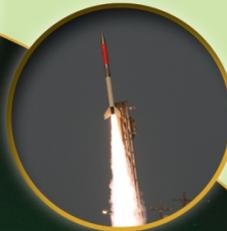




# Sounding Rockets



## Sounding Rocket Working Group

June 10, 2010



# SRPO Briefing Outline



- Program Update – Eberspecker
- SRWG June Findings – Pfaff / Eberspecker
- NSROC II Status – Eberspecker
- Rocket Motors – Brodell
- Launch Ranges – Rosanova
- Technology – Hall & Brodell

# Missions Flown Since Last SRWG



- **Core**
  - 41.084 / Conde
    - Success
  - 40.025 / LaBelle / Charm-2
    - Success
  - 36.258 / Woods / EVE#1
    - Success
  - 36.270 / Green
    - Success
- **Technology**
  - 12.067 / Terrier-Improved Malemute
    - Data obtained
- **Education**
  - None
- **Reimbursable**
  - 36.247, 36.250, 36.251 /ABL/MARTI
    - All Successful



# FY10 Schedule



			FY 2010												
#	Vehicle Type		Experimenter	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
			<b>WALLOPS ISLAND</b>												
1	Test Vehicle	12.068 GT	Hickman/NASA-WFF			▲									
2	Terrier Malemute	12.067 GT	Hall						▲						
3	Terrier Orion	41.088 UO	Koehler/University of Colorado									△			
4	Test Vehicle	12.069 GT	Hickman/NASA-WFF (TBD)												
5	Test Vehicle	12.070 GT	Hickman/NASA-WFF (TBD)												
6	Test Vehicle	12.071 GT	Hickman/NASA-WFF (TBD)												
7	Test Vehicle	12.072 GT	Hickman/NASA-WFF (TBD)												
8	Test Vehicle	12.073 GT	Hall/NASA-WFF											△	
			<b>WSMR</b>												
9	Black Brant IX	36.252 UH	Cash/University of Colorado		▲										
10	Terrier Orion	41.086 UE	Erdman/Embry-Riddle University			▲									
11	Black Brant IX	36.258 UE	Woods/University of Colorado								▲				
12	Black Brant IX	36.270 UG	Green/University of Colorado							▲					
13	Black Brant IX	36.265 UG	Bock/Cal Tech University								▲				
14	Terrier Orion	41.087 NT	Heyne/JPL									△			
15	Black Brant IX	36.213 NS	Davis/MSFC									△			
16	Black Brant IX	36.219 US	Hassler/SWRI									△			
17	Black Brant IX	36.261 UG	Clark/Boston University										△		
18	Black Brant IX	36.263 US	Judge/USC										△		
19	Black Brant IX	36.225 UG	Chakrabarti/Boston University										△		
20	Black Brant IX	36.264 UH	McCammon/University of Wisconsin											△	
21	Black Brant IX	36.269 GS	Rabin/NASA-GSFC												△
			<b>PFRR</b>												
22	Black Brant XII	40.025 UE	LaBelle/Dartmouth College												
23	Terrier Orion	41.084 UE	Conde/University of Alaska						▲						
			<b>REIMBURSABLE MISSIONS</b>												
24	Black Brant IX	36.247 DR	MARTI/USAF-ABL				▲								
25	Black Brant IX	36.250 DR	MARTI/USAF-ABL					▲							
26	Black Brant IX	36.251 DR	MARTI/USAF-ABL						▲						
27	Black Brant IX	36.249 DR	MARTI/USAF-ABL							▲					
28	Black Brant IX	36.248 DR	MARTI/USAF-ABL								△				
29	Black Brant IX	41.082 NP	BULL/NASA										△		
30	Black Brant IX	36.230 DR	MARTI/USAF-ABL (TBD)								△				

# 2011 Planning Manifest

	Mission	Launch Date	Site	PI	Project	Comments
1	41.089	Oct	WFF	Hall	SubTech IV	X-band + SMART (w/ SpaceCube). SubTech III needs to fly first
2	40.026	Nov	Norway	Lessard	RENU	Ship motors on Oct 1
3	36.255	Jan	WSMR	Krucker	FOXSI – Solar Physics Payload	DR complete. Mission on schedule.
4	36.XXX	Jan	WSMR	Cash	EXOS - CyGNESS #3	Proposed reflly – 1 year after 36.252
5	36.245	Jan	WSMR	Figueroa	Micro-X – The High-Resolution Microcalorimeter X-ray Imaging Rocket	MIT project. Needs 20 Mb/s TM – currently under development
6	41.085	Jan	WFF	Goyne	Student ScramJet Experiment	Convolutd MTO
7	36.256	Jan/Feb	PFRR	Bailey		Slipped 2 yrs due to exp. delivery issues
8	36.271	Jan/Feb	PFRR	Beasley		Refly of 36.270. Shifted from WSMR to Poker to avoid FTS supply issue
9	12.XXX	TBD	WFF	Hall	Proposed 2nd flight of Terrier-Malemute	
10	36.257	Feb	WSMR	Green	FIRE (New)	New mission - approve by Wilt S. in Aug 2008. Will use existing Green TM.
11	36.260	March	WSMR	Cook	M101 Imager	Possible - Reuse PICTURE optical bench. DR planned for July.
12	36.239	April	WSMR	Korendyke	VERIS	Possible Sci funding and personnel issues. No contact with PI
13	36.268	April	WSMR	McCandliss	FORTISS #1	FORTISS #2 in 2011
14	36.263	June	WSMR	Judge	SDO under flight mission	New grant established in Aug 2008 (via Brinton). 2 <sup>nd</sup> flt July CY11. Slipping along with SDO launch

# 2011 Planning Manifest

	Mission	Launch Date	Site	PI	Project	Comments
15	36.235	June	WSMR	Harris	HYPE #1	
16	36.XXX	June	WSMR	Kankelborg	MOSES #2	Proposed reflly of 36.193 which was flown in 2006. No MIC to date...
17	36.267	June	WFF	Pfaff		Payloads too large – split into two sep PL's
18	36.266	June	WFF	Pfaff		Payloads too large – split into two sep PL's
19	21.140	June	WFF	Pfaff		May try to use Terrier-Malemute
20	21.141	June	WFF	Pfaff		May try to use Terrier-Malemute
21	36.XXX	June	WSMR	McCandliss	FORTISS #2	Refly – actual desired month is TBD
22	36.253	July	WSMR	Hassler	RAISE #2	Fly ~one year after of 36.219
23	36.263	July	WSMR	Judge	SDO under flight	Proposed reflly
24	36.272	Aug	WSMR	Cirtain	Hi-C	Mission defined by Jeff N on Aug 4, 2009. MIC inquiry on Oct 5, 2009
25	36.262	Aug	WSMR	Kaiser	ACCESS #1 – Absolute Color Calibration Experiment for Standard Stars	
26	36.XXX	Sept	WSMR	Kaiser	ACCESS #2	Proposed reflly of 36.262
	36.173	TBD	WSMR	Nordseick	FUSP	MIC 5-8-08. Effort heated up briefly then cooled

# Failures and Anomalies



Failure	AIB lead	Status
NONE		

Anomalies	Lead	Status
- Black Brant Combustion Instability #2	SRPO	Mission was successful. The Brant throat needs to be altered to avoid pressure conditions that may be triggering the instabilities
- Conde Premature Door Deployment	NSROC	Mission was successful. Airflow forced large doors to deploy. Technique will be altered for future applications.
- LaBelle Spin Motor Ignition Failure	NSROC	Mission was successful. Most probable cause is failure of microswitch in lanyard. System is designed to avoid premature firing and thus is susceptible to single point failure. Lanyard switch design being altered.
- LaBelle Despin Anomaly	NSROC	Same mission as above. ACS handled the anomalous spin rate. Despin inspection requirements to be improved.

# Major Programmatic Concerns



- Black Brant Thrust Termination Systems
  - Several missions have already been delayed
  - Still on track for new system to be available at beginning of CY11
  - Back log of flights will be cleared as quickly as possible
- Availability of high performance sustainer motors
  - Just-in-time delivery situation extremely vulnerable to supply chain delays
  - Risk mitigation actions
    - Alternative motors under assessment

# Review of Findings from Previous SRWG Meeting

Findings from February 2010 SRWG

## High Altitude Rockets with Recoverable Payloads



Need: Assess utilizing BBXI & BBXII class vehicles with recoverable payloads to enable increased observing time for astrophysics and solar missions.

Potential solutions exist:

- Utilize the BBXI vehicle at WSMR
- Utilize BBXI & BBXII vehicles from WFF, with water recovery
- Explore alternate land-base ranges (e.g. Woomera)

Findings from February 2010 SRWG

## High Altitude Rockets with Recoverable Payloads



- General Challenges
  - Reentry Heating
    - Current recovery systems designed for <350 km apogee missions
- Land Range Challenges
  - Active guidance needed to minimize dispersion
    - Longer guidance period required due to higher apogee
    - Higher velocities achieved during guidance period = less destruct reaction time
  - Flight Termination
    - Autonomous system will likely be required
- Water Range Challenges
  - Payload Location
  - Payload Buoyancy
  - Water Impact Loads
  - Subsystem Sealing
  - Cost of Recovery Operations

## Findings from February 2010 SRWG

# High Altitude Rockets with Recoverable Payloads



- Thermal protection
  - Redesign of recovery systems will be required
  - Design practices for skin sections may have to be reevaluated
- Guidance
  - Full guidance S-19 exists, but has not been fully flight tested or utilized
- Flight Termination
  - Autonomous flight termination is under development to support national launch ranges
  - Significant development time and flight test program required
  - May not be approved for use for another 5 to 10 years
- Payload Location
  - Promising COTS systems exist. Market research will be conducted in FY10
- Payload Buoyancy
  - Several promising approaches. Will be investigated in FY10.
- Water Impact Loads on Shutter Door
  - Engineering assessment is needed.
- Subsystem Sealing
  - S-19
    - Has been discussed with Ruag. Tricky, but possible. Costly?
  - ACS
    - Feasible, but certain percentage of components will be damaged by sea water
  - TM
    - Feasible, minor loss of hardware due to sea water
- Cost of Recovery Operations
  - Cost could reach \$100K

## High Altitude Rockets with Recoverable Payloads



- **Woomera**
  - Land recovery is most desirable
  - Many (but likely not all) BBXI trajectories will likely fit on the range
  - Likely lowest NRE required
  - Recurring cost generally higher
    - Logistics costs may be an issue
    - May need to conduct missions under campaign mode
- **Wallops**
  - Boost guidance may not be required
  - Long range water recovery presents challenges and risks
  - Initial development cost potentially high
  - Recovery costs potentially significant
- **Kwajalein**
  - Boost guidance may not be required
  - Long range water recovery presents challenges and risks
  - Recurring cost generally higher
    - Logistics costs may be an issue
    - May need to conduct missions under campaign mode
  - Recovery costs potentially significant
- **WSMR**
  - Least feasible due to restricted range
  - Autonomous FTS far down the road

Findings from February 2010 SRWG

## High Altitude Rockets with Recoverable Payloads



For Next SRWG Meeting:

- A preliminary trade study will be presented
  - Focus will be on Woomera and WFF options
  - Study elements
    - First approx. for water recovery NRE
    - First approx. for WFF long-range water recovery operations
    - First approx. for Woomera range costs
    - First approx. for Woomera logistics costs

Findings from February 2010 SRWG

## Woomera Test Facility



- Concept
  - Develop a routine launching site for recoverable, high altitude astrophysics missions
- Progress To Date
  - A launcher has been identified to support BBXI out of Woomera (20K AML currently located in Nevada)
  - Initial contact made with Woomera Test Range Officials
  - Discussed collaborative opportunities with US Navy
- Next Steps
  - Conduct site visit
  - Develop preliminary cost estimate
  - Develop Preliminary Implementation Plan
  - Assess recovery technology needs
  - Pitch concept to HQ

Findings from February 2010 SRWG

## Mesquito Project



### Accomplishments to date:

- 3 launches to date. Significant trajectory deviations during boost phase.
- Avionics development has progressed, but not without challenges.

### Findings:

- Suspect fin loss and/or excessive thermal loading on booster/dart interstage
- Preliminary electrical testing underway. Full functional testing & environmental qualification pending.

### Challenges give cause to reconsider development:

- Extreme flight environment demanding on structure & component design
- Simpler passive separation will not suffice
- Not meeting or marginal on several of original user requirements



*Need to reassess core user requirements and development plan to ensure we're working toward a viable approach.*



## Land Use Developments at Poker

- Land Use
  - Special Use Permits (SU) have been issued on an annual basis in the past
  - USFWS has indicated that the SU is the wrong approach and a Right of Way Permit (ROW) is needed
    - Environmental Assessment is required
    - SRPO has contracted with an 8A firm in Alaska to complete the EA
    - Environmental Day at Poker planned during annual meeting in July
    - ROW likely not in place until 2012 launch season
- Bureau of Land Management (BLM) Cabins
  - Crowberry cabin is an issue for single stage Orion and BBXII flights
  - Considering providing another cabin so that Crowberry can be closed during launch operations
    - Concept has received warm welcome, but little progress has been made
  - Not an issue for 2011 flights, since all on BBIX

# NSROC II Status



- Revised proposals currently under evaluation
- NSROC II Selection targeted for July 15, 2010
  - 60 day phase-in period
- NSROC II Start targeted for Sept 15, 2010

# Rocket Motor Status

# Surplus Rocket Motors



- Talos
  - 21 at WFF
  - 2 at Indian Head
  - 18 stored at Hawthorn
- Taurus
  - 53 at WFF
  - 3 awaiting disposal
- Terrier MK70
  - 62 at WFF
  - 88 tagged for NSRP though the Navy
  - 175 located at Hawthorn
- Improved Orion
  - 103 at WFF (“good” series)
  - 100+ at WFF (older version)
- Improved Malemute
  - 8 at WFF
  - One was used for static firing and the other was used for 1<sup>st</sup> flight
- MLRS
  - 54 at WFF



# Black Brant Rocket Motors

- Inventory Levels
  - 8 available for NASA missions
  - 5 in inventory for reimbursable missions(MARTI)
  - 8 remaining on order of fifteen
    - Utilizing “old” steel
    - 5 have case concerns due to heat treatment
  - Additional order for twelve has been issued
    - New case material will be used
      - Same rolled/welded construction
  - Four sets of FTS hardware available for WSMR launches
    - Next version FTS on schedule for the end of calendar year
- A second case of combustion instability occurred on the May 21, 2010 WSMR Launch
  - This occurrence will impact delivery schedule

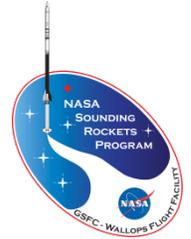
# Nihka Motors



- Nihka
  - Old Version
    - Supply essentially exhausted
    - Two available for flight
    - Three have failed inspection
    - Working on transfer of Nihka-83 from CSA
  - New Version
    - New design to update materials/vendors and mimic Brant insulation
    - Static firing successfully completed in November 2009
    - First three flight motors have been cast
      - Delivery to Yorktown will occur this month
      - Receive at WFF in July
    - Nihka test flight on schedule for August 4<sup>th</sup>



# Launch Range Updates



- Poker
- WSMR
- Norway
- Kwajalein
- Woomera

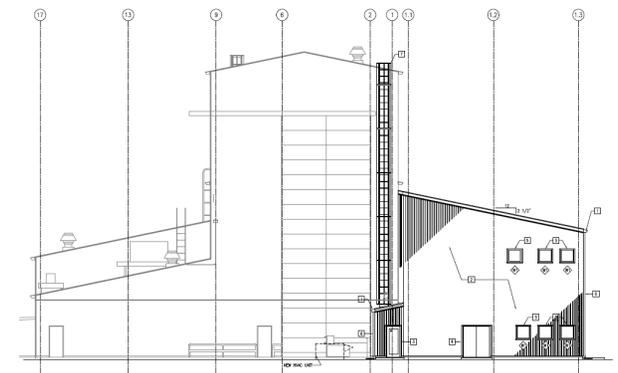
# Poker



- Clean room has been cleaned in preparation for Bailey and Beasley missions (Feb 2011)
- New radar annex to be built this summer
  - To be funded by the Wallops range
- New intercom system (MOVE) to be installed in time to support winter 2012 missions
  - NASA will provide \$1M in equipment with 10 yr service support
  - SRPO will provide additional \$140K for required key sets
  - Kudos to Rob Hurley (Code 840)
- Environmental “right of way” permit is in the works
- New control center options to be discussed during annual meeting in July

# WSMR

- VAB Phase I
  - Lab and Office Addition
  - Mandatory site visit conducted on May 20
  - Bid openings set for June 15
- VAB Phase II
  - 35% Design review held on April 7
  - 60% design review set for June 15
- VAB Phase III
  - Modification of NE side of VAB
  - Still on drawing board



# Norway Status



- **Athena launcher**
  - Maintenance and installation of payload retract assembly will take place this summer (NSROC)
- **Instrumentation**
  - Pre-mission trip planned for ground station set-up and check-out (NENS)
- **Svalbard**
  - Two missions currently being proposed
  - New launcher installed: U5
  - Need to confirm if U3 remains

# Woomera

- Initial contact with range officials indicate that BBXI dispersion will likely fit on the range
- SRPO has set a strawman campaign target date of 2014
  - HQ has not approved a campaign at this time
- The SRPO may conduct a Woomera site visit in conjunction with Kwaj site visit



Everything you have always wanted in a rocket range...

# Kwajalein

- One mission (2 launches) selected for summer/fall 2012
- SRPO has made initial contact with Huntsville
  - They are excited to work with NASA once again
  - They understand that ALTAIR is a major asset for the science community and have indicated that availability will not be an issue
- Site visit anticipated for fall 2010
- The SRPO hopes to have a firm cost estimate by late fall to assess if the Kwaj option should be included in the next AO for ROSES



Staging on Roi

# Technology Program Update

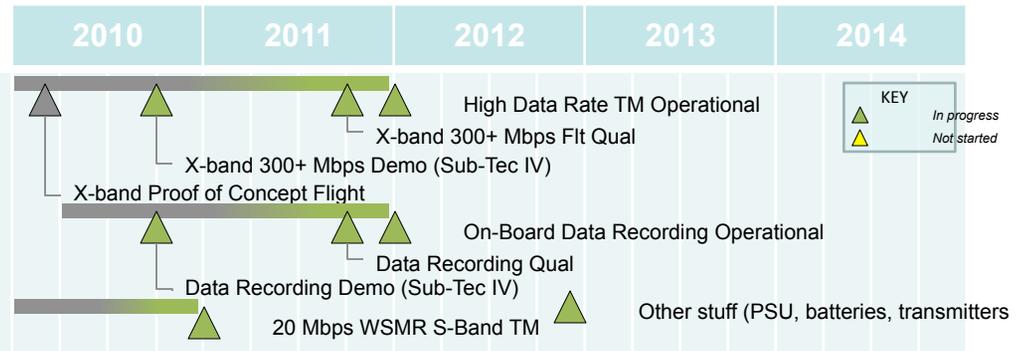


- Limited resources require strategic investment planning
- SRPO attempts to leverage partnerships within NASA and other govt agencies (DoD)
  - Vehicle development partnerships w/ DoD (Patriot, Oriole, ATACM)
  - High Data Rate technology partnerships with NASA (GSFC/SpaceCube)
- SRPO pursuing R&D funding thru IRAD, SBIR, and other research programs
  - FY11 IRAD Call-For-Proposals includes a new line of business, “*Suborbital Platforms and Range Services*”

## Data Collection Technologies

### Needs:

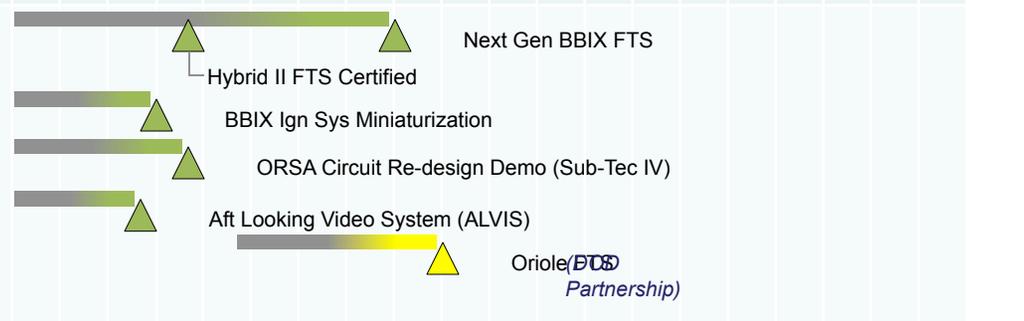
- Increase data rate
- Provide high capacity data storage



## Vehicle Systems Technologies

### Needs:

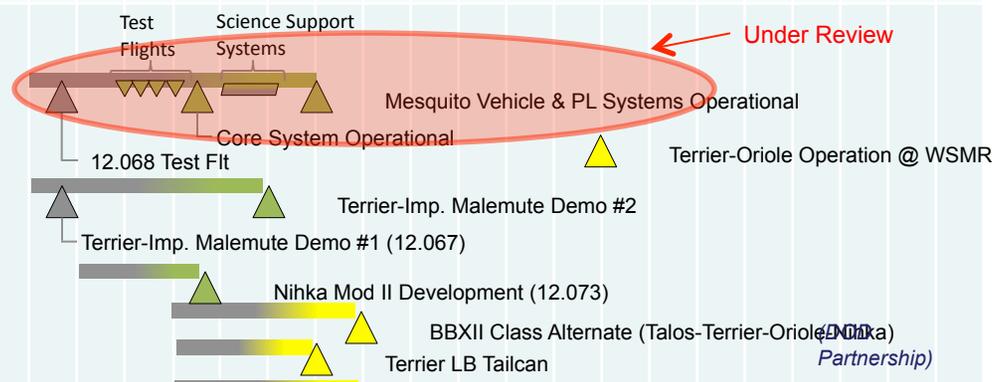
- Replace obsolete systems
- Bring systems "in-house" (reduced cost, increased control of deliverables)
- Develop systems to enhance existing vehicle systems capabilities and operations



## Vehicle Carrier Technologies

### Needs:

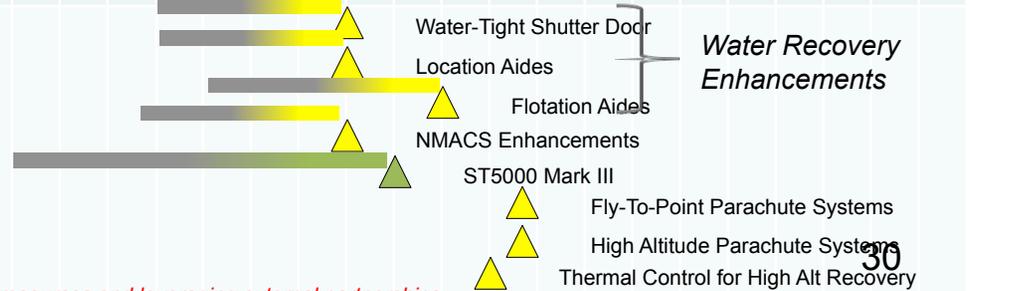
- Find low-cost, reliable alternates to legacy rocket motors
- Assess alternate vehicle configurations to sustain existing capabilities
- Assess low-cost vehicles to study the mesosphere
- Increase observation time



## Payload Systems Technologies

### Needs:

- Replace obsolete systems
- Bring systems "in-house" (reduced cost, increased control of deliverables)
- Develop systems to enhance existing payload systems capabilities and operations



Milestones subject to prioritization of resources and leveraging external partnerships.

# High Data Rate Telemetry Development



## Phase I: X-Band Proof of Concept

- 150 Mbps system demo flew on 40.025/LaBelle PFRR March 2010
- Data input from Dartmouth Central Axis Boom, GPS time input from PL TM

## Conclusions:

- No indications of problems with the flight hardware (*other than component heating*)
- Minor anomalies with range ground support equipment
- Possible degraded signal due to amp temperature

## Plan Forward:

- Investigate antenna performance & design options
  - Conduct additional ground testing
  - Continue development of more optimal flight antenna
- Ground support equipment testing & refinement
- Target development of high efficiency X-band power amp



# High Data Rate Telemetry Development



## Phase II: X-band Enhancement & On-board Recording Proof Of Concept

1. X-band Enhancement (*Building on Phase I system design successes & challenges*)
  - X-band data rate enhancement to ~384Mbps
  - Migration from linear to circular polarized flight antenna to increase link margin
2. On-board Recording Proof Of Concept
  - Development goal of ~1000Mbps for duration of no less than 10 minutes
  - Solid state memory utilized to maximize reliability
  - GSFC Space Cube is planned for processing & storing data
3. Validate Ground Support Equipment Capability to Support ~400Mbps
  - 11M down converter upgrades required to support increase rate
  - Ground Station equipment upgrades required

*Phase II culmination in test flight on SubTEC IV*



Space Cube Fit CPU

# High Data Rate Telemetry Development



## Phase III: System Standardization & Flight Qualification

- Develop high efficiency, higher power X-band amplifier
- Multi-channel encoder development
- Standardization

## Development Needs & Concerns:

- **Science community input needed**
  - » Need collaboration on encoder development requirements
    - Data channel requirements (number & type)
    - Impact of splitting exp data into high/low rate
  - » Need to assess approach to standardizing interfaces for on-board recording
- WFF based launches require continued agreement from NASA Ground Network
- Resources need to be managed closely & balanced against other technology efforts

# Upcoming Technology Demonstration Flights



- SubTEC III (WFF/Mid July 2010)
  - Primary Experiment: Autonomous Flight Safety System (AFSS)
  - Secondary Experiments:
    - FAA Autonomous Dependent Surveillance Broadcast
    - NSROC development components (*Additional Details provided during NSROC Brief*)
      - TM Gyro II, Miltech micro IMU
      - Real Time Attitude Solution (RTAS)
      - New Lithium Ion battery pack
      - Command uplink receiver
      - JAVAD-100 GPS Receiver
- SubTEC IV (WFF/Winter 2010)
  - Primary Experiment: High Data Rate TM (Downlink & On-board Recording)
  - Secondary Experiments:
    - Redesigned ORSA Circuitry
    - GSFC SMART Experiment (ORS initiative)



SMART Concept



# Terrier/Improved Malemute Development Effort



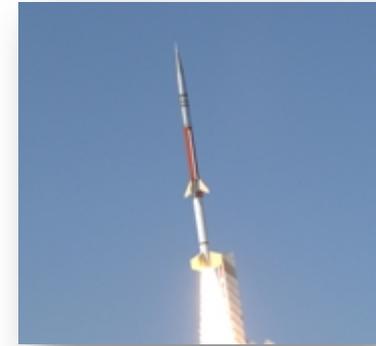
- Static firing July 2009
  - Demonstrated flight ignition system
  - Ignited at reduced pressure
  - Baseline temperature data collected
- Flight Test March 27, 2010
  - Apogee was 270 km, -6 sigma low, 2 sigma short
  - Stability Anomaly was observed
    - Worst condition during coast after 1<sup>st</sup> stage separation
    - Stability improved ~ 10 seconds into flight
    - Forward motor joint expected cause
- Second Test Flight Planned
  - Implement new joint design
  - Same mass/size payload



# Terrier/Improved Malemute Flight Performance Summary



- Lower than expected performance
  - Thrust or drag modals need adjustment
- Stability Anomaly was observed
- Motor pressure was nominal
  - No pressure increase during flight due to spinning environment
- Roll rate 5.2 cps, 1.1 cps high
  - New tailcan/fin arrangement and setting procedure
  - Reduces concern of elevated pressure from erosive burning in a higher spin environment
- Nominal temperature data
  - Relieves concern of inadequate thermal protection in a spinning environment
- Successful Ignition at Altitude
- Flight environment was measured and recorded
  - Support establishing test specifications
- Procedures and operational processes have been established with this flight



Rail Exit



Winds contorting the 2<sup>nd</sup> stage exhaust

HENU

Hz: 107.420  
Hz: 1442  
Time: 006 14:00:50:4

E1: 050.00  
R11: 14  
R11

TEXT

DSPL  
SYNTH  
VIDEO

# Flight Video



# Technology Efforts On The Horizon



Highlights of upcoming development initiatives:

1. Next Generation FTS
2. Surplus vehicle studies
3. Recovery enhancements
4. On-board video system for monitoring motor performance
5. Numerous component developments
  - Primarily sustaining efforts for standard components (timers, gps)
  - Alternate sensor suites for attitude determination

*Additional technology initiative details to follow in NSROC presentation.*