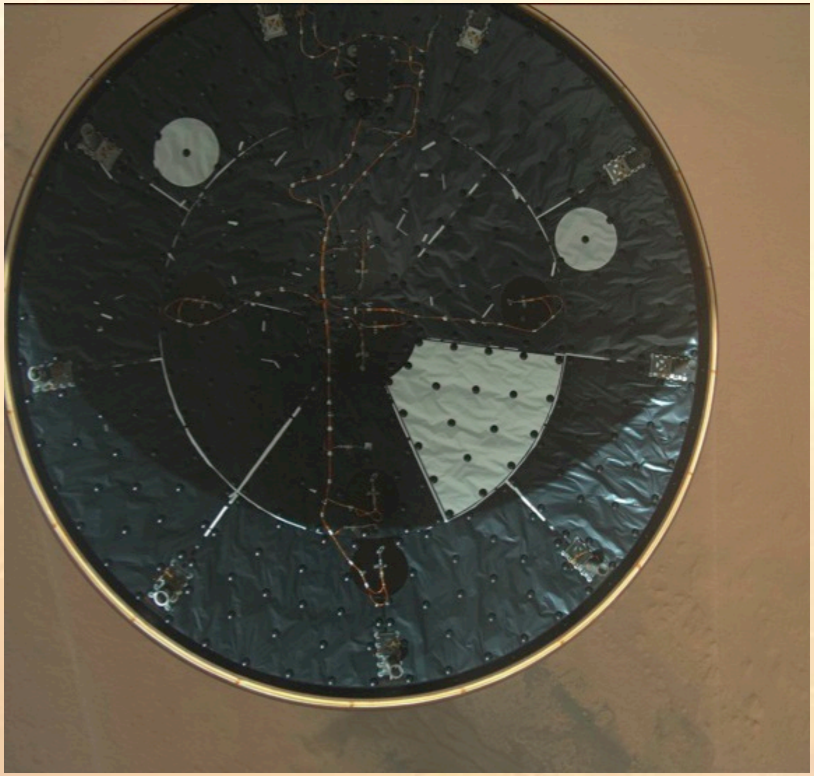

Cost Drivers

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Objective

- **Provide some perspective on characteristics or features which drive the cost of the EDL Instrumentation**

- **Using MEDLI, MEDLI2, EFT1, and Ares I-X as case studies**

- **Short answer – nothing magic – *"it all depends"***

Cost Sources

Hardware Heritage and Maturity

Measurements: Type, Quality, Quantity (Data), & Architecture

Part Count

Hardware Development

Total Cost

Integration & Testing Approach

Project Duration

Programmatics 7120.5/.8 8705.4 (A-D, E, F) Oversight

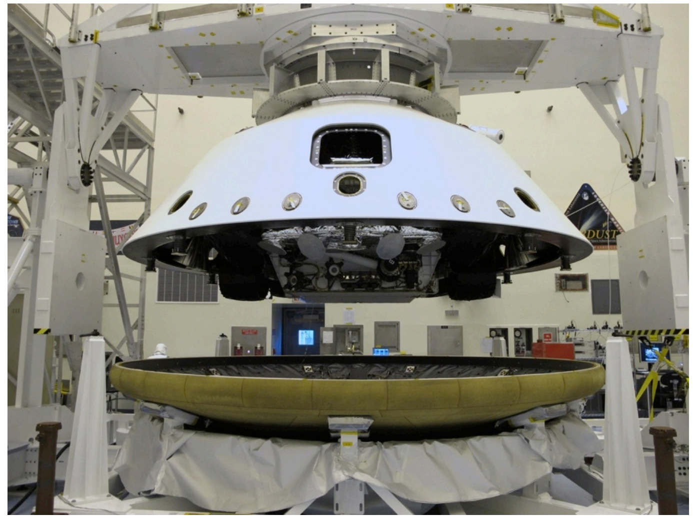
Staffing Levels – estimate vs assigned

Measurement Types

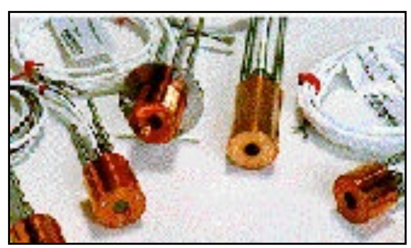
Imaging
- *Parachutes*
- *HIAD/SIAD/ADEPT, etc*
- *Visible; IR*

Aero Decelerator Attachment Loads
- *Load Cell*

Vehicle Dynamics
- *IMU*

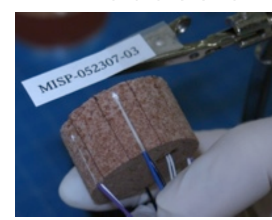


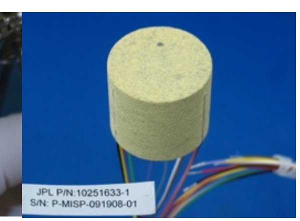
Heat Flux
- *Forebody vs aftbody*
- *Components – Convective, Radiant, Total*



Pressure
- *Surface – forebody & aftbody*
- *Inside aeroshell*
- ***Differential vs Absolute***

Temperature
- *Embedded – TPS*
  - *Depth*
  - *Type – temp range*
- *Recession*





Measurements

Measurements Drive Everything

What accuracy is needed to meet the science requirements?

- *Sensor selection*
- *Signal conditioning needed*
- *A/D – 12, 14, 16 bit?*
- *Calibration needed*
- *Location knowledge*
- *Compensation (CJC)*

How many measurements are needed to meet the science requirements?

- *Sensor quantity*
- *Channels in DAS*
- *Extent of Multiplexing*
- *Data rate/volume*
- *Harnesses*
- *Installation*

Are the measurements passive or active? Do they require excitation, amplification, etc.?

- *Signal conditioning*
- *Amplifiers*
- *Voltage levels, "cleanliness"*
- *EMI/EMC concerns*
- *Grounding approach*

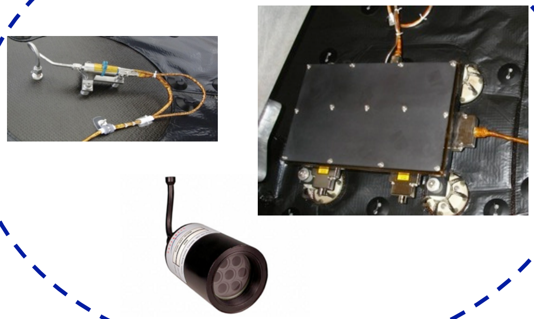
Driving Architectural Approaches

- **Data Acquisition & Signal Conditioning Approach**
  - Dedicated unit(s) – MEDLI and MEDLI2 – provide a serial data stream to the host spacecraft Compute Element
  - Use spacecraft systems to provide signal conditioning and data acquisition function (EFT-1) – analog output from sensors to spacecraft provided signal conditioning
  - Distributed approach – sensors have local signal conditioning and communication (aka CAN Bus Architecture)
- **Data Return Approach**
  - Real time data return
    - Impact is limits on data rate/volume (sensor count or sampling)
    - Risk is data drop-outs since only have a single opportunity to return the data
  - Store and forward
    - Benefit is can usually collect and store a lot more data
    - Impact is need for data storage approach and time/mission impacts for data return
    - Risk is loss of data – vehicle loss, memory loss, etc.
  - Store and physical recovery – *same as Store and Forward*
  - Some combination of all/some?

Heritage, Maturity, Development

Environments
- *Flight/Design loads specified vs component capabilities*
- ***Temperature - big driver – negotiate on continuous survival heater power***
- *Shock/Vibe - can sometimes be resolved via hardware solutions – isolators, etc.*
- *EMI/EMC – traditional shielding approaches can resolve*

Product Assurance
- *Planetary Protection – Heating can limit choices – plastic parts, etc.*
- *Contamination Control – outgassing can limit choices*
- ***EEE Parts***
- *Rest is process – takes time and staff to accomplish – depends on the mission*



Development Efforts
- *Finding candidate sensors/hardware?*
- *Demonstrate environmental compliance*
- *Do No Harm to Flight System?*
- *Meet performance needs? (Accuracy, operations, rates, analog/digital)*
- *Modify sensor to meet needs?*

Hardware Development – EEE Parts

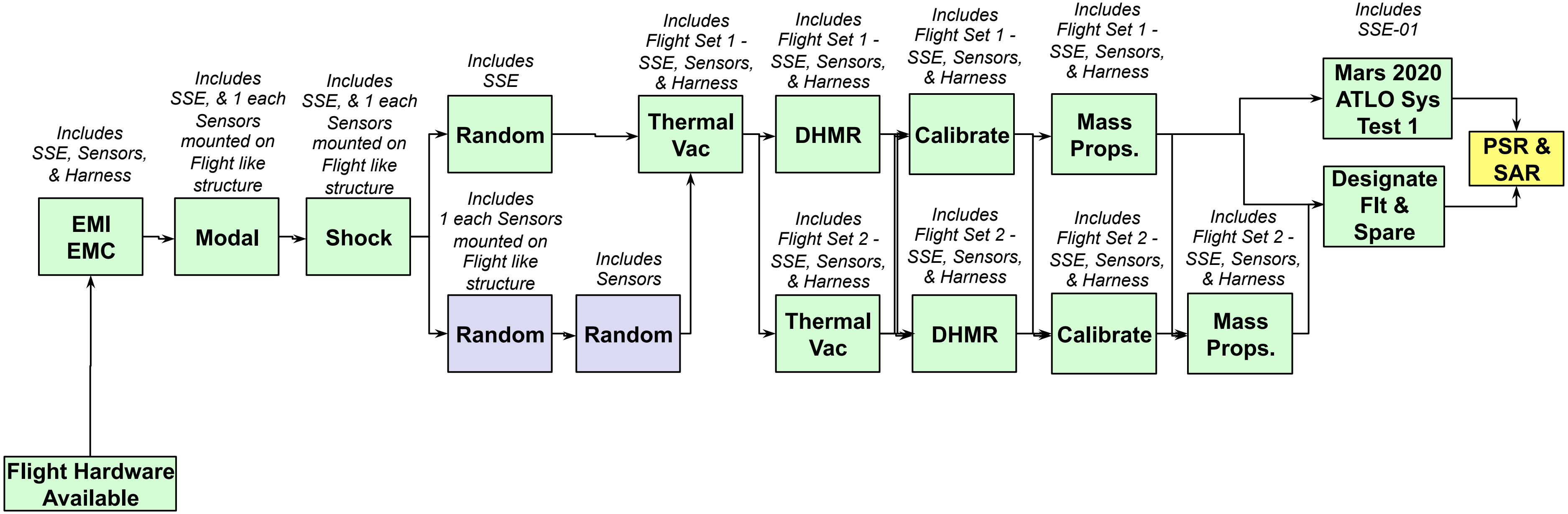
Grade	Summary	Reliability	MTBF	Cost	Typical Use
1	"Space" quality class qualified parts, or equivalent.	Highest	Longest	Very High	Space Flight
2	"Full Military" quality class qualified parts, or equivalent.	Very High	Very Long	High	Space flight or critical GSE
3	“Low Military" quality class parts, and Vendor Hi-Rel or equivalent	High	Long	Moderate	Space flight experiments and ground support
4	“Commercial" quality class parts. No qualification required.	Variable	Variable	Low	Flight Experiments and ground support

- NEPP.NASA.gov - MSFC Std 3012
- EEE Parts grade drives schedule – Grade 1 or 2 have long lead times.
- Flight tests – usually Grade 3 or 4
- Hosted payloads Grade 1 or 2

Assembly, Integration, and Testing Approach

- **Assembly, Integration, and Test Approach**
  - As a Subsystem – stand-alone?
  - As part of the integrated spacecraft/Assembly?
- **Is a dedicated end to end calibration effort needed to meet science requirements/accuracy?**
- **Channelization**
  - Is it possible to stimulate each sensor after installation and verify polarity and proper channels?
  - If cannot do sensor stimulation, can each sensor be disconnected from the harness and channelization be performed via the harness and Break Out Boxes?
- **What level of sensor location knowledge is required – laser scan, etc.?**
- **Environmental Testing Approach**
  - Qual and flight acceptance vs protoflight – impacts part count, test levels, and risk
  - Is DHMR required?
  - Where does calibration fit in the sequence?

MEDLI2 AI&T Flow



And a Whole Bunch of Other Stuff

Project Duration

- *Need a reasonable duration to implement project*
- *But if it drags on, the marching army will kill your budget*

Part Count

- *How much flight and flight spare hardware?*
- *How many EDUs needed?*
- *Sparing philosophy – full spares or kitted?*
- *GSE and test fixtures – test harnesses, BOBs, etc.*

Cost can be impacted by a wide range of additional elements

Programmatics

- *Need to decide what level of tailoring (7120.5/.8 & 8705.4) makes sense – not all processes need to be complied with*
- *Some rigor is a "good thing"*
- *What level of insight/oversight is specified by the funder? Some want more*

Staffing

- *Center policy on minimum FTE or WYE increment (0.5, 0.25)*
- *Less experienced staff = longer time to perform the task*
- *Policies and rules change over the life of the project*

Final Thoughts

- Need to consider what program is funding the effort and how that program likes to manage projects
- Need to define the limits of the measurement subsystem – what is being provided and implemented – and by whom
- The yearly end of fiscal year drama will always introduce uncertainty which will impact the cost – and cost phasing