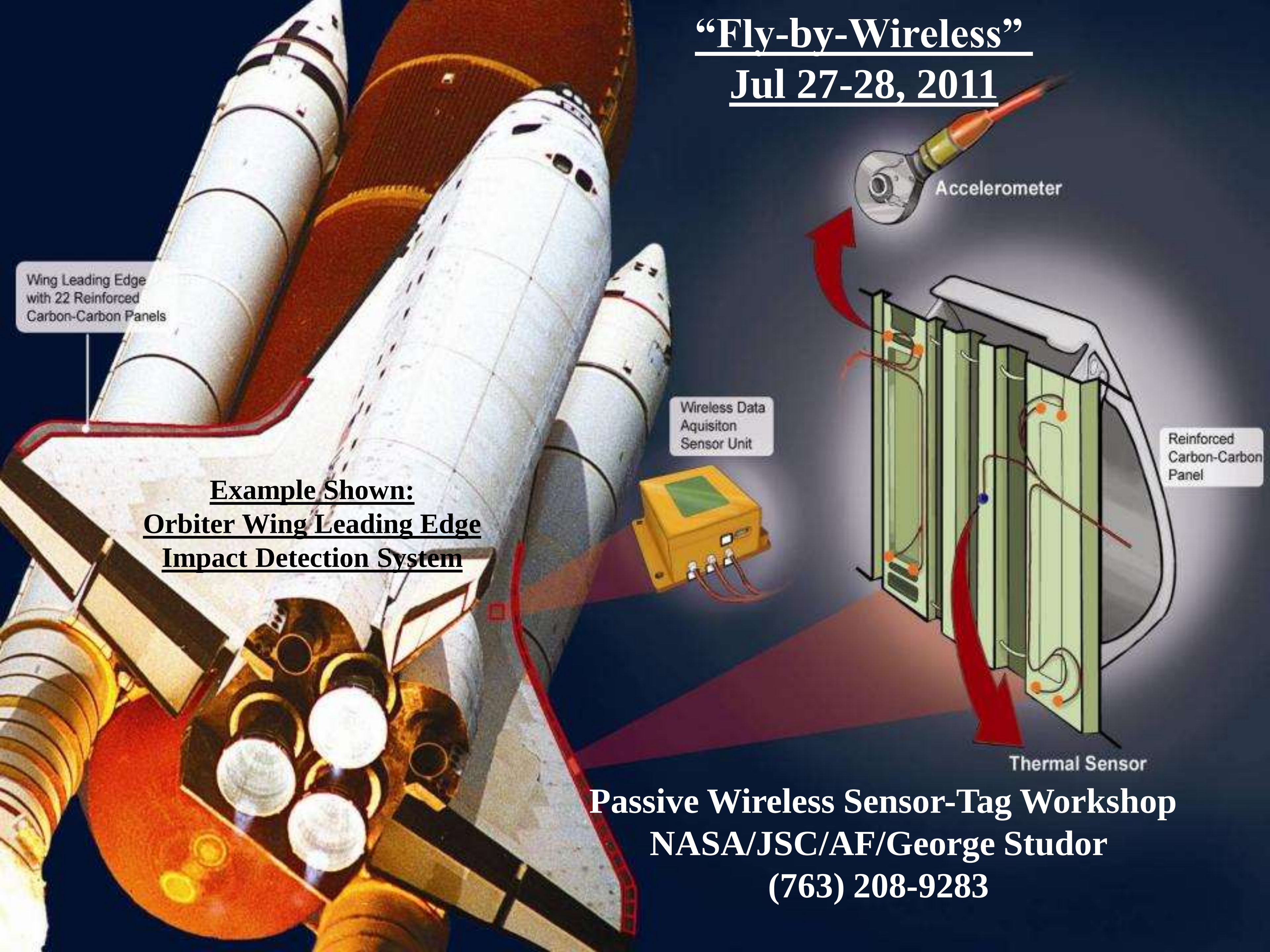
“Fly-by-Wireless”
Jul 27-28, 2011



Example Shown:
Orbiter Wing Leading Edge Impact Detection System

Passive Wireless Sensor-Tag Workshop
NASA/JSC/AF/George Studor
(763) 208-9283

"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 & 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

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”	10/28/2004
Inflatable Habitat Wireless Hybrid Architecture & Technologies Project:	9/2006
CANEUS 2006 “Lessons Learned Micro-Wireless Instrumentation	9/2006
CANEUS “Fly-by-Wireless” Workshop to investigate the common interests	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	Sept 2008
CANEUS 2009 “Fly-by-Wireless” Workshop	Mar 2009
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
CANEUS/IEEE/Univ of Maine “Fly-by-Wireless” Workshop	Aug 2010
JANNAF Wireless Sensors Workshop	Dec 2011

What Do the Two Industries 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, Flight 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. 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.
10. Operations and aging problems.
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

<u>The earlier</u> that conventional instrumentation requirements and design needs to be frozen, <u>the greater the cost of change</u>.

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

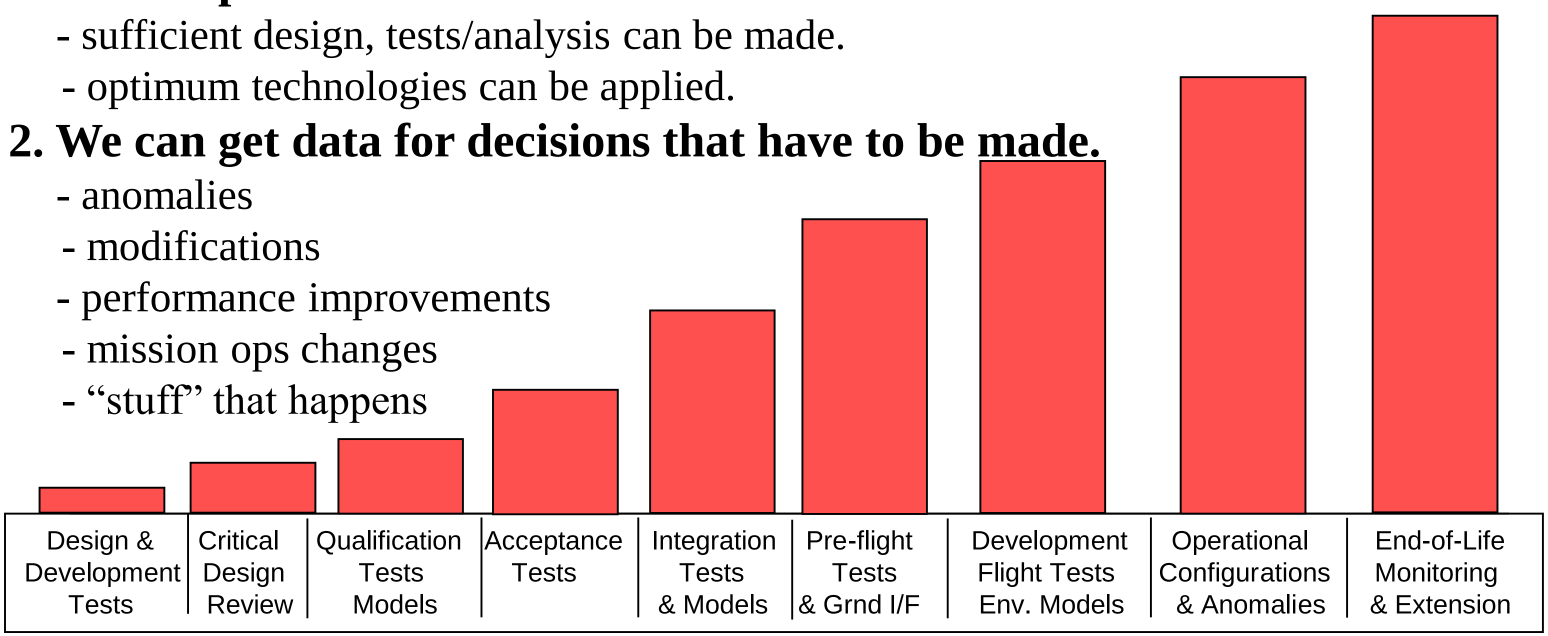
We <u>need to design in modularity and accessibility</u> so that:

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 <u>made</u>.

- 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. <u>A completely separate access path provides greater safety and reliability against common mode failures</u>.

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.

What's Needed?

1. **<u>Communication</u> 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.**
     http://sbir.gsfc.nasa.gov/SBIR/sbirsttr2011/solicitation/index.html
   - **NASA website(s) – Chief Engineer/<u>Communities of Practice</u>; 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.
4. **Architecture studies: Provisions for wireless, System Engineering Texts**
5. **Create the Wireless "Tool Box" - some priorities**
   - **<u>Smart Sensor-DAQ Micro-Miniaturization</u>** – Ex: WLEIDS -> System on a chip, Plug-n-play
   - **<u>Passive Wireless Sensor-Tag systems</u>** – 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

New Tool Box of Alternatives to Wires