDS (Phase 2 SBIR)
Date Certified	1997	2001	2000/2001	2002	2005	2007	2008
Purpose	IVHM	Thermal Models	Cargo Loads Cert Life Extension	MPS Feedline Dynamics	Wing Leading Edge Impacts	ISS Impact/Leak Monitoring	Structure Borne AE Leak Detection
Dimensions	1.7” dia. x 0.5”	2.7”x2.2”x1.2”	2.7”x 2.2” x 1.2”	3.0”x 2.5” x 1.5”	3.25”x2.75”x 1.5	3.4” x2.5”x 1.1”	1.7”x1.7”x.78”
Sample Rate	Up to 1Hz	Up to 1Hz	Up to 500Hz (3 channels)	Up to 20KHz (3 channels)	Up to 20KHz (3 channels)	Up to 100KHz (10 channels)	Up to 950KHz (on ea of 4 chnls)
Data Sync	No	No	Yes	Yes	Yes	Yes	Yes
Data Storage	None	2Mbytes	1Mbyte	256Mbytes	256Mbytes	1Mbyte	
Data Transmit / Relay	Real-time Transmit to PC	Real-time Transmit to PC / Relay	On-demand Transmit	On-demand Transmission	On-demand Transmission	On-demand Transmission	On-demand, triggered or scheduled

915 MHz RFM chip-based: see MicroRF Network Protocol ICD: copies can be obtained through Mr. Aaron Trott at Invocon, Inc – (281) 292-9903; atrott@invocon.com

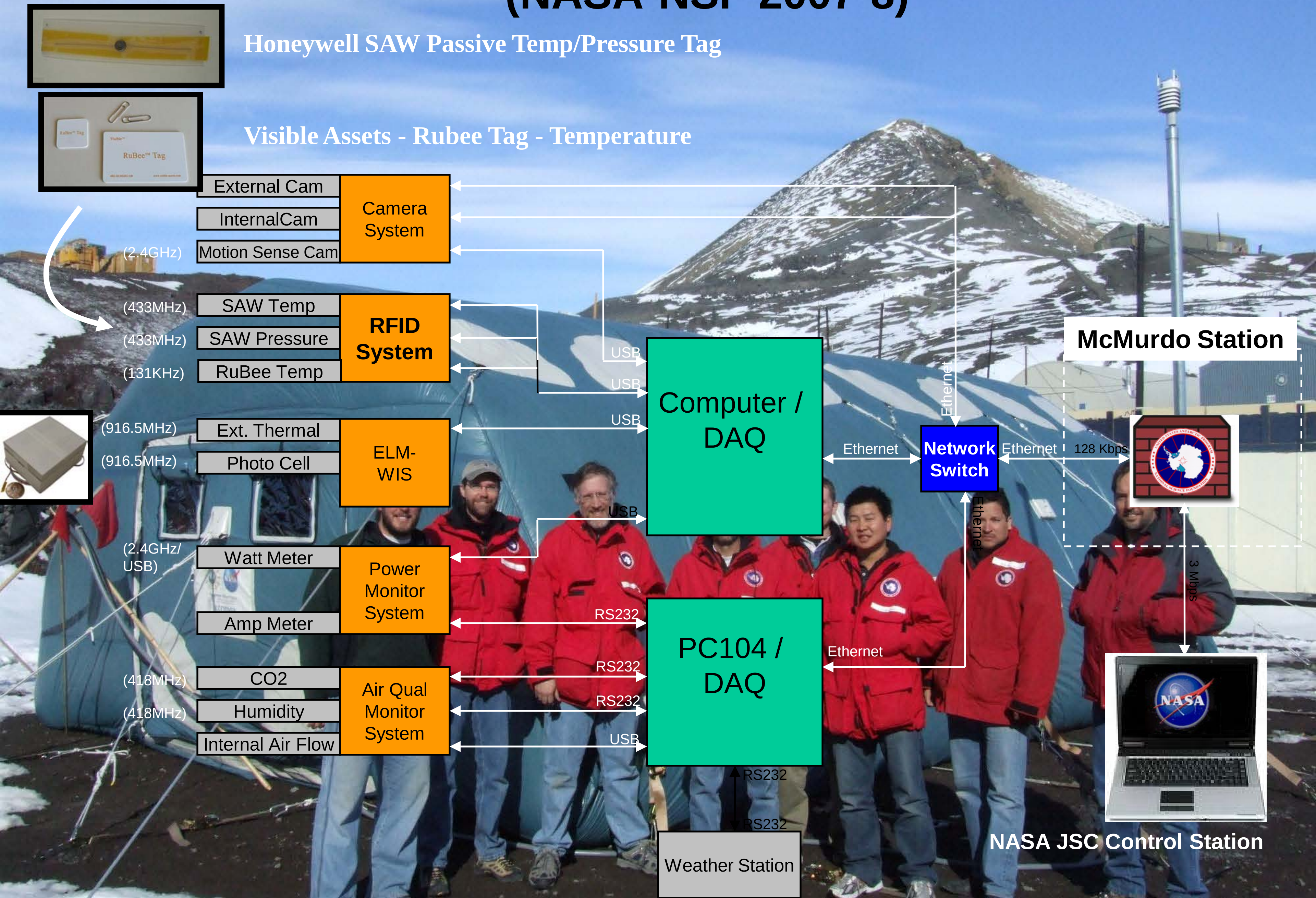
Standalone Wireless Instrumentation for Shuttle/ISS

Evolution of Micro-WIS Systems (page 2)

Micro-WIS XG

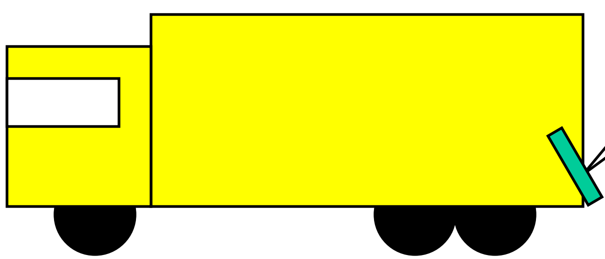
System	MicroWIS (SBIR)	Extended Life MicroWIS	MicroSGU / MicroTAU	Wideband MicroTAU	Enhanced WB MicroTAU	Ultra-sonic WIS (SBIR)	DIDS (Phs2 SBIR)
Local Data Processing	No	No	8bit micro-controller	High-speed DSP Not used on data	High speed DSP Numerous Routines	High speed DSP Numerous Routines	Very Low Power, fast Wakeup from any channel
Triggering	No	No	Data/Time Trigger	Data/Time Trigger	RF/Data/Time	Impact	AE any channel
Battery type	Tadiran 400mAhr	BCX Lithium C-cell	Tadiran 1000mAhr	BCX Lithium C-cell	Energizer L91 2-AA pack	BCX Lithium C-cell	L-91
Battery Life	9 months	10+ years	2-3 missions	1 mission	1 mission	3 years	3 years
Sensor Types	Temperature (Flight Cert) and Resistive sensors: Strain, Accelerometer Pressure	Temperature (Flight Cert) and Resistive sensors: Strain, Accelerometer, Pressure	Acceleration & Strain (Flight Cert) or Resistive sensors. Includes Pressure as Trigger Channel.	Accelerometer & Temperature (Flight Cert) or Piezoelectric and Resistive Sensors	Accelerometer & Temperature (Flight Cert) or Piezoelectric and Resistive Sensors	Ultrasonic Microphone and Acoustic Emission	Acoustic Emission Sensors Ultrasonic Microphones Accelerometers

Instrumentation for Inflatable Habitat in Antarctic (NASA-NSF 2007-8)



Prototype Passive Sensor-Tag System
GarveySpace Rocket Test - AFRL

- Monitor <u>temperature</u> of experimental LOX tank wirelessly
  - 5 tags placed on exterior of tank
  - Tags placed at same level as wired internal temperature sensors
- System configuration
  - 7-element Tx antenna
  - 64-element Rx antenna
  - ~19 ft. baseline range
  - ~25 ft. tag range
  - Azimuth: tag boresight
  - Elevation: ~40° off tag bore-sight



Garvey Spacecraft P-9 Rocket

GarveySpace - Prospector 9 – Add-on Wireless Instrumentation Demo Aug 2008

JSC/EV Passive Temperature -Tag

Temperature Passive Sensor Tags (5 x 1 ch ea) – **SOMD/EC Project**

- Real-time data acq/display during tanking in Van
- Interrogator in back of van(2.4 Ghz) includes:
  - 2 electronics boxes 19” x 16” x 4”
  - 1 Antenna (3’ x 2.5’)

JSC/Invocon, Inc.

Temperature Sensor Data Loggers (6 x 1 ch ea) – **ELMWIS & Micro-recorder**

- Extended Life Micro-WIS 2.7” x 2.2” x 1.2”
  and Micro-WIS Recorders 1.75” dia x 1.0”
- 1 RTD each
- Wirelessly pre programmed before flight(916 MHz – 1 mw)
- Real-time data avail in van during tanking(1 sample/15 sec)
- Data downloaded post flight via RF or micro-connector

JSC/Invocon, Inc.

Triax Accelerometer Data Loggers (3 x 3 ch ea) – **WLEIDS**

- Wing Leading Edge Impact Detection System (Shuttle)
- 1 Triax + 1 RTD each 3.25” x 2.75” x 1.5”
- Wirelessly pre programmed before flight(916 MHz-1mw)
- Status as req, Data downloaded after flight via USB port

JSC/Invocon, Inc.

Acoustic Emission Data Logger (1 x 4 ch ea) - **DIDS**

- Distributed Impact Detection System 1.7” x 1.7” x .78”
- Wirelessly pre programmed before flight – 902-928 MHz
- Records “events” or periodically sampled as prescribed by user
- 1 mega-sample/sec, then data download after flight
- Characterize Tanking and other events

Crew Seat Detailed Test Objective (DTO) # 695

Lead: JSC/EV17/Nathan Wells

Effectivity: STS-119, 127, 128

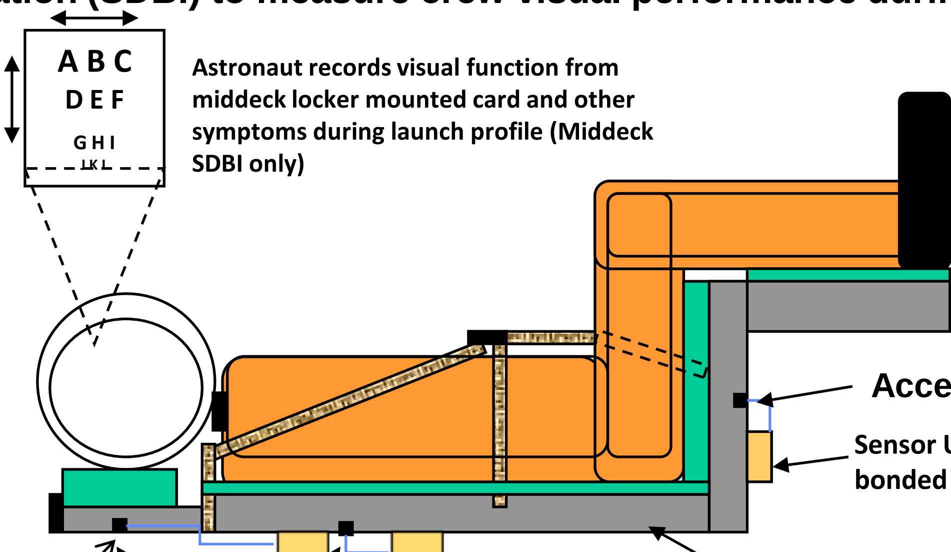
Purpose: Obtain vibration specifications for unimpeded crew performance in conjunction with a Short Duration Bioastronautics Investigation (SDBI) to measure crew visual performance during launch.

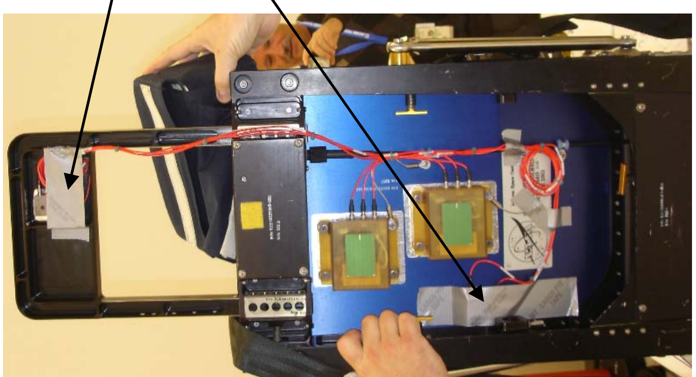
Objectives:

- Data Collection during launch only
- Instrument 3 seats each flight
- Wireless Programming

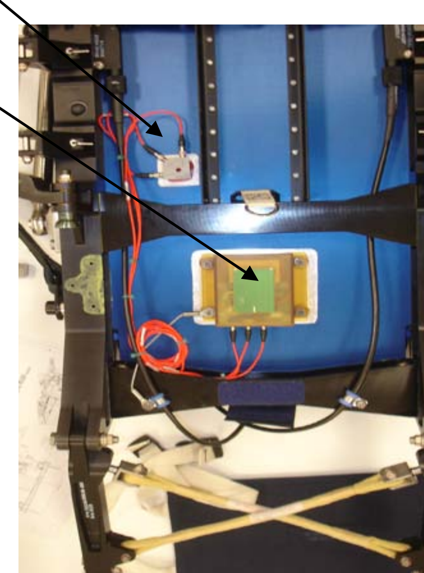
Sensor Specifications:

- 3 VDC Battery powered
- Full Scale Range: +/- 14g
- Bandwidth: 1.5 Hz to 300Hz
- Data Sample Rate: 1000 samples/sec
- Resolution: 14mg





Seatback Configuration



Seat Pan Configuration

Mutual Interest Areas identified at 2007 "Fly-by-Wireless" Workshop

Aircraft:

- Flight Test Support Kit: RFID tags, Active Tags/Loggers, Wireless Instrumentation
- <u>Frequency Spectrum for International for On-board Wireless use: Critical Sensors, Wireless Controls</u>
- <u>Passive Tag System Improvements</u>
- Weight Reduction in Helicopters
- Data Over Power lines
- Wireless Engine Monitoring
- Wireless Avionics Interconnects
- <u>Aircraft Wireless Working Group</u>
- Aircraft Wireless IVHM Working Group
- Aircraft Wireless Flight Control Working Group – Develop Super Autopilot
- Fly-by-Wireless Aircraft Test beds
- Life-cycle Cost/Benefit Analyses needed

Spacecraft:

- Weight Reductions
- Confidence in Wireless Connections
- <u>Passive Tag System Improvements</u> (2009)
- Wireless Instrumentation
- Add-on Standalone Instrumentation for Operations
- <u>Wireless Avionics Connectivity, Standards, and "plug and play"</u>
- Spacecraft Wireless/RFID Working Group
- Spacecraft Wireless IVHM Working Group
- Spacecraft Wireless for Habitats/Systems
- Onboard Wireless to external areas/systems
- Integrated Vehicle Architectures - Design for Fly-By-Wireless
- Life-cycle Cost/Benefit Analyses needed

VHM and Test:

- Standalone Wireless Instrumentation
- Secure Wireless Avionics
- Active and Passive RFID and Location Systems
- Passive RF Sensor-Tags
- Remote Operations – Internet Ops
- Scavenge/long-life battery Power

Potential Areas of Cooperation

Common Technology Areas	Common Outcomes
Less Wire Hybrid Architectures	Performance/Life Cycle $
Wireless Sensors/Instrumentation	Flight Worthiness
- Exchange Existing	Installation Simplicity
- Evaluate New	Operations Maturity
- Identify Improvements	Application Acceptance
Ground and Flight Testing	Cost/Responsive Changes
Wireless Bus/Avionics	Performance/Services
	Reliability/Security
Systems/Back-up Flight Control	Proof of Reliability/Safety
	Perf/Cost Advantages

A Way Forward

How might we work with JANNAF Organizations?

• Share emerging technology developments, standards and end user needs… look at what systems might satisfy recent CxP RFI.

• Look for common ground to potentially develop joint proposals that have payback for multiple end users.

• Look at vehicle system architectures that facilitate integrating new systems or upgrades.

• Look at SE&I level motivation/metrics that address advantages and concerns.

• Look at use of common test beds inside and outside of NASA and aerospace.

Comments/Questions? George Studor (763) 208-9283
george.f.studor@nasa.gov