Sounding Rocket Working Group

SRPO Summary

January 19, 2005

Philip Eberspeaker

Presentation Outline

- FY04 Mission Results Summary
- Significant Accomplishment Summary
- FY05-FY07 Manifest
- Manifest Planning
- Mission Cost Reference Information
- Findings from June SRWG Meeting
- Kwajalein Debriefing
- Technology Update

FY04 Mission Results

- 26 Total Missions
  - 20 Science
    - Results
      - 15 Successful
      - 5 Failures
        - » 36.184 DS – Filter Wheel Failure
        - » 35.035 UE – Magnetic ACS Failure (1st op flight)
        - » 41.046 UE – Terrier-Orion Vehicle Failure*
        - » 41.041 UE – Power Failure*
        - » 27.145 UE – Boom Deployment Failure*
  - 3 Educational
    - All successful
  - 3 Technology
    - Technology advancements achieved on all missions
  - 0 Reimbursable

20 total science "flights" with 75% success

10 total "investigations" with 80% success

26 flights with 81% success

* Part of multi-rocket experiments with experiments able to achieve success despite the failures.

Active Anomaly Investigation Boards (AIB)

Failure	AIB lead	Status
Terrier-Orion Failure (Kwaj)	NSROC (Rosenova)	Closed – most likely cause was failure in Terrier fin incident angle block. Design change implemented and new analysis tools/philosophy developed
Power System Failure (Kwaj)	NASA (Kotsifakis)	Active – Final report being written. Likely a short in the lines between TM and experiment poly switches, but nothing conclusive.
Boom Deployment System Failure (Kwaj)	NSROC (Krause)	Active -
Terrier-Orion Vehicle Failure (WSMR)	NASA (Wilcox)	Active – Failure of interstage clamp to release. Suspect stack-up of adverse conditions that leads to apparent “random” failures
Inertial ACS failure on test flight #2 (WSMR)	NSROC (Elborne)	

Recent Significant Accomplishments

- **Highly successful Kwajalein Campaign**
  - 4 major investigations (all successful)
  - 14 flights (11 successful)
  - Over 230 tons of equipment shipped
  - Special thanks to John Hickman, Glenn Maxfield, the mission teams and the support teams for their hard work and dedication
- **HQ Independent Review of the Sounding Rocket Program**
  - Report was very positive
  - The panel felt the program was being managed very effectively and funds were being used efficiently
- **ACS Development**
  - Magnetic ACS
    - 6 successful operational flights of the NSROC Magnetic ACS (Kwajalein)
  - Inertial ACS
    - Discovered glitches in Sandia software
    - Enhanced algorithms to improve system behavior
  - Star Tracker 5K
    - Continue to build flight heritage in non-controlling mode

Recent Significant Accomplishments

- **Phase II S-19 upgrade task issued**
  - Replace DMARS platform with GLN-MAC
- **Received Free ASAS rocket motor and diagnostic payload**
  - ASAS may be able to be used to expand payload diameter envelope
  - Cost of Steel-cased ASAS may be more in alignment with Brant motor
  - Terrier-ASAS flight demo scheduled for March 2005
- **MLRS motors obtained**
  - NSROC development task issued

FY05 Launch Schedule

		FY 2005	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
#	Vehicle Type	Mission												
		WALLOPS ISLAND												
1	Orion	HALL/VIRGINIA POLYTECHNIC UNIV.						△						
2	Test Vehicle	HICKMAN/NASA						△						
3	Test Vehicle	KRAUSE/NASA-NSROC								△				
4	Terrier Orion	PLAYER/LARC											△	
		WSMR												
5	Test Vehicle	KRAUSE/NASA-NSROC		▲										
6	Black Brant IX	WOODS/UNIVERSITY OF COLORADO	▲											
7	Test Vehicle	KRAUSE/NASA-NSROC				△								
8	Test Vehicle	COSTELLO/NASA-NSROC									△			
9	Black Brant IX	RABIN/GSFC									△			
10	Test Vehicle	COSTELLO/NASA-NSROC											△	
11	Black Brant IX	KANKELBORG/MONTANNA STATE U.										△		
12	Black Brant IX	MCCAMMON										△		
		PFRR												
13	Black Brant XII	LYNCH/DARTMOUTH					△							
14	Orion	LYNCH/DARTMOUTH					△							
15	Orion	LYNCH/DARTMOUTH					△							

FY06 Manifest

	Mission	Launch Date	Site	PI	Comments
1	36.216	Nov	WSMR	Martin	AeroJet ACS?
2	36.207	Nov	WSMR	Cruddance	Original proposed date – NSROC Fine pointer needed
3	36.173	Nov	WSMR	Norseick	Has been slipping for some time…
4	35.036	Dec	Andoya	Kletzing	
5	40.018	Dec	Andoya	Kletzing	
6	36.220	Dec	WSMR	McCandliss	Needs fine pointer ACS
7	36.213	March	WSMR	Porter	Original proposed date
8	36.218	June	WFF	Earle	
9	36.221	June	WSMR	Moses	MIC scheduled for Oct 22, 2004
10	36.219	June	WSMR	Hessler	MIC to be held on Sept 29, 2004
11	41.056	June	Andoya	Wheeler (PSU)	Potential international outreach mission (~$200K)
12	41.XXX	TBD	WFF	NSROC	Tech Demo Flight
13	30.XXX	June	WFF	Education Office	SubSEM
14	36.XXX	Feb	WSMR	Cash	NEED MIC – PI funding may cause slip
15					
16					
17					
18					

FY07 Manifest

	Mission	Launch Date	Site	PI	Comments
1	39.007	Jan	TBD	Chakrabarti	Imaging of plant outside the solar system (Flt #1)
2	39.XXX	Aug	TBD	Chakrabarti	Imaging of plant outside the solar system (Flt #2)
3	*36.XXX*	*TBD*	*WSMR*	*Bock*	*Astronomy – extra galactic background*
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Manifest Planning

- **Mission cost estimates are likely to be required in future proposals**
  - Factors driving cost
    - Vehicle type
    - Payload/mission complexity
    - Ability to reusable hardware (recovery, ACS, transmitters, etc)
    - Launch site and range requirements
    - Technology infusion requirements
  - SRPO will work with PIs and will provide the estimates
- **The SRPO will likely have to reevaluate cost estimates for proposals that are identified within the competitive range to assess mission phasing and resource conflicts**
  - Contingency and inventory to longer able to accommodate unanticipated requirements or resource conflicts

Manifest Considerations

- Brant / Surplus Trade Space
  - Average materials costs for a Brant mission are approximately 3 times greater than surplus vehicle
  - Average Brant mission requires about twice the effort than a surplus mission
- Impact of more Brant Flights
  - Program will only support 12 to 14 missions annually when 50/50 mix is considering

SRPO Mission Costs for Missions Launched in FY04

12.053 GT	$	1,906,036
12.054 GT	$	2,289,508
12.056 GT	$	2,179,979
Test Round Avg.	**$**	**2,125,175**
21.132 GE	$	3,039,355
21.133 GE	$	2,755,720
Black Brant V Avg.	**$**	**2,897,538**
27.145 UE	$	2,884,156
27.146 UE	$	2,601,226
Nike Brant Avg.	**$**	**2,742,691**
29.036 UE	$	2,764,258
29.037 UE	$	2,480,623
Ter. Malemute Avg.	**$**	**2,622,441**
30.054 UO	$	442,441
30.060 NO	$	731,205
Orion Avg.	**$**	**586,823**
35.035 UE	$	4,617,289
Black Brant X Avg.	**$**	**4,617,289**

36.184 DS	$	2,745,728
36.208 UG	$	3,252,497
36.209 UG	$	2,894,802
36.210 UL	$	2,087,046
36.211 US	$	1,806,273
Terrier Brant Avg.	**$**	**2,557,269**
41.035 UE	$	1,148,110
41.041 UE	$	1,816,377
41.042 UE	$	1,620,873
41.043 UE	$	1,173,602
41.044 UE	$	1,116,164
41.045 UE	$	1,173,602
41.046 UE	$	1,116,164
41.047 GE	$	1,203,862
41.048 GE	$	1,146,424
Terrier Orion Avg.	**$**	**1,279,464**

Cost Drivers

- Planning / Estimating Phase
  - Vehicle type
  - Payload Complexity
  - Launch range
  - Range support requirements
- Implementation Phase
  - Requirements evolution
    - Need for larger vehicle(s)
    - More complicated design
  - Not meeting schedule milestones
    - Sometimes drives need for redesign
    - Can compress the fabrication and/or integration schedule
      - Increases overtime
      - Increases risks
      - Stresses personnel

Rocket Motor Status

- Black Brant Motors
  - 17 units currently in inventory
  - Will run out by end of FY06
  - Brant motors must be purchased in FY05
    - May be able to purchase 1 unit with existing FY05 funding
  - Currently building casings
- Nihka Motors
  - 11 units currently in inventory
  - Bristol no longer produces the “standard” Nihka
  - ATK could probably produce a replacement, but there will be a development cost
  - Bristol can produce a replacement, but there will be a development cost
  - Development/Acquisition plan has not been developed by the SRPO
- Orioles
  - Not affordable at this time
  - Procurement is still in place, but only as a mechanism to purchase motors for Navy (reimbursable missions)

Upcoming Foreign Missions

- Norway (Kletzing)
  - Two launches (BBX and BBXII) w/ both vehicles in the air simultaneously
    - Increases WFF cost since TM assets must be deployed
  - Svalbard launcher will be moved to Andoya to support the two vehicle
  - Range support details have not been worked out at this point

Findings
June 16, 2004 Meeting

I. Letter to Ed Weiler

- 15 surplus / 5 Brant mission mix Concept
  - This approach maintains a flight rate of 20 affordable missions
  - Shifting towards more Brants will reduce the annual flight rate
- Funding restoration
  - The SRPO is operating under the assumption that no additional NOA will be provided to the program
- Maintain Brant flight rates
  - Total flight rate would drop to 12 to 14 rockets (~ 60% Brants)
  - Skill mix would be affected
  - Will this be a viable program?
- Range consolidation
  - Option: Cease resident operations at WSMR
    - A portion of the work force (50%) will have to be transferred to Wallops
      - Elimination of resident operations at WSMR will result in loss of some valuable expertise. Key personnel will not move…
    - Will not result in absolute $1M in savings as one might expect
      - Due to need for support that would have been provided under the Navy support contract, the Army cost will likely escalate to ~$250K per launch attempt

I. Letter to Ed Weiler (cont)

- Higher performance surplus vehicles
  - The SPRO is still pursuing the Patriot rocket motors
    - Progress has been slower than hoped, but environment still appears favorable

II. Systems Engineering and the Sounding Rocket Program

- The SRWG stressed that project managers should be well versed in systems engineering
  - The SRPO and NSROC agree with this assessment
  - A more effective means of communicating lessons learned amongst mission managers is being developed
  - Formal training is being considered
    - Systems Engineering
    - Risk Management
  - Informal training sessions are being considered
    - ACS, TM, vehicle systems, etc
    - Cross training
  - An engineering degree will be required for all future Mission Managers

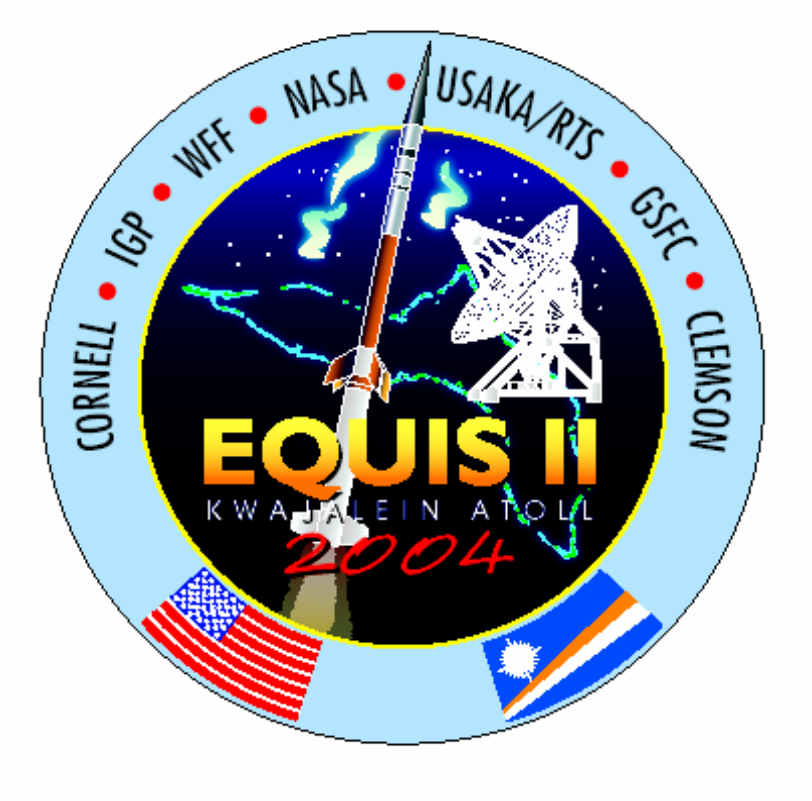
NSROC will provide details…

III. Software Control of ACS Functions

- The SRWG expressed concern over the software-based approach to mitigating phasing errors
- Response
  - There is a potential for phasing errors with any approach, thus enhanced tests and procedures have been developed to detect issues as early as possible in the hardware set-up phase of the missions
  - The software-based approach was selected because it eliminated the hardware variability from the mission development process. Holding the hardware configuration constant should reduce the possibility of confusion and minimize the potential for problems falling through the cracks

NSROC will provide details…

EQUIS II
Sounding Rocket Campaign
Post Mission Overview



John C. Hickman/810
EQUIS II Campaign Manager
John.C.Hickman@nasa.gov

The EQUIS II Campaign

- Largest Sounding Rocket Campaign in 21 years
- First equatorial research opportunity since the 1993 Guara Campaign conducted in Alcantara, Brazil
- 14 Sounding Rocket flight experiments conducted over a 2-month period from the U.S. Army Kwajalein Atoll (USAKA) Reagan Test Site (RTS)
- End-to-end project planning, implementation, range buildup, and launch operations in 16 months

The EQUIS II Campaign

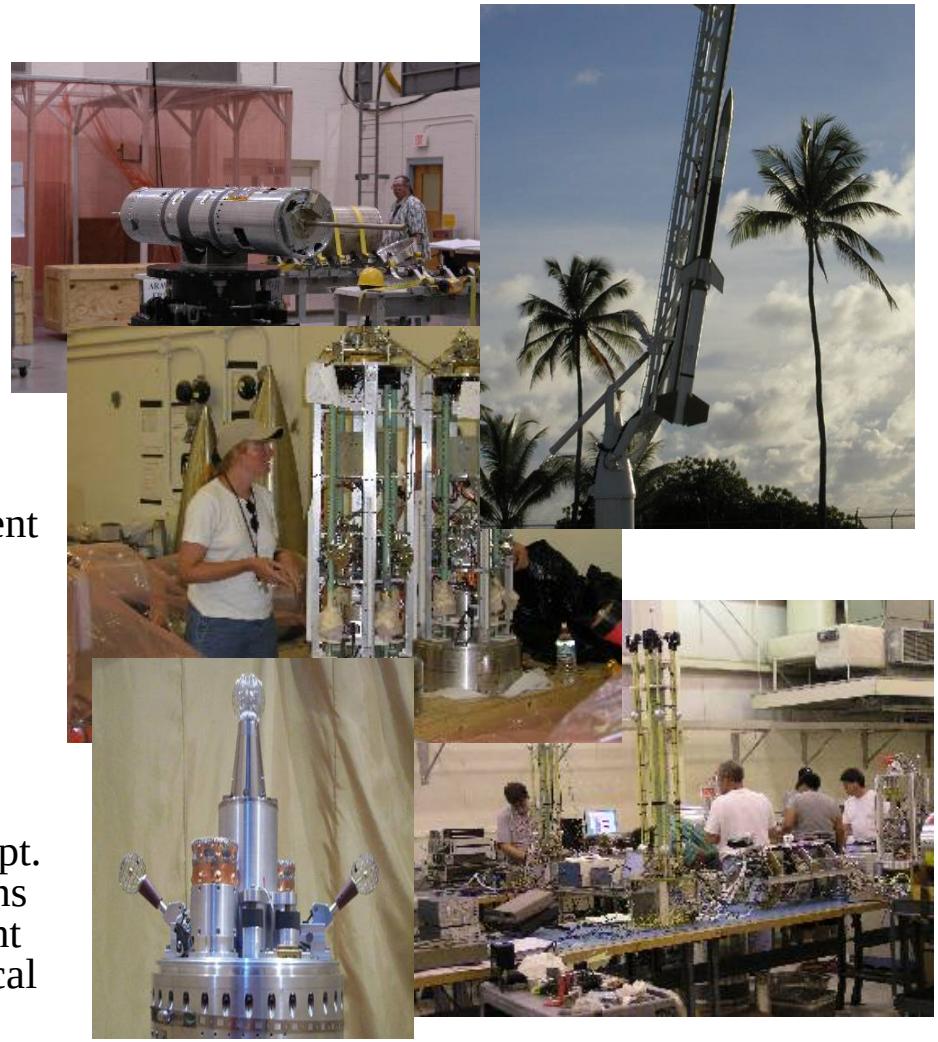
- The Campaign included an international team of researchers from
  - GSFC, several U.S. Universities, Peru, Denmark, Austria, and private industry
- 95 scientists, engineers, and technicians supported launch operations from the field
- Represented a challenging yet rewarding Campaign

EQUIS II Range

- WFF set up launch site that had not been used in almost 10 years
  - Building rehab
  - Launch pad construction
  - Launcher refurbishment & installation
  - Infrastructure augmentation
- WFF Mobile Range and personnel supplied
  - Radar
  - Telemetry (Readout)
  - Range Safety
  - Mobile launchers
  - Launcher and booster fire control
- Over 225 tons of GSE, mobile range hardware, and rocket motors shipped to Kwajalein

EQUIS II Missions

- 4 separate research investigations conducted as part of the Campaign
  - Mesospheric turbulence
    Dr. Gerald Lehmacher/Clemson
  - Gravity wave electrodynamics
    Dr. Lynette Gelinas/Cornell
  - Sporadic – E
    Dr. Robert Pfaff/GSFC
  - Spread – F
    Dr. David Hysell/Cornell
- 26 rocket motors comprising 5 different launch vehicle configurations were flown
  - Terrier Orions (8)
  - Terrier Malemute (2)
  - Nike Black Brant (2)
  - Black Brant (2)
- 27 count days between Aug. 2 and Sept. 20 were required to launch all missions
  - 3 of the 4 investigations (12 flight experiments) required clear optical sites



EQUIS II Operations

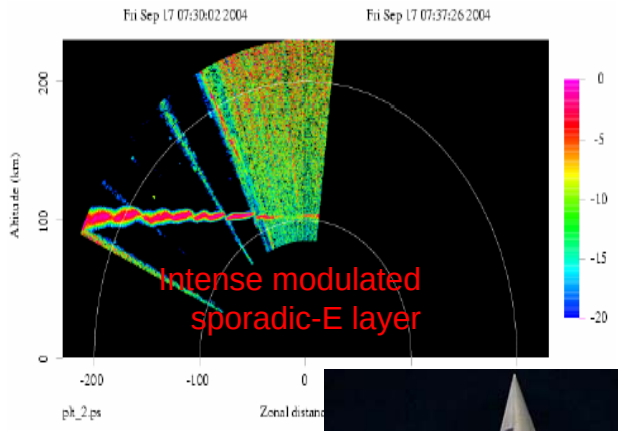
- Numerous challenges were encountered in executing this mission
  - Record rain fall in the month of August
  - Scheduling conflicts with DoD programs
  - Injury and illness of operations personnel
  - One vehicle failure
  - Two in-flight payload anomalies
- Despite these setbacks, we were able to launch all missions in the prescribed window
- Cooperation with RTS Range personnel was outstanding
  - Helped to resolve and negotiate scheduled conflicts
  - Flexibility in responding to changes
  - Helped to resume flights of Terrier Orion vehicles following vehicle failure
- Working relationship was very positive and RTS will welcome us back

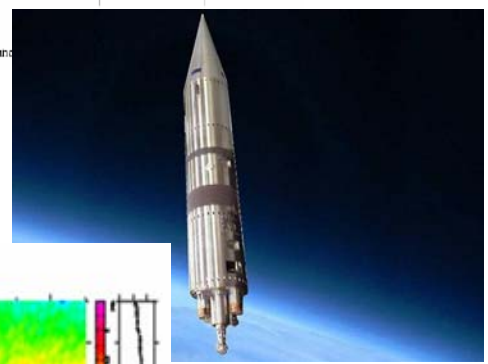
EQUIS II Science

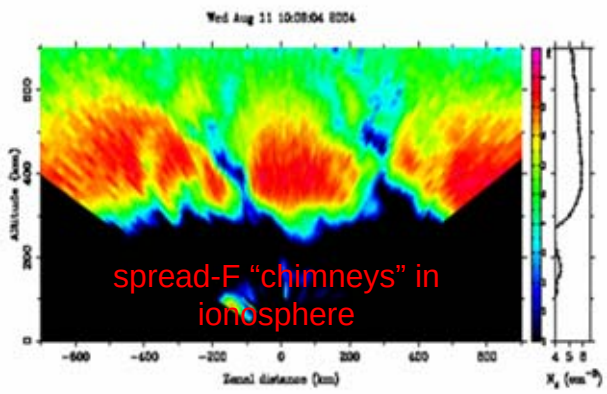
- Four ground based science instruments were used for the Campaign
  - ALTAIR Radar
  - AFRL Ionosonde
  - Optical/Photographic Instruments (TMA)
  - All sky imagers (Gelinas)
- ALTAIR exceeded expectations of researchers
  - World class backscatter radar
  - High power, dual frequency, horizon-to-horizon scanning capability
  - Direct cost was reasonable - ~$200K for 100 hours observation time
- AFRL Ionosonde was setup for EQUIS II and is still operational today
  - Project assisted AFRL with logistics and planning to open up the door
  - AFRL now operates Ionosonde independently with RTS
- Cameras and imagers were provided by experimenters
  - Project helped to set up sites and with logistics for remote islands

EQUIS II Science Results

- All 4 investigations were successful even given anomalies we experienced
  - Vehicle failure on second Hysell mission on second TMA vehicle
  - First Lehmacher experiment
  - First Gelinas experiment
- Ultimate success is attributed to:
  - Good planning at Science/HQ level to conduct each experiment twice
  - Good team work in the field in responding to anomalies
  - Good support at WFF in conducting rapid investigations
- All six Magnetic ACS systems performed exceptionally
- Initial scientific results are encouraging according to PI's
- Meeting is being planned to address EQUIS II science







EQUIS II Outreach

- Comprehensive outreach program successfully carried out during mission window
- 43 classroom programs reaching approximately 400 students were conducted on Kwajalein Island
- 200 local Marshallese students participated in outreach project conducted on neighboring island of Enniburr
- Range Commander personally thanked us for our successful outreach efforts
  - First outreach effort of its kind at USAKA

EQUIS II Summary

"The campaign has exemplified the strong science results that can be achieved by combining state-of-the-art ground-based measurements with the unique, highly detailed in situ measurements that only the sounding rockets can provide"

– Dr. Miguel Larsen, EQUIS II Campaign Scientist

EQUIS II What's Next

- Interest has been expressed in furthering opportunities for equatorial research
- Important region of study necessary to better understand the electrodynamics of the Earth's ionosphere on a global scale
  - Area where global electric circuits are completed
  - Area of frequent instabilities and large scale disturbances
  - Practical as well as scientific applications for this research
- Equatorial/low latitude research opportunities are few and far between
  - Average one "Campaign" every 10 years
  - Compared to yearly Auroral zone research opportunities
- Limited opportunities primarily driven by lack of available and politically stable launch sites

EQUIS II What's Next

- Based on experience with EQUIS II, we believe we can establish a economically viable launch site at Kwajalein/RTS
  - Equatorial/low latitude location
  - Politically stable
  - Posses a world class science instrument in ALTAIR
- Cost of establishing such a capability and using it on a more routine basis is believed to be commensurate with cost associated with launching from Alaska, Norway, Sweden, or WSMR
  - Approximate range cost were $75K per launch day
  - Basic infrastructure already exists
  - Logistics and travel commensurate with other remote launch sites
- If sufficient interest exists in the science community and at HQ, a project team will be established to further investigate this proposal
- White paper has been sent to Chief, SRPO and to EQUIS II PI's addressing this proposal in more detail

SRPO Technology Program Update

- Development of the formal SRPO Technology Roadmap has obviously been impacted by the current budget crisis
  - Previous work done is being reevaluated
  - Ability to implement new technologies very limited without a robust budget
- Obvious program needs and certain high pay-off items are progressing either through in-scope NSROC efforts or through PTO's
  - NSROC will address these items in their presentation
- An effort to refocus the technology priorities is underway
- Short term goal is to complete the Technology Roadmap and assign priorities to each task which takes into account funding and labor realities
  - Over past 18 months this has been a dynamic task

SRPO Technology Program Update

- The refocused Technology Program consist of two major parts:
  - Continual Engineering Improvements
  - New Technology Initiatives
- Continual Engineering Improvements
  - Not so much new technologies as they are subsystem and/or process improvements to increase efficiency, performance, and/or reduce cost
  - Many are in scope of the current contract and some are funded via the NSROC PTO process
  - Primarily the responsibility of NSROC to implement in-house
- New Technology Initiatives
  - True technology enhancements – doing new things with new systems for higher payoffs
  - Generally are larger development efforts that require NASA Engineering and/or NSROC to implement
  - Generally require significant investment and are tasked to NSROC via PTO

SRPO Technology Program Update

- Initial research has identified approximately 50 task, subsystems, projects, etc. that are candidates for continual engineering improvements (i.e. in-house recovery systems, next generation power systems, miniature PCM stack, low cost TM encoder, etc.)
- An additional 15 task have been identified for new technology initiatives (i.e. water recovery technologies, HASR, universal FTS, high-performance surplus based vehicles, etc.)
- New technology initiatives requiring significant investment have been put on hold for the most part pending resolution of budget issues
  - High Altitude Sounding Rocket is on hold
  - Oriole motor buy is on hold
  - Advanced water recovery techniques on hold
  - MRLS on hold
  - NSROC in-house ACS developments are proceeding
  - Studies for high performance surplus vehicles in work as time permits
    - Patriot is a candidate however availability may be an issue

SRPO Technology Program Update

- Talos Oriole flight demonstration delayed to May ’05
  - New fin manufacture, delivery, and test are pacing items
  - Delay helps to reduce workload issues
- ATK manufactured Advanced Solid Axial Stage (ASAS) will be flight demonstrated this Spring
  - Motor became available at NO COST and was transferred to SRPO
  - PTO initiated with NSROC to flight demo the motor – Terrier ASAS configuration
  - The 20.8” diameter motor has performance equivalent to a Black Brant and may be able to accommodate bulbous payloads up to 30” in diameter representing a new capability for the program
  - Flight demonstration is critical in evaluating performance capability of this motor and it is being done for a relatively modest investment
  - May provide a source of less expensive “Brant-class” motors

SRPO Technology Program Update

- SRPO Piggy Back Experiment Program
  - New duty of Technology Manger to structure a program to accommodate piggy back experiments
  - Increased demand for subsystem test flight opportunities over the last few years necessitated need for structured manifest and costing process
  - Previously implemented on a space available basis
    - For NASA and DoD partners, historically done for free or for very little direct cost depending on the scope of the effort
  - New FCA driven motto for piggy back experiments, “Nobody Rides for Free”
  - Cost model being developed based on historical cost/weight analysis
    - $1K to $3K per pound depending on complexity
    - Can help off set SRPO incurred cost for test flights
  - Current customers include
    - KSC STARS project (Spacebased Telemetry and Range Safety)
    - KSC/WFF Autonomous Flight Termination System
    - Navy IBEX experiment