Sounding Rocket Working Group
January 20, 2006

NASA Sounding Rocket Operations Contract (NSROC)

Wallops Flight Facility

SRWG Agenda - NSROC

NSROC Program	Rob Maddox
Engineering	Rick Weaver
	Dave Krause
Electrical Engineering	Shelby Elborn
Mechanical Engineering	Giovanni Rosanova
Guidance, Navigation & Control	Walter Costello
Conclusions	

Program Manager

Rob Maddox

NSROC Programmatic

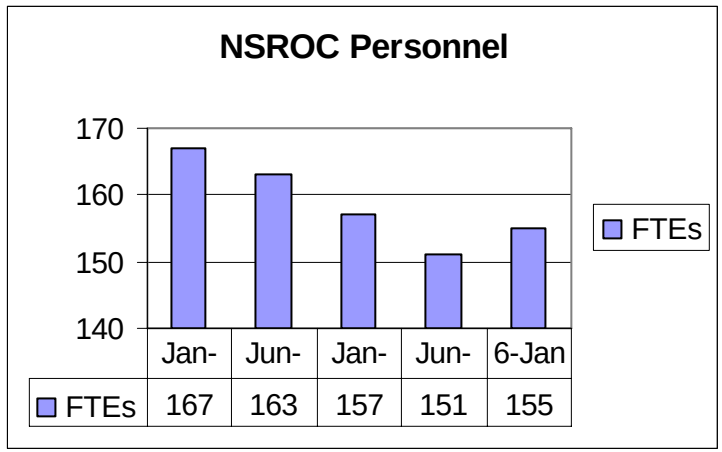
- Contract Status
  - Approaching start of contract year 8 (second contract option)
  - Maintaining Very Good PEB scores
  - NG rolled out a new sector on Jan 1, 2006
    - Northrop Grumman Technical Services (NGTS)
    - NSROC contract moved to NGTS from NGIT
    - Jim Cameron appointed sector president
    - No significant change to NSROC
- Subcontract Status
  - Sub contract mods being issued to all teammates to extend second option
  - Aerojet -- Discontinued support
  - Bristol – Black Brant motor procurement
    - Placed order for long lead items and motor casting for 6 motors
  - DTI – Oriole motor procurement on hold waiting Navy's decision to buy Orioles
  - Saab – Significant effort underway for S-19L conversions

Programmatic

- Challenges
  - Implement new technology
    - New Attitude Control Systems
    - New Boost Guidance systems
    - New vehicle configurations
    - New Electrical Systems
  - Complex Missions (Methods outside experience envelope)
    - Earle, Craven, Lessard, Chakrabarti, Technology Demo Flights
  - Budget
    - Balancing staff, procurements, reimbursable workload, to a dynamic budget
  - Schedule

Programmatic

- Staffing
  - 155 FTEs
    - Up 4 FTEs since last SRWG
  - Reimbursable Offsets for Contract Year 7 = 15 FTEs



Programmatic

- New Business Opportunities
  - JPL, LaRC and the NMP ST-9 Program
  - Navy ARAV exercises (June & Dec)
  - Air Force/MIT-LL Airborne Laser “MARTI” (August)
  - Air Force Airborne Laser “Terrier Lynx Vehicle” (July/Aug)
  - MDA Terrier Improved Orion Tracking Targets
    - Infrasound 3&4 (WSMR)
    - DTGRS (PMRF)
    - SS Terrier Slug (WSMR)
    - Dundee 3&4 (WSMR)
    - Red Dog II (WFF)
    - Thaad (WSMR)
- AGU Conference – Presentations, Videos, & Handouts

NSROC Outreach

NSROC Co-op and Intern Program

- Summer 2005 – 7 interns
- Fall 2005 – 2 Co-ops
- Established intern program with Eastern Shore Comm. College
  - 2 part time positions opened for students

- Wallops Open House – demonstrations, tours, handouts, etc.
- NSROC employee presentations to high schools

Engineering

Rick Weaver

Engineering

Engineering Concerns

- There are 31 missions currently scheduled in the next 13 months, 4 being reimbursable.
- Five of the ten PFRR missions do not have all the experiment data needed to complete design efforts.
- Design Reviews have slipped. This may lead to I&T slips/conflicts and substantial overtime.

NSROC Staffing

Finding VI: NSROC staffing

Summary:

As program budget margins remain extremely tight, NSROC is understaffed. For example, some NSROC managers lead more than one section and high levels of overtime are now commonplace. The SRWG is concerned that these tight margins with respect to manpower will result in the inability of the SRPO to support selected missions and leave the program vulnerable to increased risk resulting from an overworked staff.

The Engineering group maintained all personnel resources.

- An additional four engineers were hired, 2 ME's and 2 EE's.
- A Propulsion Engineer will begin in May
- An Electrical Technician was hired in the GNC group.
- A Dynamist position is still open.

The Vehicle System group previously worked as an independent group as well as a sub-group of the ME group. When it was decided to restructure the VS group we evaluated internal and external candidates. It was determined the VS group would be an independent group sharing a Manager until a candidate can be hired or developed within the program.

Engineering

Dave Krause

PTO 519

New Vehicles/Surplus Motors

- PTO Effort started to evaluate new vehicle configurations based on military surplus motors.
- The current short list of motors include
  - MLRS (Mesquito vehicle)
  - Patriot (Terrier/Patriot – SS Brant equivalent)
  - ATACMS (Terrier/ATACMS – BBIX equivalent)
- The current process to evaluate the potential use/effectiveness includes
  - Vehicle/Motor Prioritization
  - Performance Verification
  - Validity gate
  - Hardware checks/design (fins/interstages/sep systems/etc.)
- When a successful configuration is found, the next phase includes
  - Complete the Design
  - Prepare for a Design Review
  - Demonstration Flight Test

PTO 518

Taurus Replacement on BBXI/XII

- This task primarily looks at the introduction of the Terrier Mk 70 as the Taurus replacement in the BBXI/XII vehicle stacks.
- The 40+ year old Taurus Improved Honest John has been a great motor for the SRP.
- Unfortunately it is:
  - Old (less reliable)
  - Class 1.1 (double base propellant: nitroglycerine/nitrocellulose)
- Taurus specifics (24” diameter):
  - Total Impulse: 357,000 lbf-sec,
  - Thrust, Average = 101,565 lbf
  - Burn Time = 3.5 sec
- Terrier Mk 70 Specifics :
  - Total Impulse: 387,737 lbf-sec,
  - Thrust, Average = 62,538 lbf
  - Burn Time = 6.2 sec
- The current effort is underway.
  - BBXII Performance with Mk 70 motor as 2nd stage
  - Structural loads determination
  - Vehicle structural analysis
  - Support hardware design

Electrical Engineering

Shelby Elborn

Dual RMFT

Issues

- CDI systems require 3-3” x 4” x 1” boxes for Event Timers and Support Modules.
- Our present Event Timers will not fit in the planned MLRS 4” diameter payload.

Solution

- Designed a dual Reprogrammable Multi Function Timer
- Housed in an existing 3”x 4” x 1” box.
- Boards can also be separated and housed in a 1.75” x 4” x 1” box.
- Design uses flight proven surface mount electronics used in GPS Event Module.

Program Benefits

- Single 3” x 4” x 1” box will be needed for the CDI system.
- Single RMFT configuration will permit use in the 4” diameter MLRS
- Connector selection allows adding 2 more event timer controlled outputs.

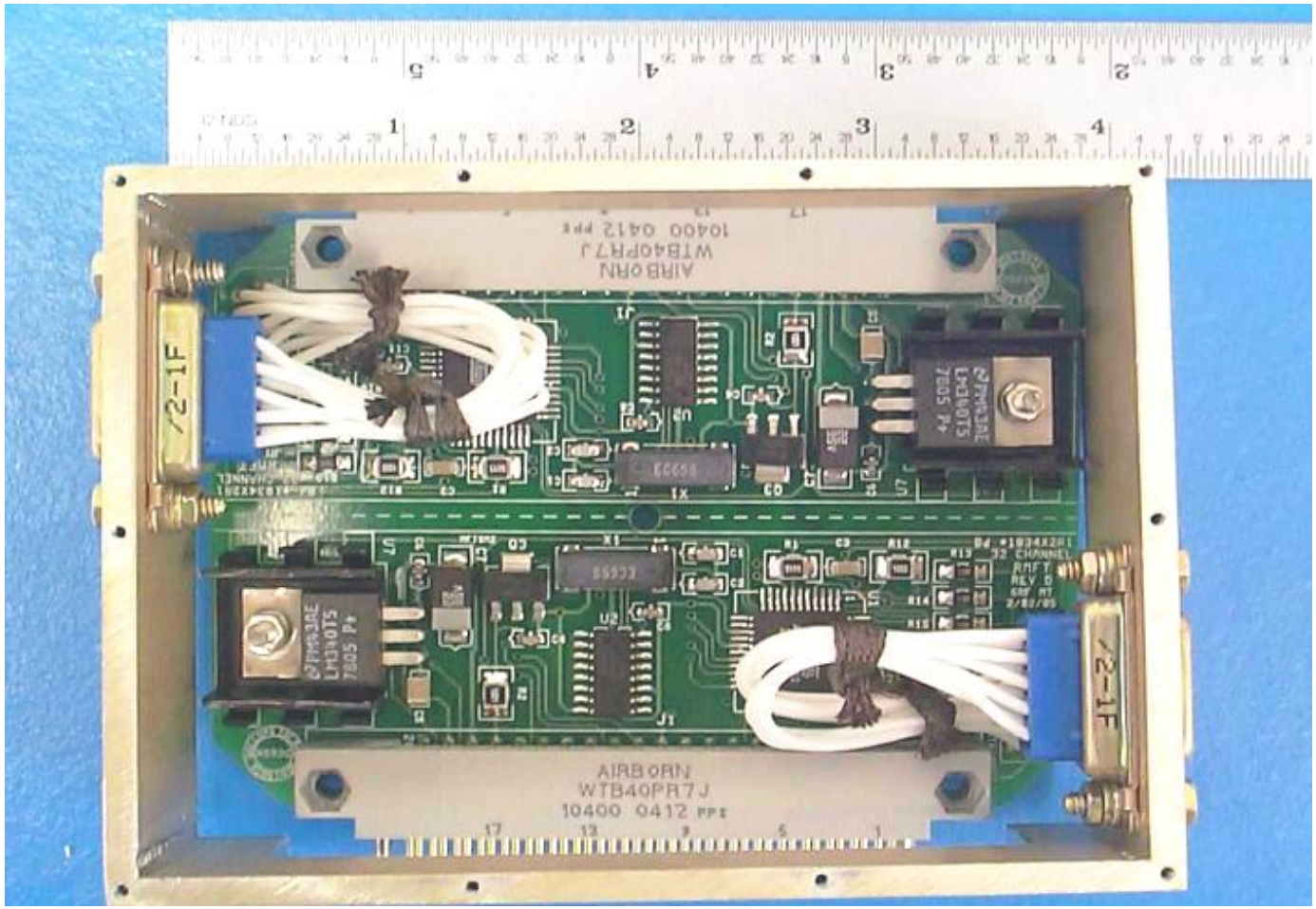
Implementation

- One of the Dual RMFT’s controls the PIB power switching of the NiMH3 batteries and the second unit driver outputs are being signal conditioned by the programmable monitor box and monitored by the LCTE.

Flight Test Results

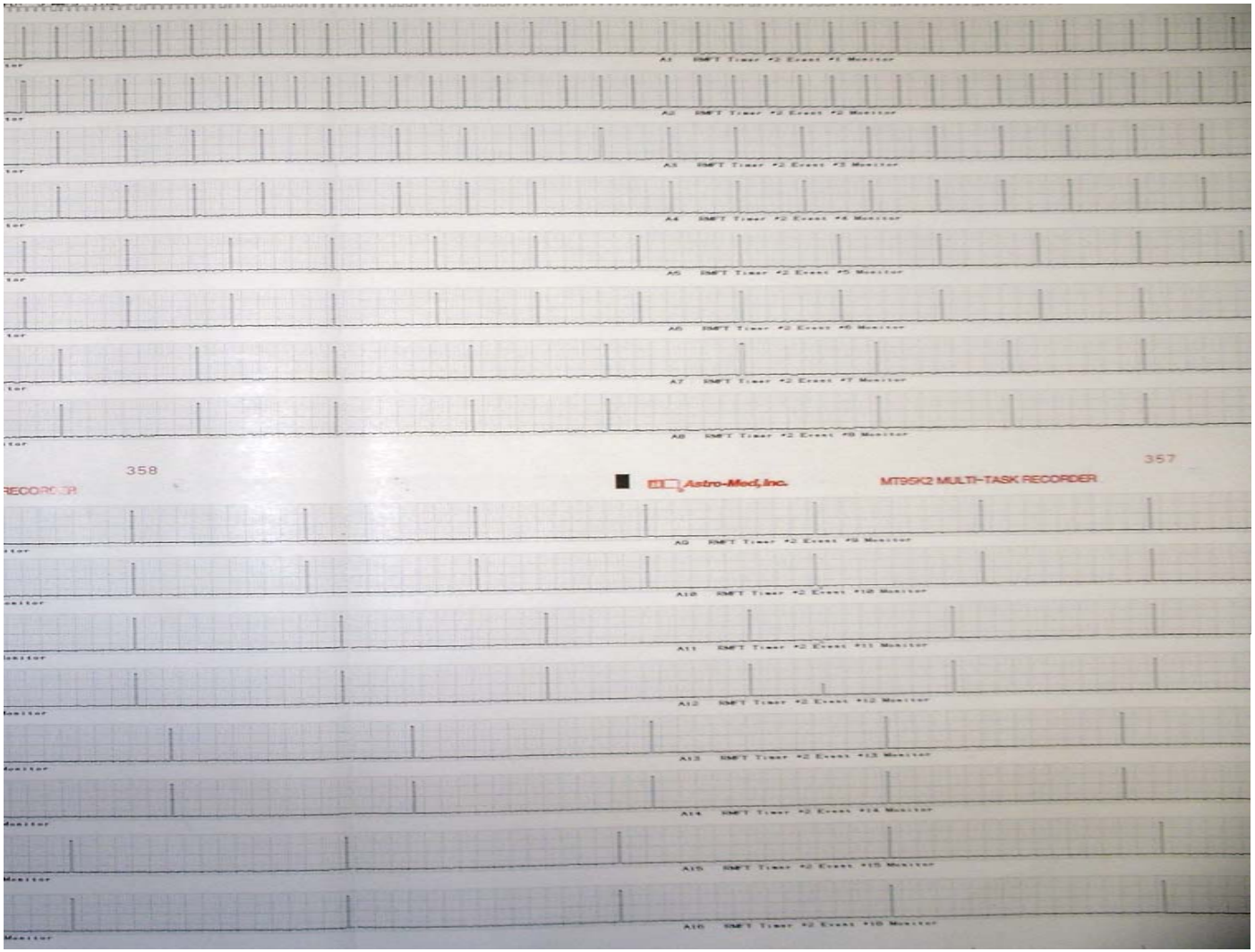
- Both timers provided all programmed events and at proper event times.

Dual RMFT



Dual RMFT

Flight Data



Programmable Monitor Box

Issues

- Monitor circuits presently cannot be fabricated until the payload is designed.
- Multiple monitor boxes stocked

Solution

- Designed a standard programmable monitor board.
- Accommodates 32 inputs up to +/-32 Volts
- Outputs 32 channels analog, RS422 and synchronous serial digital data.
- Allows setting/adjusting parallel digital data trigger level outputs.

Program Benefits

- Replaces 7 existing monitor box circuit designs
- Allows complete assembly, verification, board potting prior to stocking
- Boards will be pulled from stock and programmed for mission needs.
- RS422 and synchronous serial digital data output will simplify payload wiring.

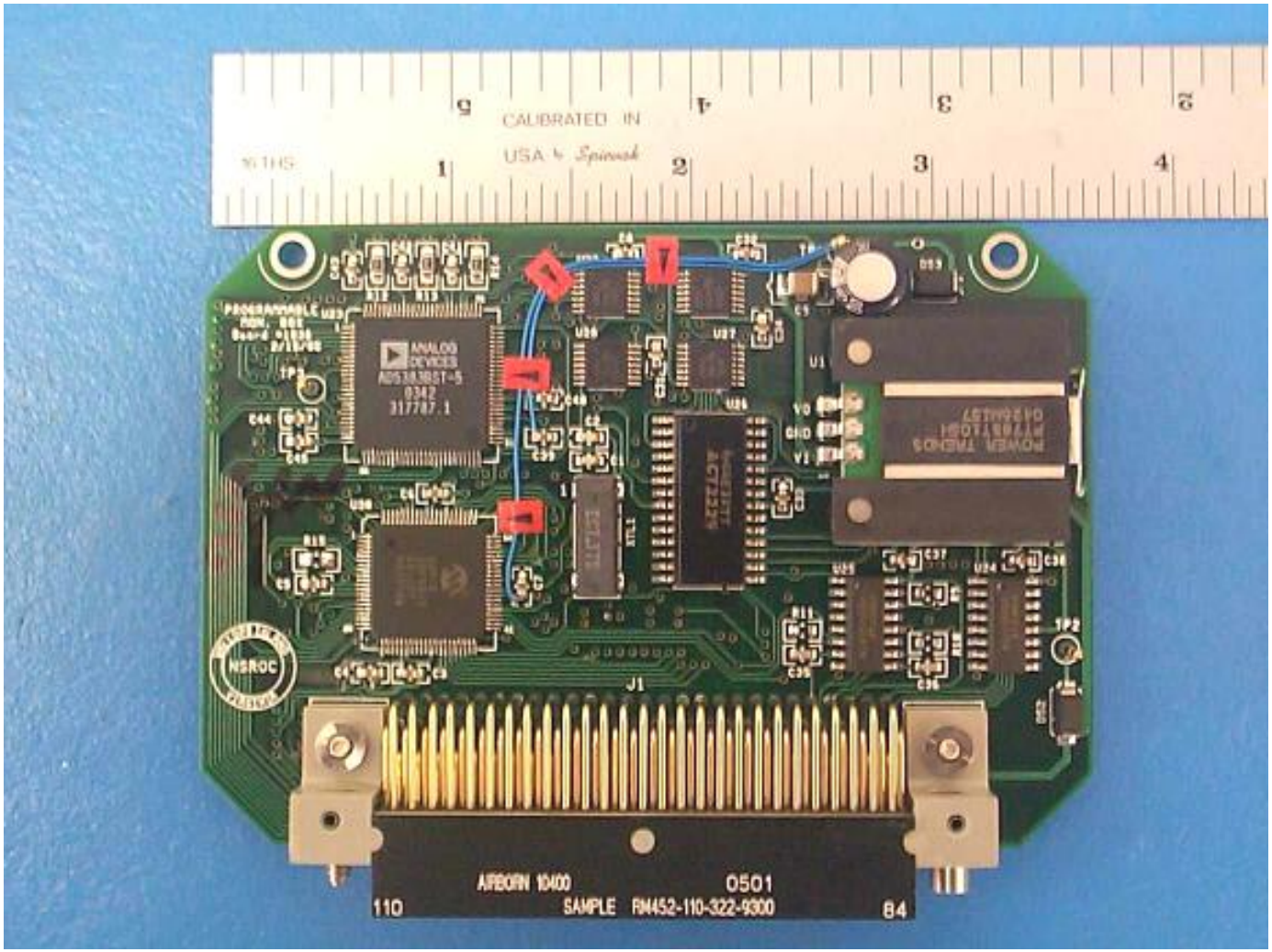
Implementation

- Used to monitor Dual RMFT driver +28V output and condition to +5 volts for LCTE analog inputs.

Flight Test Results

- Received data for entire flight on both DAC and asynchronous data outputs.
- Determined DAC data output needs additional design attention to improve data quality. Conditioned data displayed on LCTE strip chart above.

Programmable Monitor Box



Command Uplink Receiver

Issues

- Aydin Vector model RCC103 receivers have been used repeatedly since 1993.
- Aydin Vector receivers have fixed IF and video bandwidths.

Solution

- PSL has developed a WFF93 footprint Command Uplink Receiver.

Program Benefits

- These new receivers will allow replacement of the AV hardware.
- New receivers will simplify Instrumentation System wiring and allow for a more compact payload mechanical layout.

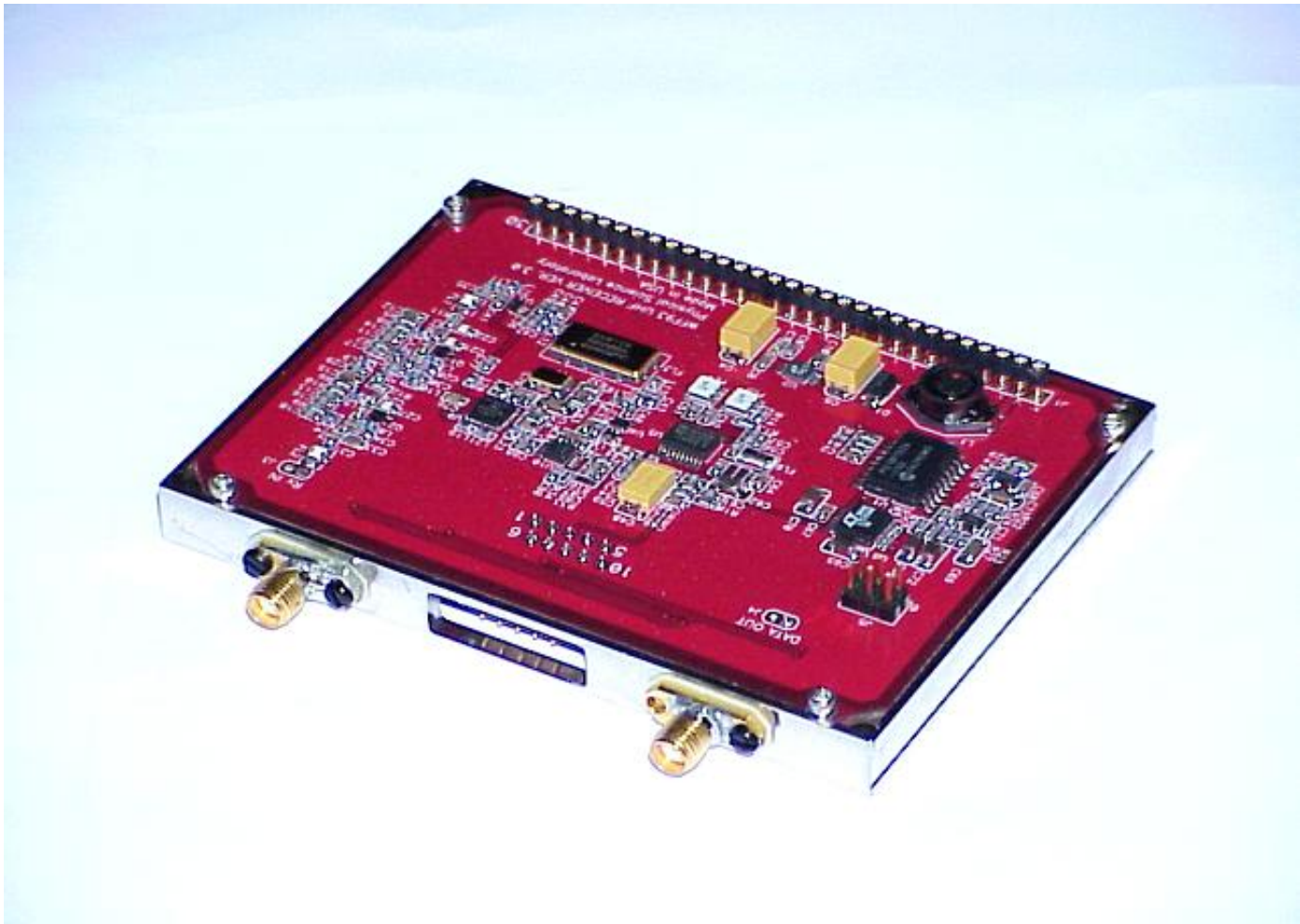
Implementation

- Configured to output ground transmitted 437.5 MHz with 115.2 K baud asynchronous data (set for character generate mode) to airborne asynchronous PCM data module input.

Flight Test Results

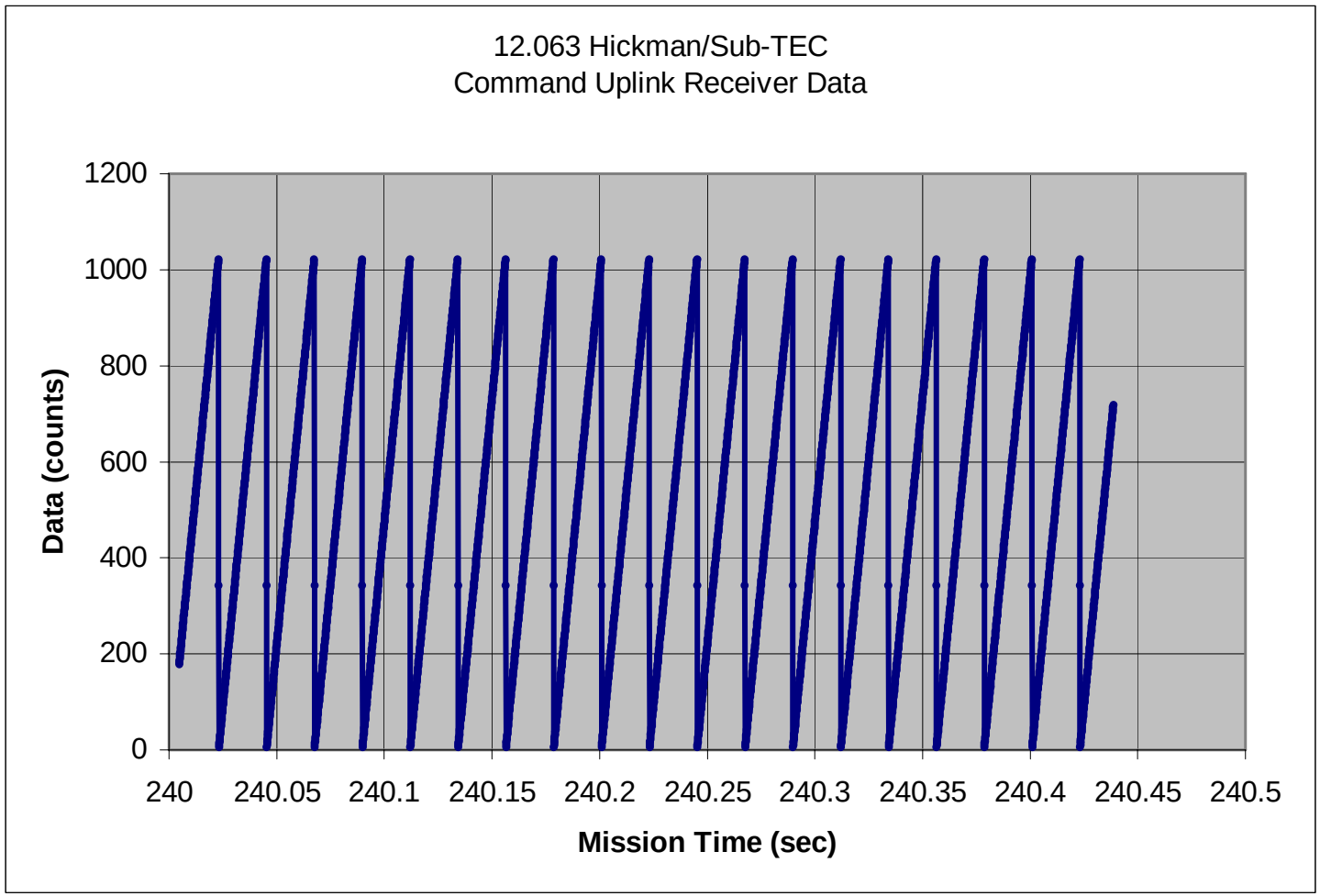
- Received 115.2K baud data entire flight with excellent data quality and strong RF signal level.

Command Uplink Receiver



Command Uplink Receiver

Flight Data @ Max Range



Analog Opto-Isolated Voltage Monitor

Issues

- Upcoming mission has a requirement for isolated ground battery systems.
- Lithium Ion batteries require individual cell voltage monitoring.

Solution

- Developed differential isolated analog input voltage monitoring circuitry.

Program Benefits

- Will allow battery voltage monitoring without voiding the isolated ground requirement..
- Allows monitoring individual cell battery voltage of series connected batteries.

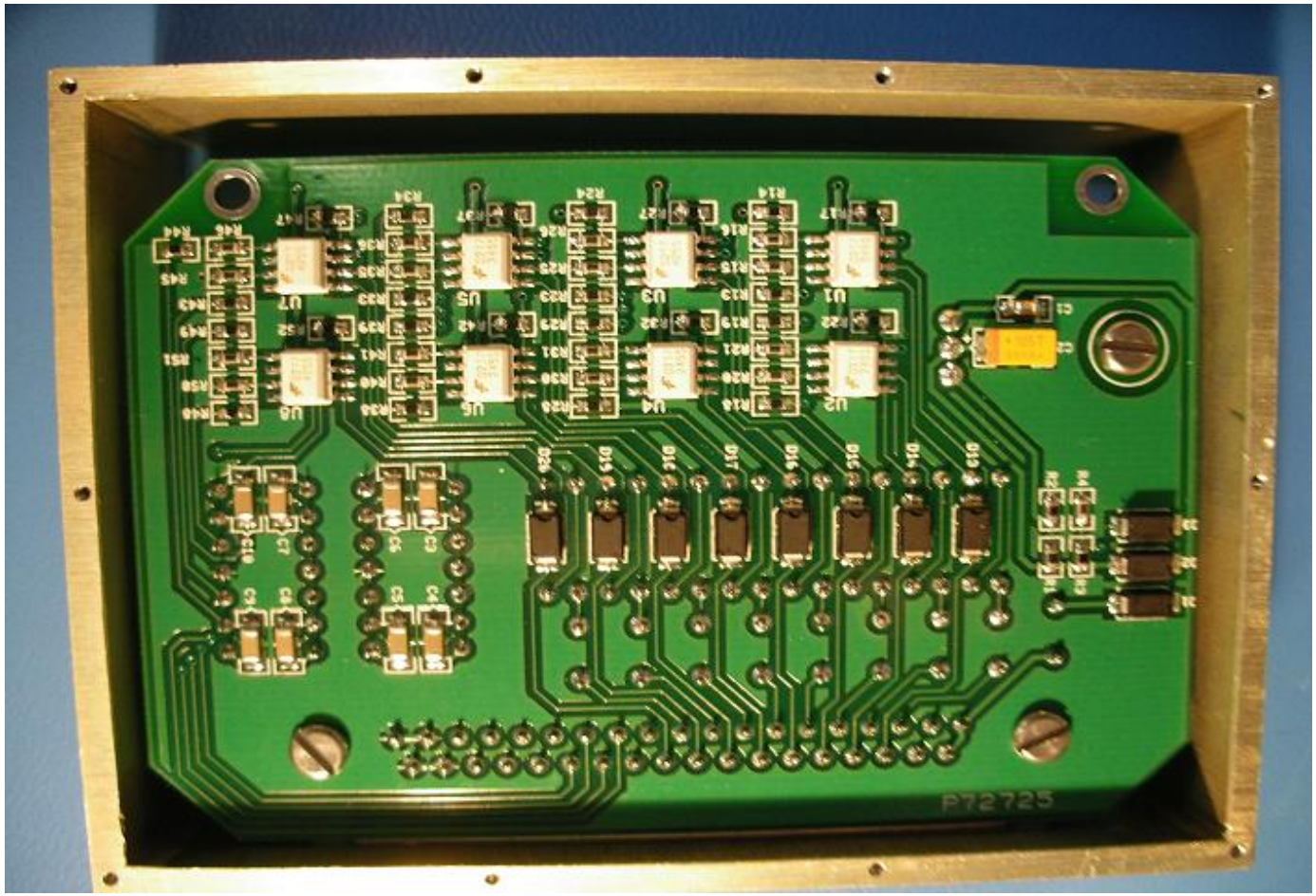
Implementation

- Circuitry used to monitor NiMH3 batteries in groupings of 3 cells each (24 cells total). Conditioned output fed to WFF93 analog data module.

Flight Test Results

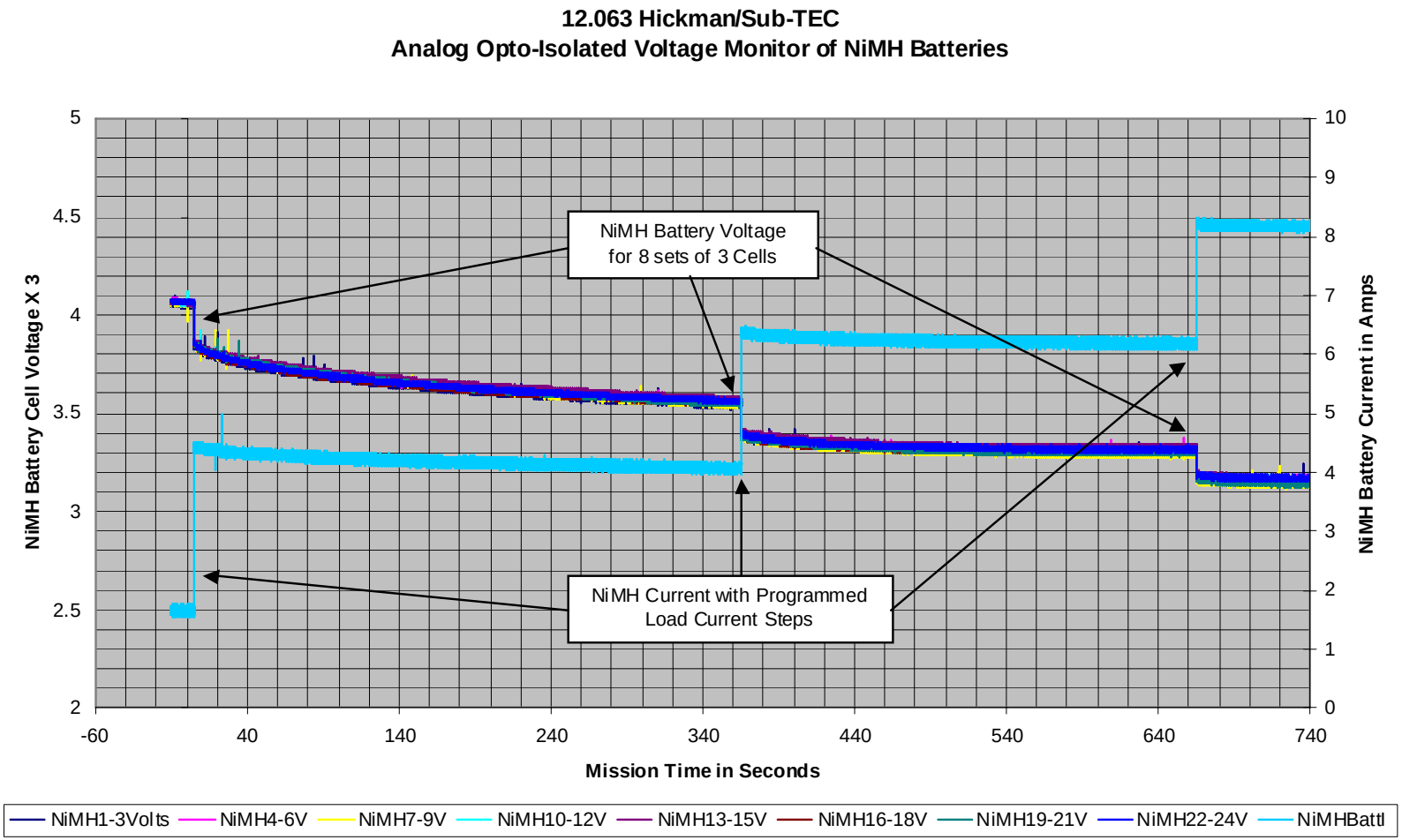
- Excellent data received for entire flight.

Analog Opto-Isolated Voltage Monitor



Analog Opto-Isolated Voltage Monitor

Flight Data



Strain Gauge Signal Conditioning

Issues

- Very limited capability to effectively signal condition strain gauges.

Solution

- Recent development of a programmable gain and offset operational amplifier allows circuit board fabrication, testing and stocking.
- Once mission requirements have been determined the circuit can be programmed for the appropriate gain and offset via external connector.

Program Benefits

- The new programmable gain and offset amplifier can be tested prior to “burning the fusible links” allowing much greater flexibility in strain gauge sensor offsetting and amplification.
- The gain and offset are set without changing components on the PC board.

Implementation

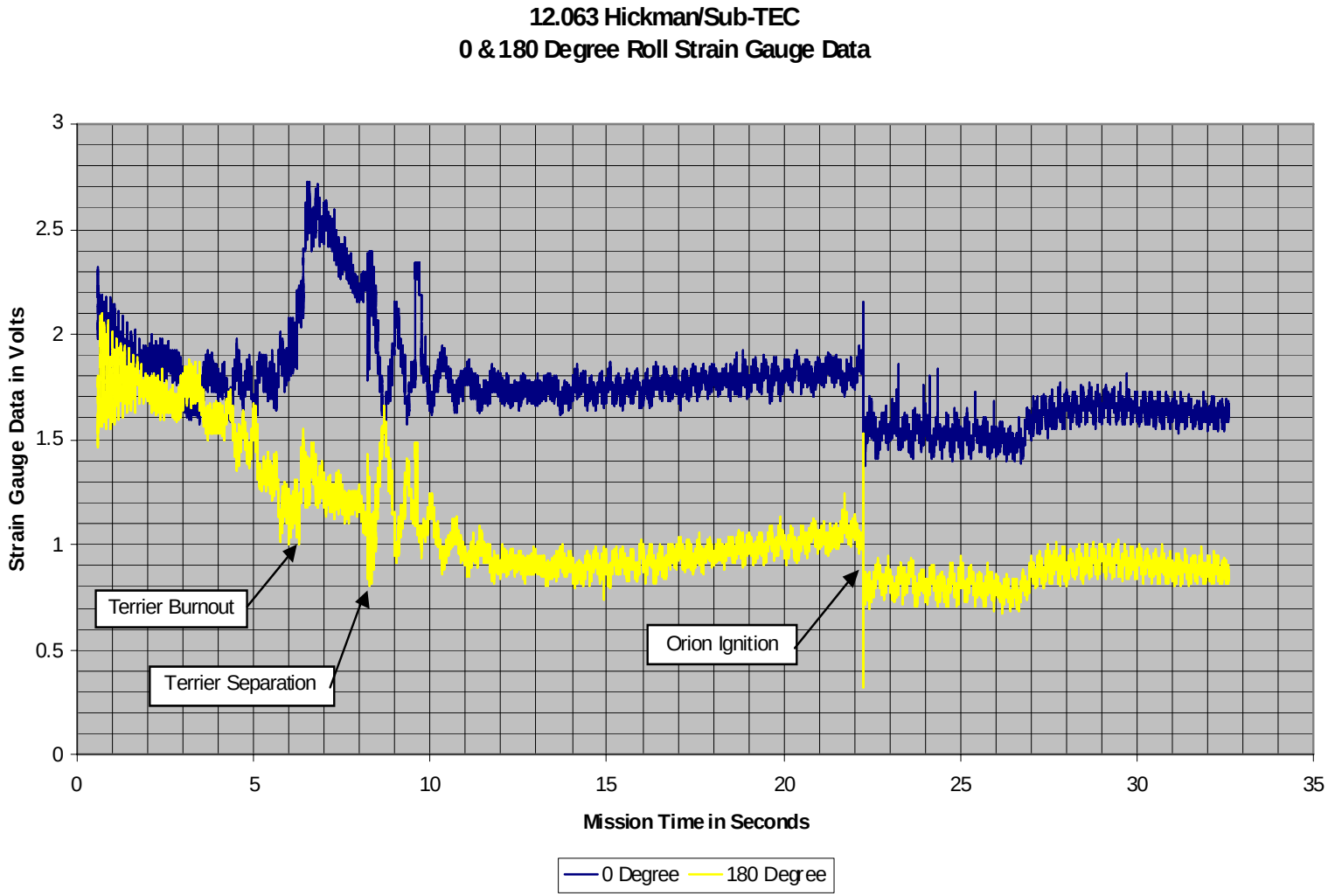
- The skin mounted strain gauges and conditioning electronics were subjected to a flight level tip deflection push/pull operational/calibration test.
- Strain gauge conditioned output (4 gauges) was fed to WFF93 analog data module.

Flight Test Results

- Excellent flight data.

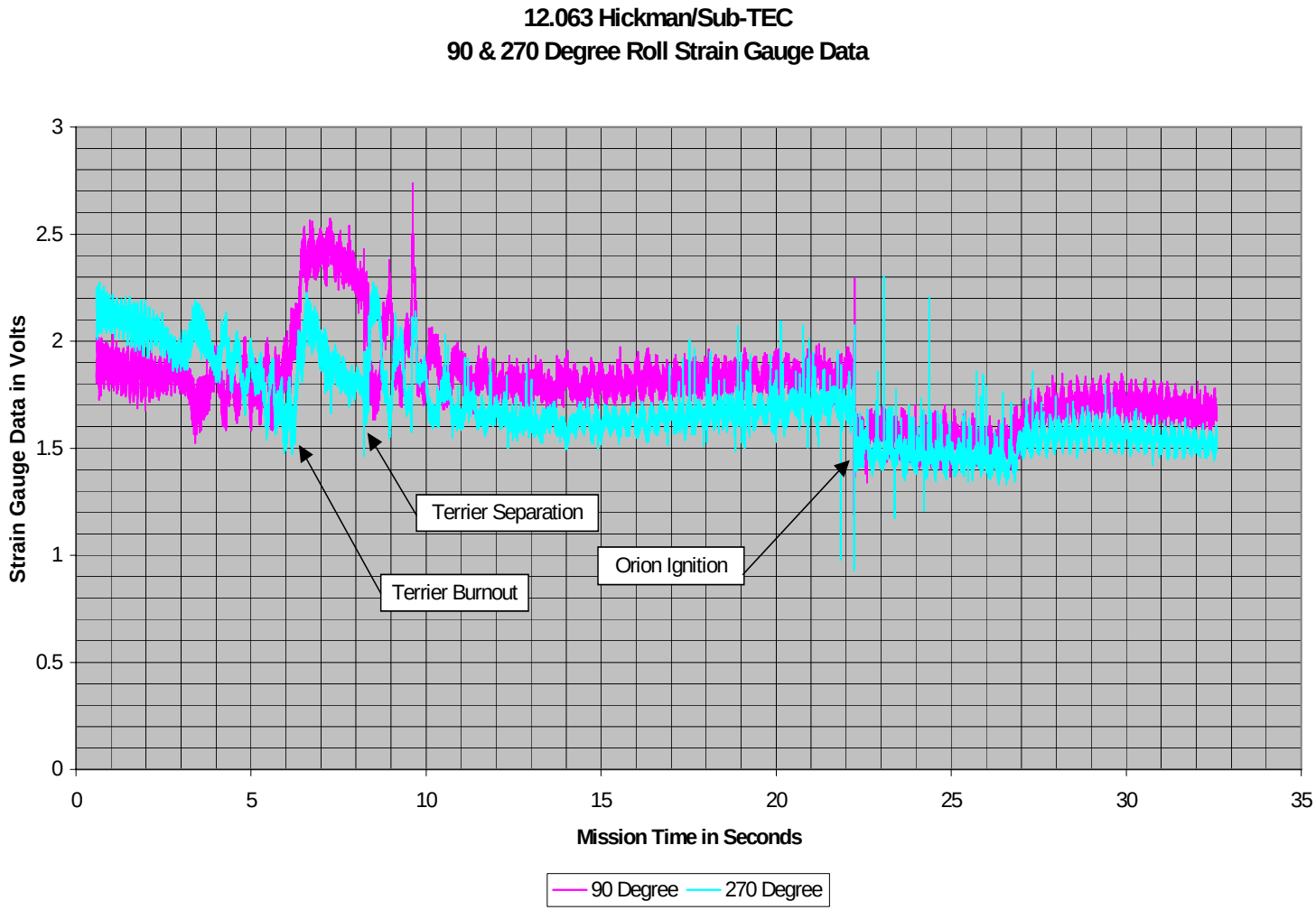
Strain Gauge Signal Conditioning

Flight Test Data



Strain Gauge Signal Conditioning

Flight Test Data



Low Cost TM Encoder (LCTE)

Issues

- No capability to provide a low cost in-house fabricated PCM encoder.
- Need low cost TM system for student payloads and low budget customers

Solution

- Developed a low cost surface mount technology encoder design.

Features

- Hardware (PCB & housing) built in-house.
- Programmable and re-configurable PCM formats and parameters.
- Bit rates up to 4 M BPS.
- Analog, parallel digital, async serial, sync serial and time event data inputs accommodated.

Program Benefits

- Encoder less than 1/3 the cost of existing encoder systems.
- Single deck accommodates analog, digital, asynchronous and time event data types.

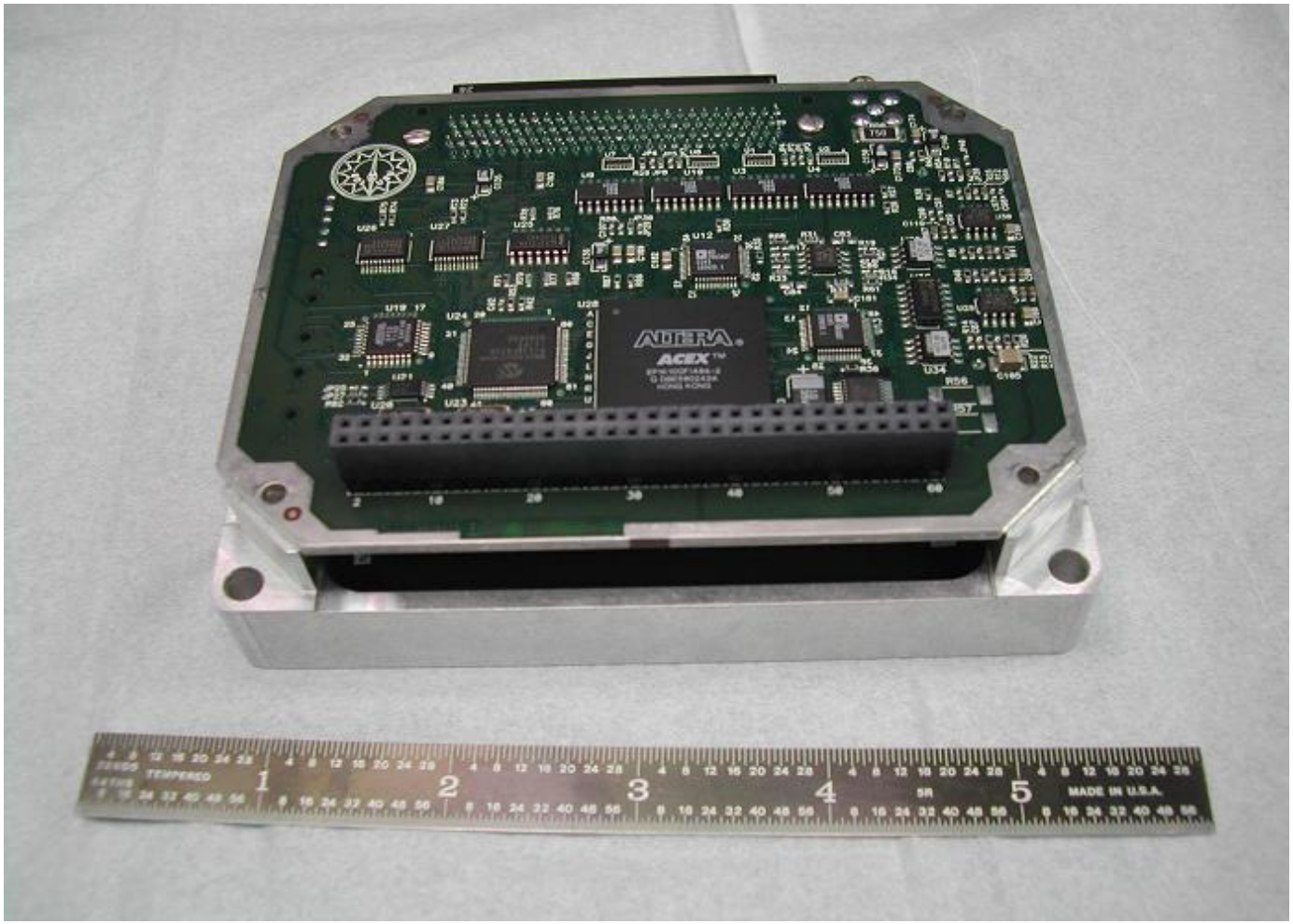
Implementation

- PCM data rate set for 5K bps. Monitored 32 analog data channels, 14 parallel digital channels. PCM output connected to WFF93 analog data channel input.

Flight Test Results

- Excellent data received for entire flight. LCTE flight data shown in Dual RMFT slide

Low Cost TM Encoder (LCTE)



Beacon PCM

Issues

- No method to allow TM tracking antennas to verify proper tracking acquisition prior to payload launch.
- Potential WSMR/Kodiak customers needing TM tracking assessment tool/method.

Solution

- Designed an 8 channel analog input PCM encoder and power control system to fit within a 2.75 inch test rocket nose cone.

Program Benefits

- Allows range TM tracking as well as Radar assets to certify proper tracking operation prior to actual payload launch.
- Eight analog data channels allows assessment of payload health during flight as well as providing a mechanism for Range TM to certify proper data decommutation and recording.
- Can be used with the MLRS as an inexpensive TM tracking assessment tool or for a low cost student payload instrumentation package.

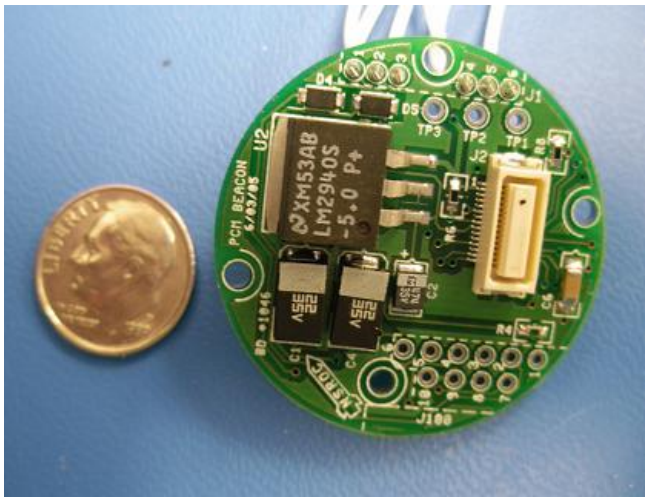
Implementation

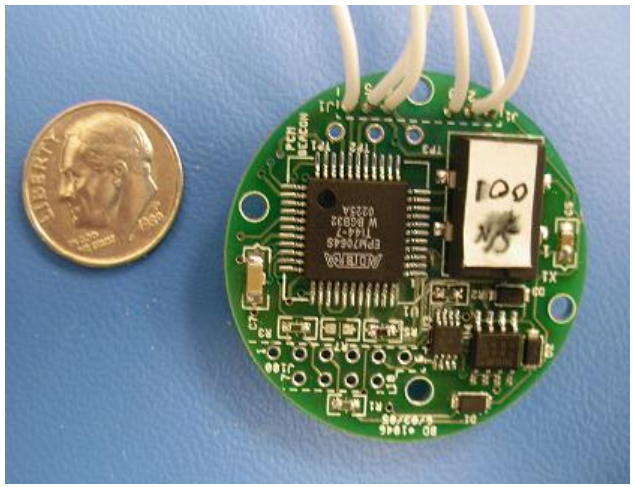
- Unit configured for 8 analog data inputs and data rate set for 3.906 K bps. Encoder digital output fed to analog data channel input of WFF93 encoder.

Flight Test Results

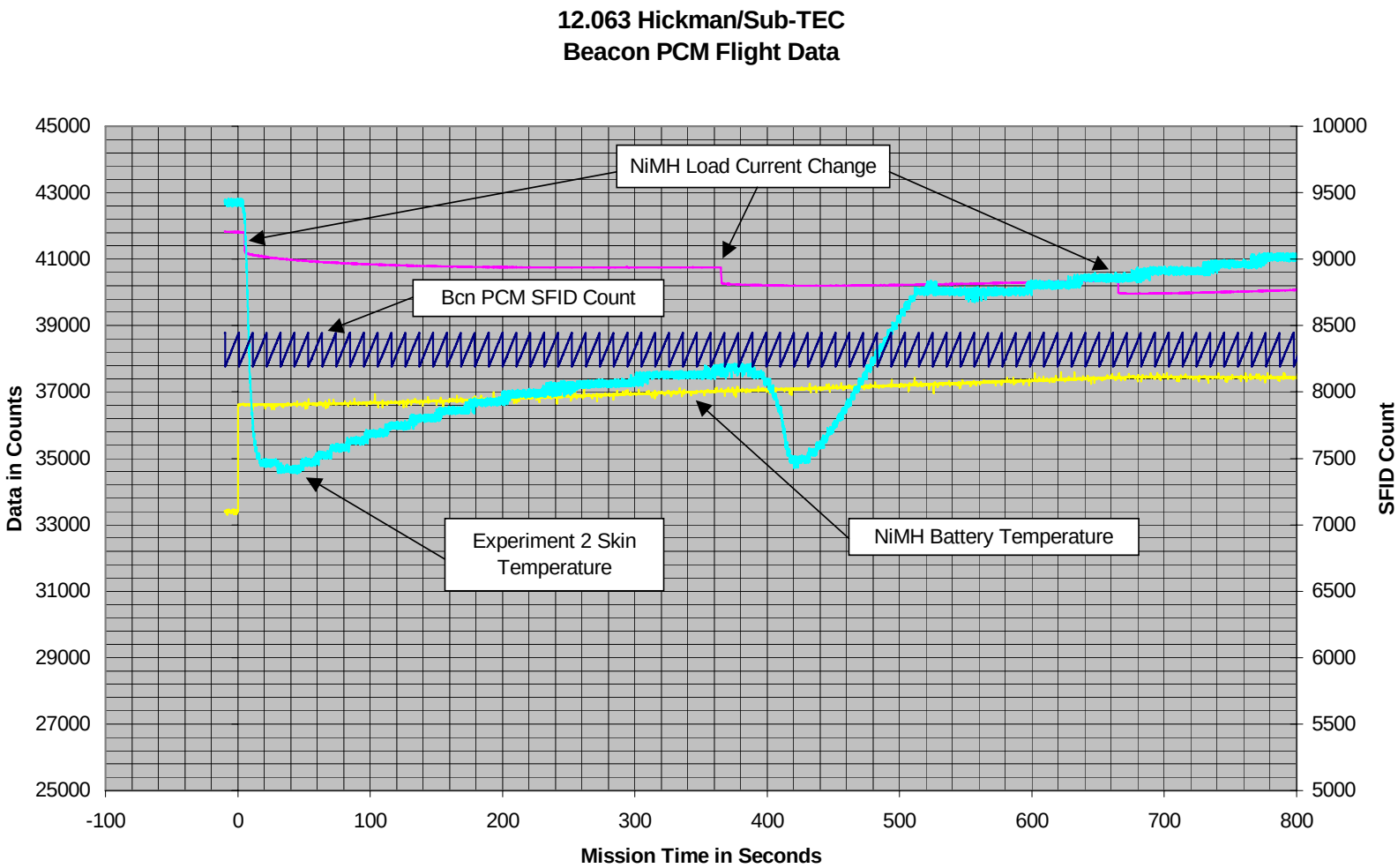
- Excellent data received for entire flight.

Beacon PCM





Beacon PCM
Flight Data



Payload Power System

Issues

- Payload power systems are wired after the decks have been fabricated.
- No testing can be performed until the wiring has been completed.

Solution

- Designed a +28V power system in a box.
- Controlled using an RS232 interface from the GSE.
- Incorporates bus voltage monitoring and Internal/External status monitoring.

Program Benefits

- Reduces the landline requirements.
- Allows power system to be tested prior to installation in the payload.
- Incorporates bus monitoring and provides analog and RS232 outputs.
- Simplifies payload wiring.

Implementation

- Used to provide +28V NiMH battery power to 4 sets of high power load resistors. Current set for ~2.5 Amps for 3 switched outputs and 1.5 Amps for continuous load output.

Flight Test Results

- Flight configured with no G-Switched power backup and no inadvertent power switching noted throughout flight.
- No problems switching via RS232 pre-flight and no in-flight anomalies.

Payload Power System

Nickel Metal Hydride Batteries

Issues

- Existing Nickel Cadmium battery systems are heavy.
- NiCad batteries are being phased out due to environmental concerns.

Solution

- Utilize new battery technology.

Program Benefits

- Reduces overall payload weight.
- Easier disposal of exhausted cells.

Implementation

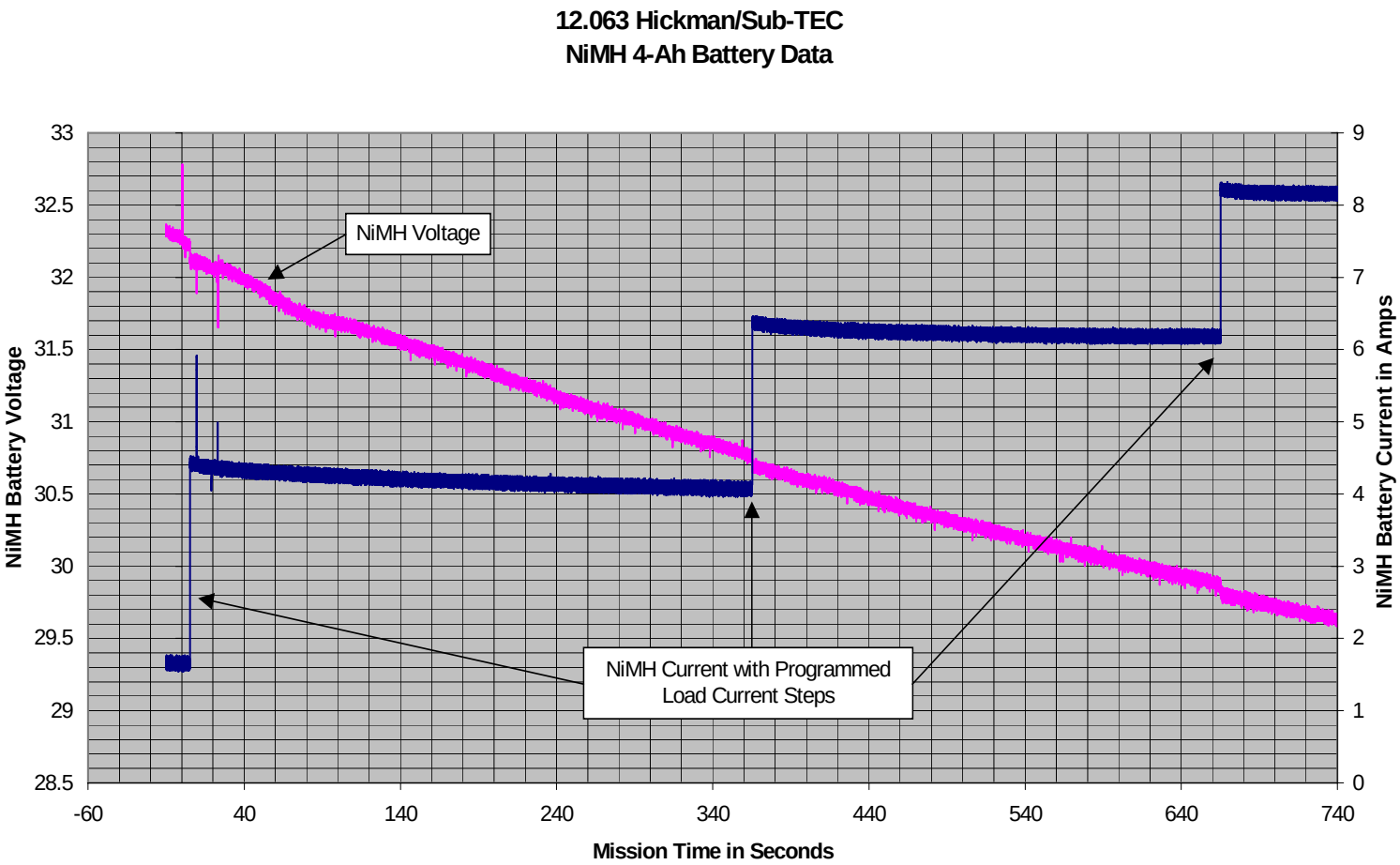
- Used to provide power for the PIB switched power outputs from 1.4 Amps to ~8 Amps at end of flight.

Flight Test Results

- Batteries provided excellent power with pack voltage measured to be 28.8 volts at +840 seconds at over 8 Amps load current.

Nickel Metal Hydride Batteries

Flight Data



Mechanical Engineering

Giovanni Rosanova

Mechanical Engineering

General Updates

- Two new full-time Mechanical Engineers
- Vibration loads study progressing. Flight of 12.063 in December gave a critical missing data point that will allow further refinement of data trends. Next steps:
  - Dedicated vibration environment measurement flight
  - Draft new testing policy
  - NASA Non-advocate Review of data and new testing policy
  - Implement new testing policy
- Innovations and new capabilities
  - Sealed skin-mounted antenna interface for water-recovery
  - T&E lab has new programmable thermal-vacuum chamber
  - New rocket-propelled sub-payload design for Lessard

Vehicle Engineering

Terrier Clamp Release RTF

- Conducted two formal technical reviews and many hours of testing to verify changes. NASA Non-advocate Review Board cleared system for flight.
- System will only use pistons from tactical assembly. Each pin is hardness tested to confirm its material properties.
- Completed changes to assembly procedures to ensure more repeatable clamp release force range. Motor crew trained and briefed on lubricants and assembly techniques incorporated into procedures.
- Pyrotechnics output energy has been quantified within the system and factor of safety calculated and deemed adequate.
- System flew successfully on 12.063 Hickman on December 20th
- Measured flight vibration environment in vicinity of clamp release electronics to verify current testing loads. Data still being analyzed. Similar environment will be measured on 12.058.

Guidance, Navigation & Control

Walt Costello

GNC Topics

- Boost Guidance Systems
  - Future Situation
  - Current Situation
- GPS Velocity Vector Input to NIACS
  - Seybold 41.068 WSMR April 2006 (test round)
  - Earle 36.218 Wallops Sept 2006
  - Robertson 41.069/070 Andøya June 2007
- Celestial ACS
  - Celestial Missions
  - Hardware
  - Challenges
  - Air Bearing Testing
- Poker Flat Campaign, 2007

GNC – Boost Guidance Systems

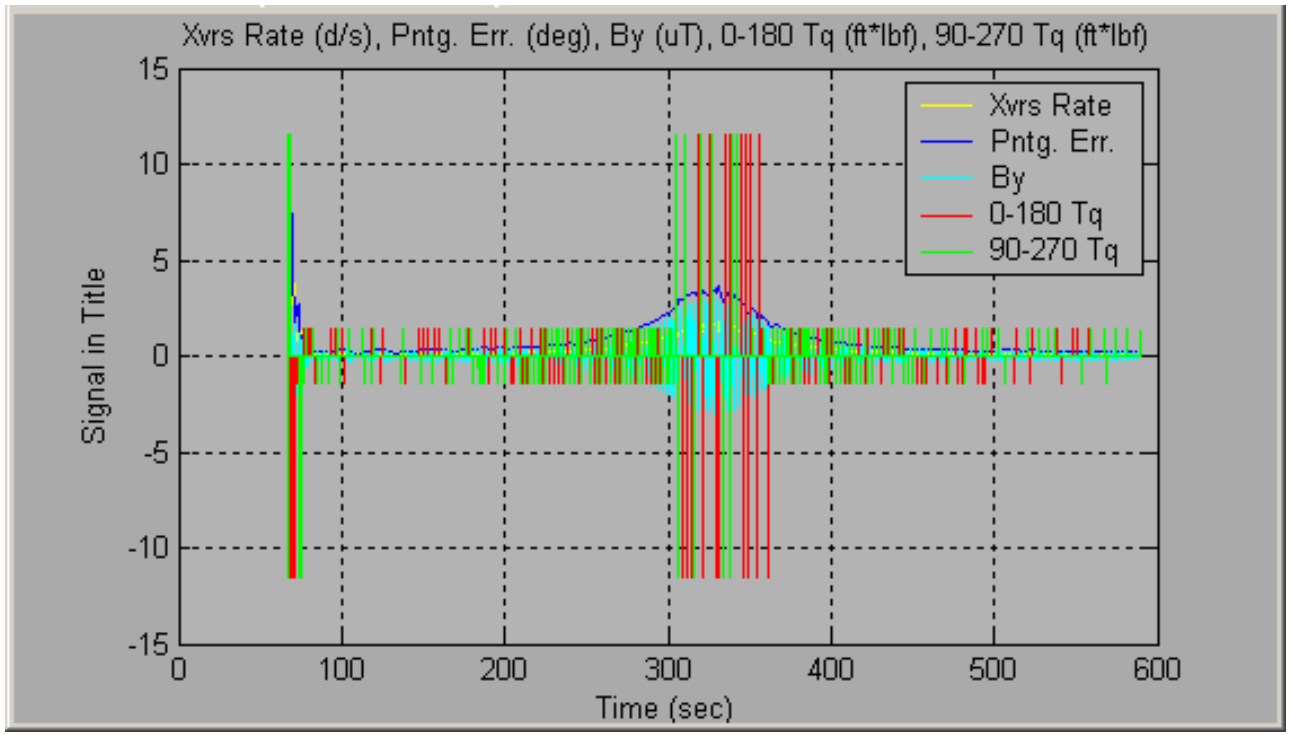
- Future Situation
  - 4 S-19L systems to be delivered (2 in April & 2 in June 2006).
    - Strap-down LN-200 may be adequate for Rail Attitude Hold only
    - More reliable without gimbal
    - Reimbursable missions made procurement possible
    - Unresolved – IS THERE TO BE A TEST MISSION?
  - S-19G design available
    - Tap off NIACS/Celestial GLN-MAC or self contained
    - Can be IIP-capable like DS-19
  - Both designs:
    - Build on existing DS-19 design & software
    - Replace DMARS
    - Incorporate SAAB Guidance Processor Unit
      - Accepts raw LN-200 data

GNC – Boost Guidance Systems

- Current Situation
  - 2 refurbished MIDAS gyros left for S-19A system (one is modified TM gyro)
    - Scheduled for Rabin & McCammon
    - Also have 2 operational but un-refurbished MIDAS
  - 3 S-19D w/DMARS
    - Korendyke hard landing damaged one DMARS
    - 2 Available S-19D scheduled for Kankelborg & McCandliss
    - NASA to obtain 2 additional DMARS excess at Sandia
      - NEVER HAPPENED
    - Approx 4 month refurbishment cycle for S-19D
    - T100 gyros – delaying DMARS refurbishment
      - One damaged on Korendyke – other should be checked out
      - Two apparently good T100 available from Wilkinson failure.
      - Factory relocation affecting T100 production and refurbishment

Velocity Vector
Continuous Fine Targeting

- Typical error < 1.0º.
- Gas consumption < 50% (early analysis).



Scheduled Celestial Missions

- 36.220 McCandliss Mar 2006
  - Target position within +/- 5 arc-min
  - Command Uplink to 10 arc-sec Slit
- 36.224 Cash Aug 2006
  - Initial acquisition within +/- 5 arc-min
  - Final acquisition within +/- 15 arc-sec (with uplink)
  - Less than 5 arc-min total drift
- 36.207 Cruddace Sep 2006
  - Less than 1 arc-sec/sec jitter
  - Less than 0.2 arc-min/min drift
  - +/- 2 arc min target
- 36.225 Chakrabarti Jan 2007
  - Must acquire within 1 arc-sec
  - Very precise control based on science provided “perfect” error signal
- 36.226 Bock May 2007
  - 3 arc-sec max error in 20 seconds
  - Side looking ST-5000 (Maybe two)

CACS PNEUMATICS (BASIC SPS)

SPS

(MK-6 CONFIG SHOWN HERE)

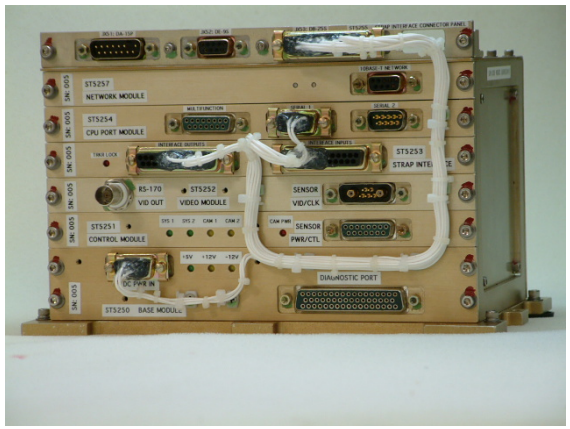
- 395 CUBIC INCH TITANIUM PRESSURE VESSEL
- TOTAL OF 4 REGULATORS
- TOTAL OF 4 TRANSFER VALVES
- 2 ROLL CONTROL VALVES (CW & CCW)
- HIGH FLOW SPIN-UP VALVE
- 2 COMPLEX MULTI LEVEL MANIFOLDS
- FLEX HOSES FOR REMOTE NOZZLE FEEDS
- CHECK VALVES, FILL VALVE, RELIEF VALVE
- 5 TRANSDUCERS
- BI-LEVEL P&Y CONTROL
  - 2 REGULATORS
  - 2 TRANSFER VALVES
- TRI-LEVEL ROLL CONTROL
  - 2 REGULATORS
  - 2 TRANSFER VALVES

Valve Driver Board
Supported Modes

Roll	Pitch	Yaw
Coarse	Coarse	Coarse
Intermediate	Intermediate	Intermediate
Fine	Fine	Fine
Differential Fine	Differential Int	Differential Int
Partial Pulse Fine	Partial Pulse Int	Partial Pulse Int
Bleed	Differential Fine	Differential Fine
Spin-up*	Partial Pulse Fine	Partial Pulse Fine
	Bleed	Bleed
	Vent	Vent

*All Modes are Bi-Directional, except Spin-up

ST5000 Star Tracker



ELECTRONIC CONTROLLER

TRACKER CAMERA

- Camera can be mounted as far as 12 feet from the electronics controller.
- Tracker camera weighs 3.7 pounds.
- Electronics Controller box weighs 6.4 pounds.

Celestial ACS Challenges

- Sandia GLN-MAC S-5/GATAR software crashed when Celestial software was added.
  - Sandia Floating Point Exception Handlers encountered and DID NOT WORK
  - Sandia S-5/GATAR did not allow troubleshooting
  - Never could obtain Sandia S-5/GATAR source code
  - We had to rewrite exception handlers and GLN-MAC – GSE interface
  - Delayed development at least five months.
- Designed & built valve driver capable of very fine thrust control
  - Operational, works well
  - Lack of linearity presents problems for observer/controller
  - Encountered valve and plumbing irregularities
- Integrating ST-5000 into NIACS tracking loop - DONE & working well
- Designing & coding state space observer/controller to overcome measurement noise and achieve required performance
  - Even more difficult than expected
  - Roll performance is not as good as pitch/yaw (was expected)
  - Best pitch/yaw performance so far achieved: approx +/- 3 arcsec (1-sigma)
  - We are competing two approaches:
    - State observer, Rate, Bias, Error Torque states @ 50 Hz with Partial Pulse
    - Simplified controller at 400 Hz (LN-200 rate) (AeroJet approach)

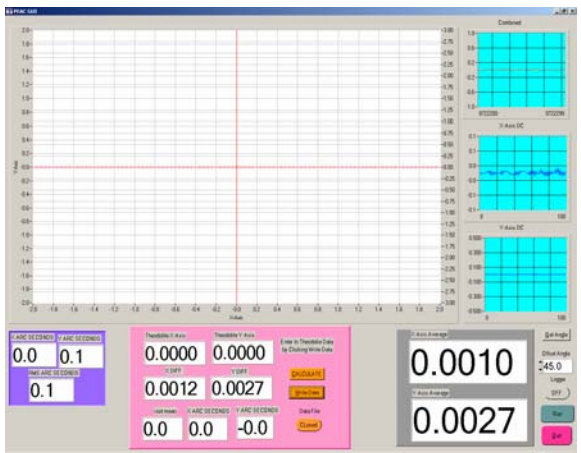
Celestial ACS Challenges (continued)

- Creating air bearing test environment capable of simulating star field and measuring fine pointing performance
  - Need to take out earth rate on air bearing
  - Mirror star targets were difficult to set up and use.
  - Fiber-optic accent lamp into collimating mirror provides excellent star field
  - Need better ST-5000 “Learn Mode”
  - New Laser Auto Collimator (Lackey) is providing excellent performance.
  - Off-center ST-5000 mount caused roll-pitch coupling (dumb but corrected)
  - Lackey off center (may cause some error) and hard to determine absolute position.
  - Need to improve quantification of performance.and environmental error sources
- Designing processes and writing procedures to minimize risk and ensure success
  - Proceeding fairly well
- Accomplishing the above efficiently and rapidly
  - We are doing the best we can

Celestial ACS Challenges (continued)

- Costello 12.058 Test Flight anticipated difficulties
  - Max apogee 120 Km – aerodynamic error torque will exist: ~ 15% @ 100 Km
    - Max acceleration 0.05 deg/sec^2 = 180 arcsec/sec^2
    - Max error torque @ 100 Km ~ 0.0075 deg/sec^2 = 27 arcsec/sec^2
  - No experiment telescope – therefore performance will have to be inferred from Celestial ACS data and back-correlated to Lackey data from air bearing.
- Fine pointing performance (< 1 arc-min) WILL require uplink command on science instrument.
  - Precise ground alignment is not possible with NSROC technology.
  - GLN-MAC random walk may be worse than expected (or may be environmental).
- Very fine pointing performance (~ 1 arc-sec) WILL require upgraded rate gyros.
  - Near-term approach:
  - Retain GLN-MAC
  - Add Digital IMU (candidates cost ~ $80,000 ea)
  - Or could use surplus analog TRIGs (requires greatly increased development time)
  - Almost certainly required for Chakrabarti
  - May be required for Cruddace

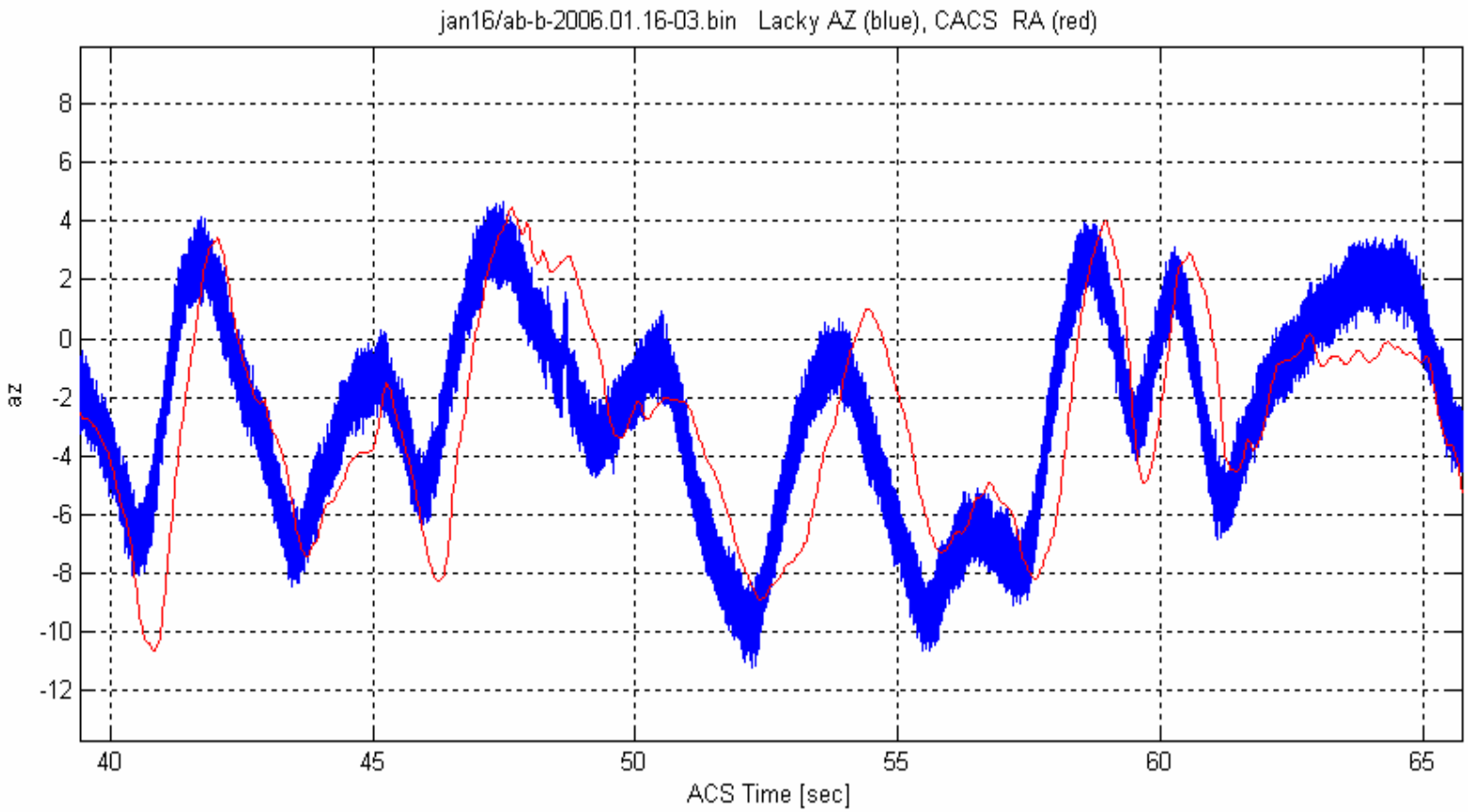
T100 Laser Auto Collimator the LACKEY



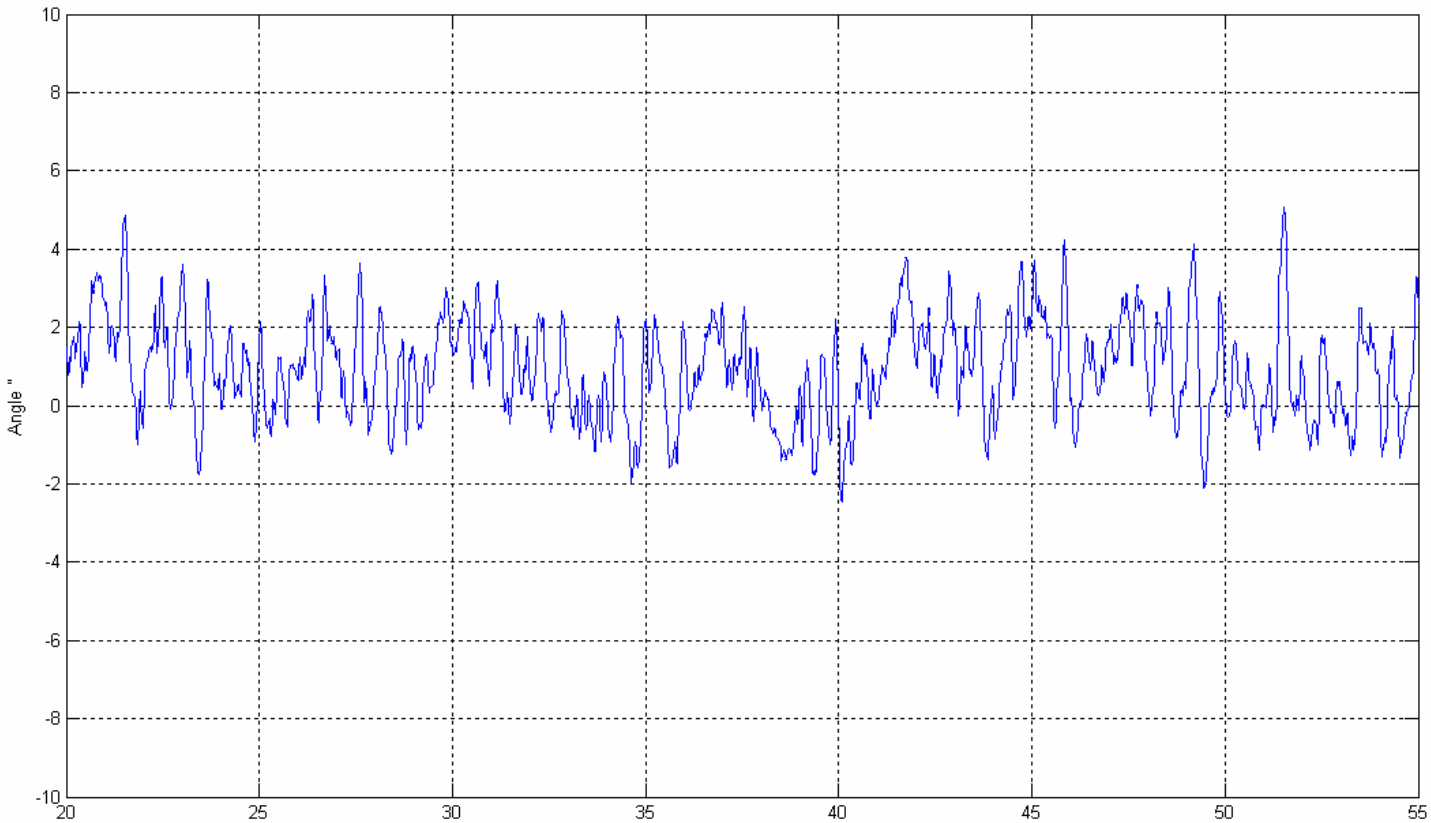
Measures Angular Offset,

- Accurate to +/- 0.1 arc-sec
- Time sync signal for GLN-MAC
- No position sync
- Performing Very Well

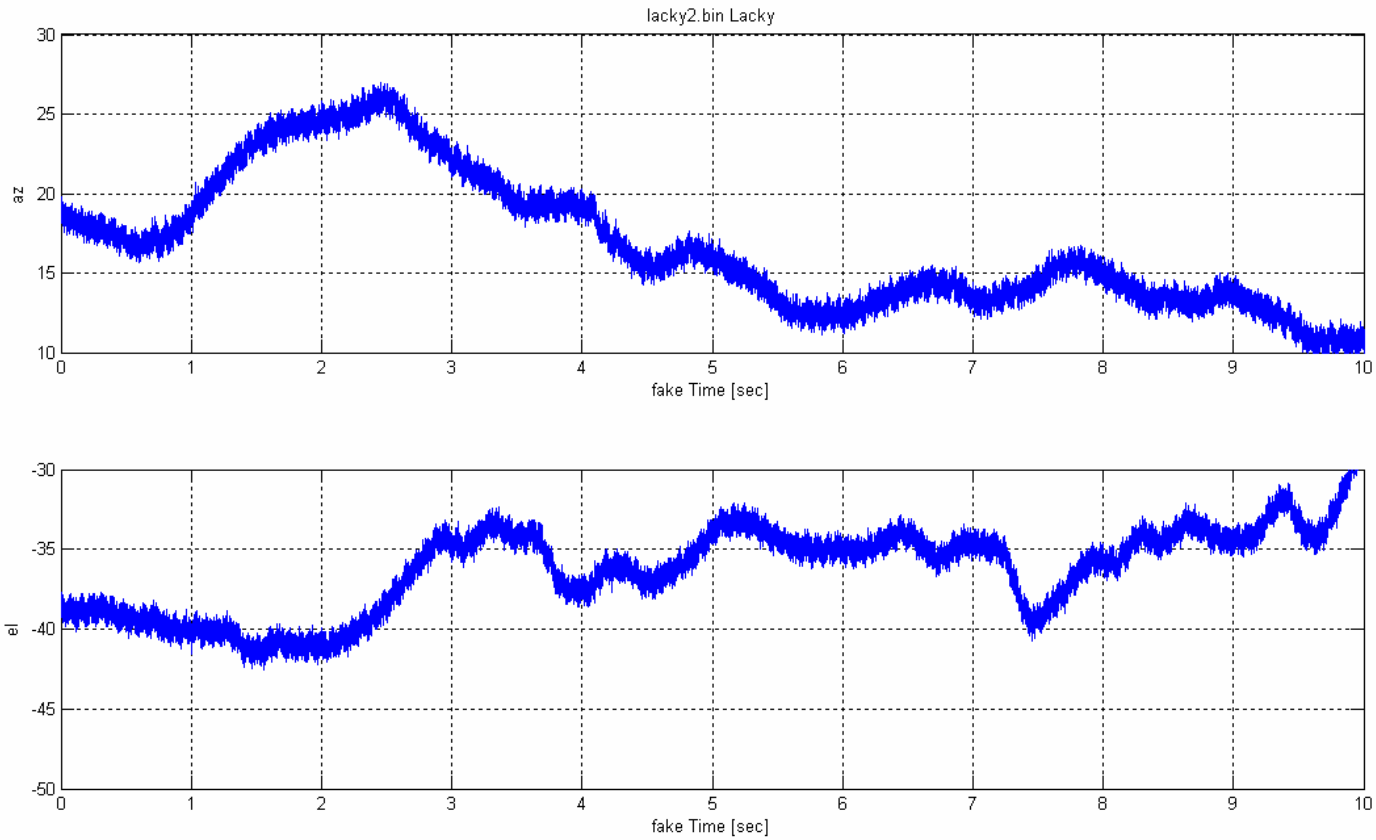
Laser Autocollimator Compared to Celestial



Celestial Position



Laser Autocollimator Position



Celestial Continuous Improvement Road Map

- Interface for experimenter error signals (Chakrabarti)
- Finer, quieter pneumatic valves (Chakrabarti)
- Interface for 2nd star tracker (Bock)
- GSE – replace S5/GATAR – first version DONE – need upgrades
- Valve driver diagnostics
- Simplify targeting and mission planning
- Speed up Lost in Space (second and subsequent)
- Mission independence of software
- Software in the loop (SWIL) simulation
- Hardware in the loop (HILTS) simulation

Poker Flat Campaign 2007

- Larson –
  - 2 NMACS
  - Similar to Joule
  - Also 2 chemical rockets
- Lessard –
  - NIACS under consideration
  - Complex sub-payloads
- LaBelle –
  - NMACS
  - Straightforward mission
- Craven –
  - NIACS
  - Trajectory modification similar to Conde
  - Also three instrumented chemical rockets

Thank You For Your Support

- NSROC ACS stands ready to support experimenters worldwide.
- Questions?
- Comments?
- Observations?

Conclusions

- NSROC is committed to continuing the SRPO mission and program successes.
- NSROC's Primary Goal is to satisfy the Code S PI mission requirements.
- NSROC is committed in expanding the technical innovations while
  - Meeting the requirements of the PIs
  - Maintaining a cost effective environment
  - Making effective use of the in-house talent, experience and hardware.
- NSROC's receipt of the SRWG findings is important for future growth planning.