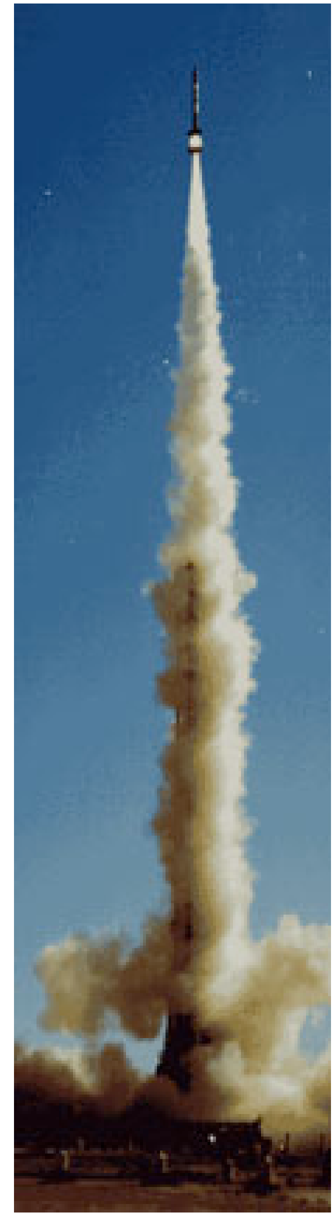
Sounding Rocket Working Group
January 19, 2005

NASA Sounding Rocket Operations Contract (NSROC)

NASA Wallops Flight Facility

SRWG Agenda - NSROC

NSROC State of Affairs	**R Maddox**
NSROC Operations	**J Scott**
AIB Activities	
41.046 AIB	**G Rosanova**
12.056 AIB	**S Elborn**
NSROC Engineering	**R Weaver**
ACS	**W Costello**
Configuration Control - Hardware and Software	
NMACS Kwajalein results	
ACS innovations on upcoming flights	
Summary	**NSROC**



NSROC State of Affairs – Rob Maddox

Programmatic

- Contract Status
  - Approaching end of contract year 6
  - Very good PEB scores
- Subcontract Status
  - No significant issues
  - Minimized Aerojet support
  - RSS acquired by Hurley Industries (no impact to NSROC)

Programmatic

- Accomplishments
  - Kwajalein Campaign
  - Demonstrated new technical capabilities
    - NIACS, NMACS, GLNMAC, ST5000

Programmatic

- Challenges
  - Implement new technology
    - Attitude Control Systems
    - New surplus vehicle configurations
  - Mission scheduling
    - Advance planning
    - Staggered integrations
    - Reduce Overtime
      - Kwajalein overtime cost ~ $6k/day for 3 months
  - Complex Missions
  - Budget

Programmatic

- Staffing
  - 2 Key Personnel left NSROC during this period
    - Marketing Manager
    - Business Manager
    - Vacancies being filled with existing personnel
  - 157 FTEs
    - Down 6 FTEs since last SRWG

Programmatic

- New Business Opportunities
  - NASA New Exploration Program proposals
  - Navy “At Sea Demo”
  - Air Force/MIT-LL Airborne Laser “MARTI”
  - Air Force Research Lab “RESE program”
  - DARPA Scramjet
  - Army “MCAFT”
  - ATK Elkton “ASAS demonstration”

NSROC Operations – Jay Scott

NSROC Operations
Finding: Systems Engineering

- Current staff
  - Five MM's
    - 38 active missions = 7 _ per MM
  - Background
    - 2 engineering degrees
    - 3 technical
    - 100+ years experience
- Future training
  - Discipline mentors & training
  - Systems Engineering course
  - Mission de-brief reviews

NSROC Operations
Finding: Systems Engineering

- New hire requirements
  - Eng. Degree
  - Min. 5 years experience on payload team
- Mission assignments
  - Attempt to match ability/training to payload
    - Sometimes difficult
      - Limited resources
      - Flexible schedules

41.046 AIB - Giovanni Rosanova

41.046 Anomaly Investigation Board (AIB)

Giovanni Rosanova
AIB Chairman
January 19, 2005

The Mission

- Terrier Mk70-Improved Orion
- TMA release payload with Peruvian Beacon
- Payload: 350.50 lb, 108.29 in., 14” diameter – Outside envelope (Light and Short)
- Other than Peruvian beacon and radar transponder, no additional instrumentation on board
- Third and final mission in second Hysell series
- Launched from the Super-HAD mobile launcher on Roi-Namur

The Anomaly

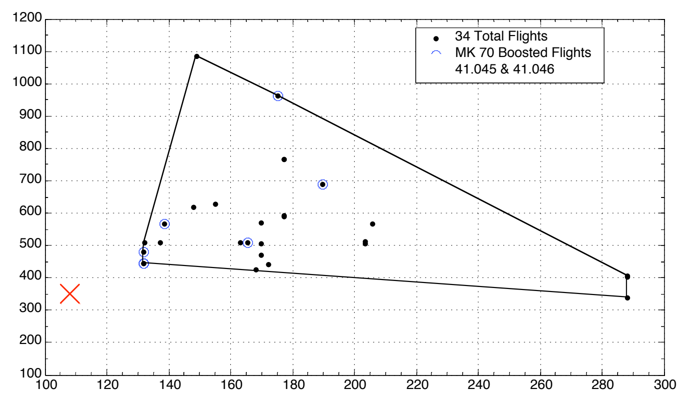
- Launched at 0851 UT
- First stage burn initially appeared nominal
- No second stage ignition was witnessed
- No TMA release was witnessed
- Radar data: rapid divergence from nominal trajectory near the end of first stage burn.
  - Only payload radar transponder was tracked
  - Radar on Roi-Namur (launch site) did not track
- Impact point well short of predicted booster impact
- Pinger indicated payload in 15,000 ft. of water

Findings

1. Payload separated from vehicle stack at or near Improved Orion lap joint at end of first stage burn
2. Separation of payload precipitated by aero-elastic or mechanical anomaly during first stage burn, most likely due to weak link in Terrier fins.
3. Unlikely that failure caused by electrical problem.
4. Unlikely that failure caused by procedural problem.
5. Unlikely that failure caused by problem in processing or preparing vehicle at Wallops.

Findings

6. The 41.046 failure not similar to 41.028 failure in which Terrier clamp did not release.
   - 41.046 anomaly centered on structural failure which induced an aerodynamic imbalance, ultimately causing payload to separate from second stage motor.
   - However, AIB could not prove that the clamp did indeed release on 41.046, since no skin tracks obtained.
7. The evolution of the Terrier Mk12/Mk70-Improved Orion vehicle design was largely based on flight heritage, and not on thorough engineering analysis.



Action Items

1. Define payload envelopes for Terrier Mk12/Mk70-Improved Orion as currently designed.
   - Include redesign of fin incidence adjustment interface on Terrier 4.8 ft^2 fins such that factor of safety against failure greater than 1.5.
2. Define requirements for Flight Performance and Mechanical analysis needed when pushing or expanding envelope of any flight vehicle (Length, Weight, Dynamic pressure, other flight dynamics parameters).
3. Obtain a complete drawing package for every vehicle in the Sounding Rocket stable.

Action Items

4. Develop process to ensure that weather environment at launch site are considered during mission planning.
5. Develop work instruction for collecting and accounting for mechanical safeties.
6. Develop process to ensure that ALL experiments are present and functioning during I&T and sequence tests.

Action Items

7. Develop process to ensure correct material used in fabricating all sounding rocket parts, whether made in NSROC machine shop or by external vendors.
8. Fit check all vehicle hardware, including payload motor adapters, to flight motor prior to field operations.
9. Conduct the following tests.
   - Load test Terrier 4.8 ft^2 fins from the same lot that flew on 41.046
   - Load test Orion fins from the same lot that flew on 41.046
   - Appropriate tests to determine if fin flutter could have occurred on 41.046.
   - Attempt to fill Terrier fins with water to determine if moisture infiltration was possible on 41.046.

Conclusion

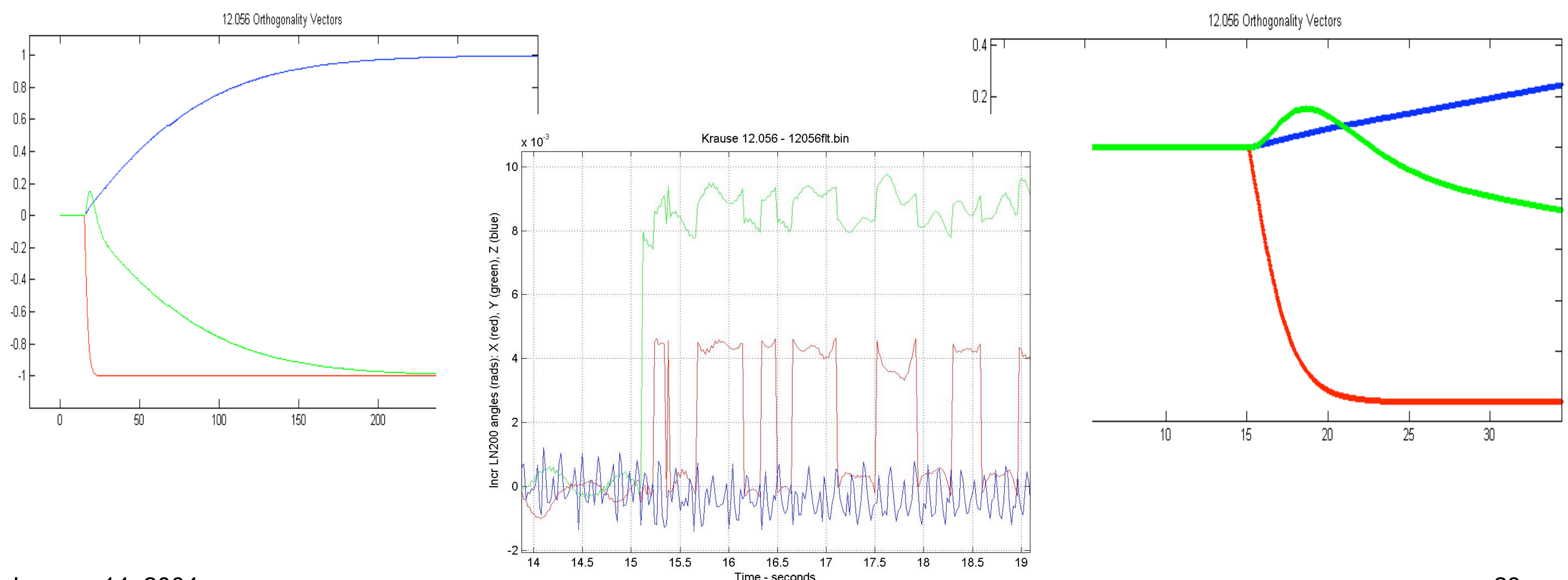
- All action items are entered into NSROC's Corrective Action Tracking System: Assignees and due dates.
- Some actions are already being implemented in part.
- Drag separation on Terrier-Orion will fly for the first time on 2 February (Navy Target)

12.056 AIB - Shelby Elborn

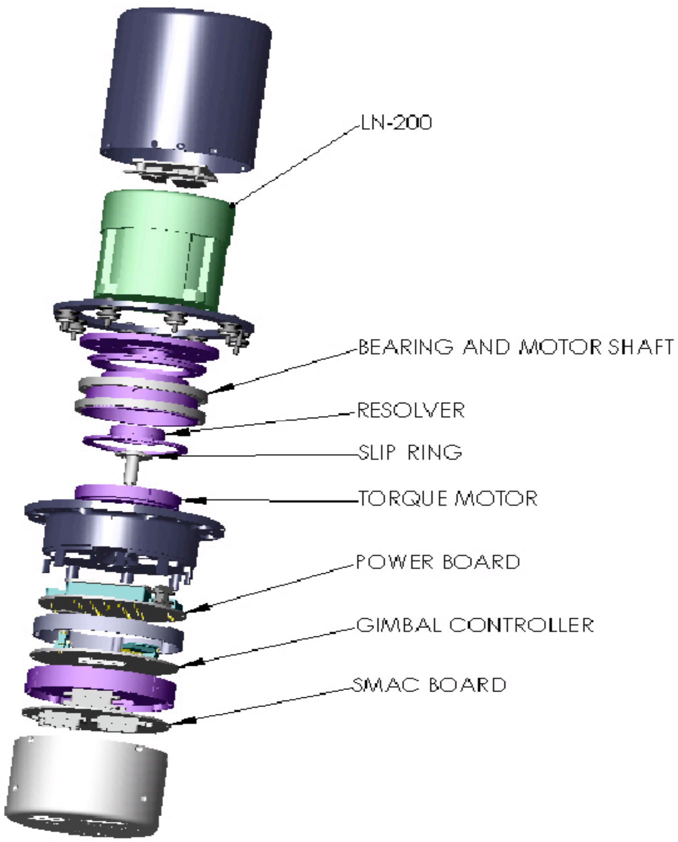
12.056 Flight Anomaly

Findings

- The LN200 status bit overwrote the gyro delta theta x data.
- The implementation of the axis rotation allowed the system to lose orthogonality.
- The delta theta x gyro asynchronous data was incorrectly scaled.
- The asynchronous delta theta y experienced a voltage shift.
- NSROC code was built on sample code provided by Sandia.



GLNMAC Overview



- GLNMAC designed by Sandia
  - ~36 flight tests by Sandia
  - Data transferred to NASA/NSROC in 2002
  - Piggyback Sandia unit on flight 36.208/Feldman on 12/16/03
- GLNMAC 03N001 1st unit manufactured by NSROC
  - Nominal flight on 12.054
  - Refurbed and flown on 12.056
    - Drift test
    - Verify gimbal freedom @2.5Hz
    - Acceptance Level vibration

Return to Flight

Identify and Correct Software problems

  – Delta theta x overwrite issue corrected
  – Othogonality algorithm updated
  – Delta theta x scaling corrected
  – Refined telemetered data products
  – Refined software structure

- Component Level Checkout
- Air Bearing with flight pneumatics and flight code.
- Added a unmodified piggyback GLNMAC S/N 03N001
  – Leave major issues in the flight code
  – Fix the TM scaling issue for proper postflight analysis
  – Include the LN200 status message in the TM data
  – Monitor the IMU directly from the LN200

12.061 Flight Results

- LN200 Accelerometer Status bit was set and handled correctly on the control GLNMAC.
  - Piggyback GLNMAC repeated 12.056 flight events.
- Loss of orthogonality problem was corrected and verified on the control GLNMAC.
  - Piggyback GLNMAC lost orthogonality
- Delta Theta x scaling was corrected and verified on the control GLNMAC.
  - Piggyback GLNMAC experienced incorrect scaling
- No cause was found for the delta theta y shift experienced on 12.056.

Engineering - Rick Weaver

Engineering - Rick Weaver

Mission Scheduling

- There was previous concerns about resource conflicts due to missions slipping in small increments. This was reduced tremendously as fourteen missions were part of the Kwajalein campaign, thus a defined end date. This did create conflicts as the missions were initially scheduled sequentially for I&T but slips had them conflicting through I&T leading to substantial overtime.
- FY05 should have minimal conflicts as there has been minimal discussion about mission slips.
- Most missions are meeting or ahead of schedule.
- Only two FY05 missions have not had a Design Review.

Staffing

Contract Staffing Level

One new hire in the GNC group (PhD).
One transfer from Electrical to GNC.
Mechanical lost two engineers and one drafter.
Electrical lost five engineers.

- **We are in the process of evaluating the appropriate balance for all groups.**
- **Technical Staff supporting several concurrent missions.**
- **The current launch operation schedule is busy, and 05 looks as if the work load will remain constant.**

Metrics

- NSROC is graded on it's deliverables; Requirements Definition Meeting, Design Review, Mission Readiness Review, and Mission Closeout Report. The rating is on a scale of 1-5. Below is for CY04
- RDM – 19 averaged 4.7 (94%). One mission rated a 3.0
- DR – 16 averaged 4.5 (90%). One mission rated a 3.0
- MRR – 21 averaged 4.5 (90%). One mission rated a 2.5.
- MCR – 13 averaged 4.9 (97%). Zero missions below 4.0.
- Total Deliverables 69 averaged 4.6 (92%). Only 3 lower then a 4.0.
- Science Requirements Packages are a very useful tool, when completed, providing more concise information.

Metrics

- 387 NCRs were generated. Most mission related NCRs were closed prior to the affected mission's MRR. Very few were kept open after missions were completed.
- Significant NCRs that affect other payloads or standard hardware are elevated to the Corrective Action Tracking System (CATS).
- The CATS process has demonstrated a positive improvement in utilization. 24 Corrective Actions were created.
- A new performance tool utilized in 04 was the Change Request. The Mechanical Engineers used this extensively throughout the year with EE, GNC, and Flight Performance beginning later in the year. 268 Change Request were created.
- NSROC has established that designs are base lined at Design Review and changes after DR must have a Change Request.
- These tools lead to a more efficient, effective quality product.

GNC – Walt Costello

NSROC GNC

- Response to SRWG Findings
- ACS Performance – Kwajalein
- GLN-MAC Anomaly – Krause 12.056
- Data Reduction manual
- Developmental ACS Missions

SRWG ACS QUERY

- **III. Software Control of ACS Functions**

- The SRWG has followed the development of the in-house ACS system at NSROC since its inception. In general, we commend NSROC for taking on this task and for their innovation in attempting to improve the systems.

- One feature employed by the new NMACS system (i.e., the NSROC ACS system that aligns the payload spin axis with the magnetic field direction), that we heard about at the meeting, utilizes a software implementation to command the nozzle phasing within the ACS rather than a hardware implementation (e.g., by switching connectors) to achieve this function. As phasing errors are more likely to go unnoticed in a software implementation, this new approach does not give the user any added confidence that the system will perform as required. The SRWG would like to better understand the rationale for this new approach.

NSROC ANSWER TO SRWG ACS QUERY

- The NMACS and NIACS ACS systems will be used for different missions that will require a variety of payload configurations. The ACS may be located ahead or behind the CG. The nozzles may or may not be remotely mounted. The ACS may even require orientation such that the ACS section has to point in the reverse direction (i.e. male joint pointing aft). These things require phasing changes not only in the nozzles but also the gyros, rate sensors, magnetometer, and other sensors.

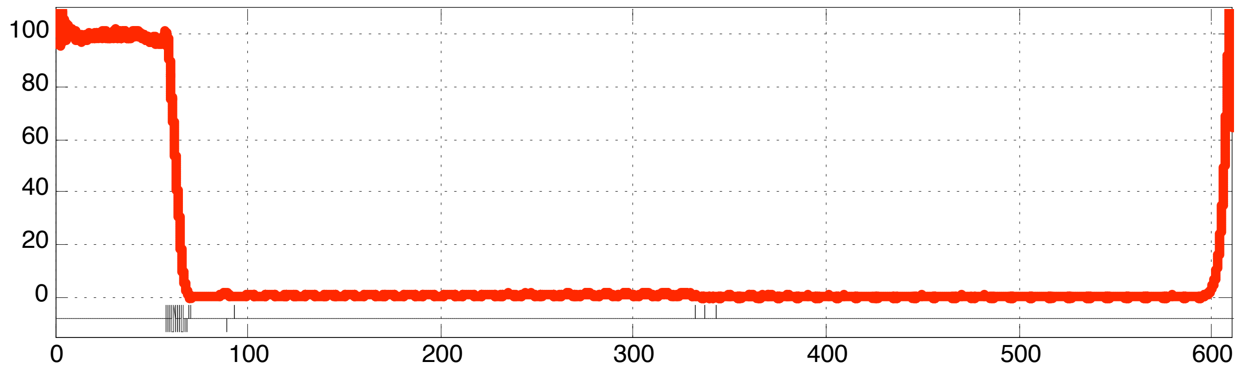
- NSROC feels it best to control phasing completely in software, in order to minimize drawing changes and minimize the number of engineers and technicians who must be concerned with the effect of system configuration on phasing. Insofar as possible, the ACS drawing set and wire lists will be the same for most if not all missions. There will be no need to revise drawings and wire lists for each mission in order to account for payload configuration. This will reduce cost, effort, confusion among missions, drawing mix-ups, and the potential for mechanical assembly error. (***continued***)

NSROC ANSWER TO SRWG ACS QUERY (page 2)

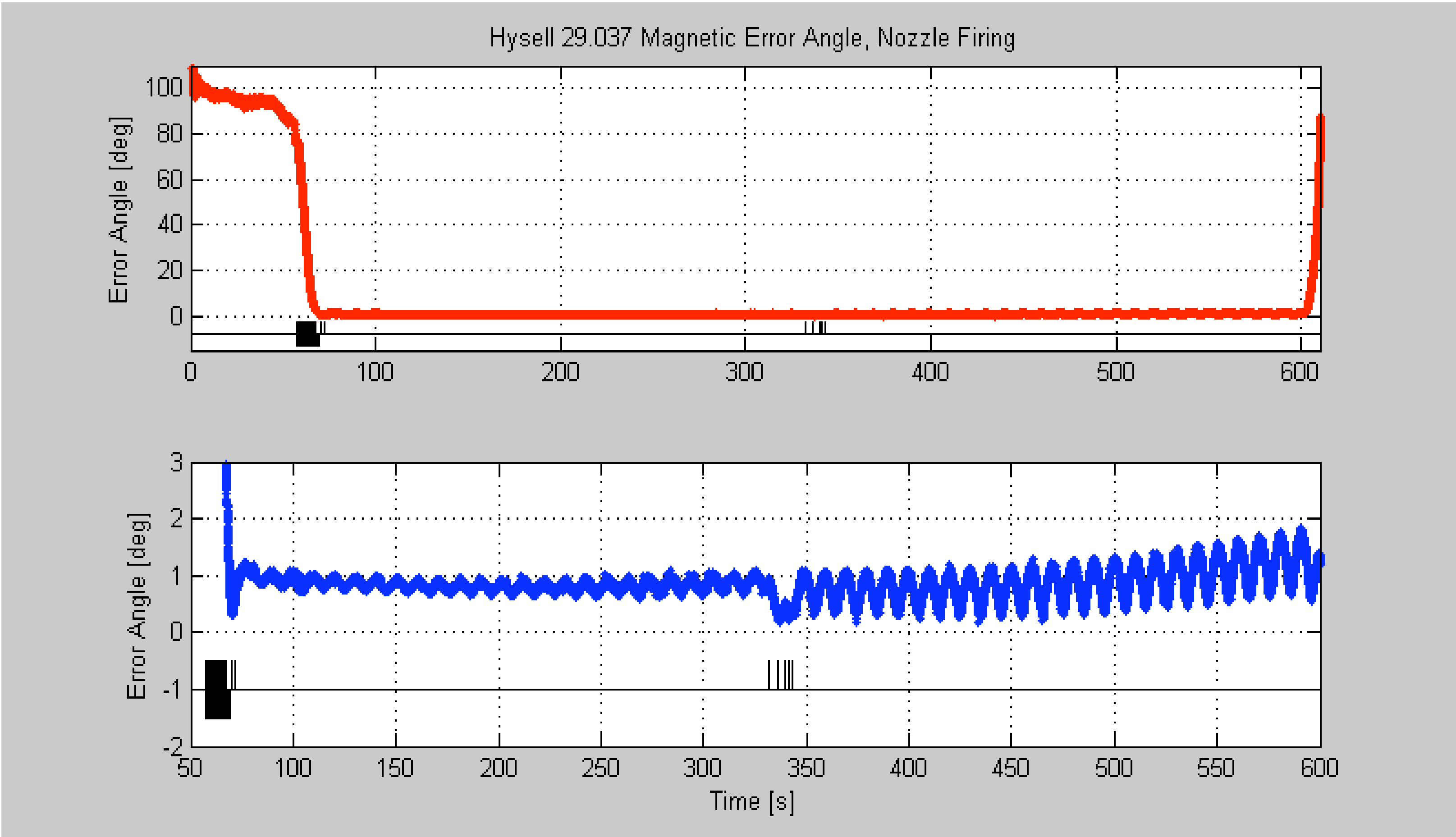
- NSROC recognizes that software design is inherently less visible than hardware design and is inherently less understandable and therefore more frightening to engineers outside the software discipline. However, digital techniques are rapidly proliferating and are becoming pervasive in the industry. The answer is to ensure that end to end phasing tests on the completely assembled payload are always conducted just prior to sending the payload to the rail. NSROC has implemented this requirement. It is the best and only way to ensure correct phasing no matter what methods are used to implement phasing.

- NSROC has increased it's software engineering staff and has implemented software processes and procedures that are consistent with the state of the art for systems of the complexity and risk inherent in sounding rockets. NSROC is confident that software quality can be maintained and wishes to reassure the sounding rocket community that our approach will both increase efficiency and reduce risk.

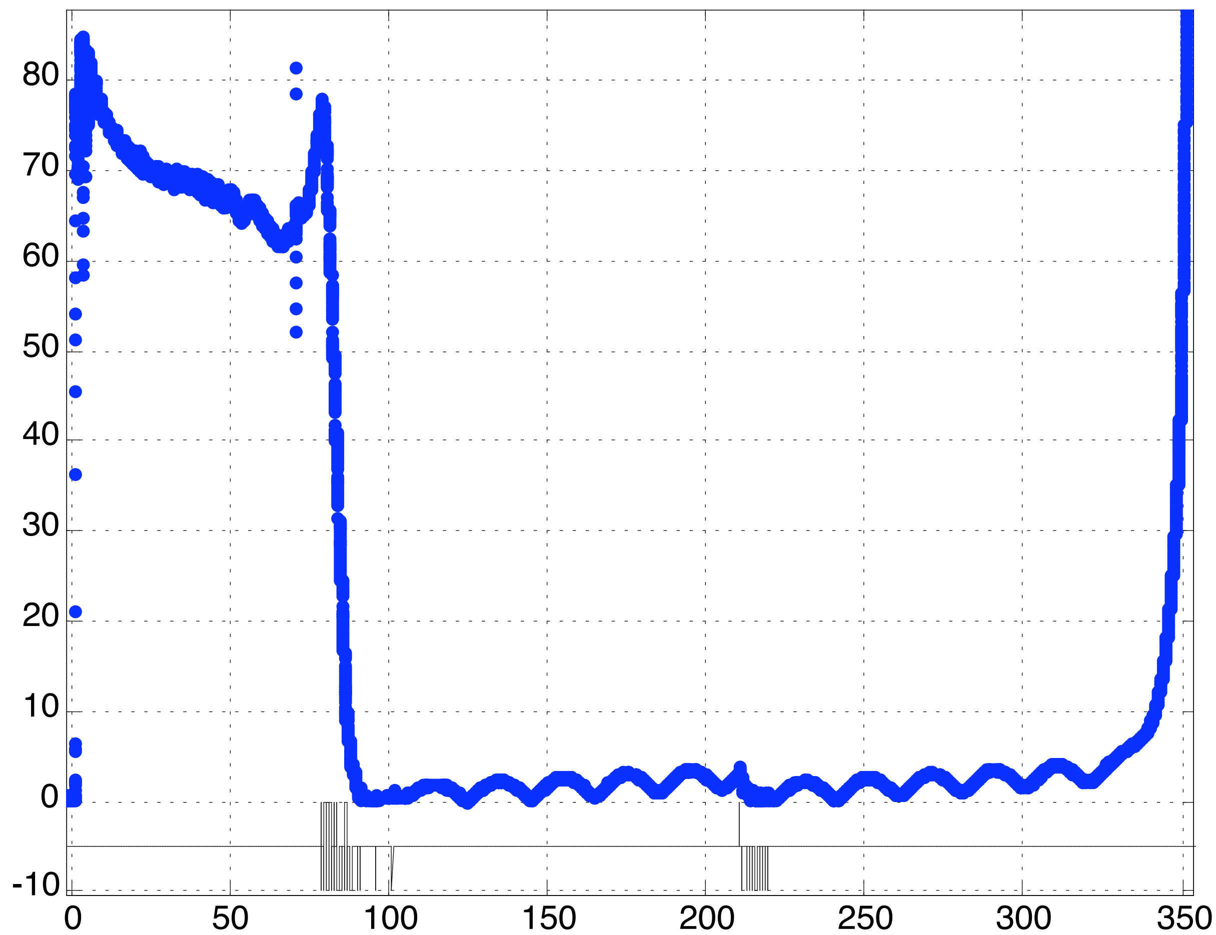
Hysell 29.036 At Kwajalein



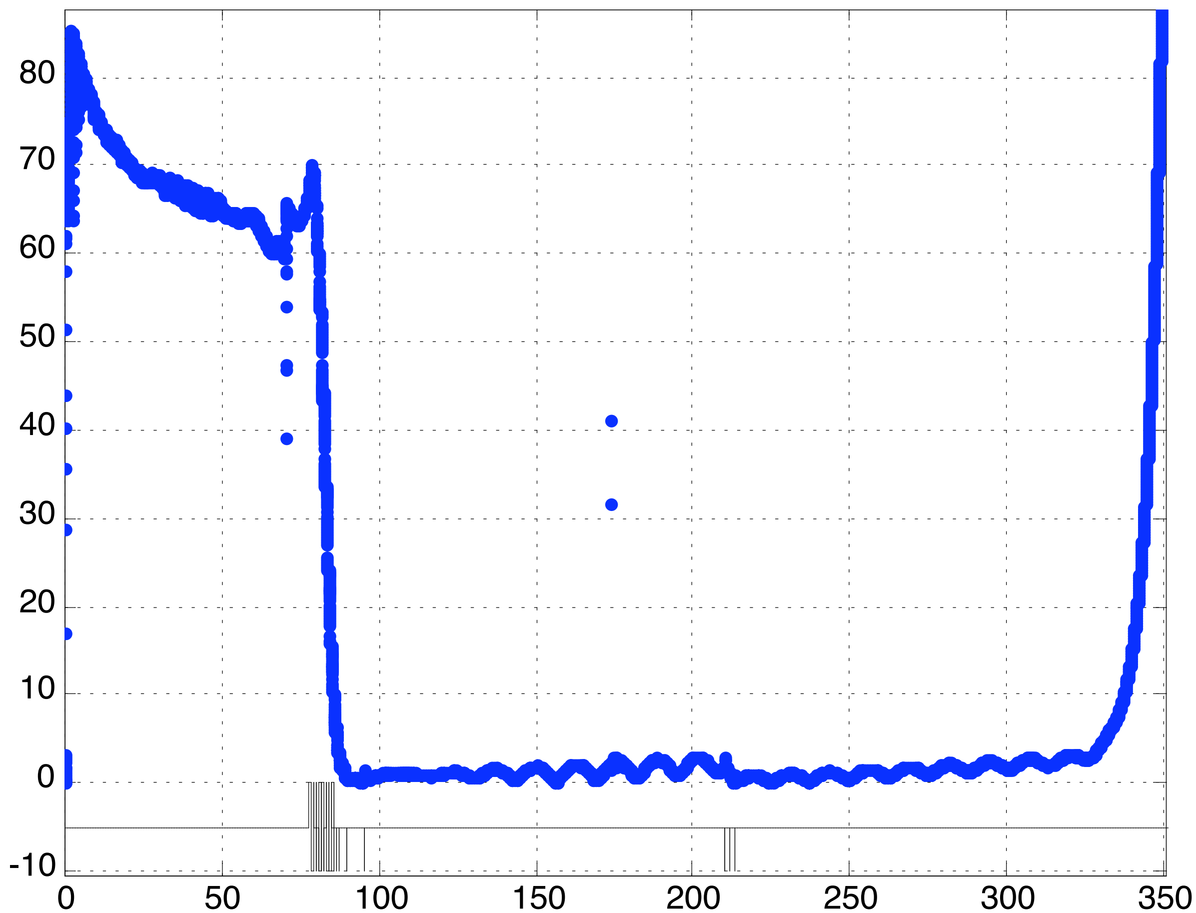
Hysell 29.037 At Kwajalein



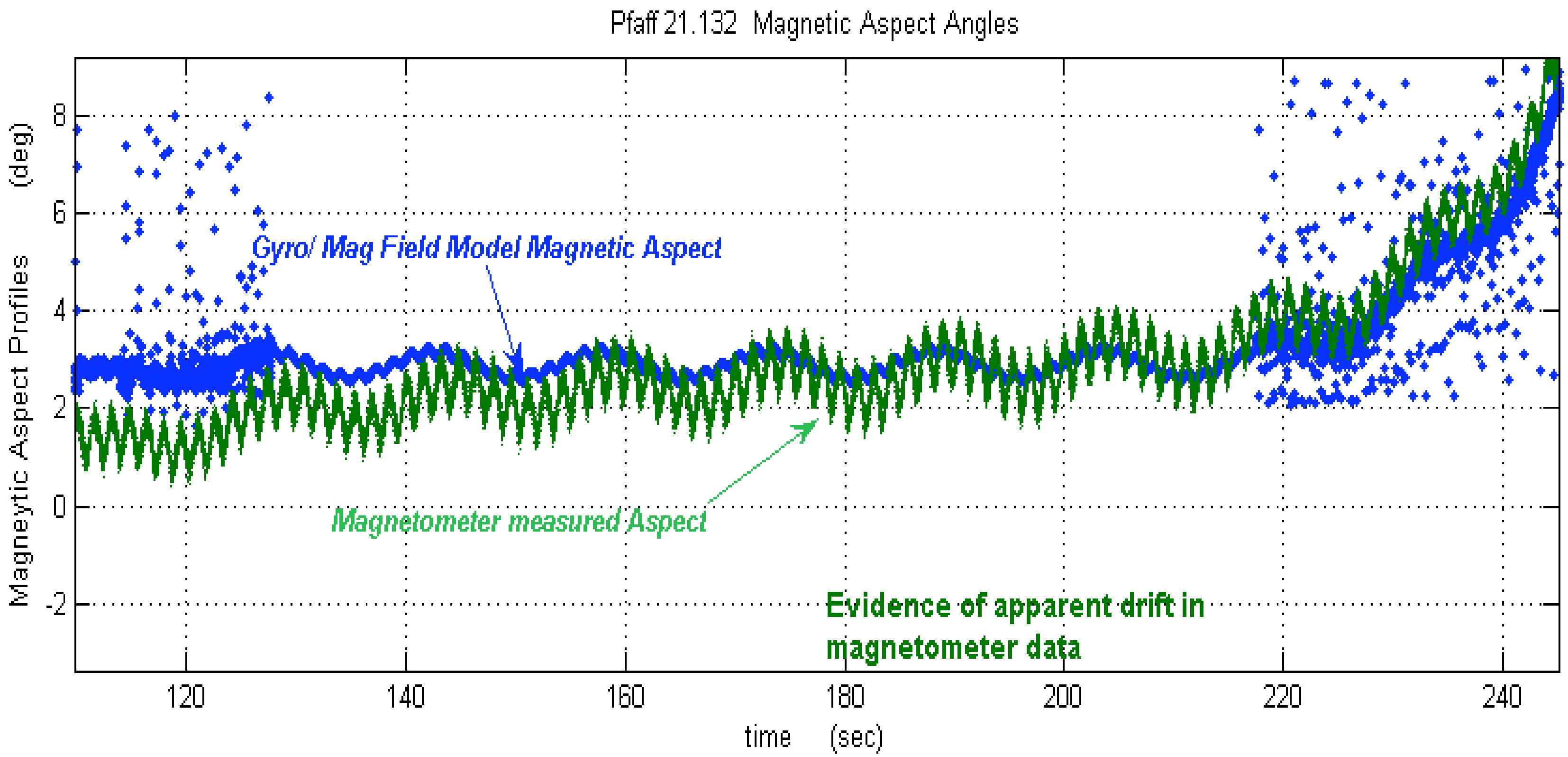
Gelinas 27.145 At Kwajalein



Gelinas 27.146 At Kwajalein



Pfaff 21.132 At Kwajalein



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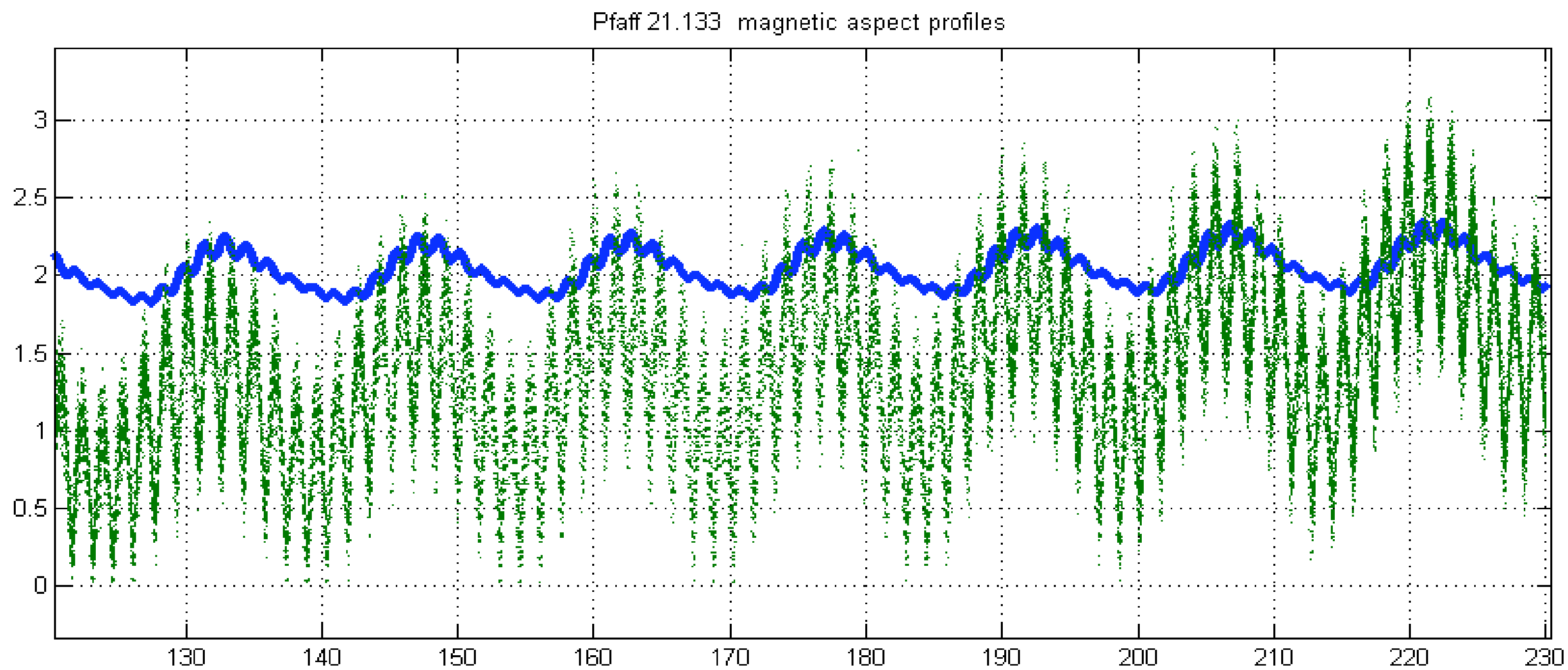
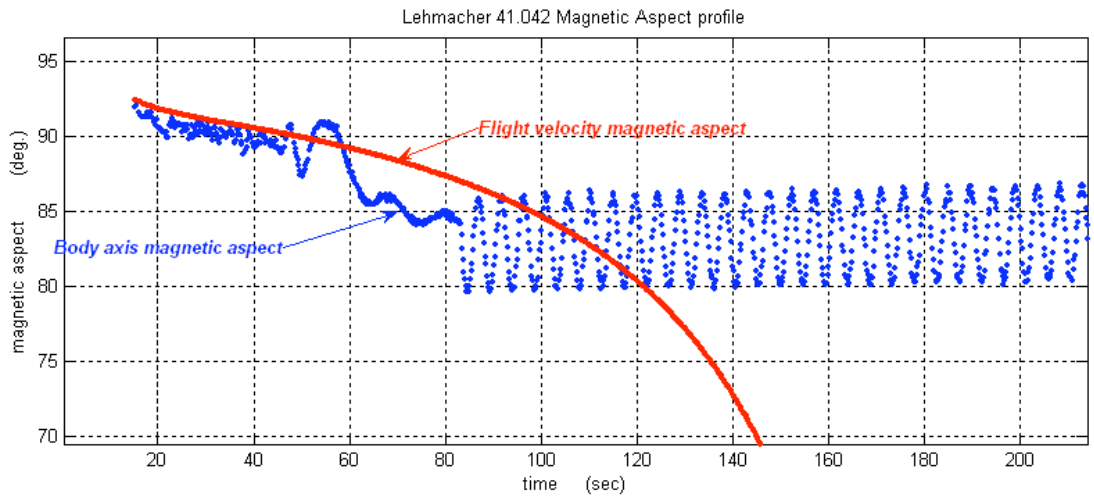
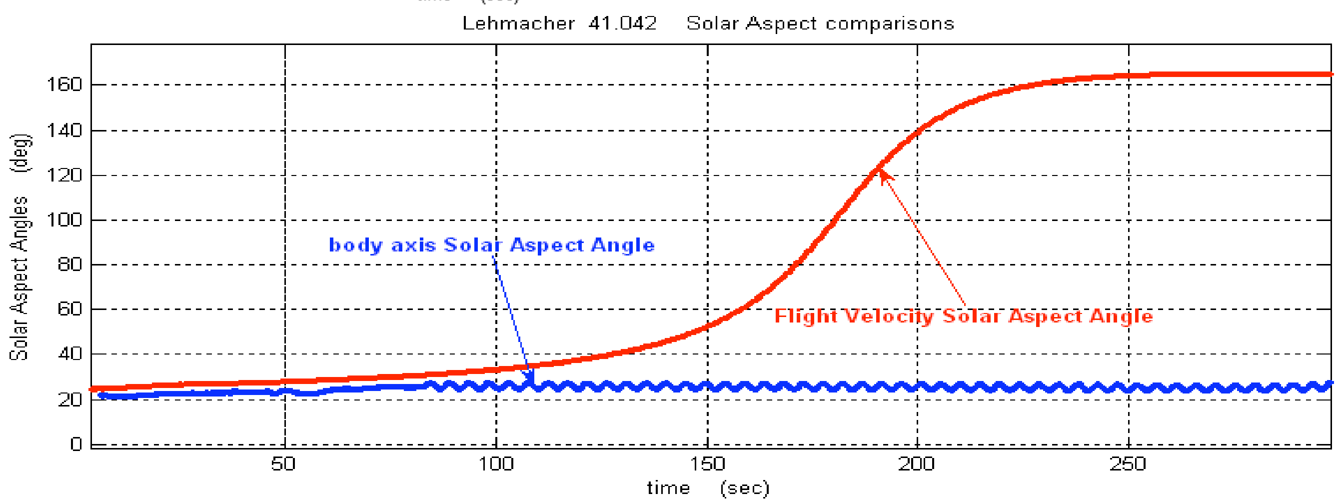
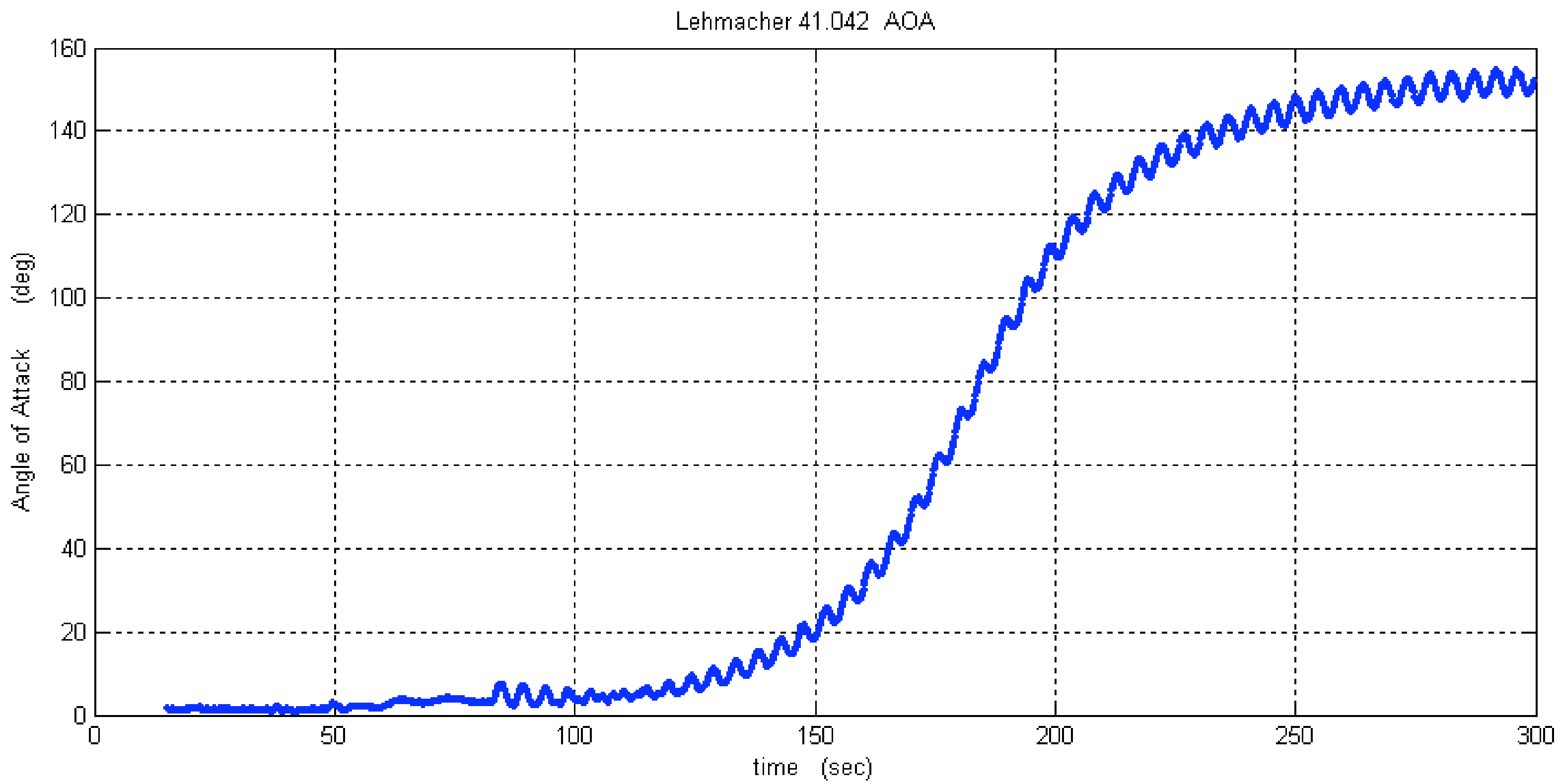


Lemacher 41.042 At Kwajalein





Lemacher 41.042 At Kwajalein



NSROC Data Reduction Manual

Chapter 1. Introduction

Chapter 2. Coordinate Systems and Data Formats

Chapter 3. Trajectory and Positional Data And Routines

GPS, Radar, MagVec, SolPos

Chapter 4. Flight Sensors (MIDAS, GLN-MAC, Mag, Sun, Horizon)

Chapter 5. Attitude Analysis Software (MatLab)

Chapter 6. Accuracy and Error Analysis

Appendix A. Symbols and Abbreviations

Appendix B. Sensor Data Sheets

Appendix C. Sample Software and Data

Appendix D. References

- Coming Soon – ask now if you would like to be a “Beta Tester”

ACS Development
Planned Flights

NIACS Test 2	Krause 12.062	Jan 2005
NIACS 1st Op	Lynch 40.017	Feb 2005
NIACS 2nd Op	McCammon 36.223	July 2005
Celestial Test 1	Costello 12.058	May 2005
Celestial Test 2	Costello 12.059	Aug 2005
Celestial 1st Op	Cruddace 36.207	Nov 2005
Celestial 2nd Op	Nordsieck 36.173	Nov 2005

- NRACS – Micro-gravity - can do with either NMACS or NIACS

Conclusions

- NSROC Is Committed to Continuing the Mission and Program Successes
- Satisfying the Code S PI Mission Requirements Is Still NSROC's Primary Goal
- NSROC Is Committed in Expanding the Technical Innovations While
  - Maintaining a Cost Effective Environment
  - Meeting the Success Requirements of the PIs
  - Making Effective Use of the In-House Talent and Experience
- NSROC's Receipt of the SRWG Findings Is Important for Future Growth Planning