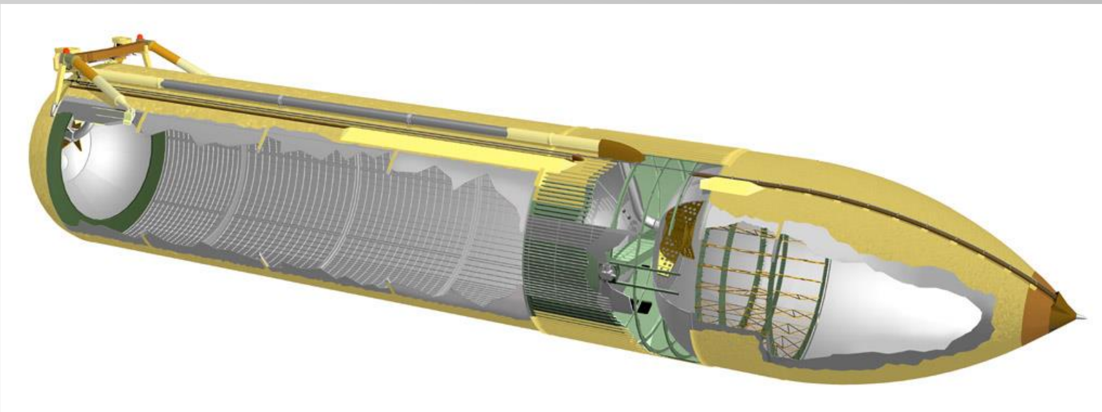
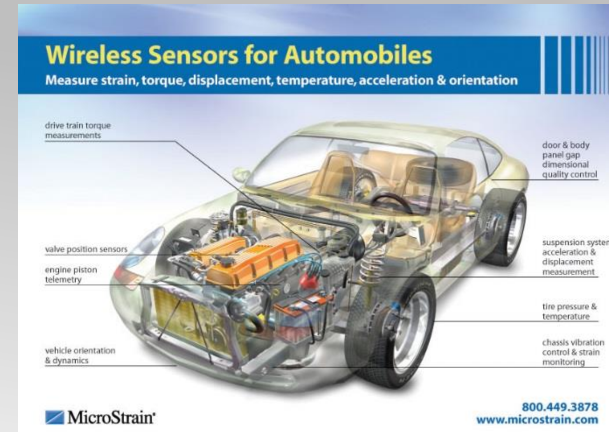
Advanced Wireless Sensor Nodes - MSFC 2016

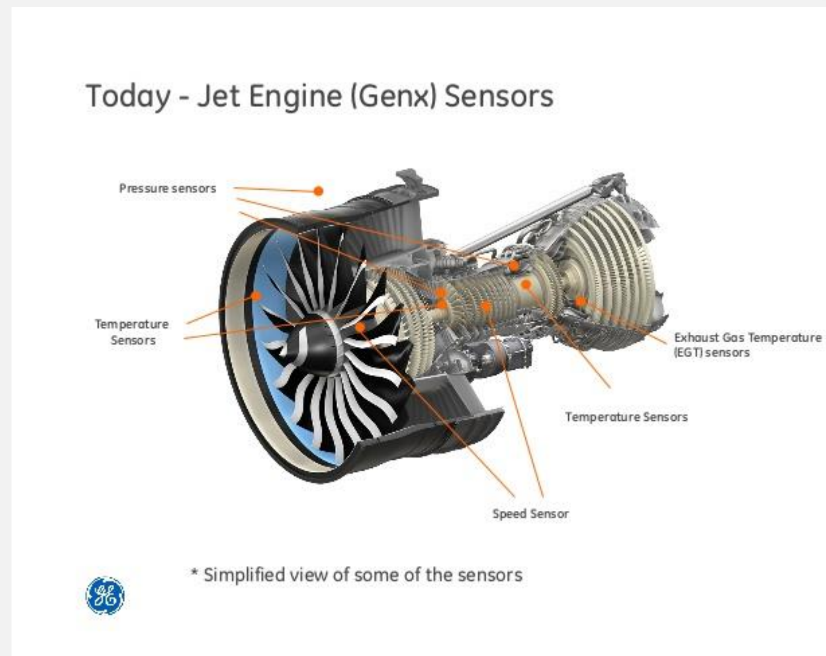
Kosta Varnavas – Electronic Design Branch – ES 36

Jeff Richeson – ES35 ESSSA/ Jacobs





Sensor proliferation is exploding…



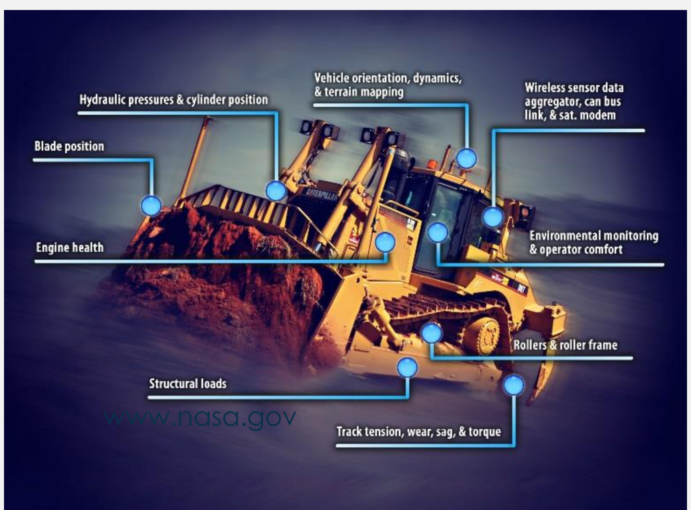
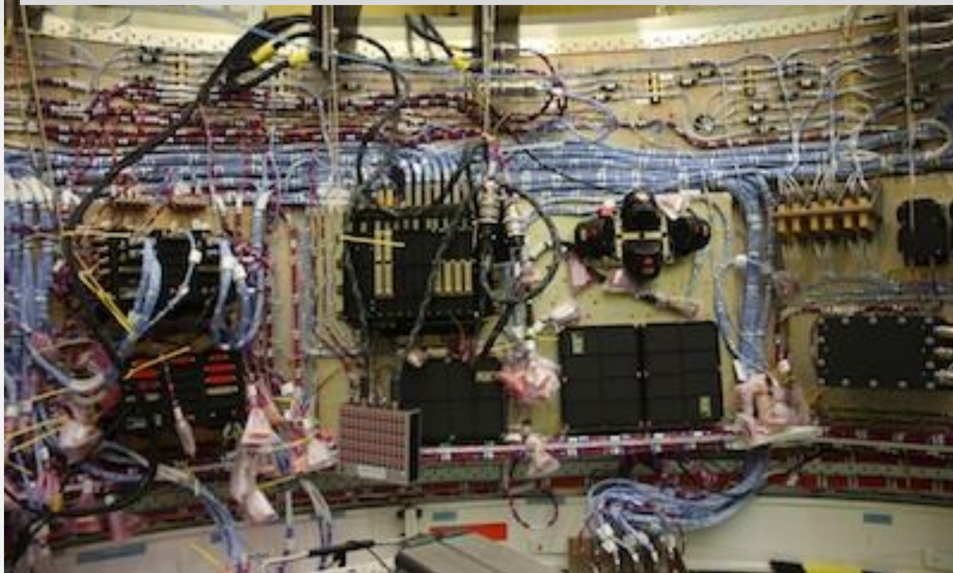


Image Sources: Google Images

DRAWBACKS TO HARDWIRED SPACECRAFT BUS ARCHITECTURES

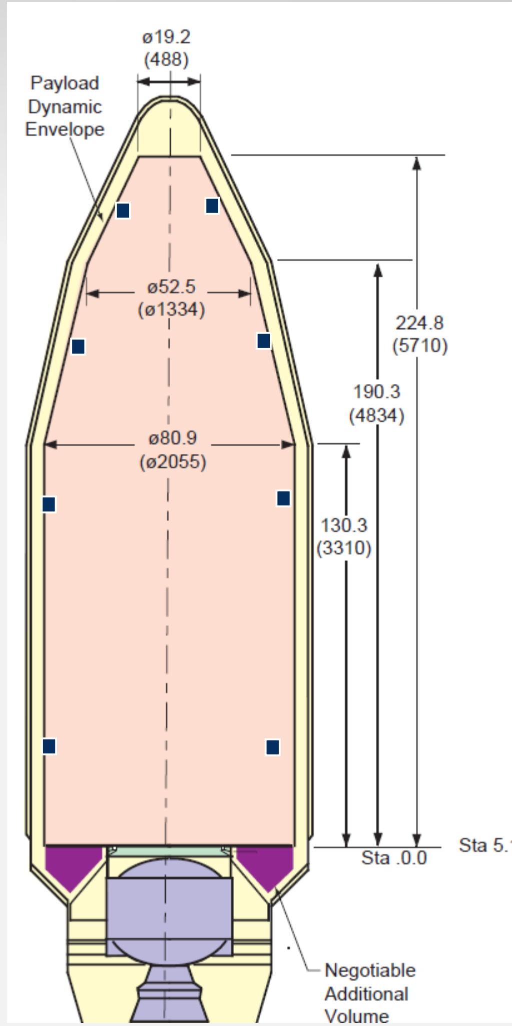


- Failures of wires and connectors
- Mass of cabling and electrical interfaces
- Physical restrictions on wired sensor placements (tankage, bulkhead penetrations, etc)
- Undesired ground loops on the communication paths; long wire runs acting as antennas

Image Sources: Google Images

ADVANTAGES OF WIRELESS TECHNOLOGY

- Covers common-mode faults due to structural failure that may affect critical wiring!
- Lower mass
- Redundant data access nodes improves robustness
- Low-power battery-powered sensor packages can last years and be placed in difficult locations for wires to reach (penetrations, high vibration, rotating structures and components)



- Internal Shroud Temp and Shroud Sensor Module

Gateway to Telemetry Downlink

- **Source: Taurus Launch System Payload User's Guide**

www.nasa.gov

How Wireless Sensors Could be Used on Launch Vehicle

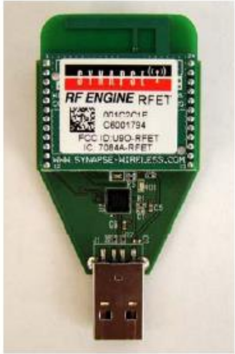
The Chosen ZigBee Module

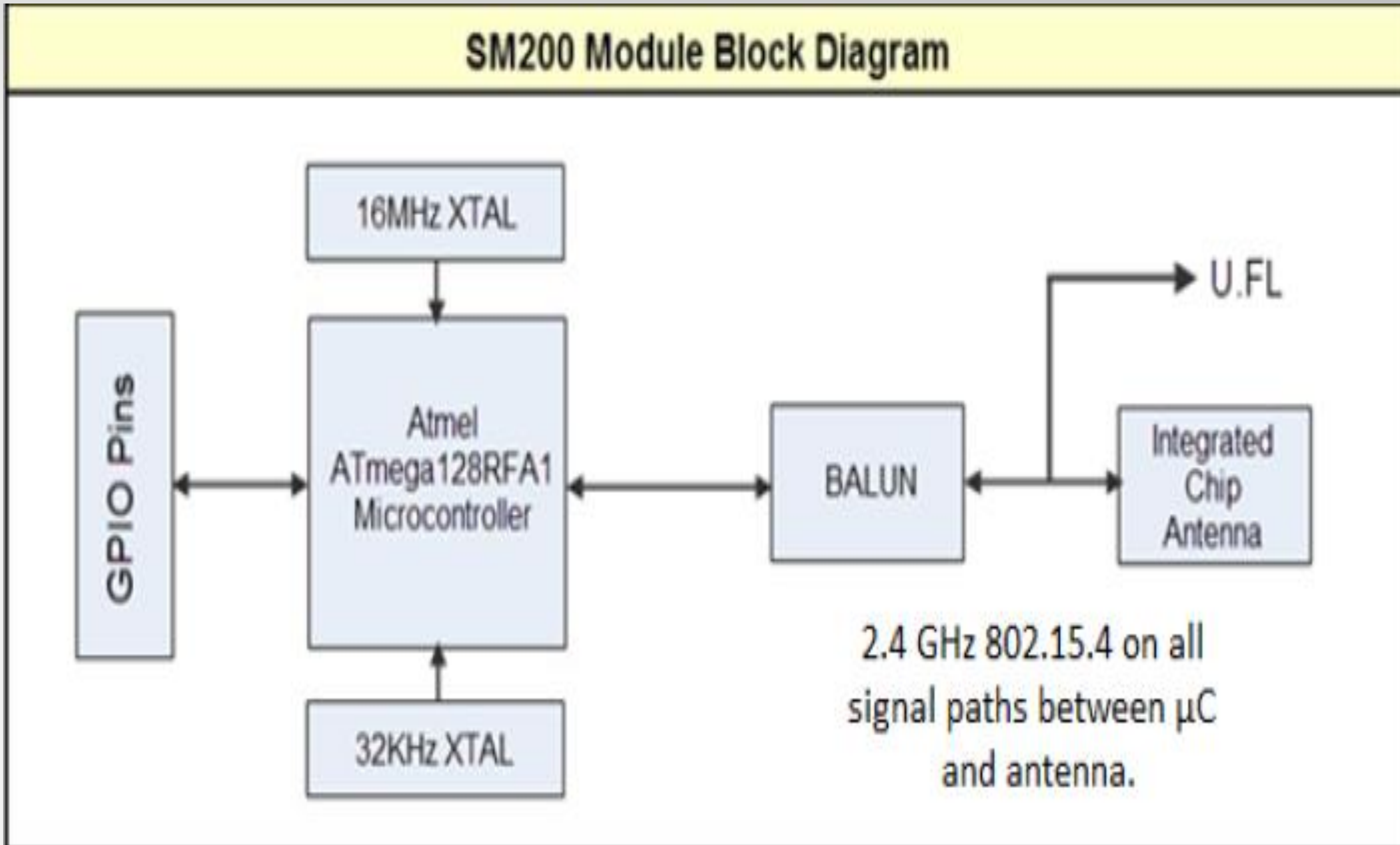
- The Synapse RF200 Modules, contain a complete A/D, Microcontroller ,802.15.4 radio and Mesh Protocol Software Stack.

- Capable of uploading new software into each module over the air (OTA).

RF200P81 / SM200 Synapse 2.4 GHZ IEEE 802.15.4/ZIGBEE® RF TRANSCEIVER
RX: 22.5 mA (@ 3.3 V)
TX: 22.5 mA (@ 3.3 V)
33.86mm x 33.86mm
20 GPIO and up to 7 A/D inputs

SN132 SNAPstick USB module

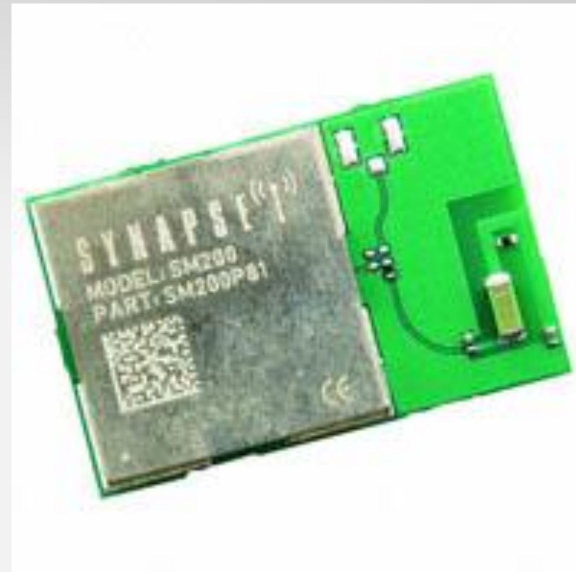


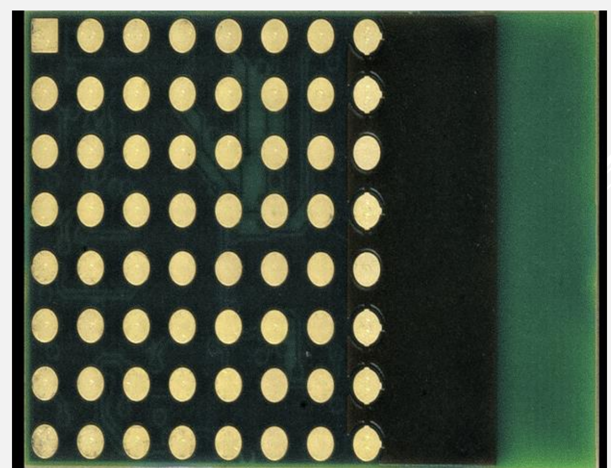

SM200 Module Block Diagram
16MHz XTAL
GPIO Pins
Atmel
ATmega128RFA1
Microcontroller
BALUN
U.FL
Integrated
Chip
Antenna
32KHz XTAL
2.4 GHz 802.15.4 on all
signal paths between µC
and antenna.

WIRELESS SYNAPSE FOOTPRINTS

Through Hole (DIP)

Surface mount





Comparing the two generations

GEN 1

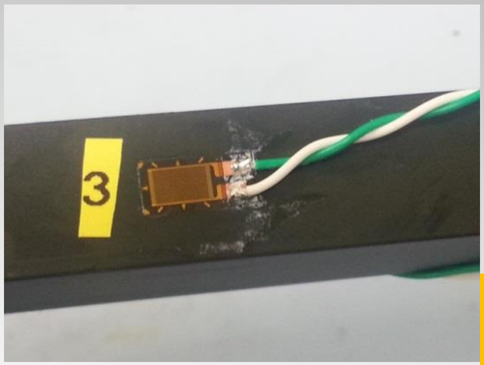
Generation One

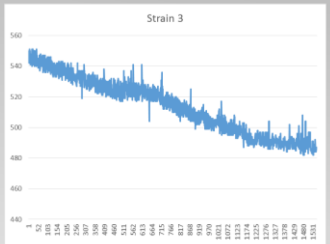
- 6 gauges all powered at same time.
- Strain gauged excitation voltage is straight off main battery rail.
- Op amp only has a 200 gain. This is a fixed gain set by on board resistor.
- No shunt or other method for onboard calibration.
- No Power Management.

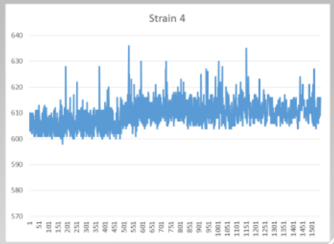
Generation Two

- Only 1 Gauge
- Each strain gauge has an independent constant voltage regulator driving the excitation voltage.
- Power management hardware.
- Op Amp has much larger and adjustable gains.
- Power management software.

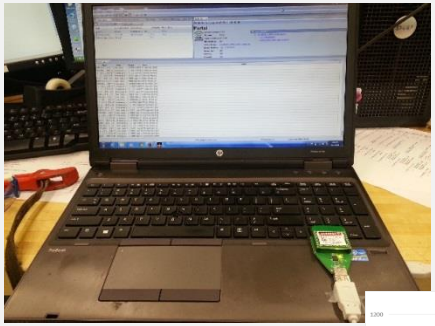
WIRELESS SENSOR SYSTEMS DEVELOPMENT

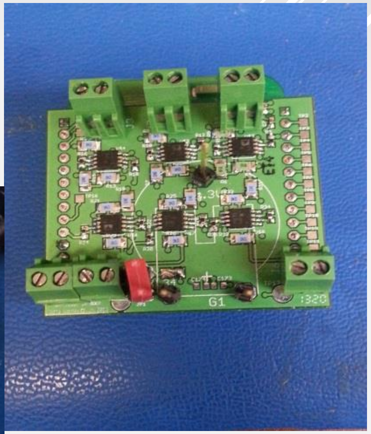


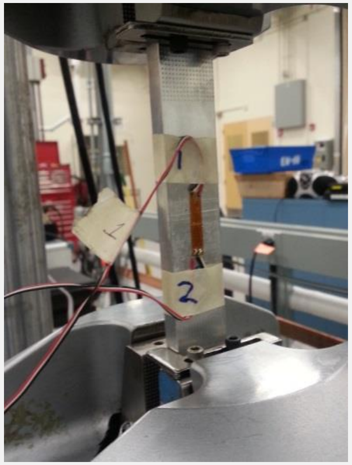


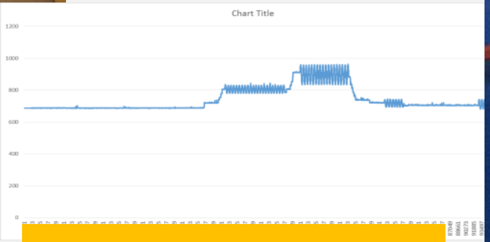


Wireless strain gauge on quadcopter

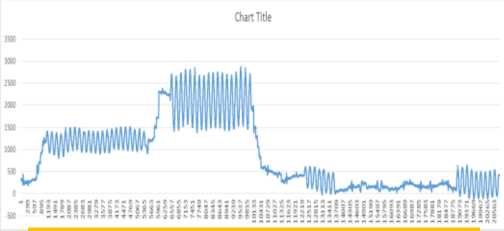




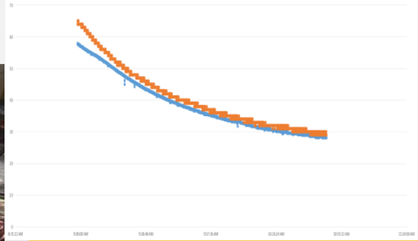




Wireless Strain gauge At Materials Lab Pull Test



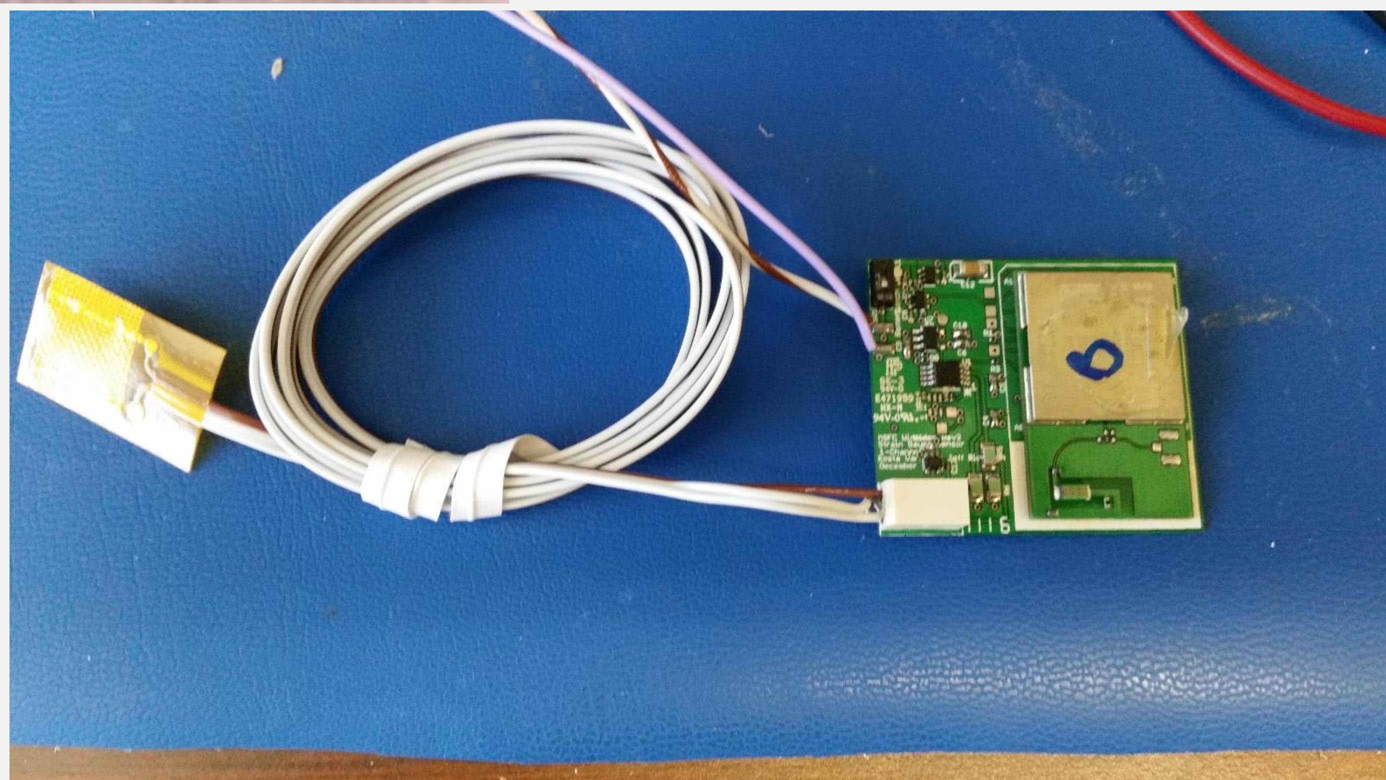
Materials Lab Strain gauge Pull Test

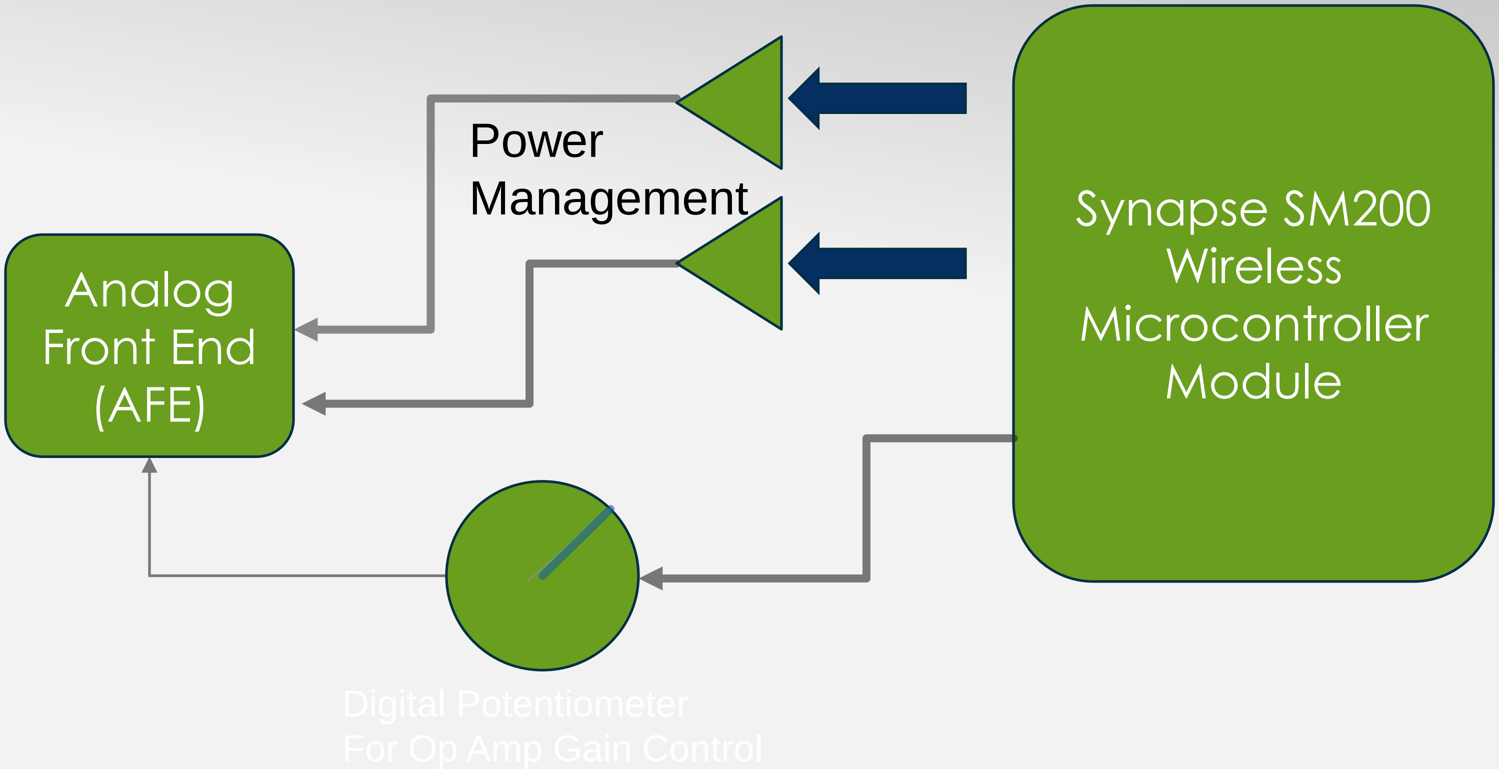


Combined wireless and reference K-type Thermocouple measurements.

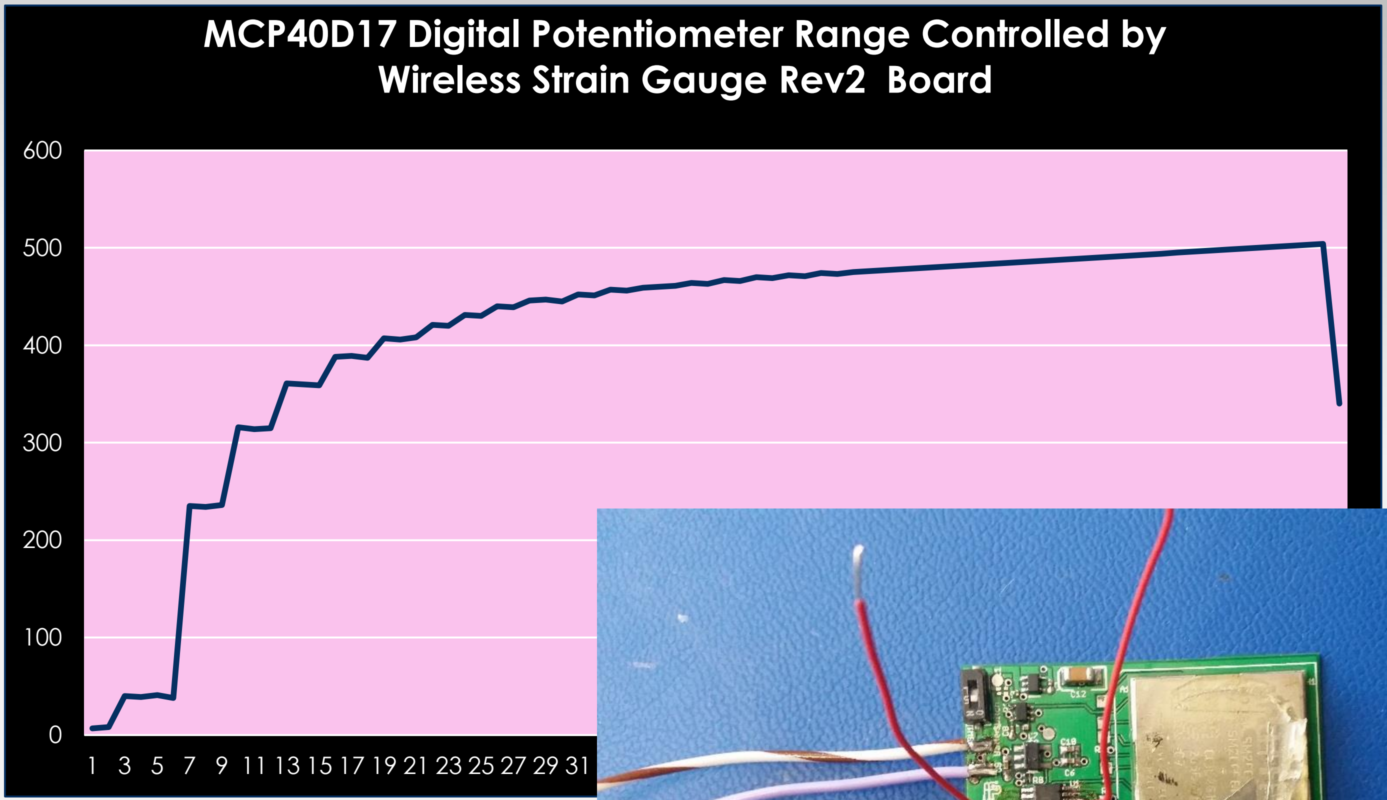
Gen 2 Wireless Strain Gauge
* 1 Channel
* With Battery
* 1.5 “ x 1.3 “ without case.

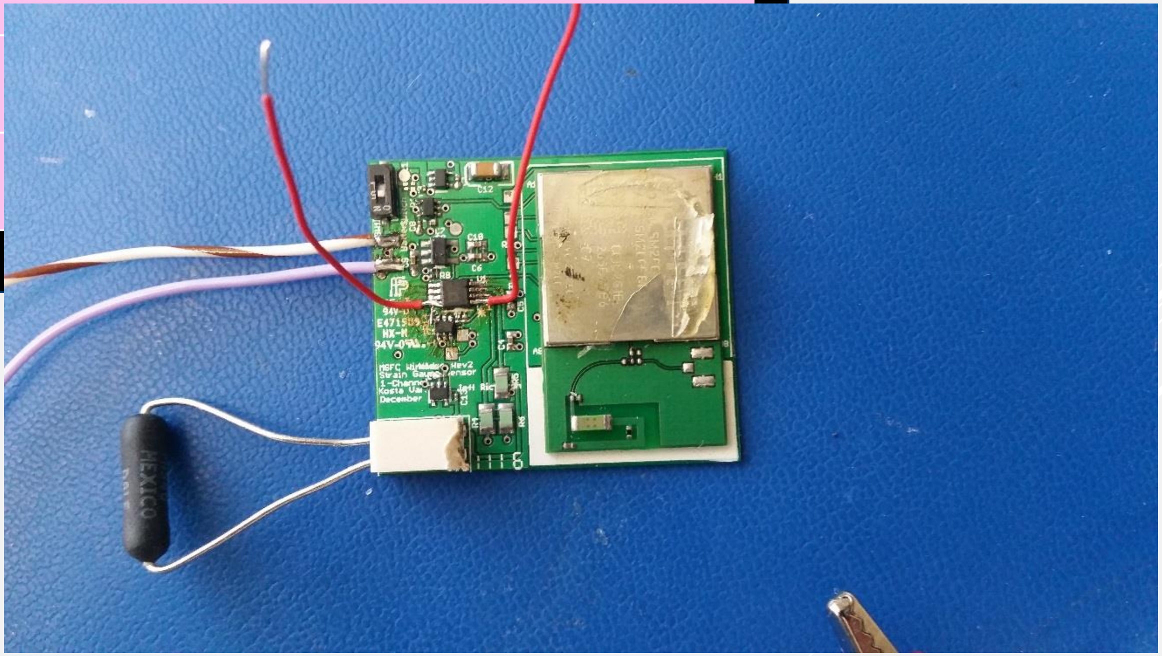
Gen 2 Wireless Strain Gauge with power leads And strain gauge Attached.





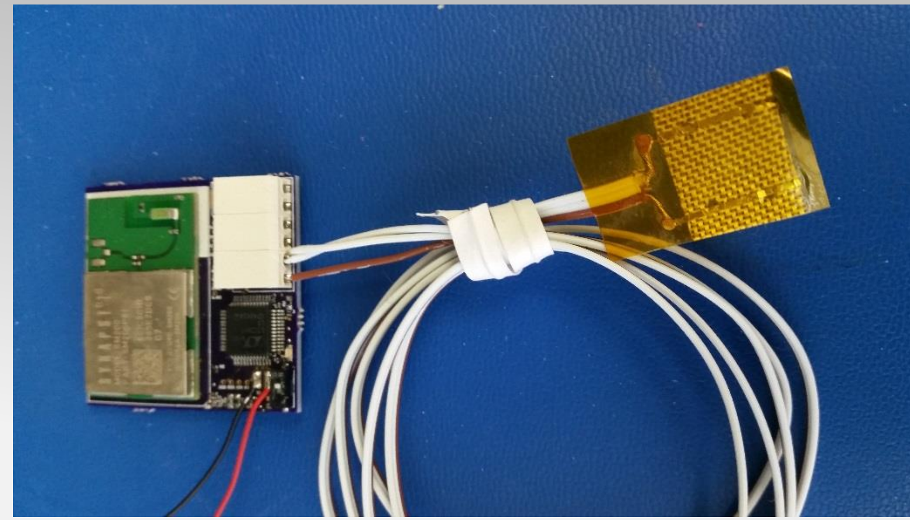
BLOCK DIAGRAM WIRELESS STRAIN GAUGE





Test of op amp gain change using digital potentiometer and 350 ohm reference resistor.

Wireless Temp Board



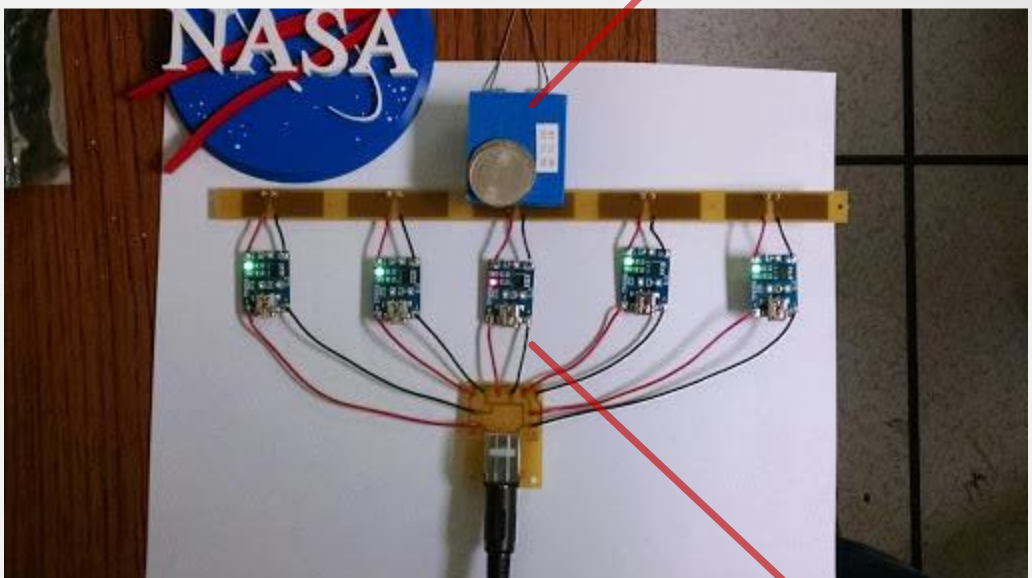
With RTD

Can measure :

- virtually all standard (type B, E, J, K, N, S, R, T) or custom thermocouples.
- Automatically compensate for cold junction temperatures and linearize the results.
- 2-, 3-, or 4-wire RTDs.
- Thermistors.
- Diodes.
- SPI bus controlled.

3-D printed (additive manufactured) casing for the 5-bay charging system was designed and created. Same as the blue housing for sensor node.

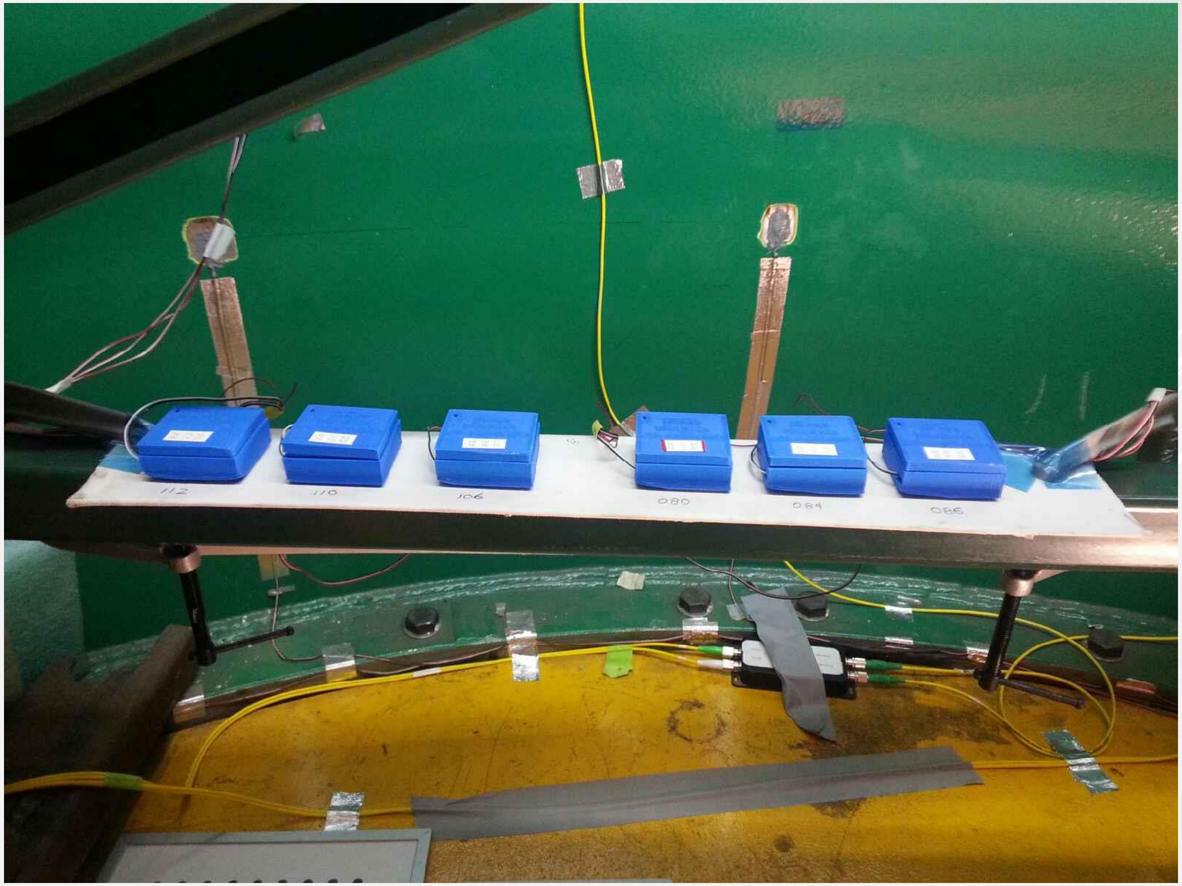
This is one wireless module on charging circuit. Charging bay has room for 5 modules.

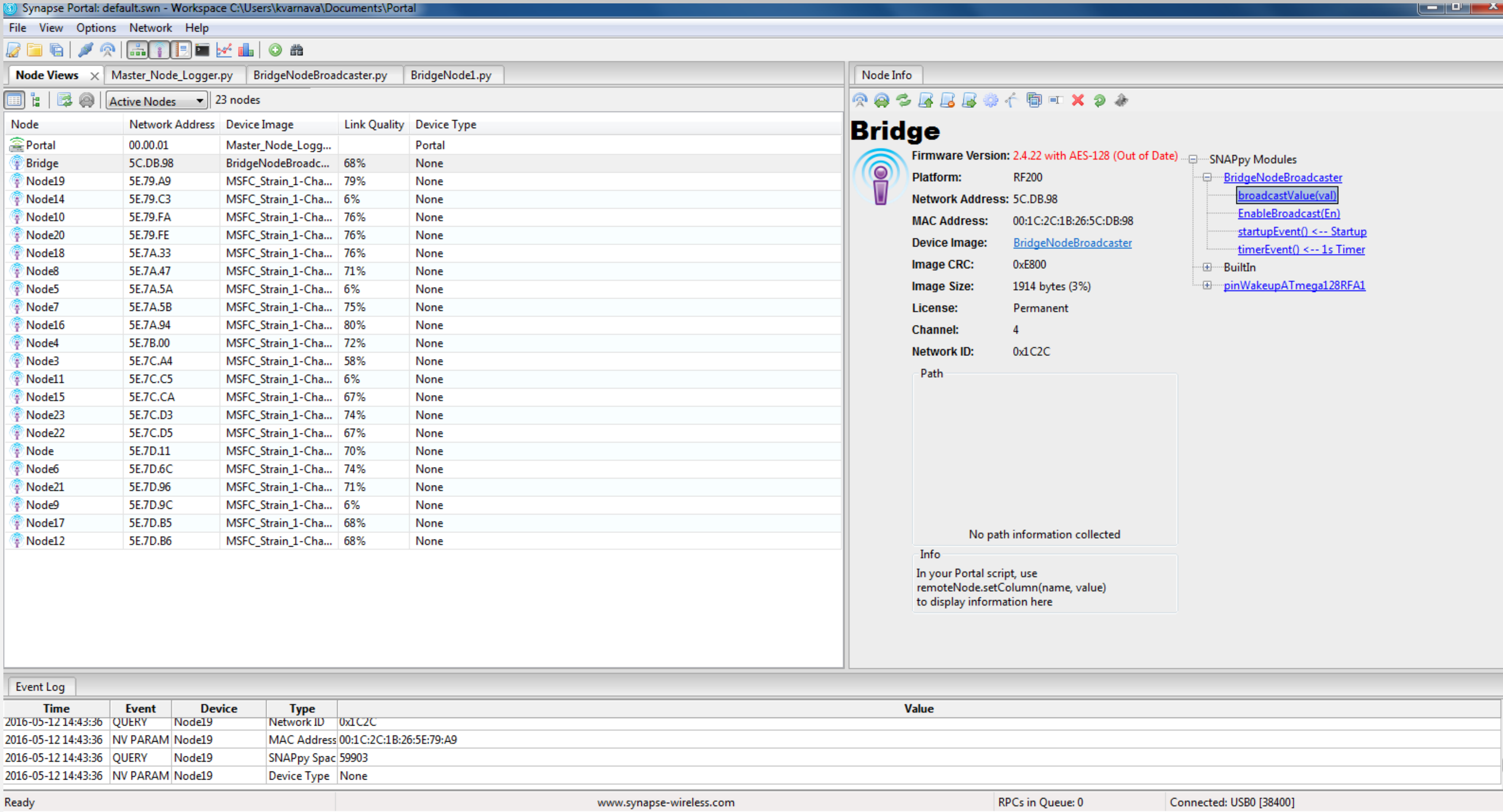


Commercial charging nodes , are specific for charging and preventing over charging of Li-ion batteries.

Composite Shell Buckling Test

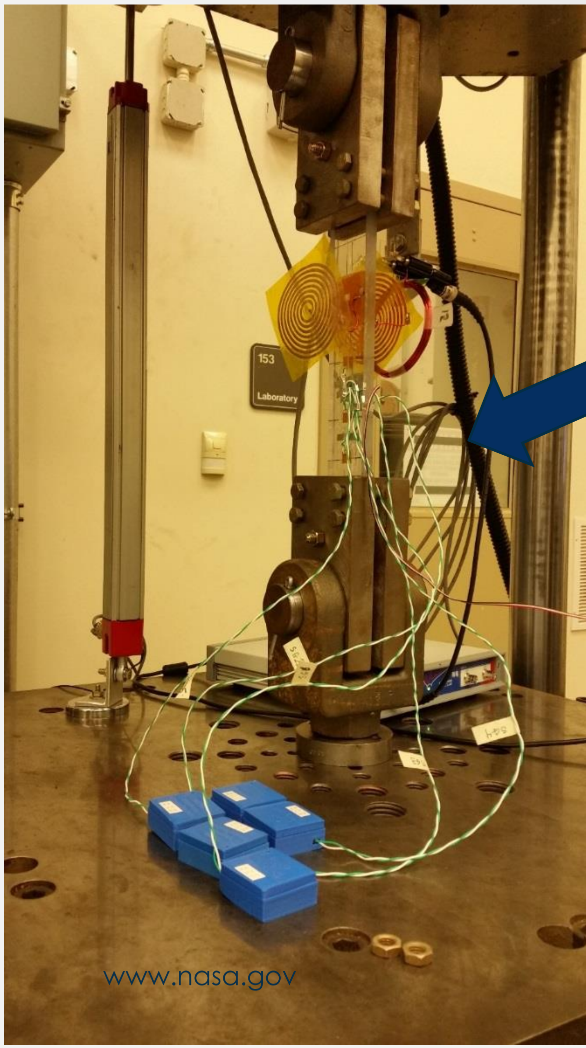
20 – 1 Channel MSFC Wireless Sensor inside Composite shell

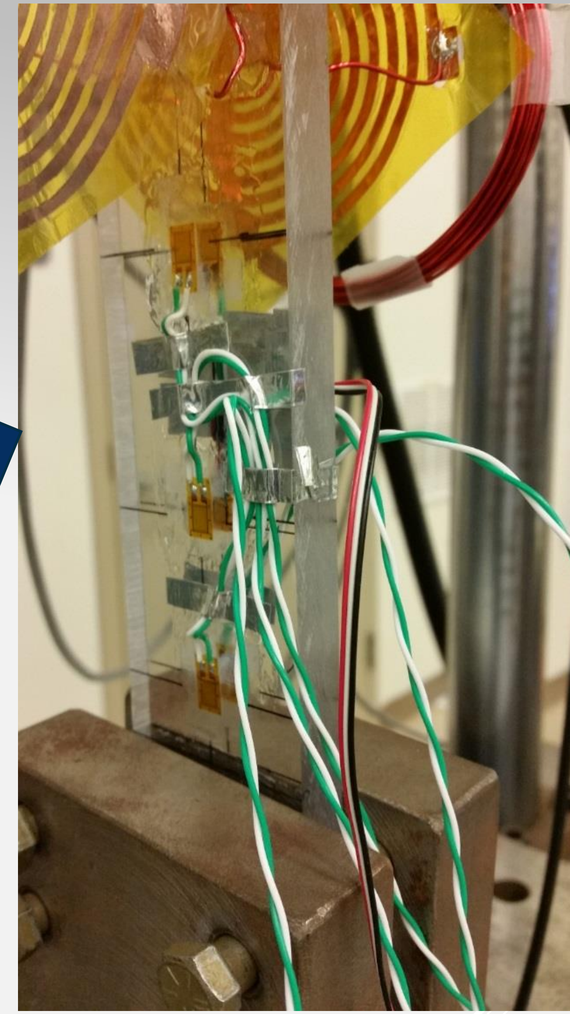




Control GUI – Large amount of interference caused all of the nodes to drop out shortly after test began. The test article was in a safety keep out zone so there was no way to fix or restart with fewer nodes after testing started.

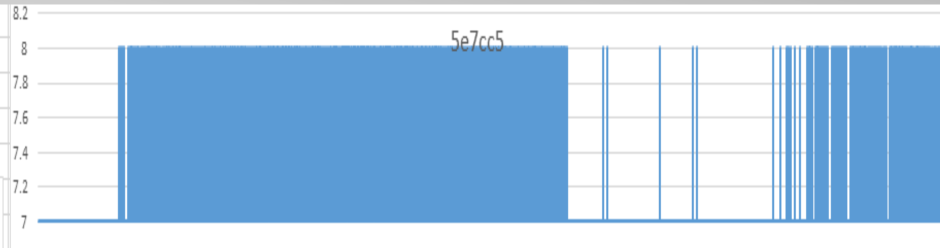
Test Lab Pull Test July 2016 Setup

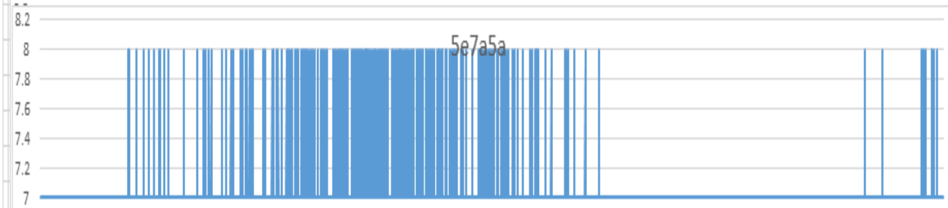


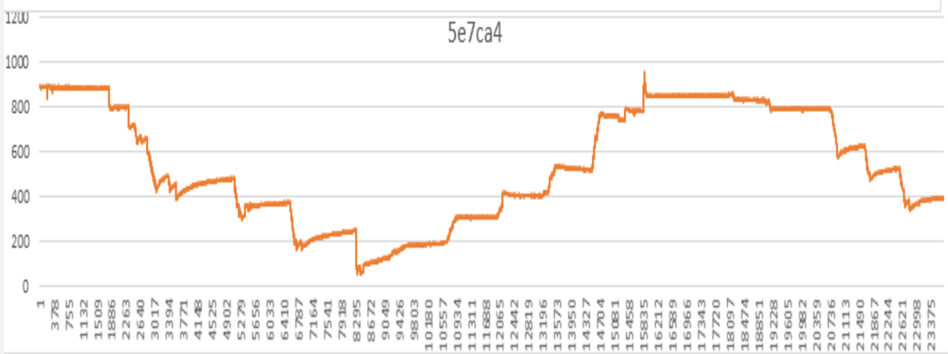


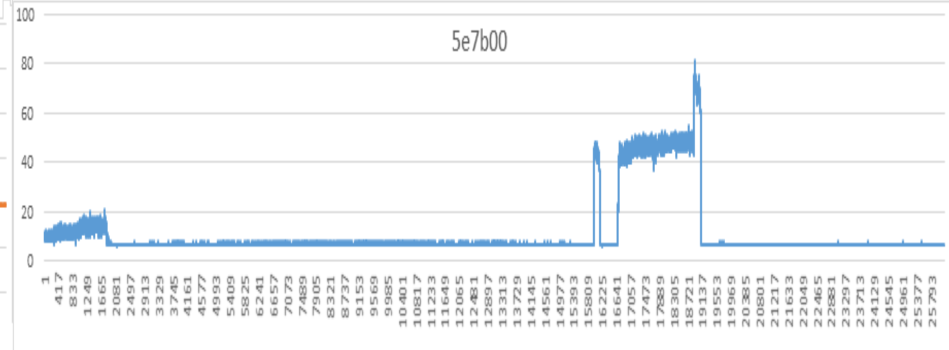
Test Lab Pull Test July 2016 Data Results

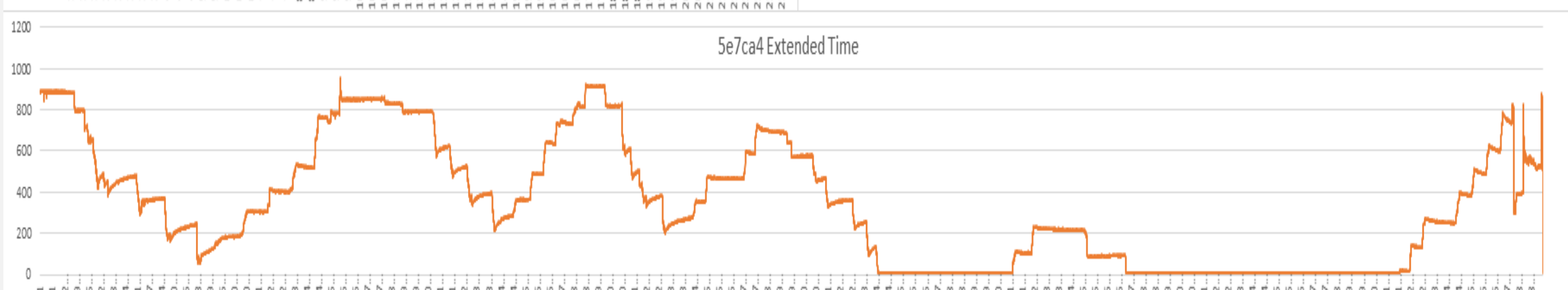
5e7b00	26175	packets
5e7ca4	**79348**	packets
5e7a5a	24553	packets
5e7cc5	26585	packets
5e7a47	24692	packets











Better Battery and Power Management

Calibration shunt that can be switched in and out of circuit by software.

Coming In Gen 3

Advanced Software Controls

- Kosta Varnavas ES36
  - kosta.varnavas@nasa.gov
  - 256-544-2638
- Jeff Richeson ES35
  - James.j.richeson@nasa.gov
  - 256-961-0128

Back Up Charts

SM200 Specifications

Table 1.0 Specifications		SM200P81/PU1	RF200P81/PU1
Performance	Outdoor LOS Range	Up to 1500/2500 feet at 250Kbps	
	Transmit Power Output	3 dBm	
	RF Data Rate	250Kbps, 500Kbps, 1Mbps, 2Mbps	
	Receiver Sensitivity	-100 dBm (1% PER, 250Kbps)	
Power Requirements	Supply Voltage	1.8 - 3.6 V	
	Transmit Current (Typ@3.3V)	22.5 mA	
	Idle/Receive Current (Typ@3.3V)	20.5 mA	
	Power-down Current (Typ@3.3V)	0.37 µA	
General	Frequency	ISM 2.4 GHz	
	Spreading Method	Direct Sequence (DSSS)	
	Modulation	O-QPSK	
	Dimensions	29.8mm x 19mm	33.86mm x 33.86mm
	Operating Temperature	- 40 to 85 deg C.	
	Antenna Options	Integrated Chip Antenna / External Antenna	
Networking	Topology	SNAP	
	Error Handling	Retries and acknowledgement	
	Number of Channels	16	
Available I/O	UARTS with HW Flow Control	2 Ports - 8 total I/O	
	GPIO	38 total; 7 can be analog-in with 10bit ADC	20 total; 7 can be analog-in with 10bit ADC
Agency Approvals	FCC Part 15.249	FCC ID: U9O-SM200	FCC ID: U9O-SM200
	Industry Canada (IC)	IC: 7084A-SM200	IC: 7084A-SM200
	CE Certified	Yes	Yes

Generation 2

Only 1 Gauge

- **Another version coming with 3 gauges for 3-dimensionl measurements**

Each strain gauge has an independent constant voltage regulator driving the excitation voltage

- **This provides solid voltages for more accurate measurements.**

Power Management Hardware

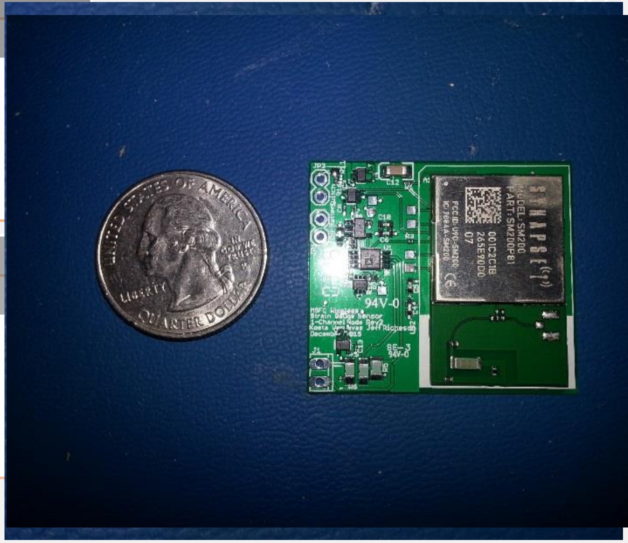
- **The power for each gauge sub circuit can be turned on or off by software saving battery power.**

Op Amp has much larger and adjustable gains

- **Gains up to 1000 and is variable under**
- **software control via digital potentiometer.**

Power Management Software

- **Software can control power management**
- **hardware to maximize battery life.**



DRAWBACKS TO HARDWIRED SPACECRAFT BUS ARCHITECTURES

- Failures of wires and connectors
- Mass of cabling and electrical interfaces
- High cost of late design changes in hardwired bus architectures; DFI change costs
- Development time overhead for allocating routes and places, shields, connectors, brackets, cable trays, fasteners, supporting structure, etc.
- Physical restrictions on wired sensor placements (tankage, bulkhead penetrations, etc)
- Undesired ground loops on the communication paths; long wire runs acting as antennas
- Electromagnetic compatibility issues (EMC), crosstalk, solar flux across wires
- (from Amini, et al 2007)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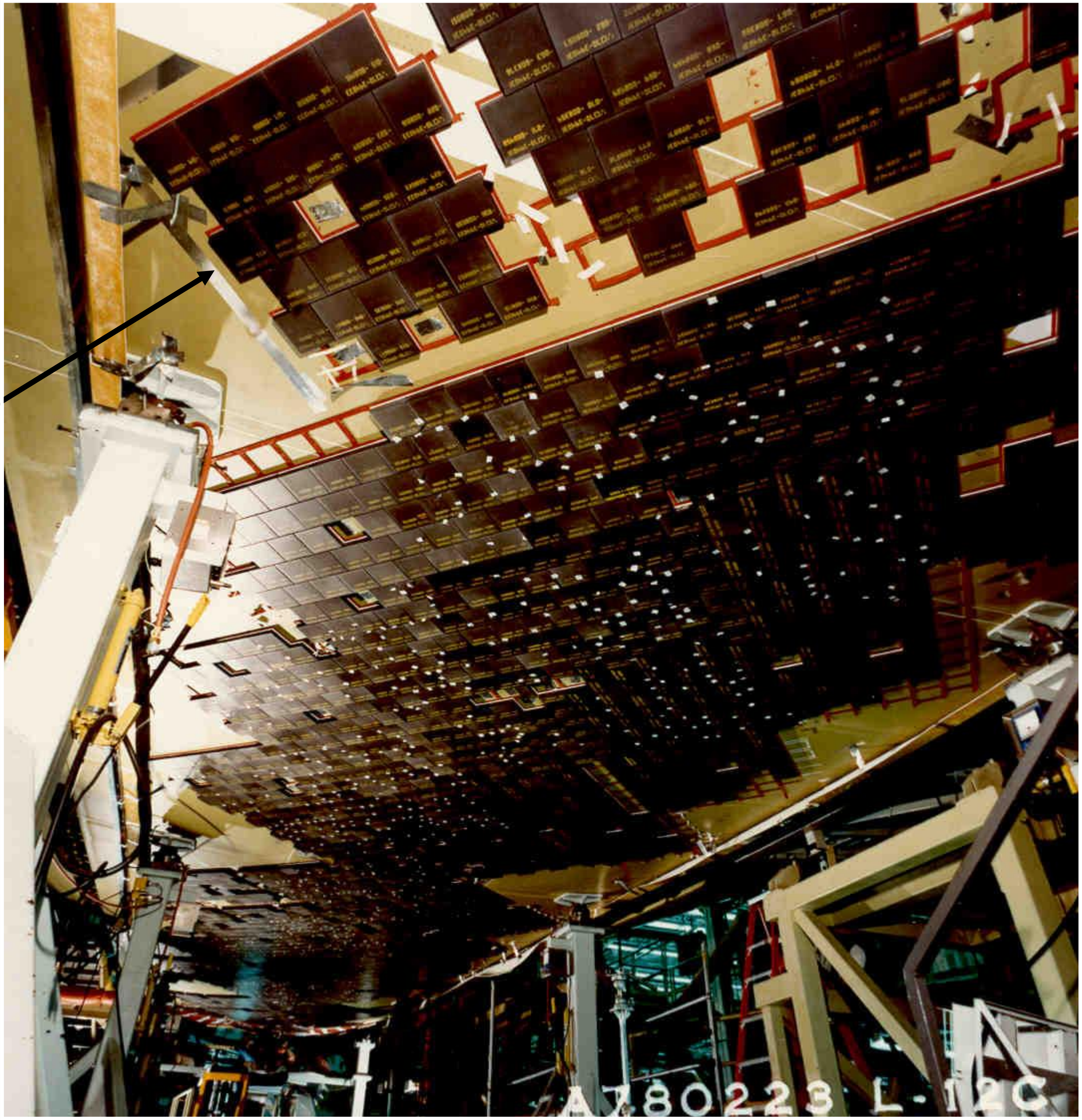
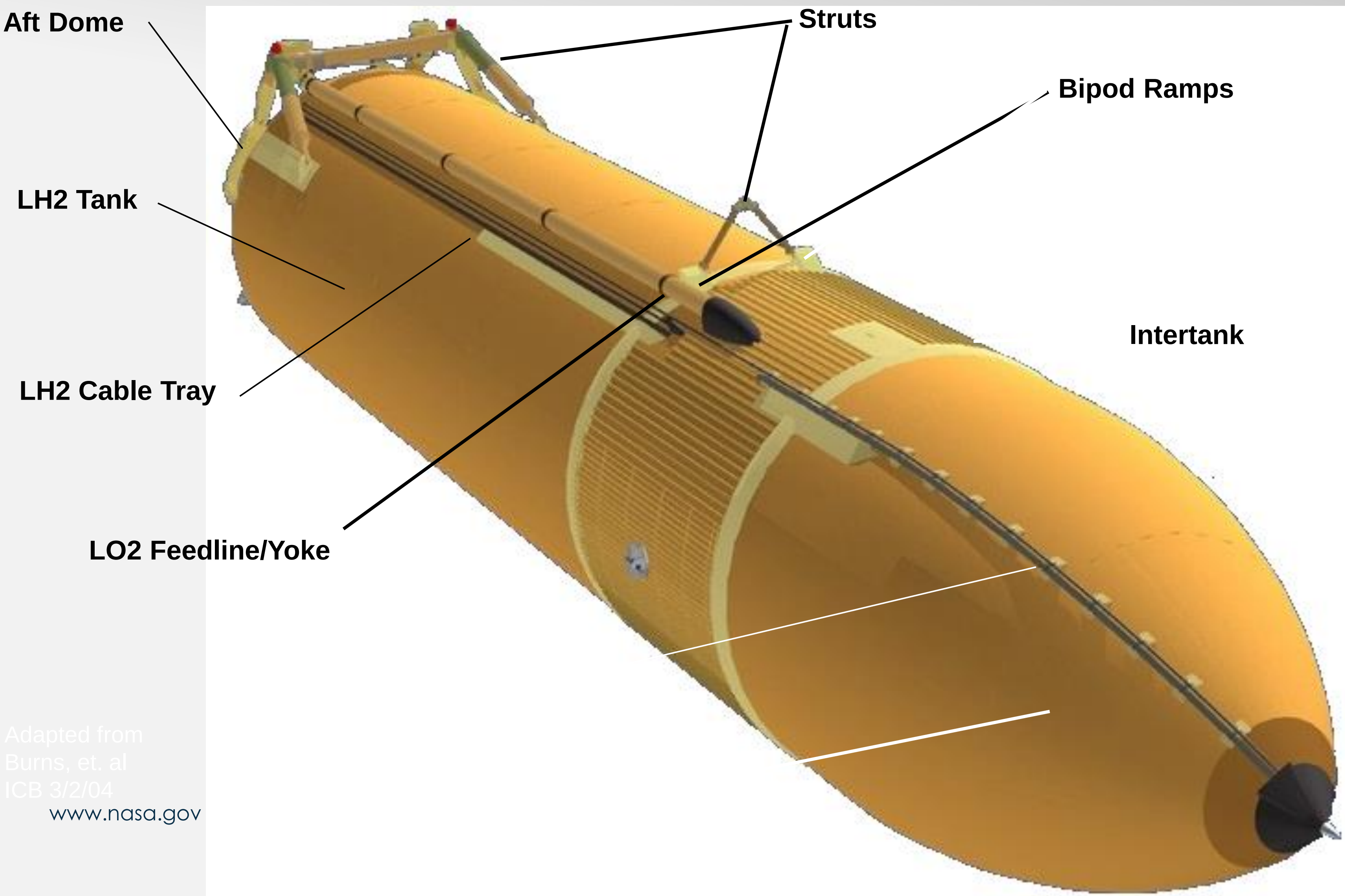
TILES DURING INSTALLATION ON THE SPACE SHUTTLE



Note grouping of tiles by array

ET CAPABILITIES & CONSTRAINTS



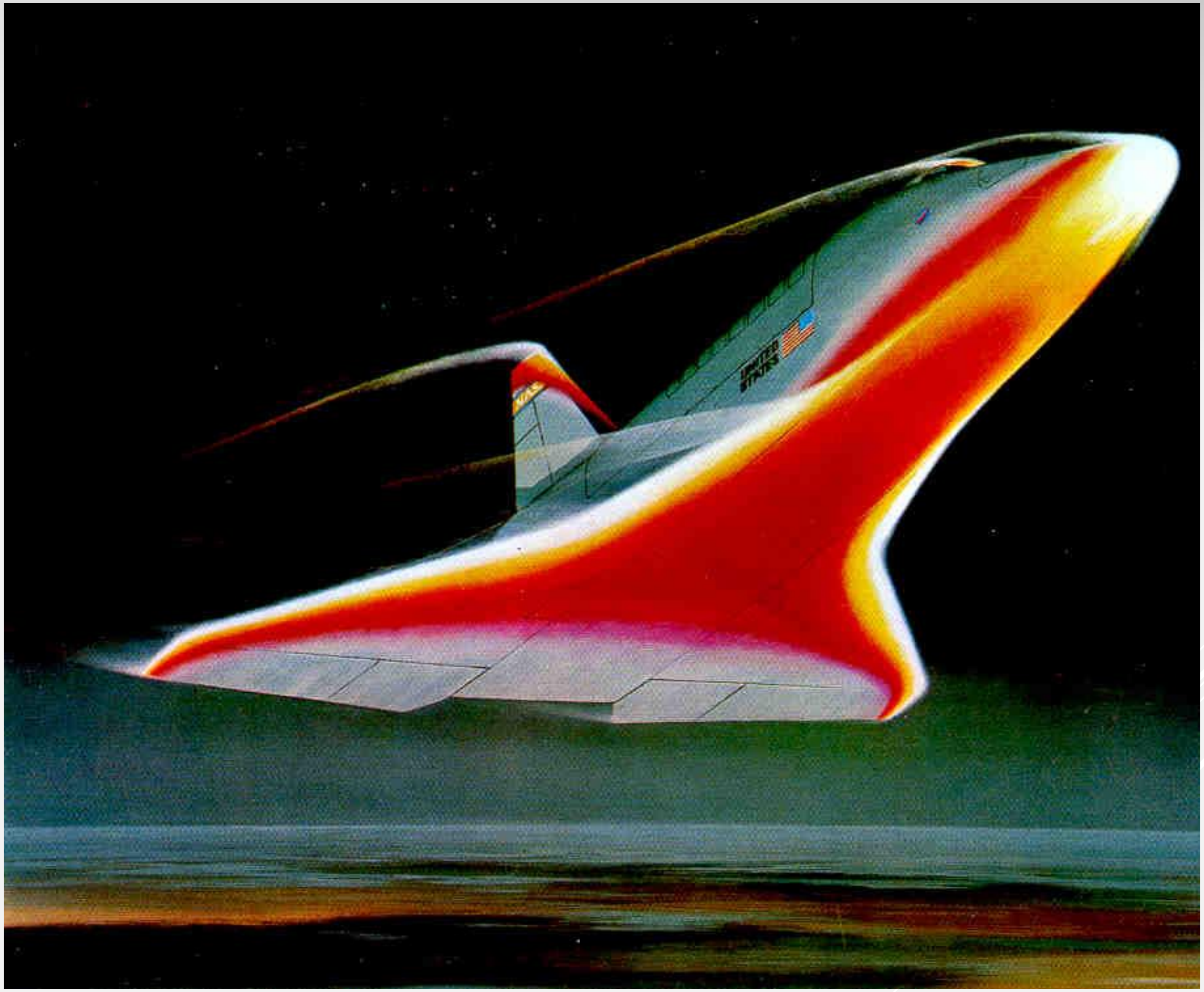
Adapted from
Burns, et. al
ICB 3/2/04

www.nasa.gov

SPACE SHUTTLE DURING REENTRY

The tiles prove to be "one of the most successful subsystems on the Orbiter."

-- Aaron Cohen, Orbiter Project Manager



Success of the tiles is a tribute to Robert Beasley, Inventor

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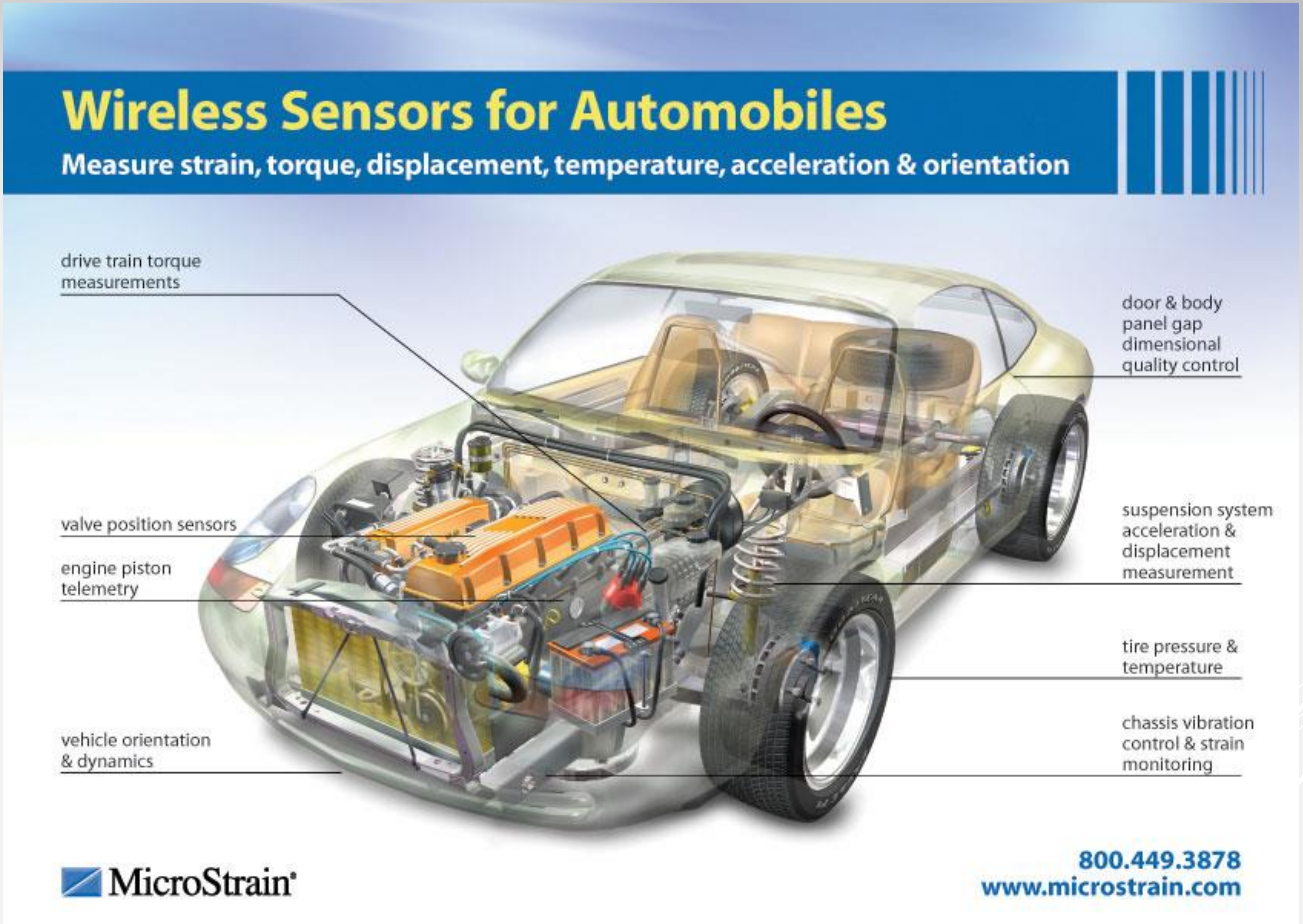
http://www.lr.tudelft.nl/live/binaries/72bd2130-888f-4040-8997-fb2245aa24a2/doc/Delft_


Wireless Sensors for Automobiles
Measure strain, torque, displacement, temperature, acceleration & orientation
drive train torque measurements
door & body panel gap dimensional quality control
valve position sensors
engine piston telemetry
suspension system acceleration & displacement measurement
tire pressure & temperature
chassis vibration control & strain monitoring
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