PHM for Space Applications Panel:

Space Propulsion System

Wireless Sensor Technology (WST) Needs/Challenges

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Wireless History

- Wireless technology was invented in the late 1800s
- Fast forward to 1962, the first communication satellite (Telstar), was launched
- In 1979, the first automatic cellular network was developed
- Wi-Fi then became popular with the public in 1997
- Decades later, wireless sensor technology (WST) is being used for many common applications: security systems, computers, sensors
- A wide variety of space propulsion systems could benefit from WST
- This presentation is scoped to needs/challenges specifically for the following:
  - **Solids**
  - **Liquids**
  - **Air-breathing Hypersonics**
Solids

- **Description**: Solid rocket motors (SRMs) generate thrust from burning solid propellants (fuel and oxidizer)
- **Applications**:
  - **Launch Vehicle**: Solid motors are used to boost a space vehicle from a pad
  - **Missile**: SRMs provide the thrust for strategic and tactical missiles
Solids (cont.)

- **WST Needs/Challenges:**
  - Parameter measurement: stress, strain, temperature, humidity, acceleration, deformation (multiple measurement types from a given sensor is a plus)
  - Unique identification capability
  - Auto-ignition avoidance (energetic material compatibility / EMI requirements)
  - Long-term reliability (on the order of 40 to 50 years)
  - Tight repeatability (minimal drift is a must)
  - Robust (especially in terms of temperature and G-shock)
  - Calibrate-able (if embedded)
  - Wireless reader (usable on a strategic missile confined within silo)
  - Light-weight (grams) and small (minimal impact to assembly/performance)

**BOTTOM LINE:** Need to define *system readiness* via *propellant/liner/insulation system health status* (pre-flight focused)
Liquids

- **Description**: Liquid rockets generate thrust from burning liquefied propellants (fuel and oxidizer)
- **Applications**:
  - **Launch Vehicle**: Liquid rockets are used to boost a space vehicle from a pad, as well as for maneuvering it in space

![Image of liquid rocket engine](http://rocket.com/files/aerojet/images/media/spaceshuttlemain1_0.jpg)
Liquids (cont.)

- **WST Needs/Challenges:**
  - Parameter measurement: speed (pump), temperature, pressure, flow, acceleration, position (multiple measurement types from a given sensor is a plus)
  - Unique identification capability
  - Tight repeatability
  - Robust (especially in terms of cryogenic-to-high-temperature thermal shock)
  - Smart / local processing with data validation and calibration capabilities
  - High-speed processing capability (on the order of milliseconds for operational control)
  - Reusability

**BOTTOM LINE:** Need to define propulsion system capability via overall system health status (pre-flight, flight, and post-flight)
Air-breathing Hypersonics

- **Description**: Hypersonic engines generate thrust from burning fuel using external ram-air (oxidizer)
- **Applications**:
  - **Cruise Vehicle**: Hypersonic engines provide the thrust for cruise vehicles
  - **Missile**: Hypersonic engines provide the thrust for missiles

http://rocket.com/files/aerojet/images/media/hypersonics1.jpg
http://rocket.com/files/aerojet/images/media/hypersonics2.jpg
Air-breathing Hypersonics (cont.)

- **WST Needs/Challenges:**
  - Parameter measurement: position (shock-train; actuator), speed (pump), temperature, pressure, flow, acceleration (multiple measurement types from a given sensor is a plus)
  - Unique identification capability
  - Tight repeatability
  - Robust (especially in terms of high-temperature)
  - Smart / local processing with data validation and calibration capabilities
  - High-speed processing capability (on the order of milliseconds for operational control)
  - Reusability

**BOTTOM LINE:** Need to define **propulsion system capability** via **overall system health status** (pre-flight, flight, and post-flight)
## Summary

### Space Propulsion System WST Needs/Challenges

<table>
<thead>
<tr>
<th>Parameter Measurements</th>
<th>Solids</th>
<th>Liquids</th>
<th>Hypersonics</th>
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<td>- Temperature</td>
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<td>- Speed (pump)</td>
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<td>- Flow</td>
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<td>- Position (actuator)</td>
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<td>- Flow</td>
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<td>- Position (shock wave)</td>
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<td>- Robust</td>
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<td>- Humidity</td>
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<td>- High-speed</td>
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<td>- Reusable</td>
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**BOTTOM LINE:** Space propulsion WST needs and challenges have been defined, now the PHM community is being asked to deliver.