NASA Wireless Mission Support Concepts

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Topics

- Introduction
- Center Case Studies
- Wireless SBIR Topic
- Conclusion

Introduction

Introduction

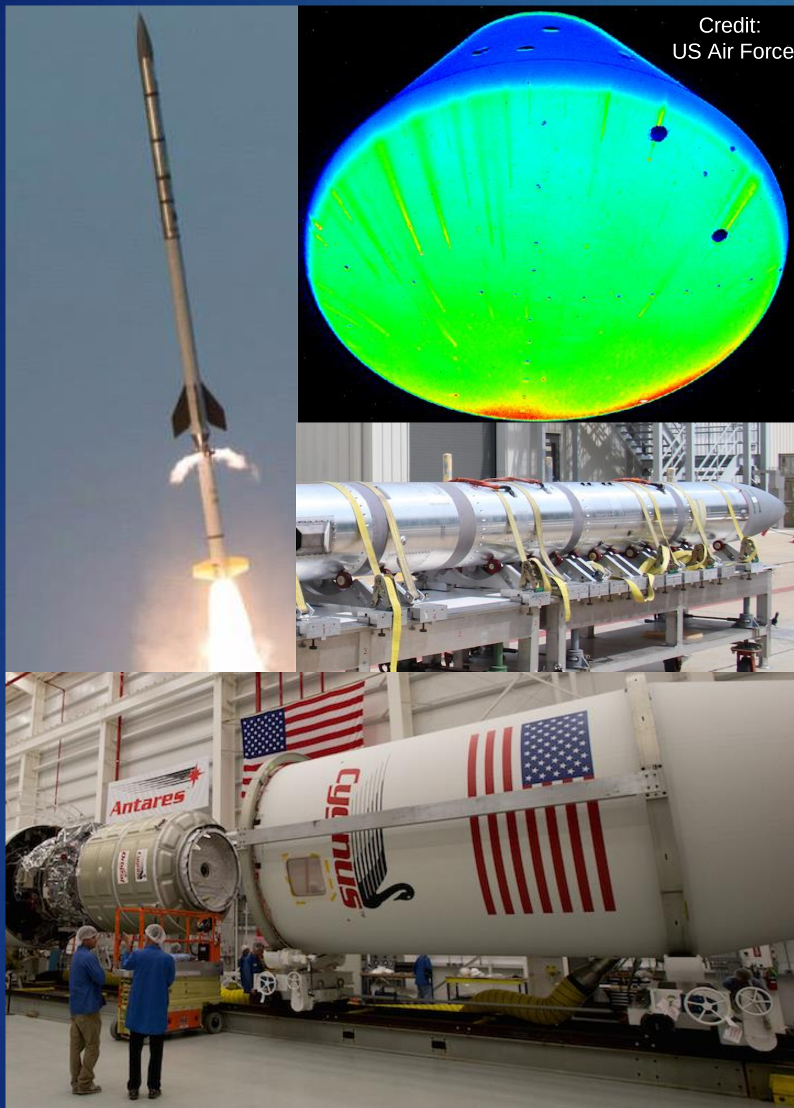
- NASA has many operational environments that present data networking challenges across multiple domains. For example:
  - Need to reduce mission resources for power, mass, cable complexity, etc.
  - Need to improve reliability in extreme environments by, e.g., mitigating folded wires in long-duration cold soaks
  - Need to have the ability to rapidly change out sensors for failure resolution, upgrade sensors as technology improves, or add new sensors in operations.
  - Need to reduce the overhead associated with sensor mounting and the channelization process
  - Need light, unobtrusive means to "instrument" humans
- With these issues, NASA is looking at applying wireless technologies to the space mission environment

Introduction

- With the needs come challenges as well
  - Potential RFI/EMI issues
  - Certifying new materials for spaceflight
  - Displacing "old school" thinking
- In this presentation, we will examine mission challenges from the perspective of multiple NASA Centers.
  - These are not the only Agency challenges but this is to give a flavor of the concepts being developed
  - We will also discuss the new SBIR opportunity for NASA Wireless development.

Center Case Study – ARC

ARC – Mission Need



- Cost efficient methods for flexible flight instrumentation for both human and robotic spacecraft
- Methods for integrating sensors into composite materials for structural and thermal monitoring during ascent and reentry
- Reliable measurements of vehicle dynamics during critical phases of flight
- Integration into flight vehicle processing cycle meeting range, crew and mission safety requirements

ARC – Mission Need

- Major issue for adoption of wireless technology for space missions is compliance with ALL safety requirements – this is particularly true for human-rated spacecraft
  - Power source and electrical safety
  - Range and vehicle safety inhibits
  - Radio emissions near rockets and pyrotechnics
  - Interference with critical avionics and flight systems
- Secondary concerns are reliability of the wireless systems in the presence of powerful RF sources such as transmitters and immunity to common-mode and single-point-of-failure fault modes
- Additional capabilities such as automated management of wireless sensors can greatly reduce the overall life-cycle cost

ARC – Mission Need

- Primary need for significant miniaturization of sensors together with improvements in power source and inhibit capabilities
- Primary need for significant improvements in environmental tolerance including space radiation
- Secondary need is the development of the best protocols, architectures and fault tolerance needed for reliable operation aboard spacecraft
- Cost effective deployment aboard spacecraft will significantly enhance rate of adoption
- Long-term vision is the use of wireless technology for flight and mission critical functions, producing significant reduction in the cost and time needed to develop and configure spacecraft, while delivering even higher levels of reliability than wired interconnects

Center Case Study – GRC

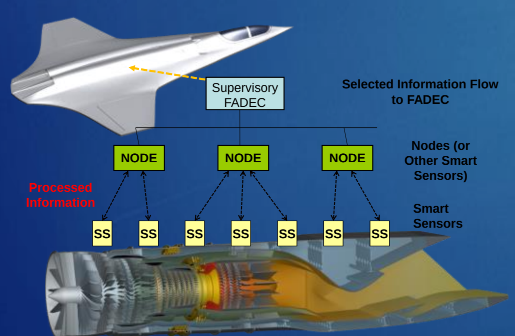
GRC – Mission Need

High Temperature Smart Wireless Sensor Systems
Aeronautic Engine Systems
Venus Surface Applications

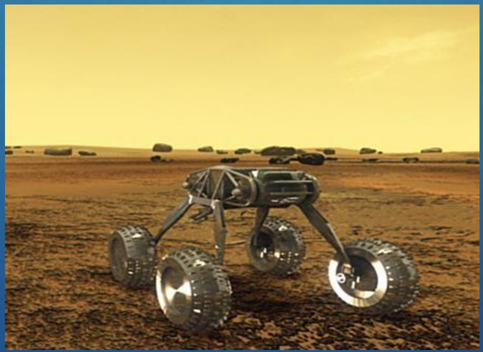
Self- Contained Smart Sensor Systems with Simpler Implementation: "Lick and Stick" Technology
Leak Monitoring
Fire/Environmental Monitoring

Con Ops: Harsh Environment Smart Wireless Sensor Systems for Applications Such as: Distributed Engine Control, Propulsion Health Management, More Intelligent Engine Systems, and Planetary Exploration e.g., Venus Surface Missions

Con Ops: Multiparameter Detection using Smart Wireless Sensor Systems with Flexible Installation "Like a Postage Stamp". Minimal Size, Weight, and Power Consumption With Hardware Applicable for Space Relevant Environments



Distributed Smart Sensor Concept for Propulsion Systems



Venus Surface Rover Concept

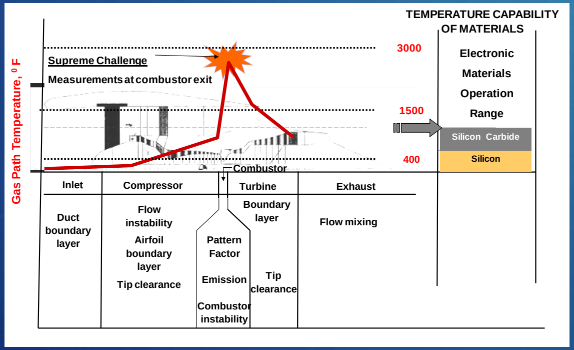
Launch/Space Craft Needs: Fuel and Toxic Gas Leaks, Fire/Environmental Monitoring

GRC – Mission Need

SOA implementation and issues: Wires add weight, complexity, and are often one of the main causes of sensor failure

Drives Toward High Temperature Smart Wireless Sensors

- Present technology limitations do not allow harsh environment electronics implementation
- Future implementation of sensor technology can be significantly enhanced by:
  - Improving the ease of integration
  - Decreasing the burden on the vehicle by decreasing the wire count
- Processing at the source can significantly enhance resulting information; Drive intelligence to the local level
- Provide measurements not presently available e.g., Venus simulated environments in Glenn Extreme Environment Rig (GEER)



High Operation Temperatures Limit Technology Options for Smart Wireless Systems in, e.g., Engine Applications

Drives Towards "Lick and Stick" Sensor Technology

- Commercial technology not designed for space applications
- Objective: Enable the addition of sensor systems without the burden of wiring
  - Ability to add new capabilities with improved reliability
  - Ease of implementation in vehicle, cabin, and teststand applications
  - Local processing providing the user only the information needed

Shuttle X43 Helios ISS

Hydrogen Safety Monitoring | Hydrogen Safety Monitoring | Fuel Cell Safety and Process Monitoring | Life Support Process and Safety Monitoring

Hydrogen Sensor Application Examples: Core Sensor Nearly the Same; Hardware Implementation Tailored for the Application Each With Different Configurations

GRC – Mission Need
Wireless Vision- Approach

High Temperature Smart Wireless Sensor Systems

Develop High Temperature Sensor Systems, e.g., Mature High Temperature Electronics

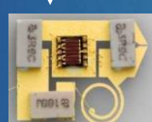
Ring Oscillator Operational at 500°C

Move Toward High Temperature Stand-Alone System Technology: Proof-of-Concept Demonstrated

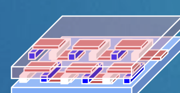
Significant Wiring Exists With Present Sensor Systems That Limits Flight Implementation (Engine Teststand Example)

High Temperature Sensor Systems

World Record High Temperature Electronics Device Operation

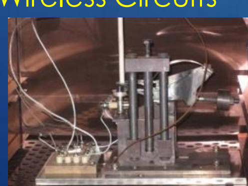


High Temperature RF Components



Energy Harvesting Thin Film Thermoelectrics

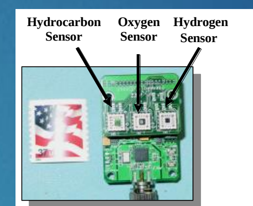
Process at the Source with Simple Wireless Circuits



Wireless seismometer and circuit in an oven (operational for 20 day at 500°C.

"Lick and Stick" Sensor Technology

Mature Core "Lick and Stick" Technology for Space-based Smart Microsensor Leak Detection Applications



"Lick and Stick" Leak Detection System: Three Sensors with Multiple, Adaptable Configurations Including Antenna

Meet The Needs Of Multiple Applications Building From This Core Set Of Smart Microsensor Technology

Fire Detection/Environmental Monitoring System for possible Space Craft Habitat Applications (Wireless Design Available)

Wireless Oxygen Sensor With Hub for Possible International Space Station Environmental Applications

Multiple Applications: Each Electronics System Based on the "Lick and Stick" Core with Wireless Communication Option

Jet Engines Emissions

Aircraft Fire Detection

Rocket Engine Teststands

Environmental Monitoring

Center Case Study – JSC

JSC – Mission Need

Autonomous Logistics Management (ALM)

Integrated tracking of location and availability of all items to facilitate decision making with respect to consumables usage, spares availability, and the overall health and capability of human exploration mission vehicles and habitats and their subsystems

Maximize the efficiency of access to hardware and consumables

Eliminate the high dependency on ground support

Will significantly reduce the cost of crew search time, especially when lost item re-launch is not an option

Passive-Tag RFID Sensing

Provide a passive tag sensing system to permit increased situational awareness, including high accuracy, real-time localization of tags and sensing, with tags applicable to human wearable, machine, and structural applications

Enhance safety in human/machine mixed environment

Provide low-mass sensing infrastructure for spacecraft by eliminating wires and minimizing battery dependence

Greatly lower multi-system cost using single infrastructure

JSC – SOA Challenges

- Nearly every application has a different sensing infrastructure!
  - Robotic localization and orientation: image capture and processing; IR imaging for humans; optical target recognition and alignment
  - Sensing: wired instrumentation with heavy mass penalty; Battery-powered wireless nodes with limited life span.
  - Logistics management: human search and/or ground support; UWB battery-powered tags
- Difficulties?
  - Optical correlations can be slow and/or computationally intensive
  - Human gesture tracking has problems distinguishing multiple appendages with IR
  - UWB tracking
    - Limited accuracy unacceptable for many applications
    - Accuracy degrades in conductive spacecraft environment
    - Accuracy degrades when habitat volume cannot accommodate sufficient receiver baseline length
  - Wireless sensing
    - Typically dependent upon consumable batteries
    - Standard radios consume too much power, limiting sensor node lifetime

JSC – Wireless Vision

AES/LR REALM-1

- **6 readers + 24 antennas**
- **Ground processing**

Functions:
- Logistics tracking (AES/LR)
- *RFID sensor collection (STMD)*
- *Navigation data collection (STMD)*

Six Degrees of Freedom Logistics Tag System

Gesture recognition

6-DOF tracking

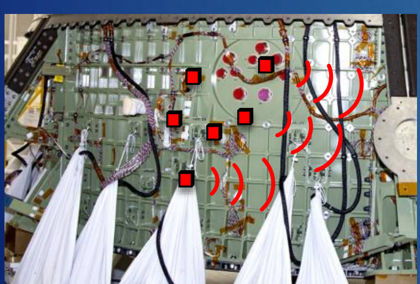
UHF

Biotelemetry
Commands

Explore Human/Machine Awareness

Environmental
Structural

Orion
Bay Modules



Orion EM2 DFI:
- Temperature
- Strain

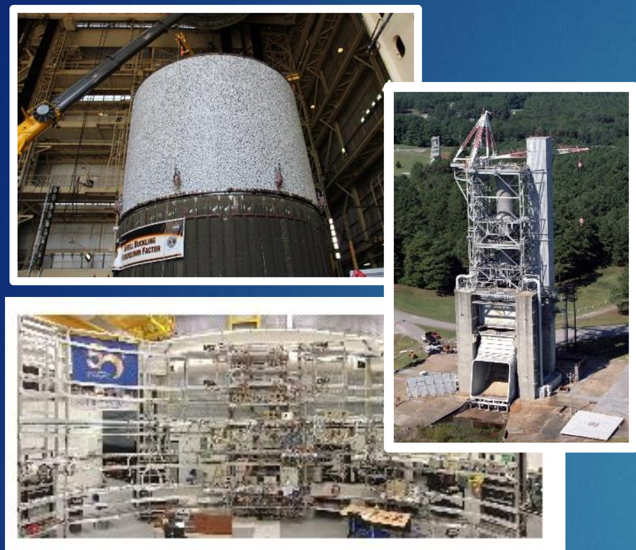
REALM-2/Astrobee:
- Reads RFID sensors throughout ISS
- Receives position & orientation

Cross-Cutting RFID Sensing Applications and Capabilities

Center Case Study – MSFC

MSFC – Mission Need

Ground Systems

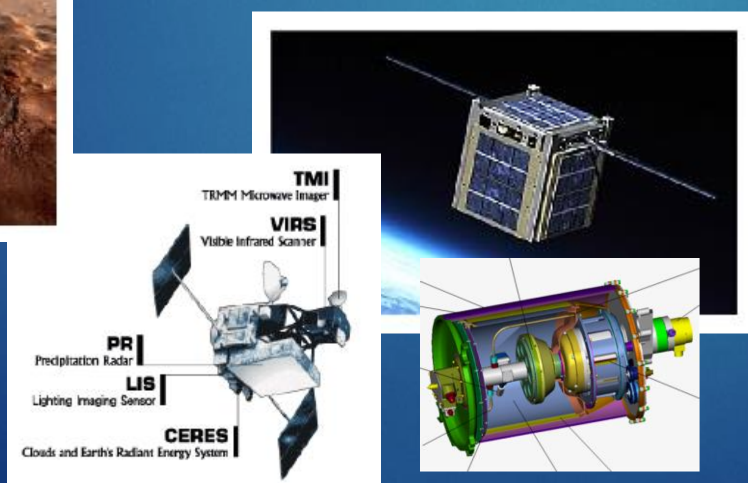


Vehicles/Manned or Unmanned

Habitats

Surface Exploration

Satellites/Payloads



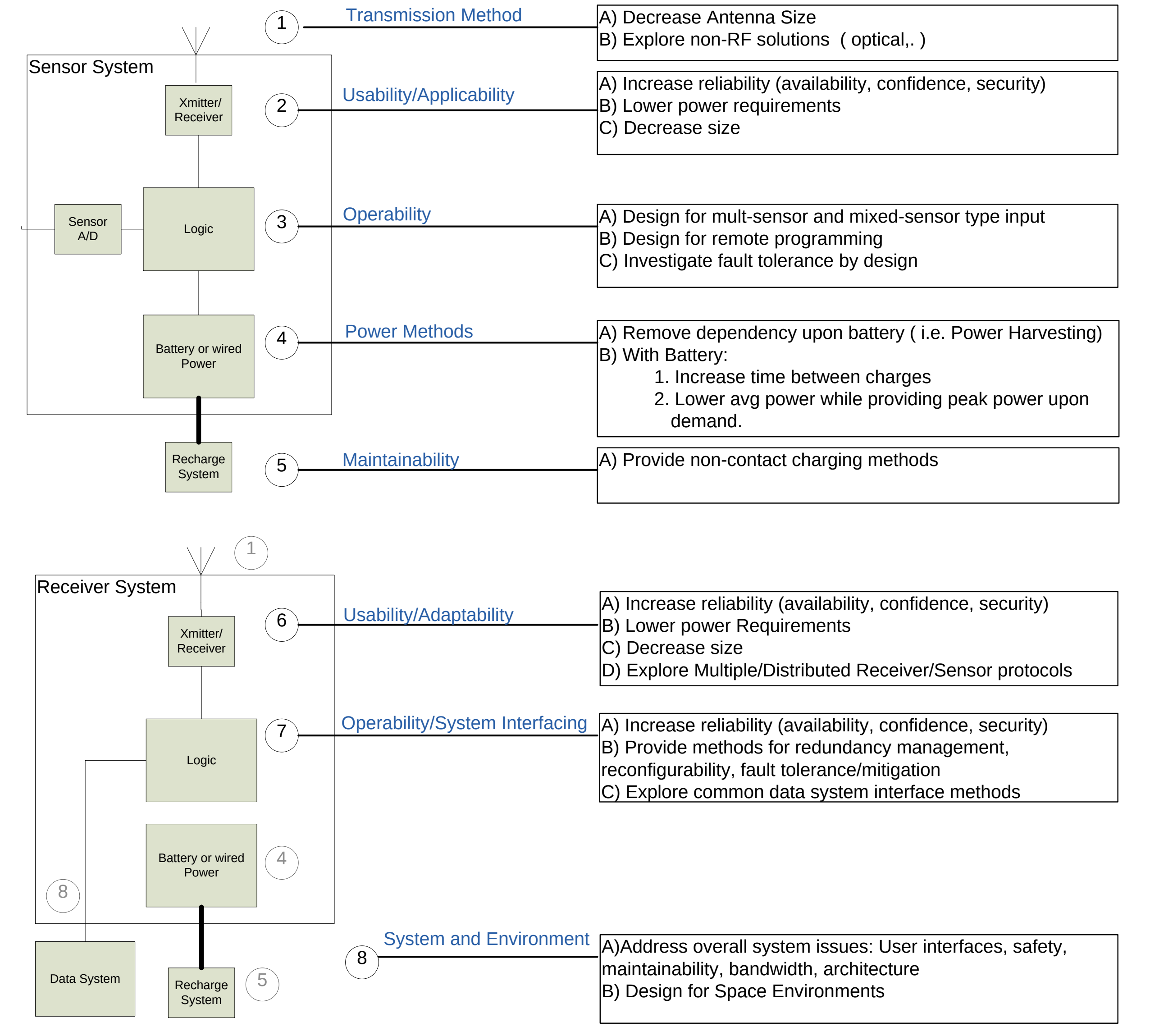
MSFC – Mission Need

Why are we pursuing wireless:

- Ability to get sensor measurements in places not accessible with cabled systems: inside tanks, inside planetary craters, wing leading edges, on systems that are moving.
- Allows adding new sensors quickly and at any point during the entire life cycle - reducing cost and schedule.
- Provides for less wires, connectors, penetrations
  - Fewer Cables == Weight savings!
  - Weight is not just the cables, it is insulation, bundles, brackets, connectors, bulkheads, cable trays, structural attachments, and reinforcement, and of course the resulting impact on payloads/operations.
  - Cable design can be complex and time consuming to create and maintain
  - Cable/Connectors difficult to change with new data requirements.
  - Cables/Connectors can be a source of failure and require mitigation of hazards
  - Cables provide little design flexibility
  - Cables can be a source of noise
- Wireless systems can be configured for alternate paths (mesh networking) to provide for greater redundancy.

MSFC – Mission Need

Wireless development areas



Center Case Study – SSC

SSC – Mission Need


RS 25 Engine Test


RS 25 Engine Assembly


Rocket Engine Test Stands

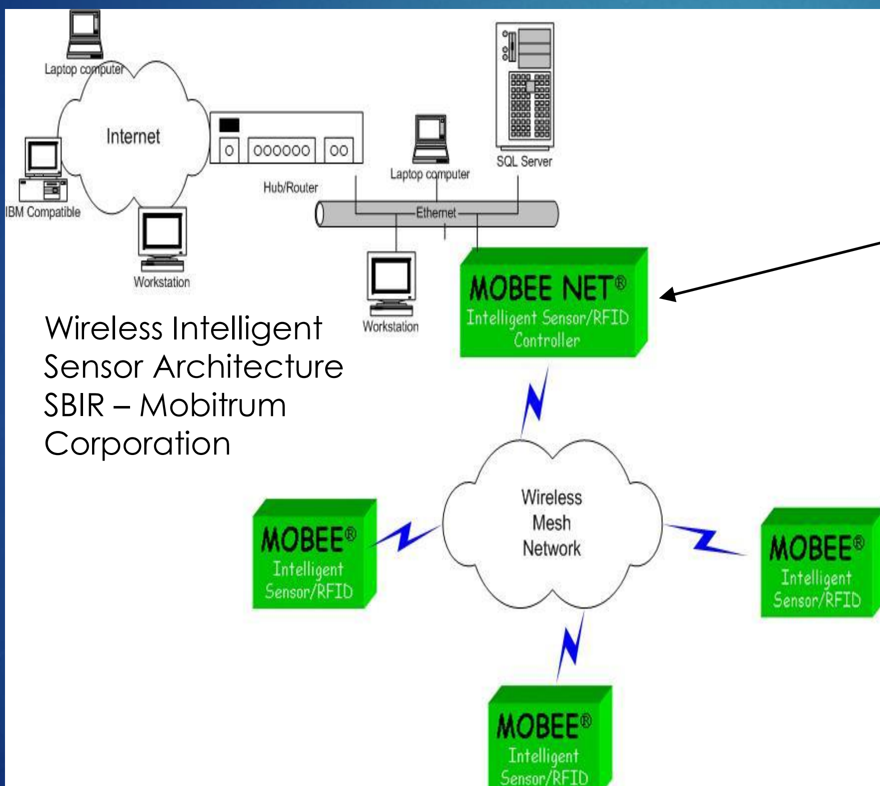
- Rocket Engine and component testing
- Government and Commercial Costumers
- Thousands of sensors and instruments used to make measurements
- Facilities occupy a large area, requiring extensive cabling for instrumentation and sensors.
- Test stands are massive and cable runs are very long. Succeptibity to noise and interference.
- Cost of cables and maintenance are high.
- Setting up additional sensors is costly in time and labor.
- Cost of configuration management and maintenance is high and cumbersome.

SSC – Mission Need

- Opportunities exist for wireless instrumentation in 2 main categories:
  - Measurements along piping carrying gases and cryogenic commodity (long distances). Particularly to monitor leaks and vacuum insulation.
  - Measurements of opportunity when measurements that were not anticipated are needed.
- Efforts in wireless sensing technology at SSC have been focused on wireless intelligent sensors for potential use in Integrated System Health Management (ISHM). Including the following capabilities:
  - Small foot print.
  - Adherence to the IEEE 1451 family of standards for smart sensors and actuators.
  - Architecture (software and hardware) to enable autonomous network sensor management, including configuration and robust operations.
  - ZigBee and WLAN protocols.

SSC – Mission Need

- Rocket engine test facilities of the future must become more agile in hardware and software implementations and operations. Long distance cabling should be replaced by wireless. Sensor network capabilities should replace current hardwired sensor systems.
- An integration of power harvesting, wireless, and intelligent sensing will enable affordable testing with superior service.



Wireless Intelligent Sensor Architecture SBIR – Mobitrum Corporation

Mobee Intelligent Sensor/RFID Controller

Mobee Intelligent Sensor/RFID

NASA Wireless SBIR Topic

NASA SBIR Topic

- NASA will have a wireless topic as part of the FY16 SBIR call Z6.01 Wireless Technology (see http://www.sbir.nasa.gov/)
- SBIR Abstract:
  - The Wireless Technology topic seeks proposals to extend the advantages conferred by terrestrial wireless technology to aerospace avionics. Wireless sensor networks can effectively support an array of sensors crucial to vehicle operations and mission support. Embeddable passive wireless sensors can greatly increase the vehicle's sensing and telemetry capabilities, including providing low-cost techniques for vehicle health management in future missions.

NASA SBIR Topic

- Specifically, this subtopic solicits the following technologies:
  - Low power, low mass, and small volume components, where sensor/actuator modules are less than 20 grams in mass and less than 1 cc in volume. Of particular interest are highly scalable systems for measurement and data acquisition where total subsystem mass would be under 1 Kg and would operate under 3 W of power.
  - Components capable of surviving and operating in aerospace environments requiring tolerance to extreme temperatures, shock and vibration, and radiation effects that exist for satellites, launch vehicles, planetary and space habitats, deep space exploration systems and landing/re-entry systems.
  - Techniques that decrease reliance upon batteries or eliminate the need for charging and battery replacement, including novel approaches for electromagnetic energy harvesting, generating and storage methods; including capacitive, hybrid and acoustic power harvesting technologies.
  - Wireless technology, protocols, architectures and software systems that support redundant networks that can dynamically reconfigure to reestablish connectivity and function after temporary interruptions or component failures, including internal fault detection capability.

Conclusion

- NASA has a variety of uses for wireless technologies to assist developers meet mission needs
- Wireless technologies can be enablers for new mission concepts, especially for missions into extreme exploration environments.
- NASA will specifically invest in new wireless technologies for missions as part of the FY2016 SBIR call.
- Wireless is important to NASA at all Centers for both spaceflight and for aeronautical uses.