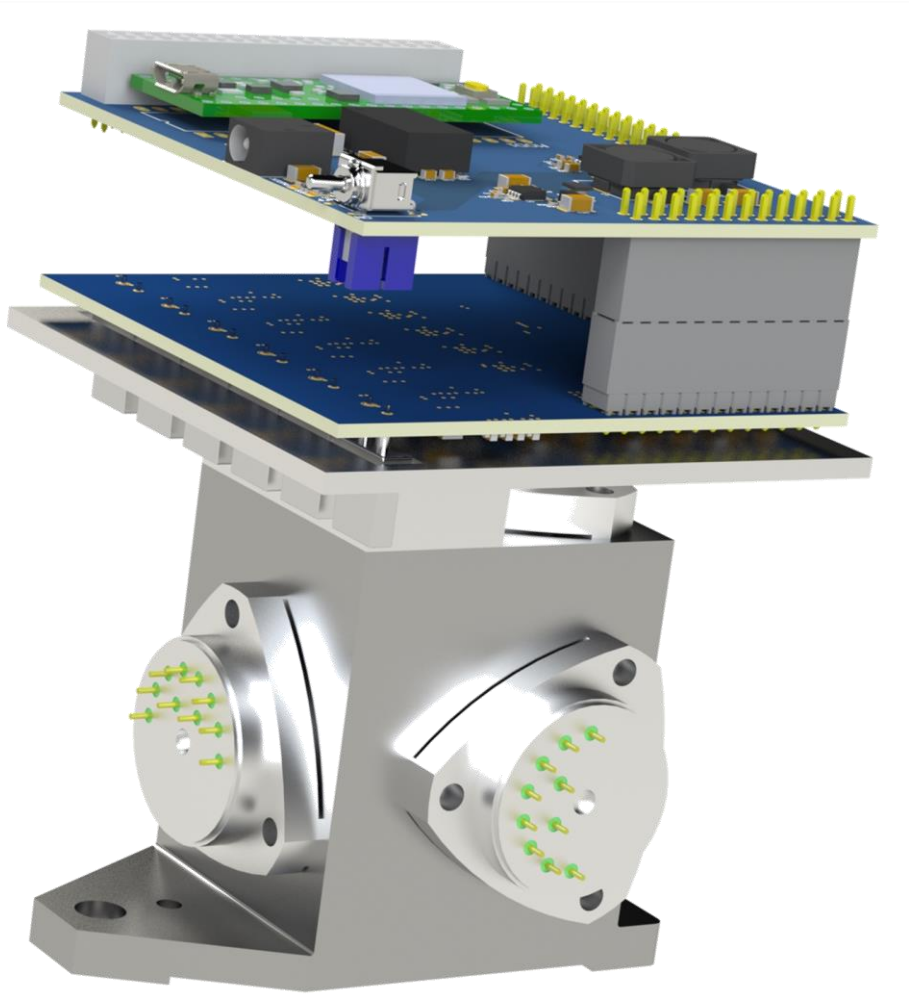


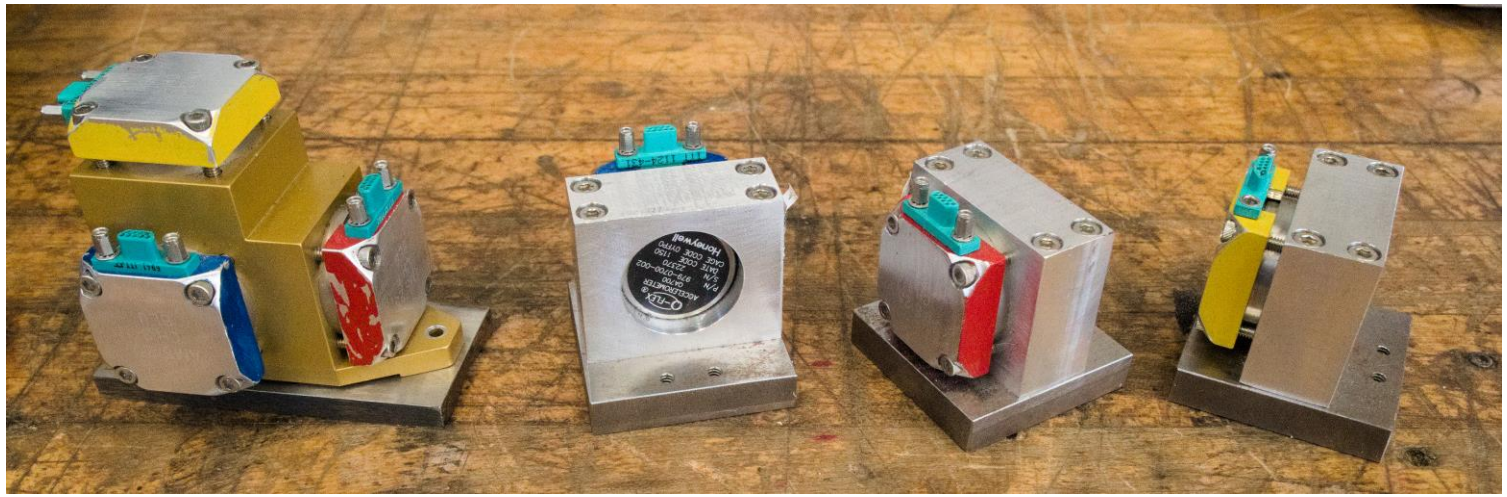
Angle Measurement System (AMS) DAQ Miniaturization

Jonathon Ponder (NASA Glenn Research Center)
Kenneth Toro (NASA Langley Research Center)
January 9, 2024

AIAA SciTech 2024
Orlando, FL

AMS Background

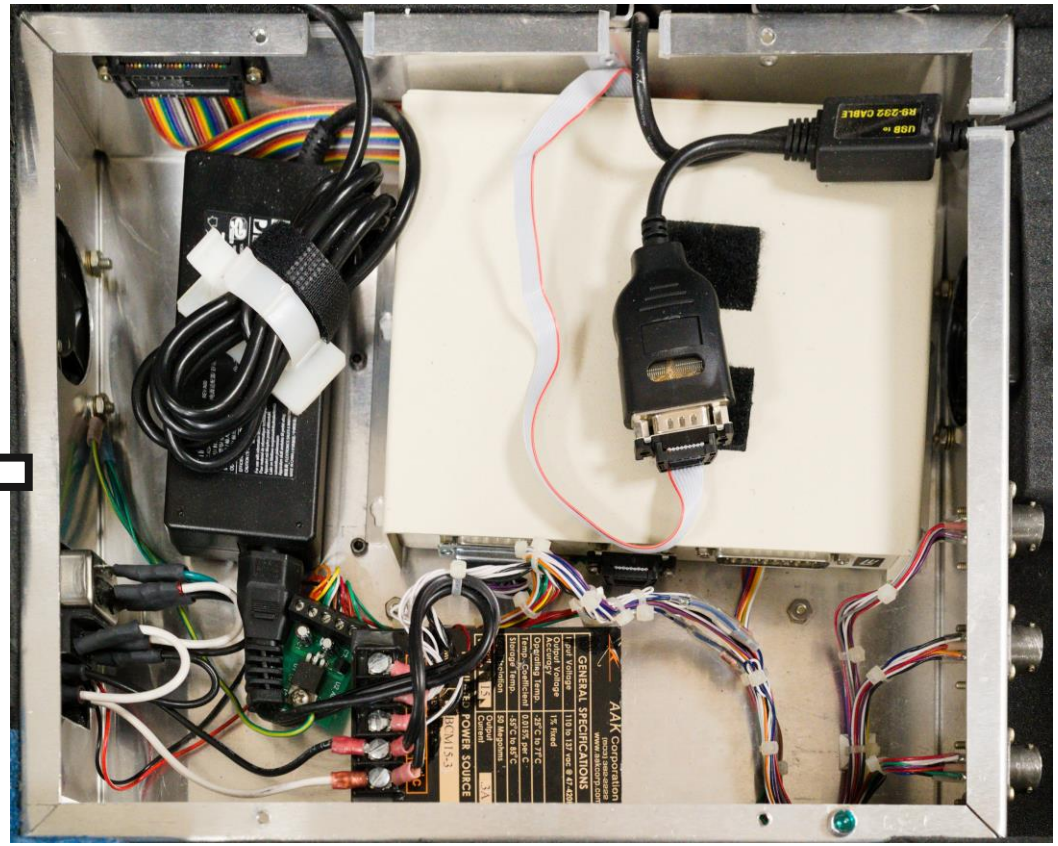
- **The Angle Measurement System (AMS) was originally developed in the 90's to check taper fits, and was further developed to measure pitch and roll angles**
- **System comprised of:**
  - Three independent single-axis accelerometers
  - Three 3 orthogonally mounted accelerometers
- **Is a transfer standard from a precision calibration system to wind tunnel models, on the order of 0.01-deg**
  - Model buildup
  - Alignment checks
  - Taper checks
  - Check loads
  - Balance/sting deflections
  - In-situ sensor calibrations



Tri-axis package (left) and three single-axis sensors (right)

AMS Components

AMS Suitcase with laptop and sensors



Supporting electronics under laptop

AMS Suitcase: What's Inside Current System?

- **Commercial DAQ system**
  - 6-channels, 24-bit, sequential sampling
  - Serial interface to host, USB-to-serial converter required
- **Precision Foil Resistors for conversion of Q-flex signal current to voltage**
- **Potted industrial DC power supply for Q-flex power**
- **Laptop PC to compute angles from Q-flex signals**

DAQ system

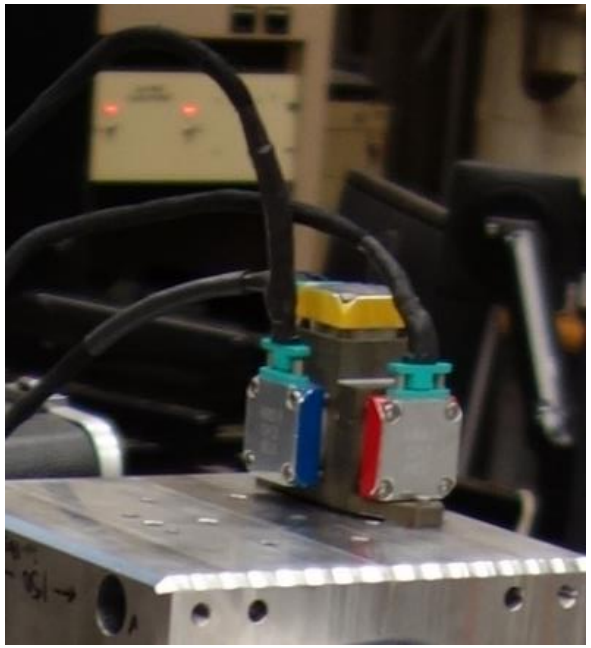

Dropping resistors

DC Power Supply


Laptop PC

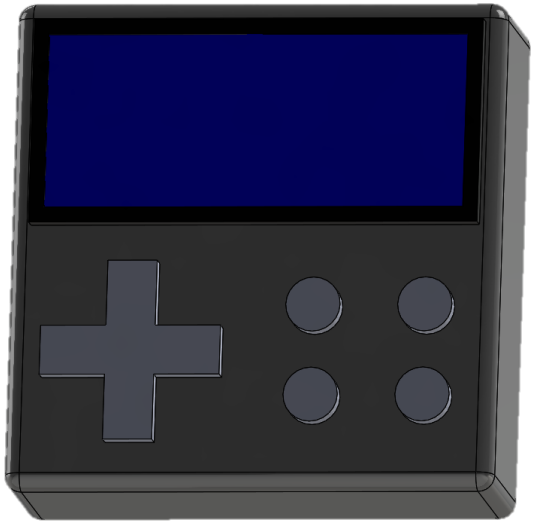
Miniaturized AMS DAQ

- **Current AMS units rely on a DAQ system contained in a suitcase**
- **The goal is to integrate all required components into a small packages while improving performance, accuracy and stability**

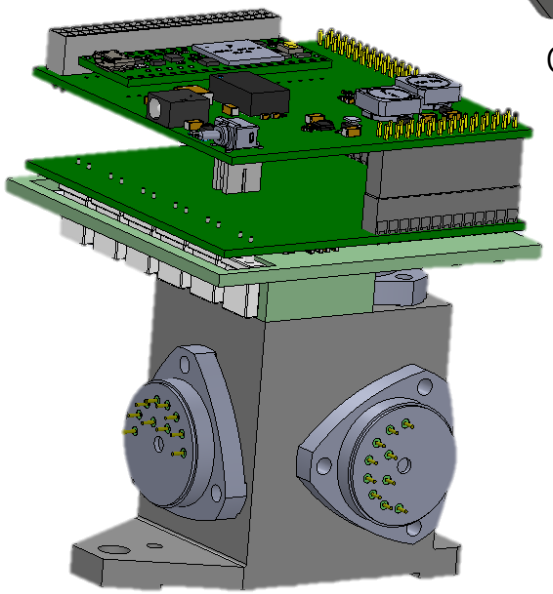


Current AMS Head Unit

Current AMS DAQ Suitcase



Concept for Handheld DAQ system



Concept for Head Unit integrated DAQ system

Miniaturization and Integration

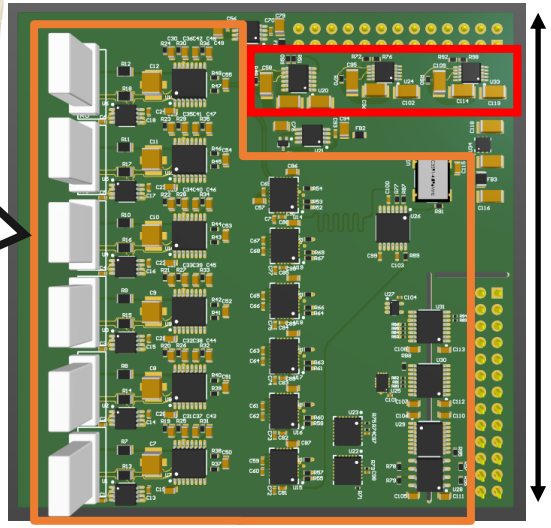
Current DAQ

Commercial DAQ system replaced with custom, purpose-built system Zero-TCR resistors

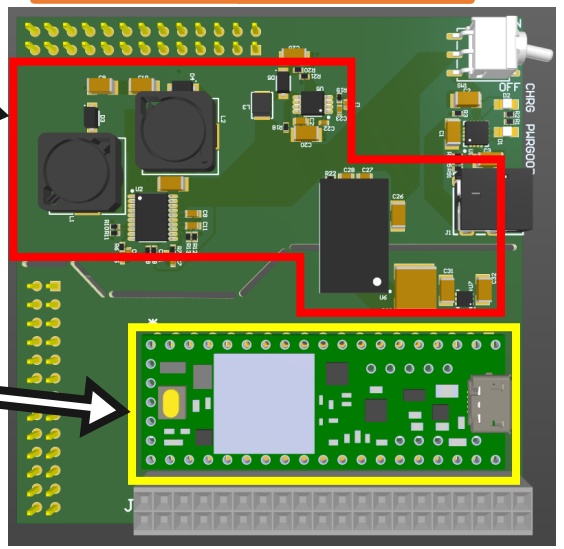
Industrial Power Supply replaced with custom ultra-low noise supplies powered and fully isolated supply for computing module, all by a single 3.7V Li-Ion battery

Laptop replaced with Arm Cortex-based module

New DAQ

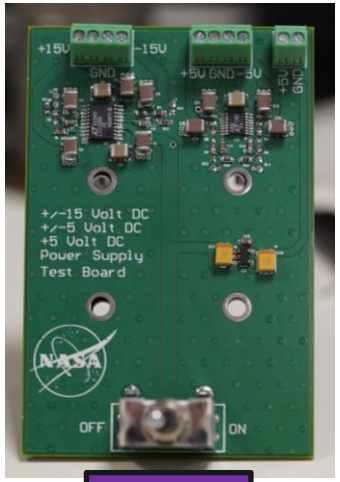


2.8” Square

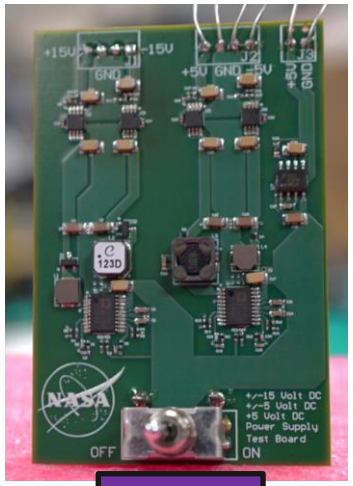


Power Supply Miniaturization Test Boards

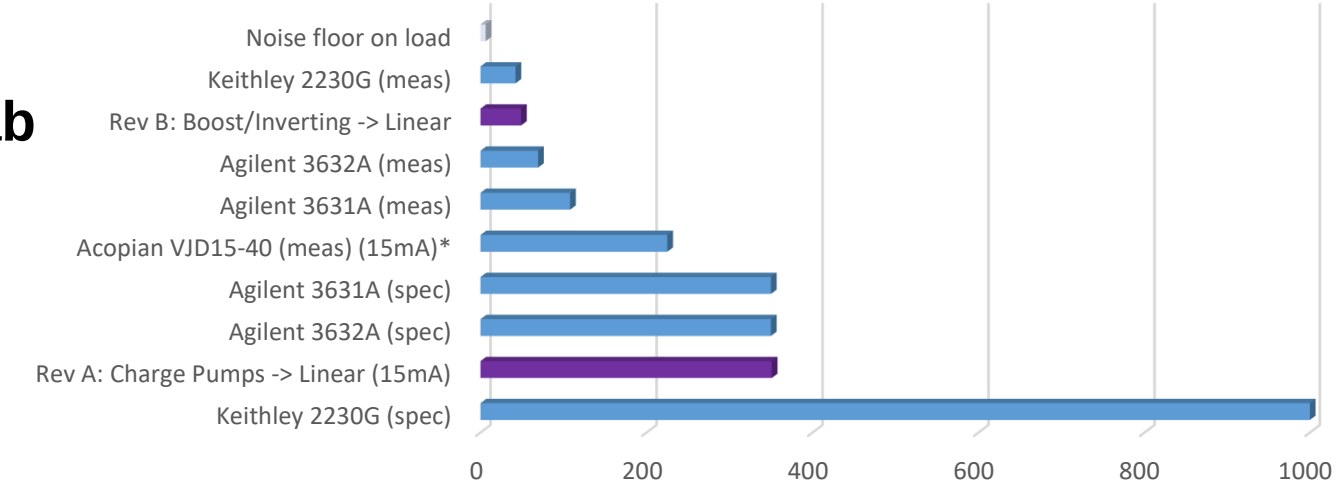
- **Achieved noise performance exceeding industrial DC power supplies and most lab bench DC power supplies**



Rev A



Rev B

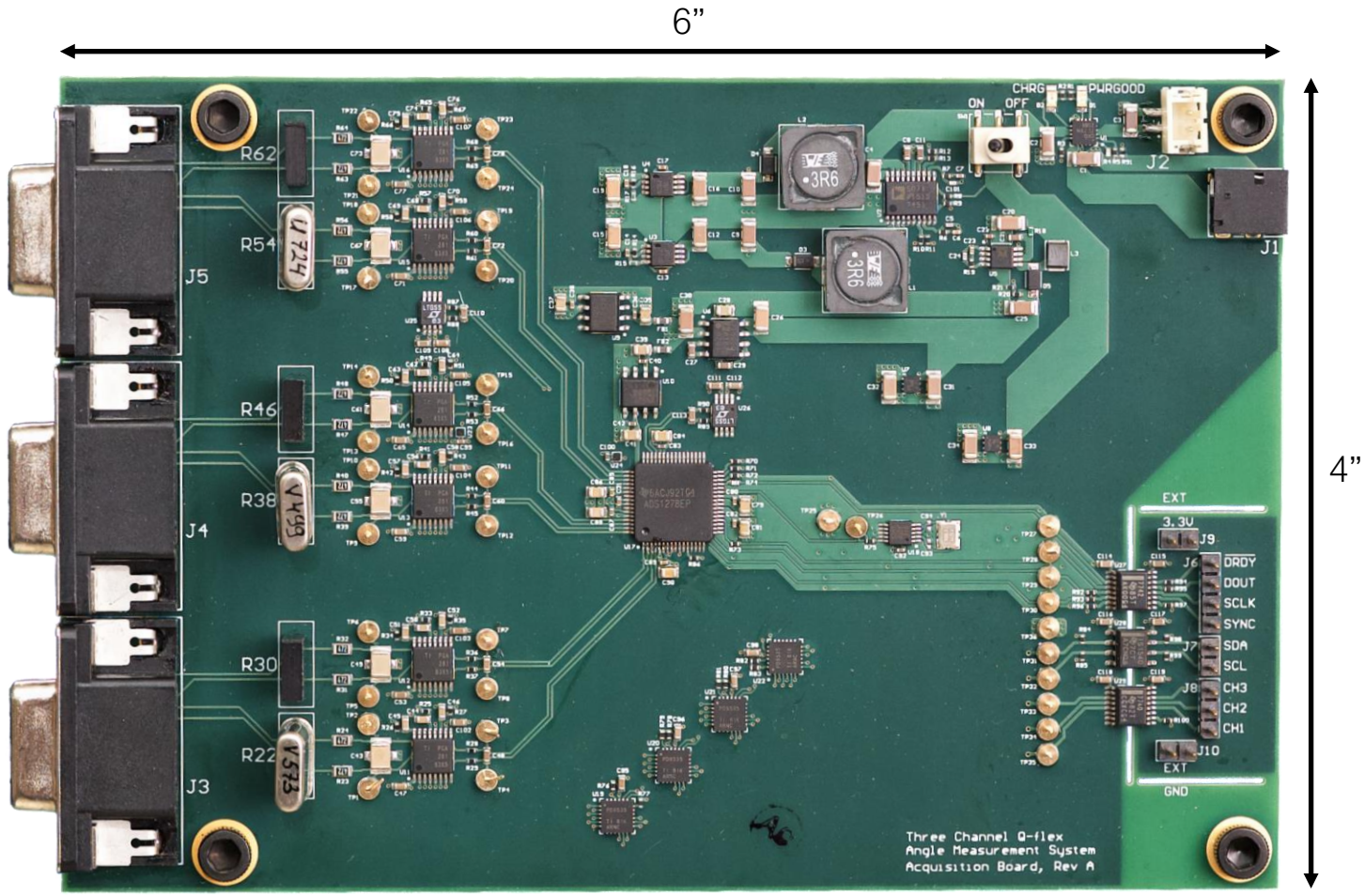


+/-15VDC @ 45mA, triple QA supply comparison:		
Ripple and Noise (10Hz-100kHz)	RMS (µV)	Pk-Pk (µV)
Rev A: Charge Pumps -> Linear (15mA)	351	3100
Keithley 2230G (spec)	<1000	<3000
Agilent 3631A (spec)	<350	<2000
Acopian VJD15-40 (meas) (15mA)*	225	1670
Acopian VJD15-40 (spec)*	not spec'd	1500
Agilent 3631A (meas)	108	738
Agilent other (meas)	69.4	587
Rev B: Boost/Inverting -> Linear	48.8	366
Keithley 2230G (meas)	42.2	291
Noise floor on load	6.14	63.3

*: Standard 8x6 standalone QA-2000 supply.

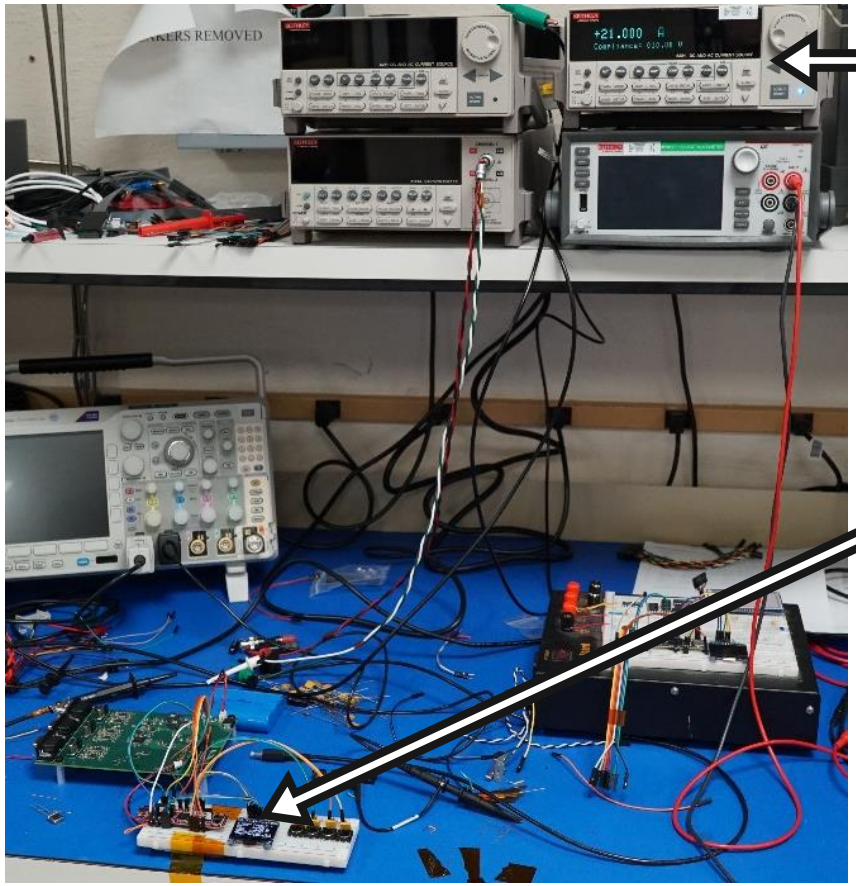
DAQ Miniaturization Rev A Test Board

- **24-bit simultaneous ADC**
- **Integration of dropping resistors for Qflex current signals**
- **Programmable Gain Options**
- **+/-15VDC power supply for use by 3 Qflex sensors**
- **Li-Ion battery management**
- **Fully Isolated communications with control board through magnetic isolation ICs and PCB routing**
- **DC power supplies**



DAQ Miniaturization Rev A Test Board

- **nanoAmp resolution demonstrated with Rev A board**
- **Triaxial cabling between current source and DAQ board with guard driven by source**
  - Twisted pair, shielded cable conveyed signal with additional noise
- **Additionally, nA resolution required re-ranging of instrument amp from full-scale input setting**
  - ~119dB SNR was achievable with ADS1278 ADC, data sheet specs 118dB



Laboratory testing of Rev. A test board with current source

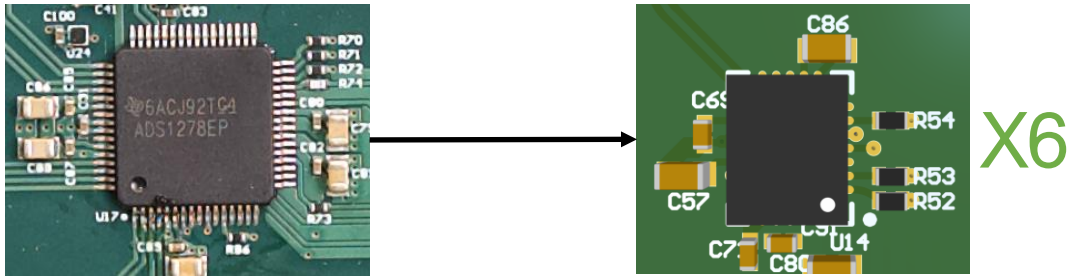
Laboratory current source (Keithley 6221)

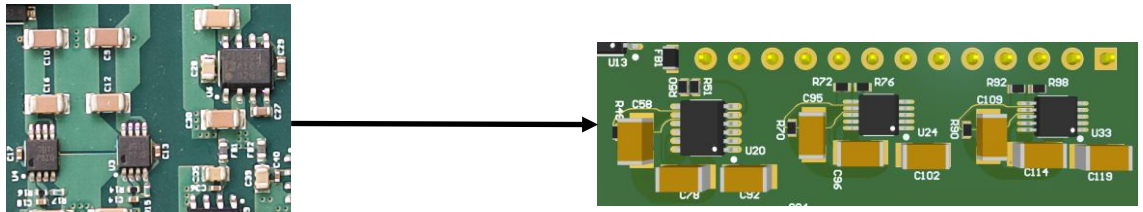
AMS DAQ readings

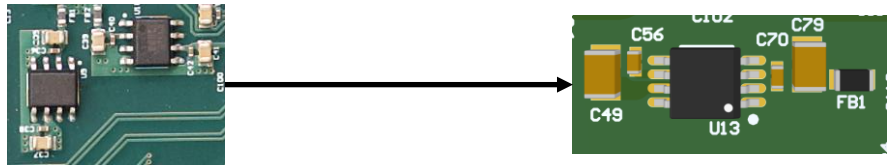
Triaxial connection

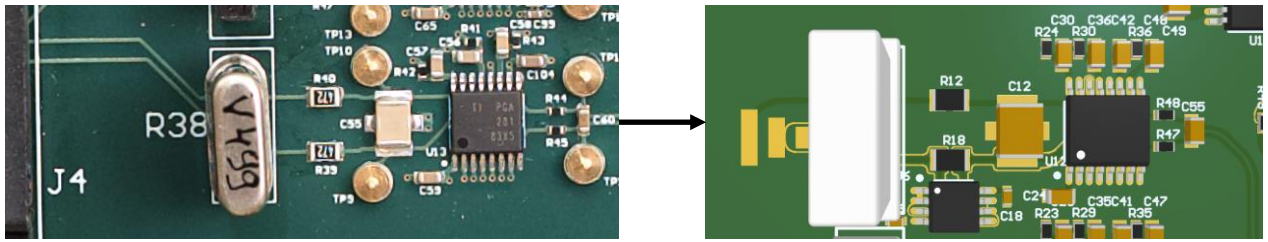
Upgrades for Rev B Boards

- **ADC: ADS1278 8-ch 24-bit ADC to 6x ADS1283 32-bit ADCs**
  - Lower noise floor, down to 130db
  - Improved Resolution
  - Greater Accuracy
  - Higher Stability
- **+5V and +/-15V regulators: TPS7A30 & TPS7A49 to LT3042 & LT3093**
  - Will help accommodate the noise floor improvements provided by the ADC upgrade
- **Upgrade voltage references from ADR45** to LTC6655-***
  - Will further accommodate the noise floor improvements of the measurement system
  - Will help provide stability improvements offered by the ADC upgrade
- **Added full guarding around Qflex signal nets between sensor and instrument amplifier**
  - Prevent leakage of signal current from the net due to surface contamination
  - Net voltage is buffered by an op-amp and used to drive the guard
  - The voltage on the signal nets will see no potential to leak
- **DSUB connector and twisted pair cabling replaced with triax to maintain guard and shield signal.**



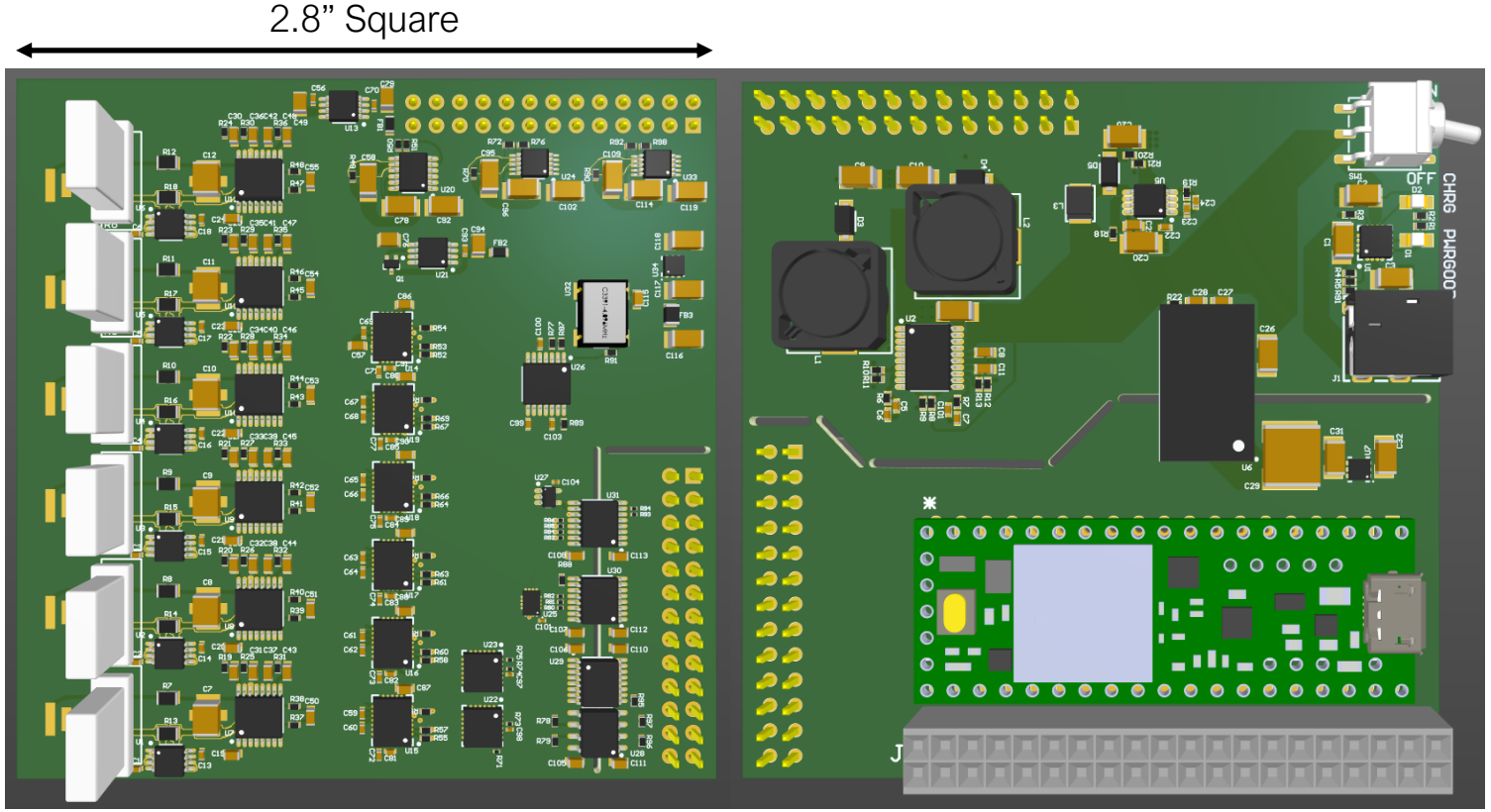






DAQ Miniaturization Rev B Boards, In Development

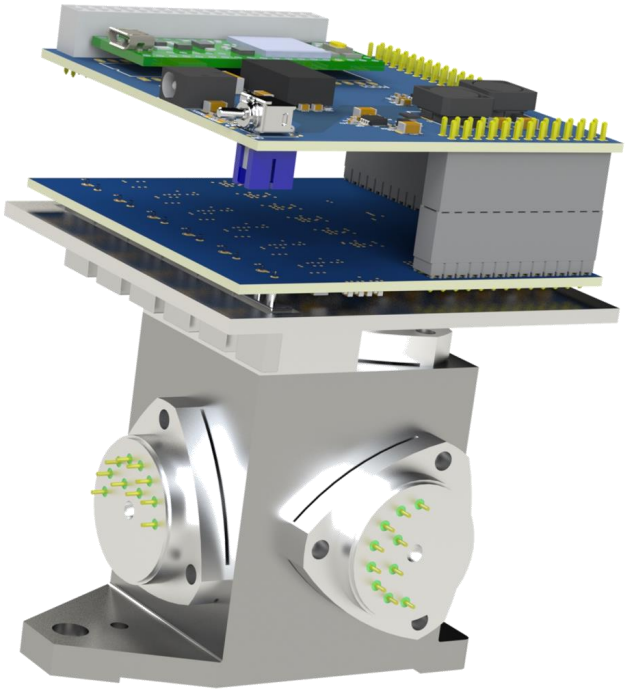
- **Reduced form factor board layout**
- **2 PCB stack up**
  - Connect back-to-back
  - Sandwich a battery
- **Addition of onboard processing by module board on .6” wide riser**
  - Arm Cortex M4
  - Control ADCs and Amps
  - Filter/Process Data
  - Provide user interface via Display/Button board connecting via header
  - Provide interface and data transmission via serial/Ethernet
- **Addition of fully isolated DC/DC converter in switching power supply section**
  - Provides an isolated ground and voltage rail to processing module



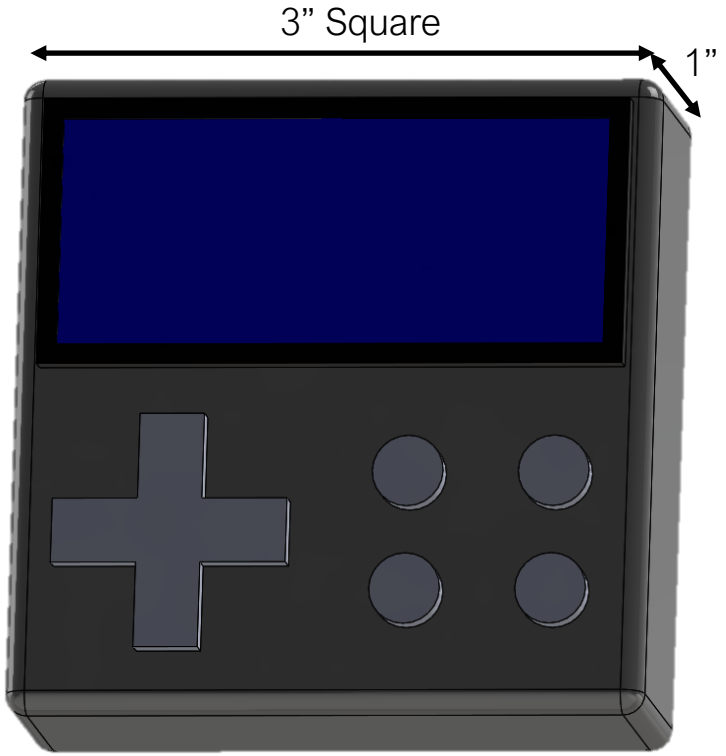
View of Rev B boards; ADC board on left, and power and control board on right

Integration of Rev B Boards

- **Can be mounted atop an AMS sensor head within the 3” length of the sensor head footprint**
- **Additionally, can be enclosed in a handheld unit and connected to the sensor head via cabling**
- **In both scenarios, the DAQ unit can transmit data to a host data system via serial or Ethernet**



Concept for Head Unit integrated DAQ system



Concept for Handheld DAQ system

Summary

- **An integrated, miniaturized DAQ system is being designed for the NASA AMS**
- **System performance will exceed the current suitcase system**
- **Test PCBs have been evaluated**
- **Improvements have been made to the initial integrated DAQ test PCB**
- **Future work:**
  - Finalize layout of Rev B designs
  - Fabricate and assemble Rev B PCBs
  - Evaluate Rev B PCBs
  - Integrate Rev B PCBs with AMS head unit