Example Shown:
Orbiter Wing Leading Edge
Impact Detection System
“Fly-by-Wireless” Update

• What do we mean by “Fly-by-Wireless”? 
• Common Problem and Motivation 
• Recent Examples 
• NASA’s Future and Basis for Collaboration
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 & integration methods to reduce cables & connectors.

2. Vehicle provisions for modularity and accessibility.

3. A “tool box” of alternatives to wired connectivity.

What it is NOT:
• A vehicle with no wires.
• Wireless-only for all control systems.
### “Fly-by-Wireless” Focus Areas

#### (1) System engineering and integration to reduce cables and connectors
- **Capture the true program effects** 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/pins, # of penetrations, overall weight/connectivity, total data moved/lb).
- **Design Approach** that doesn’t assume a wires-only approach, but optimizes all practical options, providing for the inevitable growth in alternatives to wired connectivity.

#### (2) Provisions for modularity and accessibility in the vehicle architecture
- **Vehicle Zone Accessibility** – Considers standalone sensors along with system assembly, inspections, failure modes/trouble-shooting, system/environment monitoring, remove & repair.
- **Vehicle Zone Modularity** – Vehicle wired buses provide power, two-way data/commanding, grounding and time in a plug-and-play fashion. Wireless networks are standardized by function and are also plug-and-play.
- **Centralized & De-centralized approaches** are available for measurement & control.
- **Entire life-cycle** considered in addition to schedule, performance, weight & volume.

#### (3) Develop Alternatives to wired connectivity for the system designers and operators.
- Plug-n-Play wireless devises
- Wireless no-power sensors/sensor-tags
- Standalone wireless smart data acquisition
- Standardized I/Fs, networks & operability
- Wireless controls – back-up or low criticality
- Robust high speed wireless avionics comm.
- Data on power lines, light, structure, liquids
- No connectors for bulkheads, avionics power
- Robust software programmable radios
- Light wt coatings, shielding, connectors
- RFID for ID, position, data, & sensing.
- Inductive coupling for rechargeable batteries
“Fly-by-Wireless” Activities

USAF Reserve Report to AFRL  11/15/1999
DFRC Wireless F-18 flight control demo - Report  12/11/1999
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
NASA/AIAA Wireless and RFID Symposium for Spacecraft, Houston  May, 2007
AVSI/other int'l. 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

AFRL announces “Wireless Spacecraft” with Northrup-Grumman  Mar 2009
CCSDS Wireless Working Group  Apr 2009
JANNAF Wireless Sensor Workshop  Apr 2009
ISA 100.11a finishes new standard for security for Industrial use  Sep 2009
NASA begins Wireless Avionics Community of Practice  May 2010
AVSI releases request for Agenda item at New World Radio Conference  Jun 2010
What Do the Two Industries Have in Common?

Wires!!

Aviation  
- Aircraft  
- Helicopters  
- Unmanned Aerial Vehicles  
- Internal/External Robots  
- Balloons  
- Crew/Passenger/Logistics  
- Jet Engines  
- Airports/Helpoports  
- Engineering Validation  
- Ground Support

Space  
- Manned Spacecraft  
- Launch/Landing Systems  
- Unmanned Spacecraft  
- Internal/External Robots  
- Inflatable Habitats  
- Crew/Scientists/Logistics  
- Rocket Engines  
- Launch Sites  
- Engineering Validation  
- Ground Support

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

What do these have in common?

2. Mobility & accessibility needs that restrict use of wires.
3. Performance issues that depend on weight.
5. Limited flexibility in the central avionics and data systems.
7. Need to finalize the avionics architecture early in the lifecycle.
8. Manufacturing, pre and post delivery testing.
9. Schedule pressure, resource issues, security and reliability.
11. Civilian, military, academic & international institutions.
12. Life-cycle costs due to wired infrastructure.
13. **Need for Wireless Alternatives!!**
Common Motivations

• Reduce Cost/Schedule of Wired Connectivity
• Increase Reliability/Maintainability
• Increase Safety
• Increase Security (some more than others)
• Increase System Functionality
• Changes in System Engineering & Integration, Vehicle Architecture and Technology Development/Awareness
• Decrease Size, Weight and Power
Motivation: The Cost of Wired Infrastructure

- **Expenses for Cabled Connectivity** begin in the 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 always work well 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 to make changes 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 can be prohibitive.
**Motivation:**

Cost of Change for Wired Instrumentation

The earlier that conventional instrumentation requirements and design needs to be frozen, 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 more sustaining costs.
- The greater number of integration and resources that are involved, the greater the cost of change.
- Without mature/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 be made.
   - anomalies
   - modifications
   - performance improvements
   - mission ops changes
   - “stuff” that happens
**Motivation: Increase Vehicle 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 can be Increased:

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

**Through Structural and System Simplicity:** Greatly reduced cables/connectors that get broken in maintenance and must be trouble-shot, electronics problems, sources of noisy data and required 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 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.
Motivation: Safety

- **Reduced Response Time** to respond with changes in monitoring.
- **Increased Options** for sensing, inspection, display and control.
  - e.g. rotating equipment, human interfaces, unpowered areas.
- **Fewer Structural/Material Failure Points** - Penetrations, connectors, wiring, and sensor connection complexity.
- **Better Opportunities Correct/Upgrade** for safety deficiencies.
- **Increase redundancy** with backup and add-on systems.
Conceptual Hybrid SMS Architecture
(Centralized and Decentralized)
(Wired and Wireless)
(Standard Sensors and Smart Systems)

- Integrated Health Monitoring
- Structural Health Monitoring
- Environmental Monitoring
- Air Handling
- Water Handling
- Mechanical Systems
- Deployable Crew and remotely operated sensors, imagers and interrogators

Bus (wired, fiberoptic, wireless)

Remote Health Node (RHN #1)
- X-ducer
- Smart System
- X-ducer
- Smart System
- X-ducer

RHN #2
- X-ducer
- Smart System
- X-ducer
- Smart System
- X-ducer

RHN #3
- X-ducer
- Smart System
- X-ducer
- Smart System
- X-ducer

Access Point
- Handheld or Deployable RHN #4

RHN #5
- X-ducer
- Smart System
- X-ducer
- Smart System
- X-ducer
- Smart System
- X-ducer

Standard Centralized Wired Data Acquisition Instrumentation

Note: Not all need to be accessed during flight, some accessed after a flight phase or event is flagged
JSC Habitat Development Unit with Hybrid Architecture

Location: JSC “Rockyard”
August 2010

Airlock Habitat

Habitat Sensing:
CO2, Smoke, Humidity
Air Flow, Air Pressure
Accelerometers, Temperatures
Also Wireless to Temperature in Airlock

Hybrid Instrumentation includes
JSC WSN Network of Dust-based sensor-nodes

Note: HDU is on its way to participate in the NASA “Desert RATS” testing in August.
Substitute New Radio Module
ISA100.11a radio (Nivis, LLC)
10 initial run, then 100 units

Current JSC WSN with dust protocol (TSMP)
20 made so far

Initial Application:
8 nodes in HDU with up to 10 channels each for humidity, temperature and differential pressure

Test WSN Nodes in Habitat Test Bed

Note: ISA100.11a is typically for a low data rate system

WSN ISA 100.11a Testing at JSC:

RF issues:
- Data delivery reliability
  - multi-path, interference, noise
- Data throughput rate
- Interoperability-2.4 GHz 802.11

Power issues:
- Radio/networking component
- Low power, full mesh networking
- Sensing/processing component
- Scheduled & event-driven sensing

Application issues:
- Feasibility of sensing transients
- Usefulness of MAC-derived apps
- Time synchronization

Protocol issues:
- Which protocols best apply when?
- Modifying existing commercial protocols or using as-is
- Investigating future standards-based protocols
Lunar Electric Rover – “Desert Rats”
Instrumentation Installed June 2010
Shuttle Main Engine Ignition Acoustic Environment

OMS Pod Loading due to Acoustic Pressure – potentially out of cert life
• Discovered at FRR, 2 weeks prior to STS-129 – Nov 2009
  – Add Triax inside OMS Pod – 20K/sec and high dynamic range

• Add Acoustic Monitoring – STS-130 and subs:
  – 20 -315Hz @ max 180 dB Sound Pressure Level (SPL)
Project M RR1 Lander
Developmental Flight Instrumentation

Wing Leading Edge Data Recorder
High Data Rate
Low Data Rate

Micro Strain Gauge Unit (MSGU)

RR1 Tests at Caddo Mills, TX
Armadillo Aerospace
Tethered Lander flight test 05/22/10
Lander Free flight test 06/23/10
NASAs Future: Current Manned Spaceflight Challenges

• **Space Shuttle:**
  
  • Monitoring for safety of flight thru end of program
  
  • Use of Shuttle assets after it is retired

• **ISS:**
  
  • Long term maintainability – all systems
  
  • Increased scope of on-orbit structural validation
  
  • Rapid module leak location system
  
  • ISS utilization increases – HD video, wireless audio, other WLAN needs
    
    • Drag-thru cables that impede rapid hatch closures
  
  • Need a new transportation method for getting to ISS post-Shuttle retirement

• **Future Programs:**
  
  • Ground test instrumentation, development flight test instrumentation
  
  • Operational flight instrumentation and deployments with EVA/robotic missions
  
  • Weight, power and volume reductions for vehicle and wireless systems
  
  • Standardization of wireless interfaces and systems
1. Communication of needs and capabilities → Link the “Communities of Practice”
   - Personal investment: News items/alerts, email and web-based networks
   - RFIs – Such as the flurry of them that happened this summer
   - RFPs – SBIR/STTR Cycles, Challenges, Space Grant, etc.
   - IPP Seed fund: http://www.nasa.gov/offices/ipp/technology_infusion/seed_fund/index.html
   - NASA website(s) – Chief Engineer/Communities of Practice; Office of Chief Technologist
   - Other agencies – DOD, DOE, DOT, NIH, DHS
   - Industries: Oil and Gas; Aerospace; Medical; Transportation; Construction; Home

2. Business case studies: Cost – Benefit of Wires/Wireless; Metrics
3. Evaluate various “less-wire” technologies that are already being developed
   - Cooperative exchange of testing, results and hardware/systems.
   - Use real world environments and test scenarios to solve a real problem.


5. Create the Wireless “Tool Box” - some priorities
   - Smart Sensor-DAQ Micro-Miniaturization – Ex: WLEIDS -> System on a chip, Plug-n-play
   - Passive Wireless Sensor-Tag systems – increase channels, sensor types, miniaturize interrogator, work in typical avionics bays,
   - Extremely High Data Rate LANs for video and other sensors –VLAN is emerging
   - Standardized and Ruggedized Networks for reliability, modularity and competitive selection

What’s Needed?
Purpose: Mature NASA Wireless Avionics Connections technology and applications through an agency-wide forum to share information and capture knowledge, under the Avionics CoP.

Scope:
- Limited to on-vehicle and vehicle proximity RF wireless*
- Facilities used for vehicle test and check-out and wireless systems eval.
- Support Avionics CoP in reporting and issues identification/clarification.
- Wireless Avionics CoP is not a working group. Occasional issues may require CoP to help find experts to man teams external to it.
- Within a range that wires might otherwise have been run, but functionality or practicality may favor wireless.

Members: Lead: JSC/George Studor
Center POCs at each NASA center
SBIR/STTR Phase 2 Project Search
(Cross-Agency Leveraging)

At approximately $1.3M for each 2 year project… there is a lot being invested.. Note: other agencies not listed: DOT, NIH, etc….
And I haven’t listed the many Phase 1 Projects…

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ISS Leak Location System

Let’s make it smaller, faster cheaper

- **STEP 1:** On-Orbit DTO to Characterize ISS AE Environment
- **Use Distributed Impact Detection System (DIDS) – Phase 2 SBIR Project:**
  (works for leaks too)
- Record acoustic emission or acceleration “events” on structures or through air
  - Window of data is recorded upon detection of an event.
  - Event characterized by exceedance of programmed threshold value.
  - Software can perform a “forced trigger” to command a data take
- **System characteristics:**
  - 4 channels per node, ~1 MHz sample rate each channel
  - Piezoelectric sensors with charge output
  - Trigger Modes: on command or user-defined threshold
  - 50 micro amp current draw

![Diagram of ISS Leak Location System components](image)

**AE Sensors**
**DIDS Unit**
1.7” x 1.7” x 0.8”
**Transceiver Unit**

**Laptop with User Interface Software**
Wireless Spacecraft

Several AFRL SBIR awards for CubeSats

Start with reducing the 15 pin connectors in a typical Cube-sat

SDM – Satellite Data Module
ASIM – Applique Sensor Interface Module
XTED – eXtended Transducer Electronic Datasheets
New Tool Box for Maintenance Work

Data Loggers – wireless and non

Wireless Sensor Network
- Standalone deployable Central Node

Active & Passive Sensor Tags
- Interrogators for Both Tags

Smart Bar Code/RFID Inventory system
- Stored Information and Location

High Data Rate Node:
- Wireless Work Control IPad – Massive Storage
- High res photos/drawings
- Wireless Location (Internal & External)
- On-board link to Vehicle Systems

Rechargeable or Long-Life Batteries
Scavenge Power options for in-flight

Plug-and-Play Antennas
RF Troubleshooting Equipment

…..Plus Flashlight and Screwdriver
Avionics Bays are Typically Crowded

Aerospace Sensing is a common need…

Aerospace Sensors Working Group
(NASA-lead, Industry and other Agency attended)
- Practical Ways to get across bulkheads without connectors
- Communicate reliably in a harsh environment with extreme multipath (but at least it is short range and not dynamically changing)
- Modular access points to change and upgrade configurations
Power Scavenging for Wireless Standalone Sensors

EADS Thermal Scavenging Sensor for VHM

Aug 12, 2010

Forwarded to me from Embraer rep on AVSI Team… stay connected through Working Groups and informal contacts.


Let’s Make the Effort to Work Together!!