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

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- 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

http://rocket.com/files/aerojet/images/media/LaunchVehAtlasV.jpg

http://rocket.com/files/aerojet/images/media/TacticalArmyTACMS.jpg

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Solids (cont.)

- <u>WST Needs/Challenges</u>:
  - 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)

<u>BOTTOM LINE</u>: 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

http://rocket.com/files/aerojet/images/media/spaceshuttleemain1_0.jpg

cp0046 15 NSS 2015 RL10 engine

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

- <u>Description</u>: Hypersonic engines generate thrust from burning fuel using external ram-air (oxidizer)
- <u>Applications</u>:
  - *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							
Parameter Measurements							
- Acceleration - Temperature	- Flow - Position (actuator) - Pressure - Speed (pump)	- Deformation - Humidity - Strain - Stress	- Position (shock wave)	- Robust - Tight repeatability - Unique ID	- High-speed - Reusable - Smart	- Auto-ignition avoidance - Calibrate-able - Light-weight & small - Long term reliability - Wireless reader
Solids	X		X		X		X
Liquids	X	X			X	X	
Hypersonics	X	X		X	X	X	

BOTTOM LINE: **Space propulsion WST needs and challenges** have been defined, now the **PHM community** is being asked to deliver