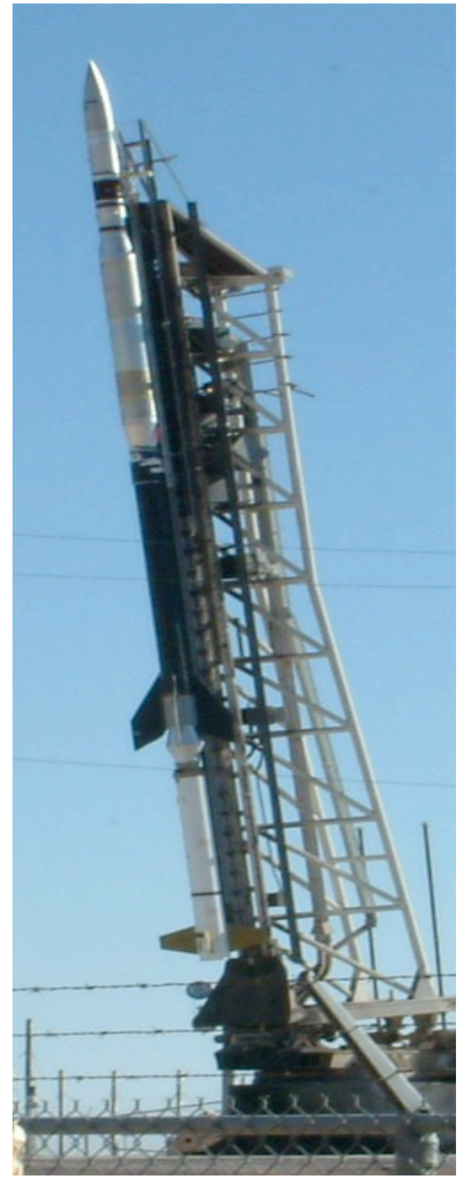
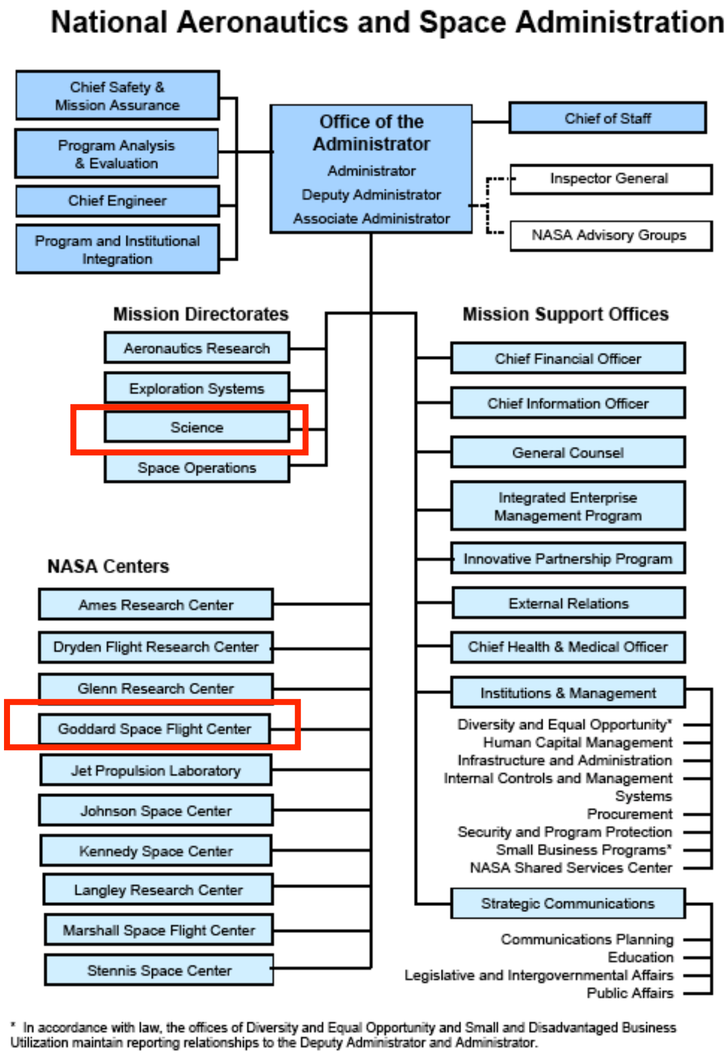
NASA Sounding Rocket Program

September 21, 2007



Briefing Outline

- Introductions
- NASA HQ Program Management
  - Organization charts
  - Research Program Structure & Management
  - Example science missions
- General Program Overview
  - Organization and Implementation
  - Project Elements
  - Foreign Operations and Ranges
  - Flight Rates and History
- Hardware Overview
  - Vehicles
  - Payloads
  - Components
- Payload Processing and Operations Overview
- Flight Manifest Projections
- ITAR Considerations


National Aeronautics and Space Administration
Chief Safety & Mission Assurance
Program Analysis & Evaluation
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Program and Institutional Integration
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Mission Directorates
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Goddard Space Flight Center
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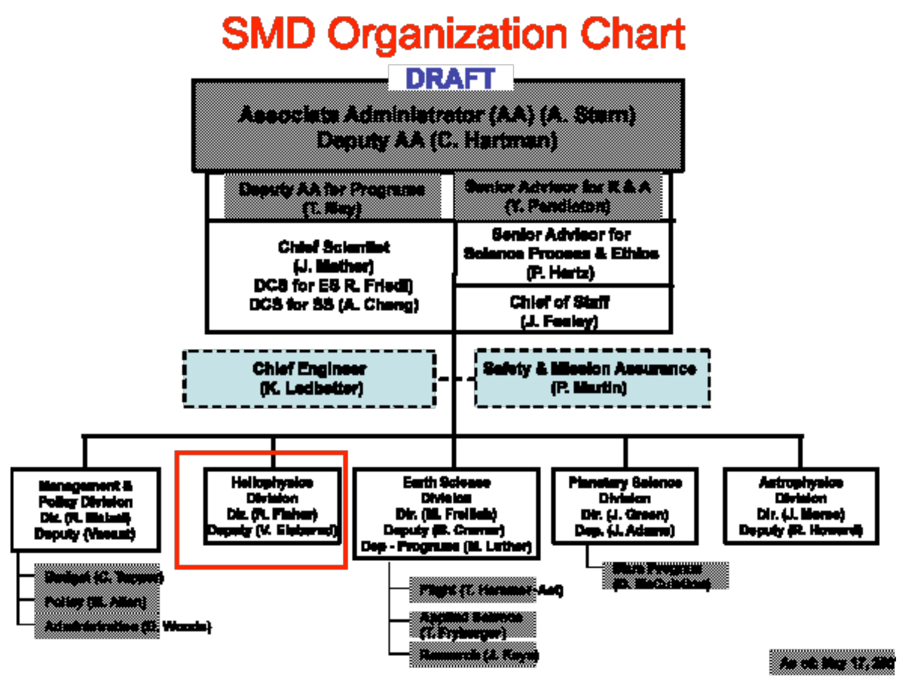
Science Mission Directorate
NASA


SMD Organization Chart
DRAFT
Associate Administrator (AA) (A. Stern)
Deputy AA (C. Hartman)
Deputy AA for Programs (T. May)
Senior Advisor for R & A (Y. Pendleton)
Chief Scientist (J. Mather)
DCS for ES R. Friedl)
DCS for SS (A. Cheng)
Senior Advisor for Science Process & Ethics (P. Hertz)
Chief of Staff (J. Feeley)
Chief Engineer (K. Ledbetter)
Safety & Mission Assurance (P. Martin)
Heliophysics Division
Earth Science Division
Planetary Science Division
Astrophysics Division

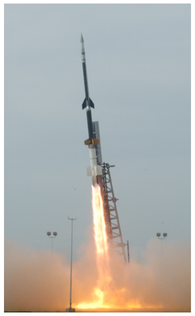
Research Program Structure and Elements

- **Research & Analysis** – basic research
- **Applied Sciences** - applied research for economic & societal benefit
- **Suborbital Research Carriers** – research facilities for developing flight experiments and for scientific research
- **Science Data & Computing Infrastructure** – data mgt, computing and networking resources for scientific research

Suborbital Research Carriers: Low-Cost Access to Space Program

- Suborbital Research Carriers: low-cost frequent access to space to:
  - Address strategic scientific problems in a wide range of scientific disciplines
  - Flight-test new technology and techniques quickly and inexpensively.
  - Train new investigators, students and NASA workforce on time scales commensurate with graduate study.
- As experimental, research projects, LCAS projects accept higher risk of mission failure with fewer bureaucratic requirements to keep costs down. (This does not mean safety is compromised)
- Carriers: Sounding Rockets, Balloons and Aircraft/UAS

Project Description: Sounding Rocket Program



Program Objective: Provide suborbital launch vehicles, payload integration, and field operations to support low-cost access to space for:

- scientific investigations in geospace, solar physics, and astronomy;
- technology development of vehicle systems;
- development & test of future space-based measurement concepts and sensors.

Organizations:

- Project Management: GSFC/WFF
- Rocket Contractor: Northrup-Grumman led team
- Payloads: various universities and national labs, selected through R&A Program
- Ranges:
  - WFF Research Range (fixed & mobile)
  - Poker Flat Research Range (Alaska)
  - White Sands Missile Range (New Mexico)
  - Andoya Research Range (Norway)

Program Description: Stable of 14 vehicles covering max altitudes from 100-1500km, using various motor combinations (Terrier, Black Brant, etc; motors either military surplus or commercially supplied), payload support subsystems, and infrastructure for payload and rocket integration & test.

Mission Rate: increasing to 12-20 missions per year, some may be multiple rockets. Auroral campaigns to polar regions every other year.

Web Site: http://sites.wff.nasa.gov/code810

Science management of LCAS Sounding Rockets Program

- **NASA Headquarters**
  - Competed Research & Analysis program is source of all SMD sounding rocket missions. Individual awards usually for 3 years.
  - R&A solicited annually: Research Opportunities in Space and Earth Sciences (ROSES) with 70+ topics in 2007, grouped by SMD divisions: A. Earth/ 26 , B. Heliophysics/8, C. Planetary/24, D. Astrophysics/11, E. Multidisciplinary/2.
    - In theory, any science community may propose use of NASA research facilities like the sounding rockets; in practice, only proposals to Geospace, Solar Physics and Astrophysics R&A usually include rocket-based investigations.
    - For LCAS projects, ROSES funds mission concept and design, science instruments (e.g. Langmuir probes, magnetometers, telescopes) and analysis of results. (Sounding Rocket Program funds actual rocket operations.)
    - Program Scientists develop priorities for the ROSES call, compete about one-third of the program every year, and lead peer review panel evaluations & develop selection recommendations.
    - Rocket missions selected in conjunction with other R&A grants, selections occur throughout year.
  - Program Scientist for Sounding Rocket Operations chairs a HQ working group of discipline-oriented scientists to prioritize and schedule selected rocket missions within Sounding Rocket Program constraints.

ROSES 2007 (partial list of discipline topics)

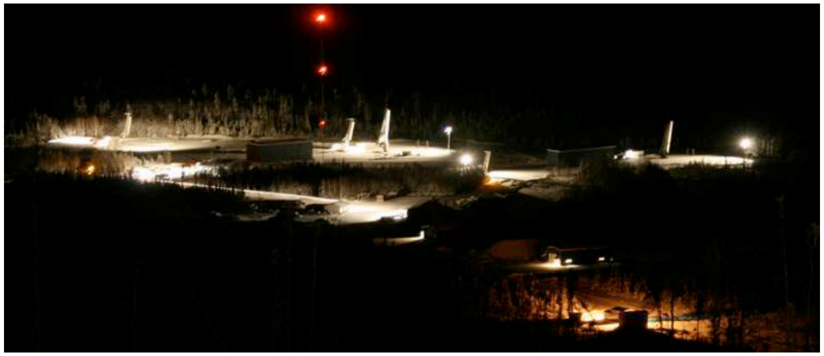
B.2	Solar and Heliospheric Physics	12/7/2007	2/8/2008
B.3	Geospace Science	5/11/2007	7/20/2007
B.4	Heliophysics Theory	4/27/2007	6/29/2007
B.5	Heliophysics Guest Investigators	3/16/2007	5/11/2007
B.6	Living With a Star Space Environment Testbeds	**Cancelled due to Solar Orbiter focused opportunity**	
B.7	Living With a Star Targeted Research and Technology	**9/19/2007**	**10/19/2007**
B.8	Living With a Star Targeted Research and Technology: Strategic Capability	**Not solicited this year**	
B.9	Virtual Observatories for Heliophysics Data	9/12/2007	11/15/2007

D.2	Astrophysics Data Analysis	4/27/2007	6/22/2007
D.3	Astronomy and Physics Research and Analysis	3/3/2008	4/11/2008
D.4	Astrophysics Theory and Fundamental Physics	4/6/2007	6/1/2007
D.5	GALEX Guest Investigator – Cycle 4	4/27/2007	6/22/2007
D.6	FUSE Guest Investigator – Cycle 9	**Replaced by D.11 FUSE Legacy Science Program**	
D.7	Swift Guest Investigator – Cycle 4	9/14/2007	11/9/2007
D.8	Suzaku Guest Observer – Cycle 3	9/14/2007	11/30/2007
D.9	GLAST Guest Investigator – Cycle 1	**7/13/2007**	**9/7/2007**
D.10	Kepler Mission Participating Scientists	3/16/2007	5/18/2007
D.11	**FUSE Legacy Science Program**	**Cancelled due to end of FUSE mission**	
D.12	**Astrophysics Strategic Mission Concept Studies**	**9/20/2007**	**11/20/2007**

Science management of LCAS Sounding Rockets Program

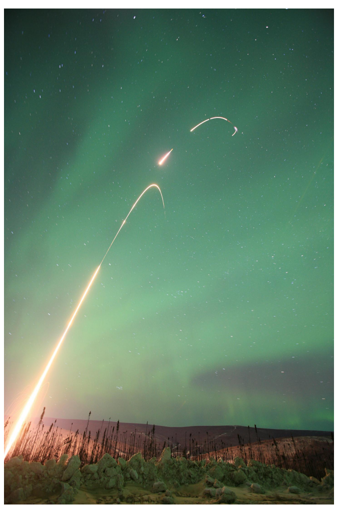
- **NASA Centers (GSFC and GSFC/WFF)**
  - Project Scientist/Sounding Rocket Working Group (GSFC): scientists from universities and national labs who are frequent users of sounding rockets; provide community input for technical capability & program implementation.
  - Sounding Rocket Program Office (SRPO) (Wallops) implements program: vehicle and payload development, integration & test, launch and operation.
  - SRPO is base-funded to provide a research facility to all NASA-sponsored investigators. This includes a baseline number of missions (20 missions in 2008): covers the cost of motors, payload support systems, integration & test, and launch/mission operations.
- **Principal Investigators**
  - Develop mission concepts & submit proposals in response to ROSES calls: co-investigators/science teams selected by PI according to expertise.
  - PI's design, build and deliver science instruments. Geospace payloads usually require integration of multiple sensors with science team participation; telescope-oriented payloads more self-contained.
  - First formal interface with SRPO during 1st year of grant, continuing interface through series of engineering reviews until experiment delivery; then hands-on integration with PI and science team at Wallops and in field for launch and flight.
  - Flight usually occurs in the 3rd year of a research investigation; schedule changes common since target phenomena may be ephemeral, also payloads are often new and experimental.
  - Students frequently involved, can participate at any level from simple data analysis through instrument design, fabrication, testing and operation.

2007 Poker Sounding Rocket Campaign



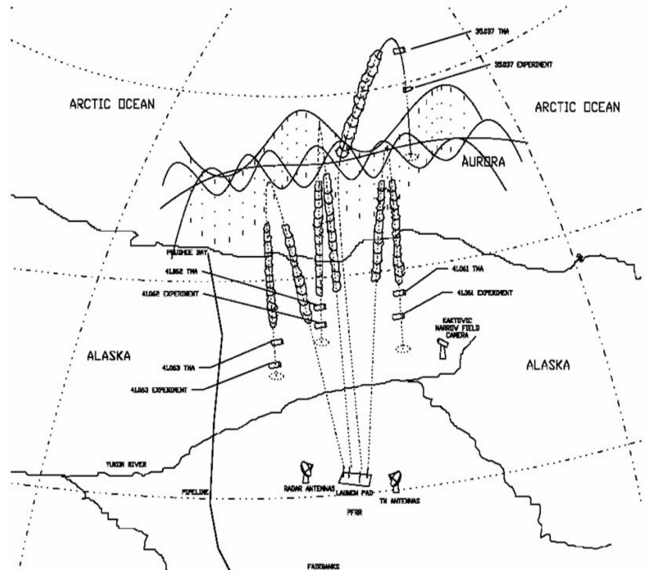
The Larsen Mission/Joule II

- Detailed structure of electrical currents in the aurora
- Four rockets launched in two salvos over 15 minute period
- Two Instrumented payloads and two Trimethylaluminum payloads
- Mission successful



The Lessard Mission/ ROPA

- Energy transfer in pulsating aurora
- Four stage launch vehicle
- Four free flying payload bodies
- Two of the subpayloads employed small rocket motors ignited after separation to increase separation distance during the data collection period
- Mission successful



The Craven Mission/HEX II

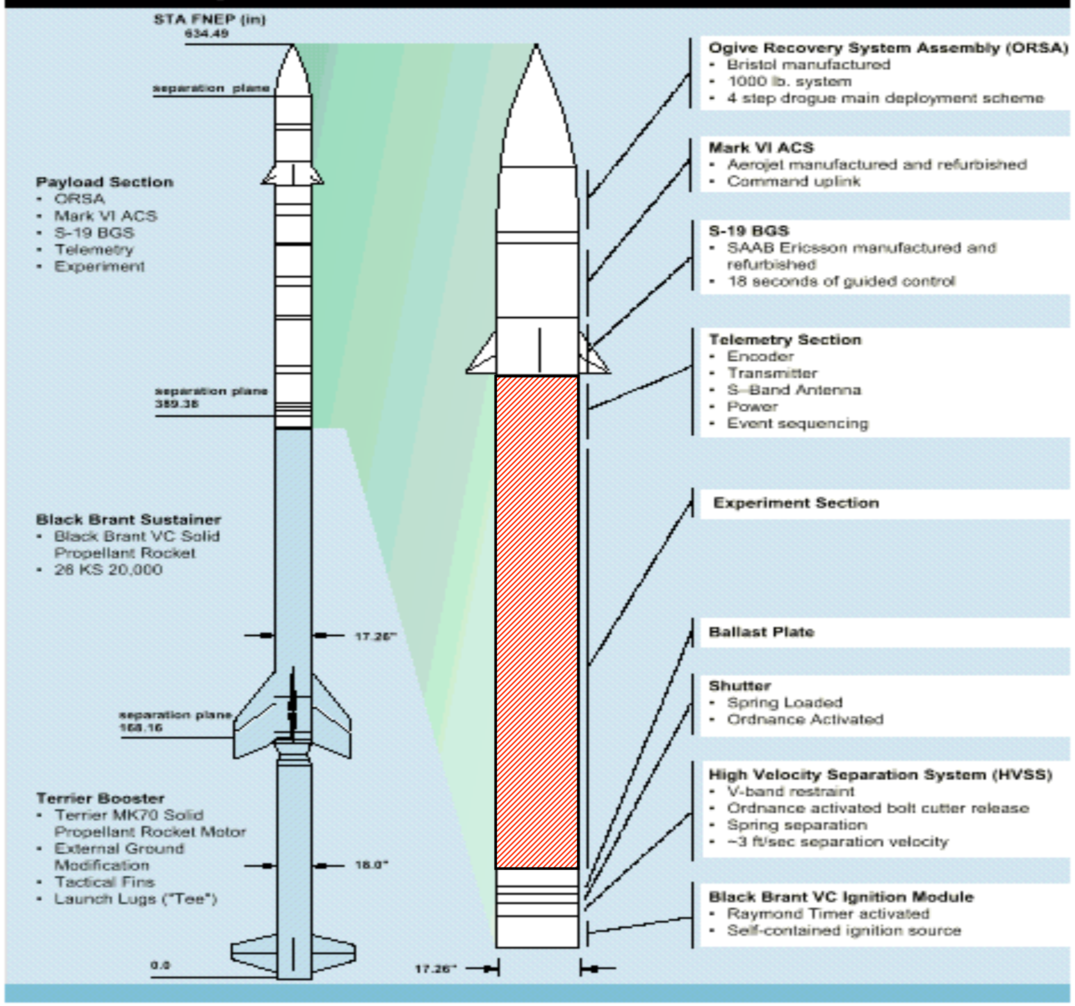
- Thermospheric winds
- Four vehicles launched within 11 minute time span
- Each payload included instrumentation and Trimethylaluminum (TMA)
- Largest vehicle employed an attitude control system to reorient the vehicle prior to 3rd stage ignition to provide flattened trajectory
- Mission successful

The LaBelle Mission/CHARM

- High frequency waves in aurora
- Four stage launch vehicle
- Complex telemetry requirements (multiple high data rate links)
- Failure of ACS payload support system – no data retrieved

Sounding Rocket Concept

Exhibit 1.A.0-1. Representative NSRP Sounding Rocket Vehicle



The Black Brant IX MOD I (Terrier MK70 – Black Brant VC) is the reference vehicle used for discussion purpose.

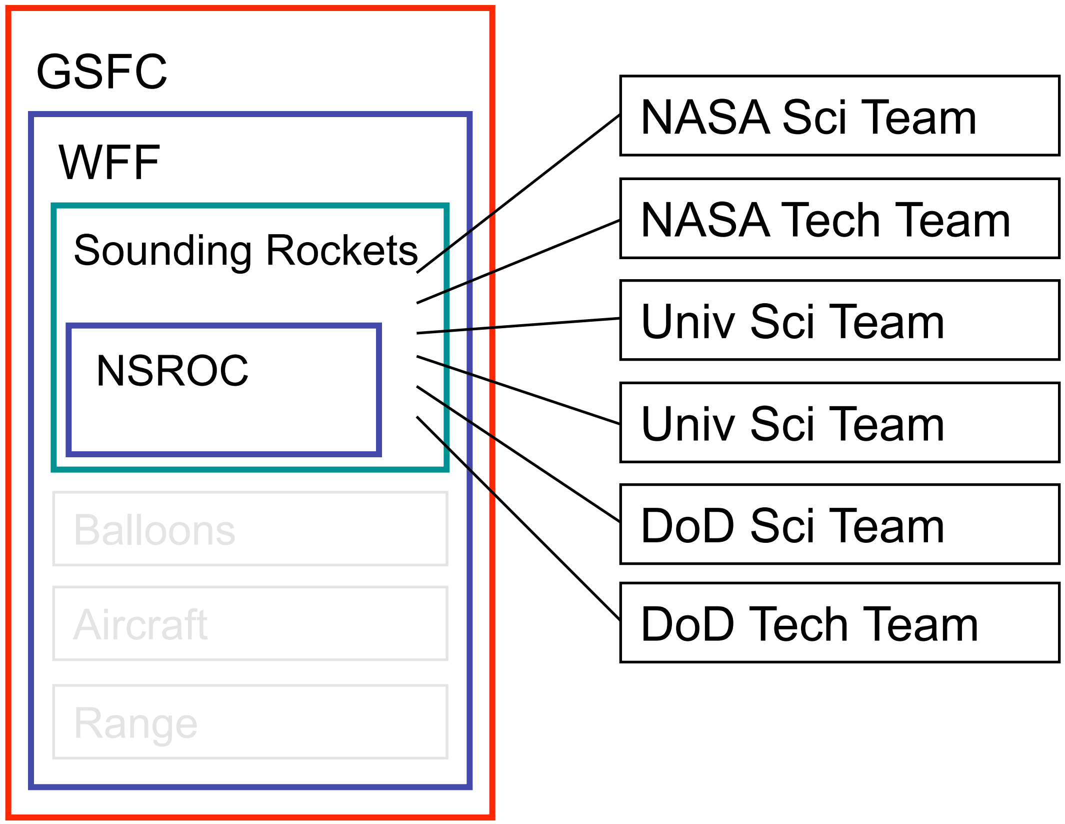
Experiments:

- Complete Telescopes (bolted on to support systems)
- Detector section provided by the customer
- Detectors mounted on structures provided by the program

Program Background

- Small Civil Service Program Office
- Some Civil Service support is provided in the engineering, safety, contracts, and resources areas
- Northrop Grumman (and subcontractors) provides program implementation via the NASA Sounding Rocket Operations Contract (NSROC)
  - Performance Based
  - Cost plus award/incentive fee
  - Structured around 20 flights/year
- The program is in year 8 of a 10 year contract

Organizational Overview



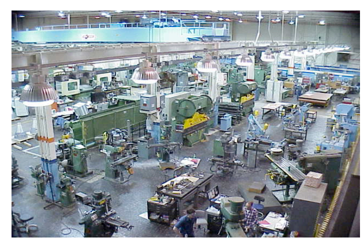
Typical Project Activities

- Payload Development
  - Attitude Control Systems
    - Magnetic
    - Inertial (coarse pointing and velocity vector tracking)
    - Celestial
  - Telemetry Systems
    - Multiple links
    - 10 Mb/s data rates
    - Command uplink
    - Video down link
  - Recovery Systems
  - Boost Guidance Systems
    - Aerodynamic control for early portion of powered flight
  - Experiment Structures
  - Deployment Systems
- Mission Analysis
  - Flight performance
  - Ground and Flight Safety
- Launch Vehicles
- Operations Support
  - Mobile range development
  - Launcher servicing and erection
  - Field operations

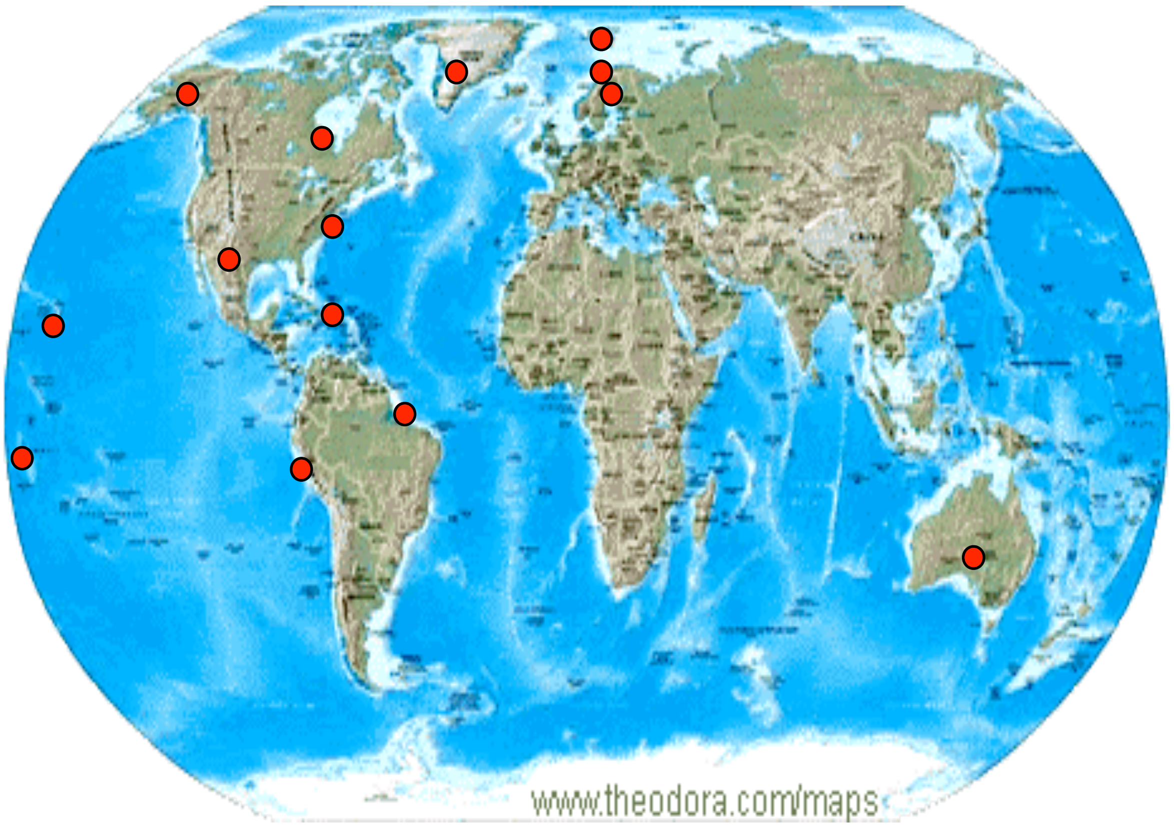









World-Wide Operations



Norway – within the auroral oval, availability of down range observation sites, and access to unique instrumentation

Australia – observation of the southern sky and large land area to support special trajectories and recovery

Sweden – Favorable ionospheric conditions

Because many scientific investigations rely on in-situ measurements, launch operations must be conducted from sites around the world.

Foreign Launch Ranges

- Andoya Rocket Range
  - Andenes, Norway
  - MOU with Kingdom of Norway in place
  - Operated by the Norwegian Space Centre
- Svalbard
  - Ny-Alesund, Svalbard (Norway)
  - MOU with Kingdom of Norway in place
  - Operated by the Norwegian Space Centre
- Esrange
  - Kiruna, Sweden
  - MOU in place
  - Operated by the Swedish Space Corporation (SSC)
  - SSC is owned by the Swedish Ministry of Enterprise, Energy, and Communications
- Woomera Test Range
  - Woomera, South Australia
  - Project Office has no record of current MOU
  - Operated by the Defense Research Center
- Reagan Test Range
  - Kwajalien Atoll, Marshall Islands
  - No NASA MOU required
  - Operated by the US Army


Andoya

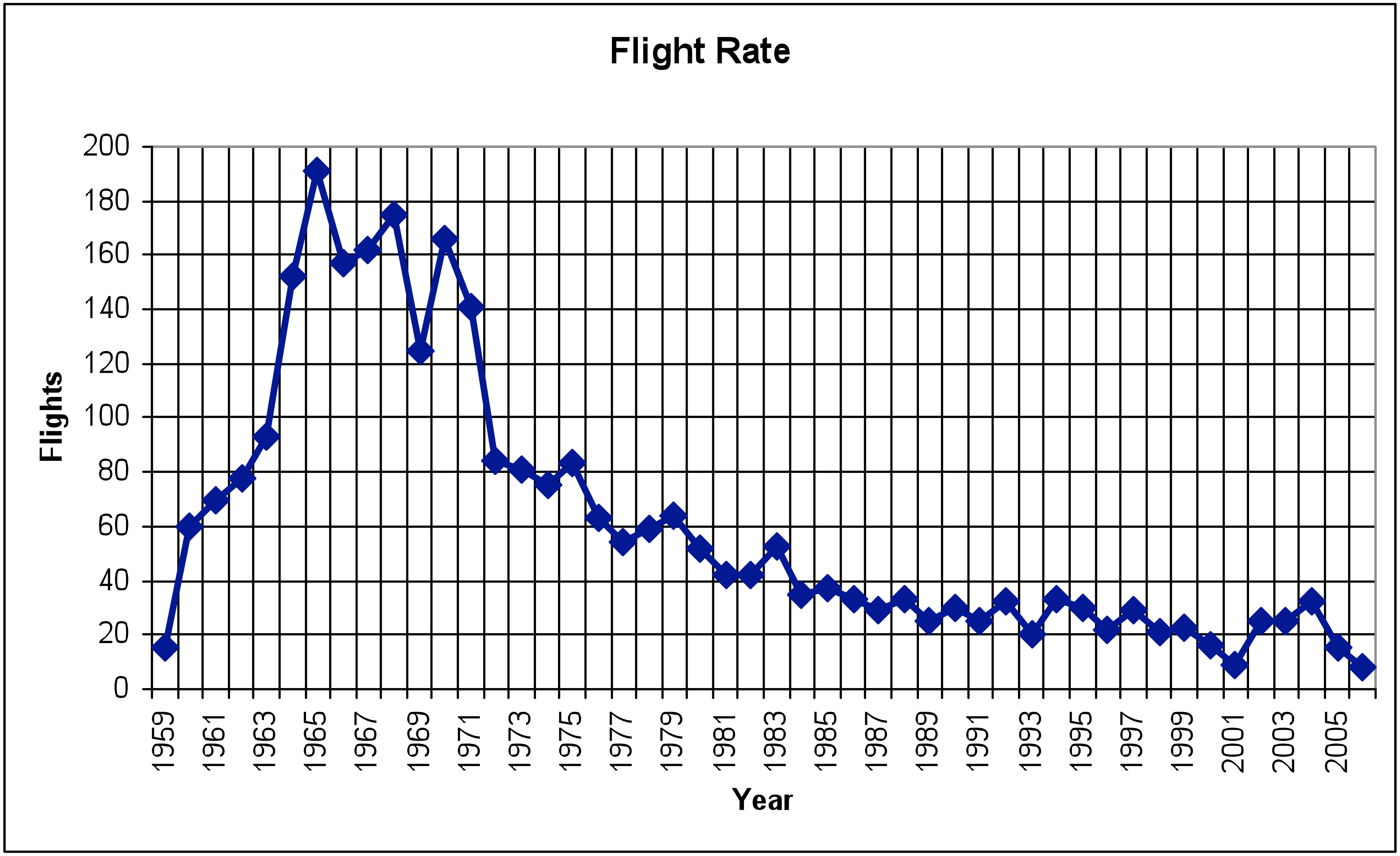

Svalbard


Esrange


Kwajalein


Woomera

NASA's Long History of Flying Suborbital Rockets

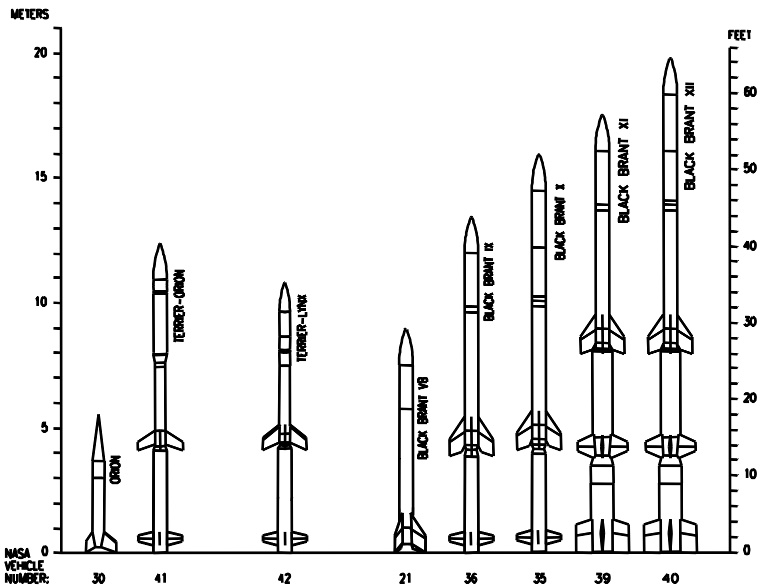


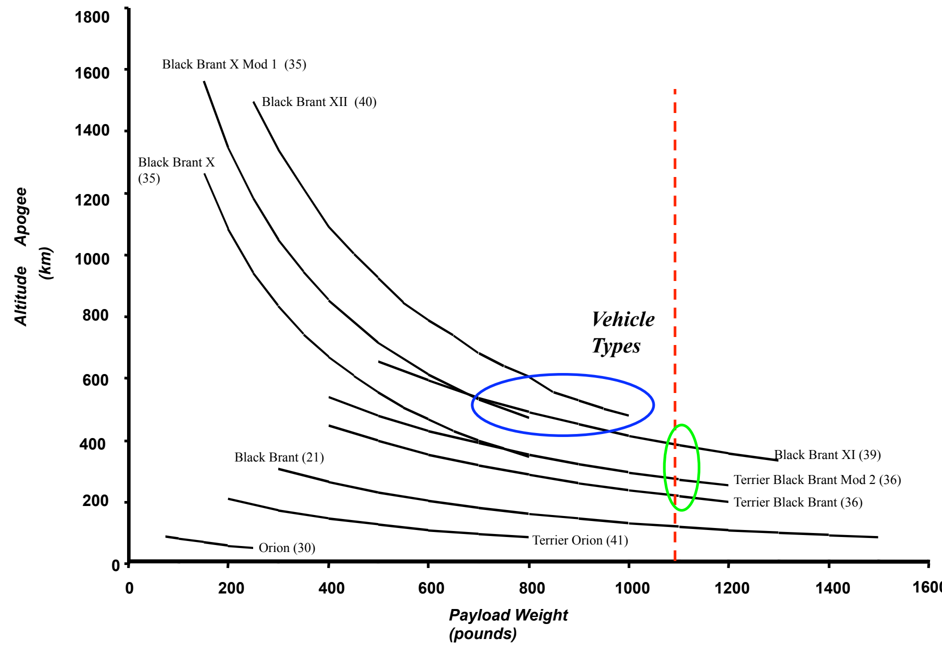
Flight History Since 2000 (FY)

Site	2000	2001	2002	2003	2004	2005	2006	2007
Wallops	6	5	7	11	4	4	3	5
WSMR	7	6	8	6	7	5	4	5
Poker	3	-	11	7	-	3	-	10
Kwajalein	-	-	-	-	14	-	-	-
Norway	-	-	2	1	1	-	1	4
Sweden	-	-	-	2	-	-	-	-
	16	11	28	27	26	12	8	24

Rocket Vehicles

NASA Suborbital Launch Vehicles



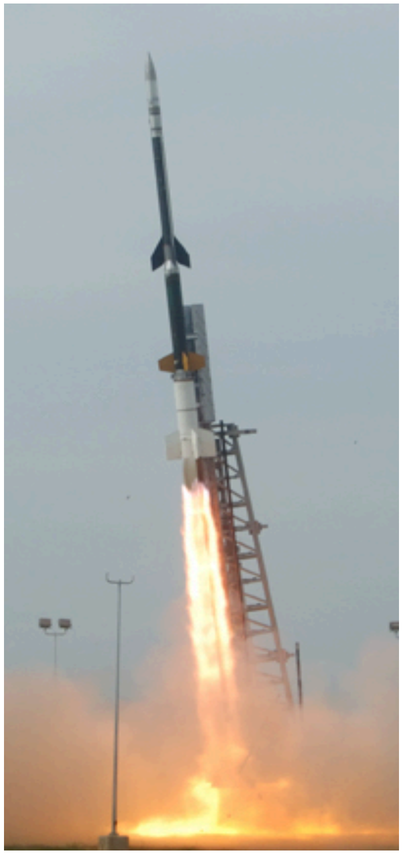


- Sounding rocket vehicles are composed of military surplus and commercially available rocket motors
- Vehicle selection is based on payload weight and scientific requirements

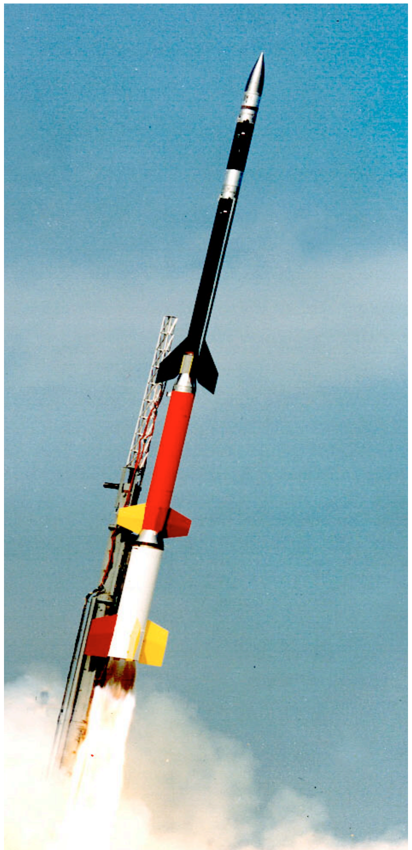
Vehicle Configurations (sample)

Terrier-Improved Orion

Black Brant IX



Black Brant XI



Black Brant XII

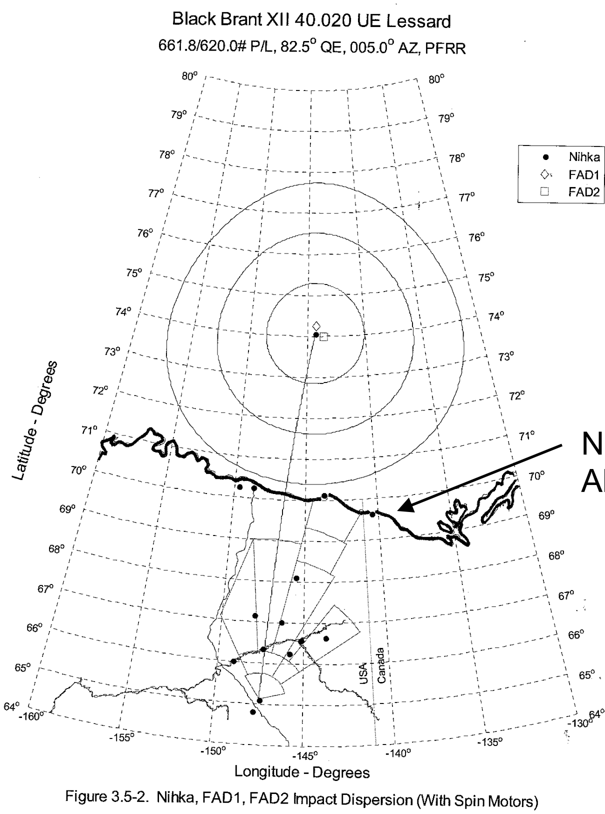
Rocket Motors

Motor	Source	Typical Age
Black Brant VC	Commercial	1 year
Nihka	Commercial	~8 years
Terrier	Surplus	20-30 years
Taurus	Surplus	40 years
Talos	Surplus	30 years
Orion	Surplus	20 years

Vehicle Performance

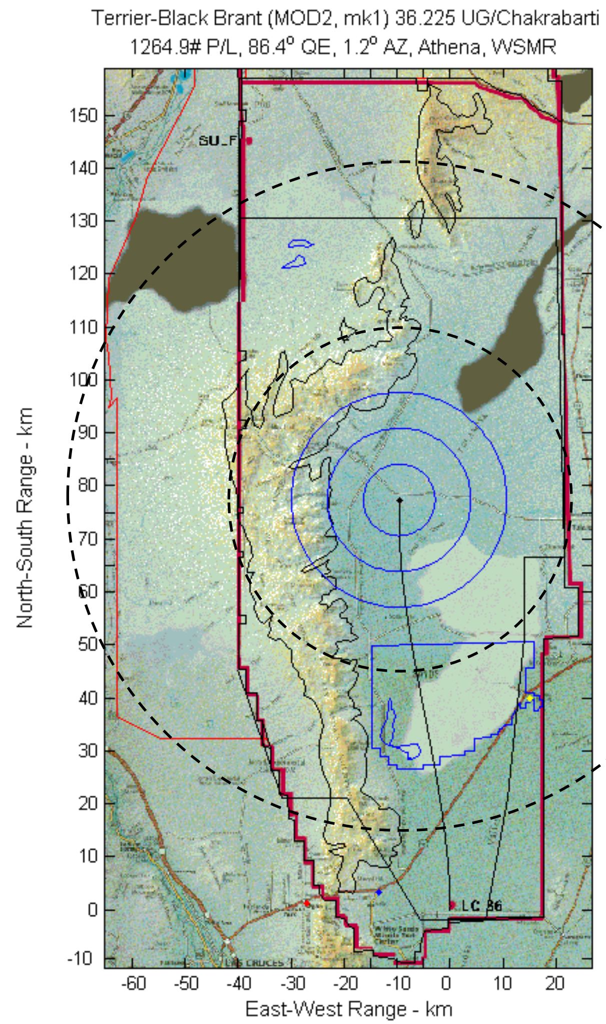
- Apogees from 50 km to 1500 km
- Impact ranges from 20 km to 1800 km
- Fin Stabilized
- S-19 guidance system only used on WSMR flights
  - Purpose
    - Reduce scrubs due to winds
    - Reduce probability of vehicle cut-down (shrink dispersion)
  - Canard system is used to maintain launcher az/el for first 18 seconds of flight
  - Produced by SAAB Aerospace (Sweden)
- Vehicle dispersion
  - Terrier-Brant
    - Without Boost Guidance
      - 1-sigma impact dispersion ~ 11% of apogee (~ 28 km radius)
    - With Boost Guidance
      - 1-sigma impact dispersion ~ 2.5% of apogee (~ 6 km radius)
  - Black Brant X and XII
      - 1-sigma impact dispersion ~ 23% of apogee (>130 km radius)

Dispersion Examples



North coast of Alaska

Black Brant XII Dispersion in Alaska



~ 2-sigma w/o boost guidance

Solid circles represent dispersion using a boost guidance system

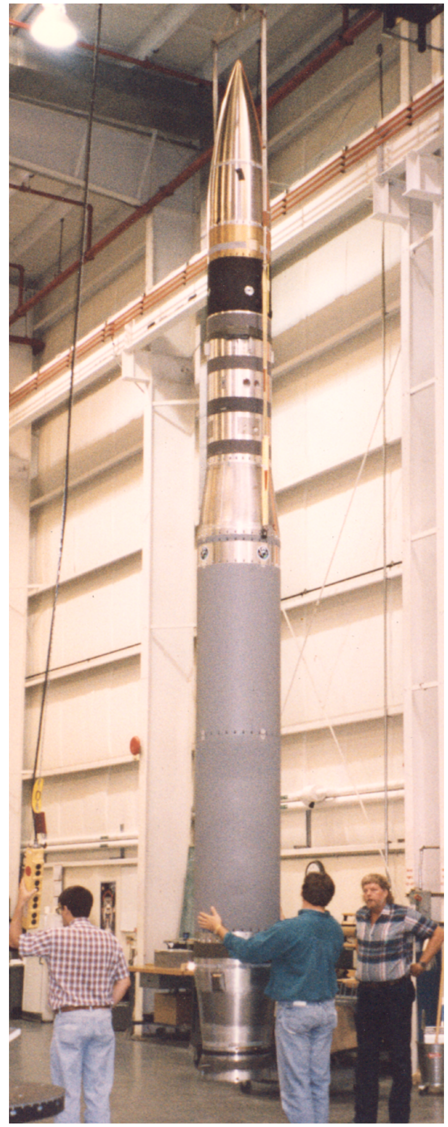
Payloads (a.k.a. Spacecraft)

Payload Support Systems (NASA/NSROC)

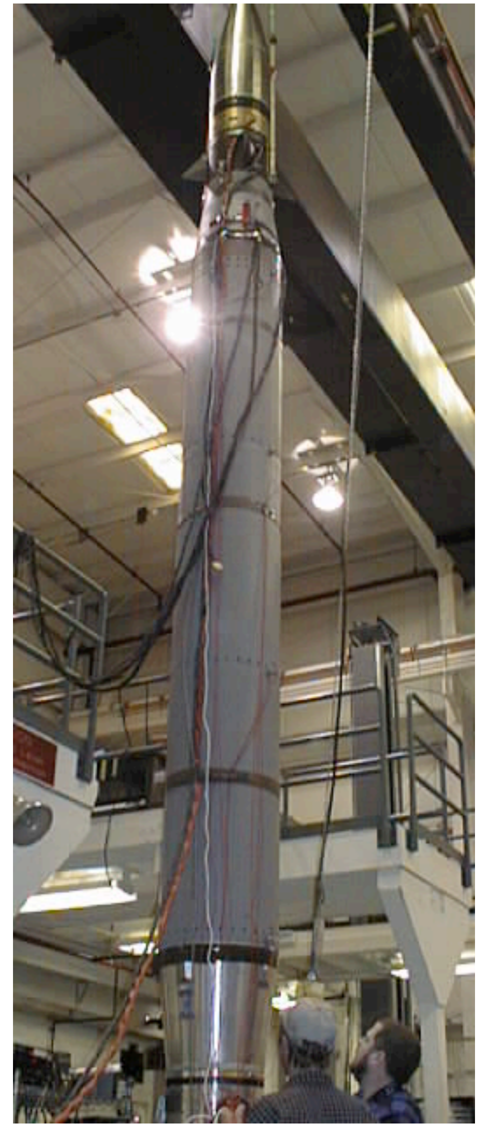
Experiment (NASA, University, or other)

Plasma Physics Experiment

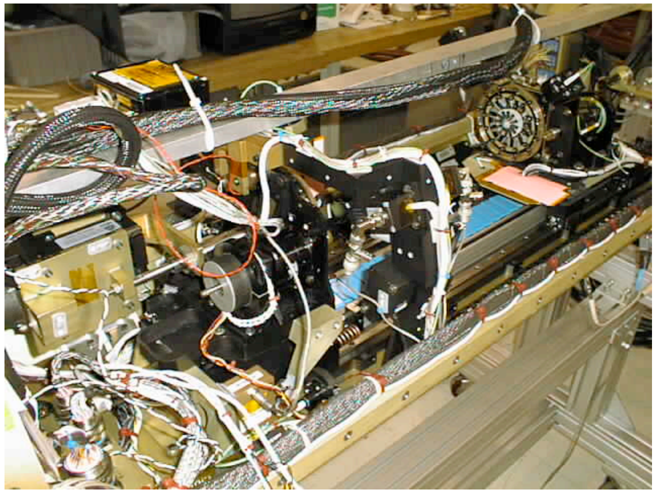
Plasma Physics Experiment



Microgravity Payload



Telescope Payload



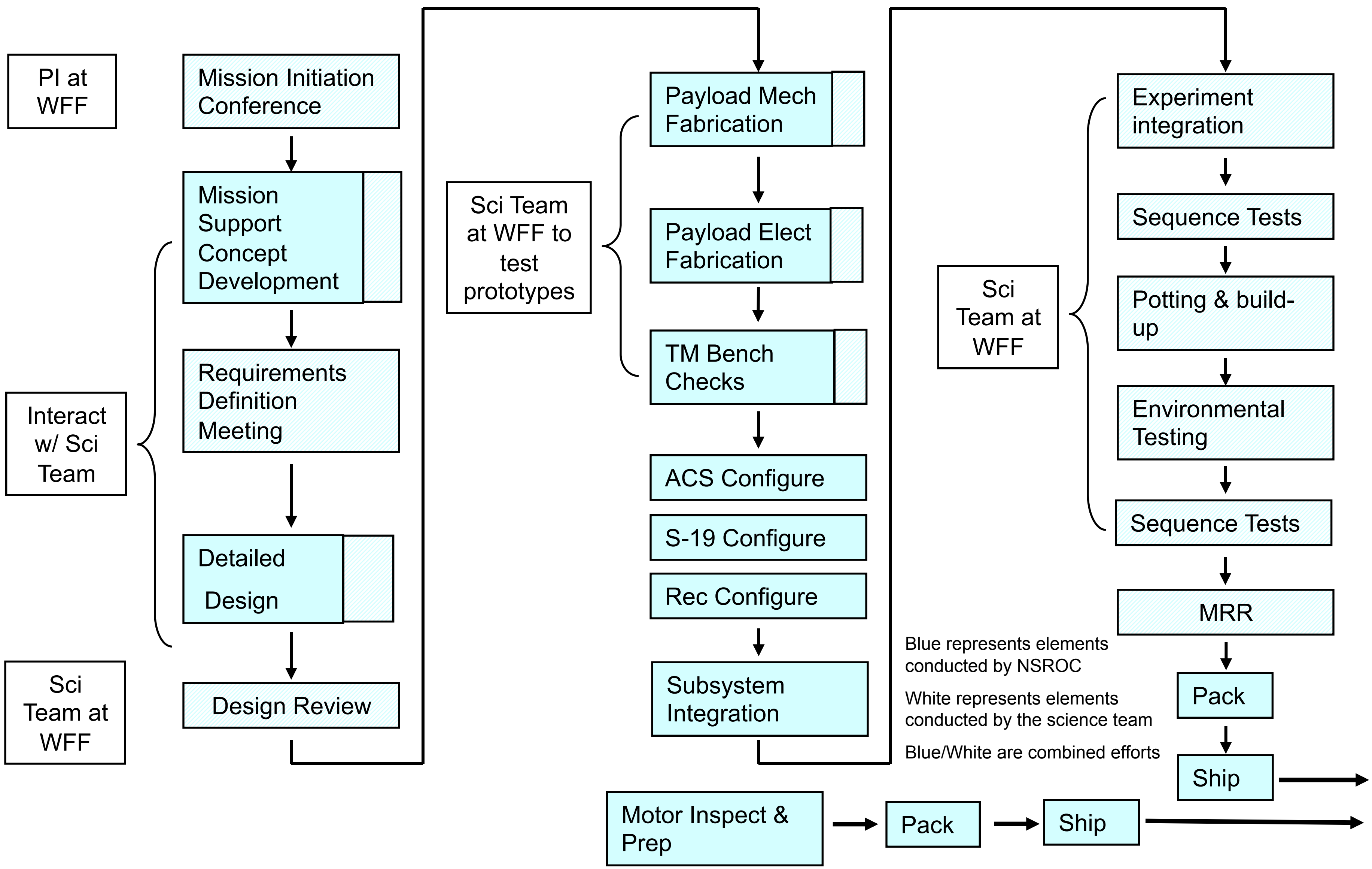
Microgravity Payload

Plasma Physics Experiment with free-flyer subpayloads extended

LaRC Inflatable Aeroshell Experiment

Ames Aeroshell Experiment

Payload Development Work Flow



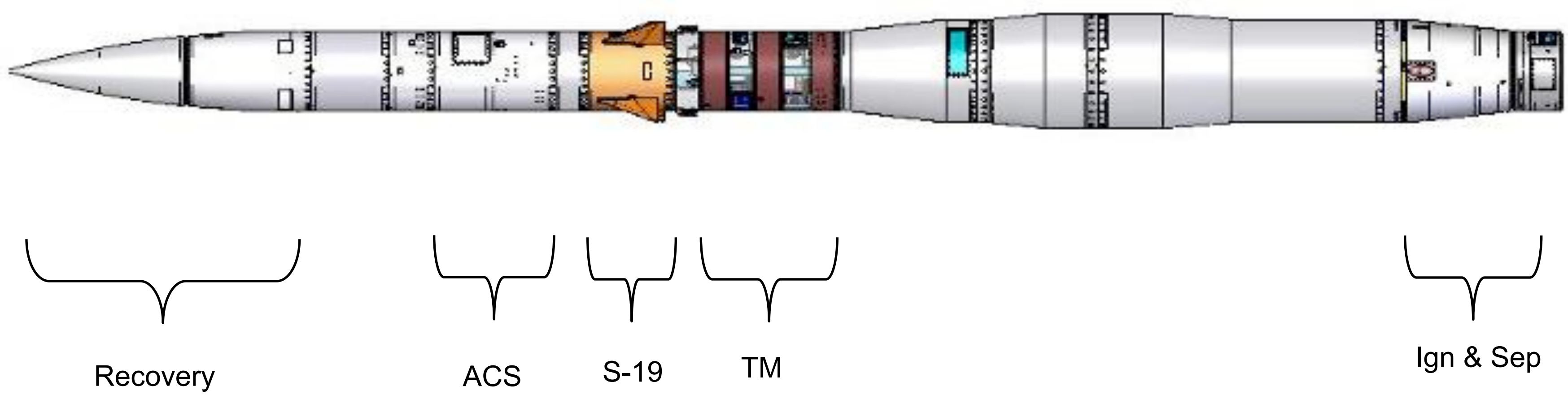
Sample Mission Time Frame (Kintner)

Mission Milestone	Date
Mission Initiation Conference	May 16, 2006
Design Review	May 22, 2007
Begin Fabrication	May 23, 2007
Payload Integration and Testing	October 9, 2007
Motor Shipment	September 24, 2007
Mission Readiness Review	November 5, 2007
Payload Shipment	November 12 2007
Project Team Travel	December 3, 2007
Science Window Opens	January 2, 2008

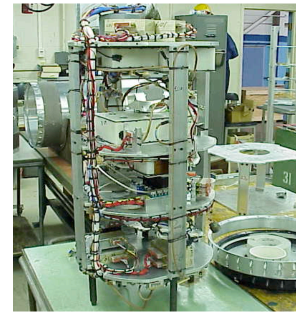
Design: 12 months

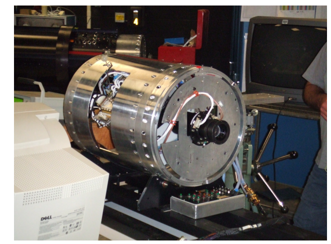
Fabricate: 5 months

Subsystems



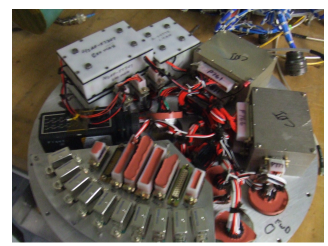
Subsystems

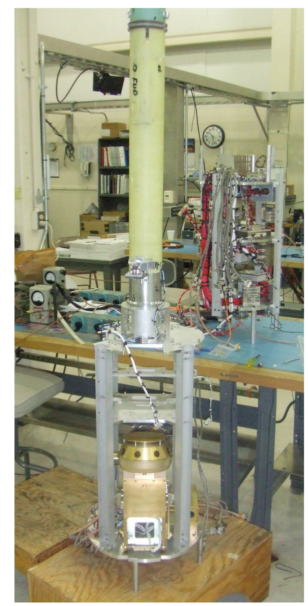




- Custom Systems
  - Telemetry
    - Standard components combined to create custom systems
  - Mechanical Structures (booms, doors, subpayloads)
    - Common baseline designs are used as much as possible

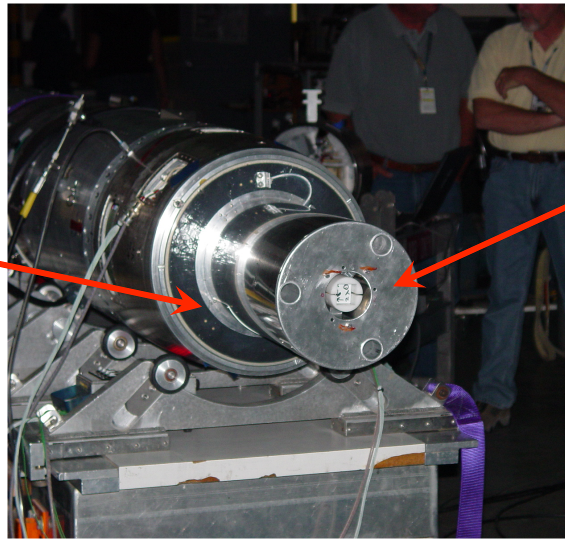
- Standard Systems
  - Attitude Control
    - Used for pointing the payload after it reaches the space environment
    - Sensors include magnetometers, star trackers, gyros
    - Uses cold gas thrusters with limited thrust
    - Pointing accuracy from a few degrees to sub arc-sec.
  - Boost Guidance
    - Uses canards to maintain launch attitude for first 18 seconds of flight
    - Reduces impact dispersion
    - Units produced by SAAB Aerospace in Sweden
  - Recovery
    - Systems can be placed on the forward or rear ends of the payload
    - Simple heat shield cover over the end of the parachute canister





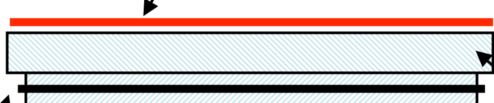
Recovery

Heat Shield – Aluminum plate layered with thermal coating



Top Hat – push off for nose tip and mount for magnetometer. Breaks off during reentry.

AvCoat Thermal Layer



O-ring

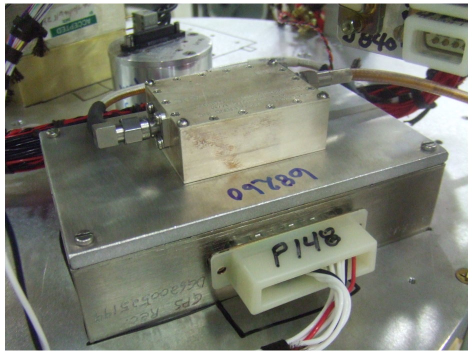
Aluminum Can Lid

Post impact at White Sands Missile Range

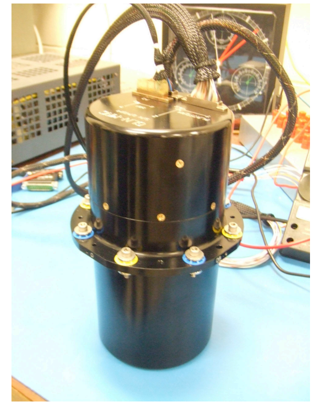
Components

GPS is used to provide positional information in TM systems and enables the determination of velocity vector information in specific attitude control systems. GPS is not used for guidance.

The program uses commercial receivers and builds power and signal conditioning as required.



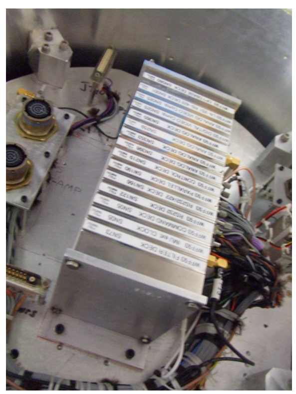
GPS Unit



Inertial Platform

The program does not develop gyros, though it does fabricate the new GLN-MAC gyro. Fabrication and testing occurs in a dedicated laboratory.

Standard modules that are combined as needed to meet data requirements



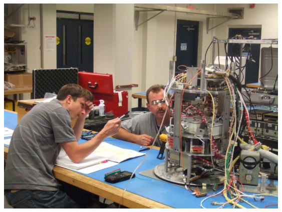
Telemetry Encoders

Batteries

Standard cells (typically NiCad) combined to create batteries to meet power requirements

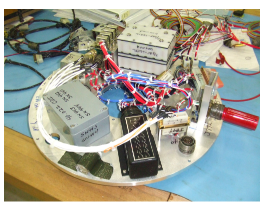
Payload Processing

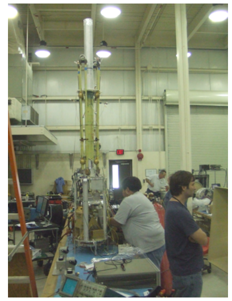
Payload Testing

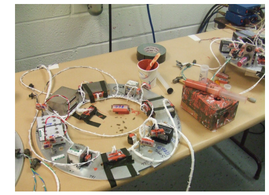


TM Bench Checks

Subsystems Checks
- ACS
- Boost Guidance
- Recovery
- Ignition Sys







Subsystem Integration w/ TM → Experiment Checks → Experiment Integration w/ TM → Sequence Tests → Potting & Build-up

Environmental Testing
- Vacuum Test
- Spin Balance
- Vibration
- Bend Test
- Deployment Tests
- Properties

→ Sequence Tests → TM Checks → Mission Readiness Review

Sci Instrument checks back at University

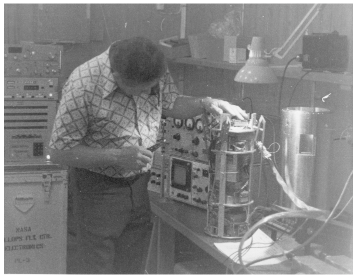
Blue represents elements conducted by NSROC

White represents elements conducted by the science team

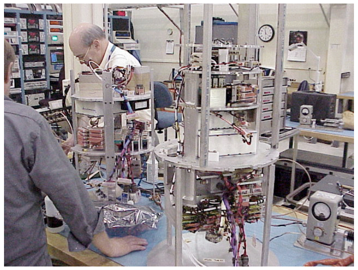
Blue/White are combined efforts

Telemetry System Testing

- General Activities
  - Verify correct power distribution
  - Test and calibrate housekeeping sensors
  - Radio Frequency Interference testing
  - Ground station readout set-up
- Conducted in the integration lab prior to arrival of the science team



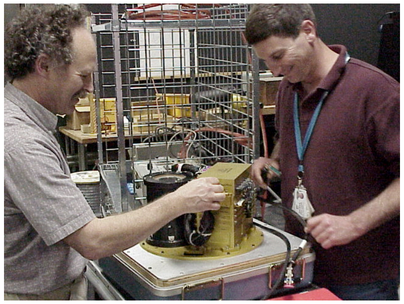
Telemetry Checks (1977)



Telemetry Checks (2006)

Subsystem Checks

- Conducted in parallel with TM Bench Checks (typical)
- Completed before the science team arrives
- Subsystems
  - Attitude Control
    - Pre integration checks conducted in separate lab
  - Boost Guidance
    - Pre integration checks conducted in separate lab
  - Recovery
    - Pre integration checks conducted in separate lab
  - Vehicle Support Systems
    - Conducted in the Integration lab



ACS Platform Pre-Integration Testing in the ACS Lab

Sequence Testing

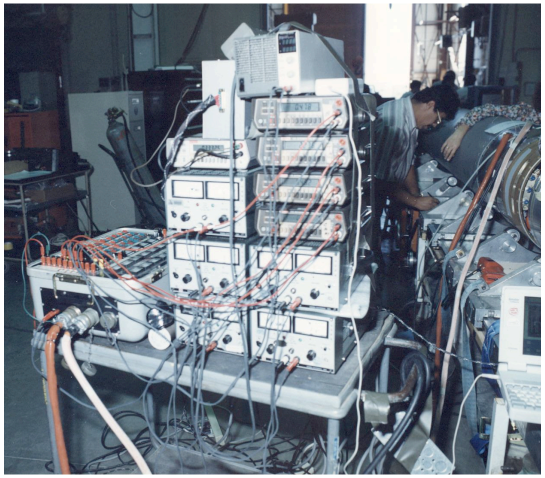
- All payload systems and team members present
- Verifies that all payload events occur at the preset times
- Verify functionality of system monitors (current sensors, voltage sensors, break wires, etc)
- Simple phasing checks conducted if ACS is used
  - Manually shift system around to see if proper nozzles respond
- The NSROC contractors obtain TAA's to cover the defense service
- If TAA can not be secured in time, a Technology Control Plan is developed

Final Sequence Test at WSMR (2002)

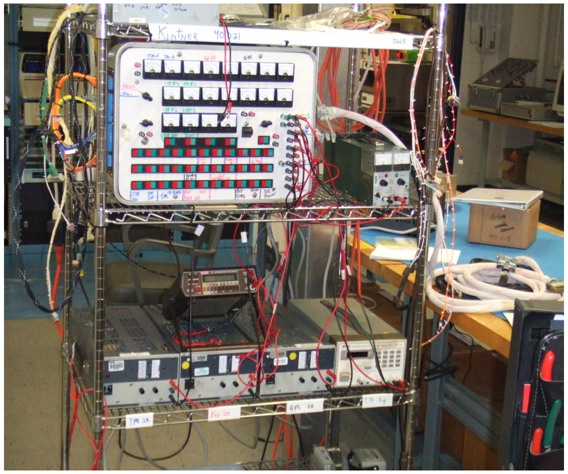
Environmental Testing

- Minimal detailed engineering analysis is conducted
  - Testing ensures the systems fulfill their function
- Minimal component testing is conducted
  - Testing is done at the system level
- Standard Tests
  - Spin Balance
  - Vibration
  - Bend
  - Deployments
  - Physical Properties

Payload Support Equipment



Payload GSE (1996)



Payload GSE (2007)

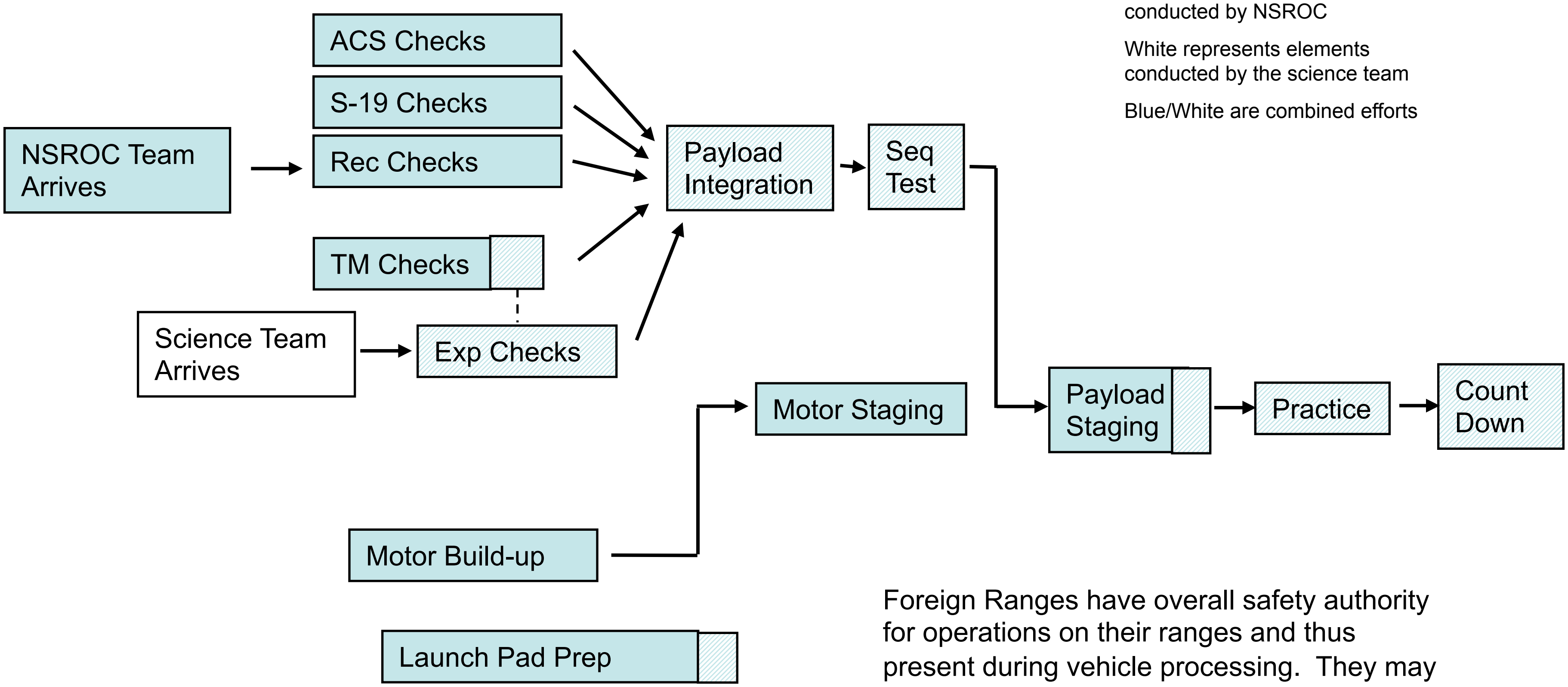
Next Generation Payload GSE

There has been little impetus to drive the evolution of the payload ground support equipment (GSE). It has been configurable, robust, and reliable.

A computer-based remote power unit is slowly being phased in. Reduces amount of copper needed between the blockhouse and pad and eliminates power loss issues.

Field Operations

Field Work Flow



Blue represents elements conducted by NSROC

White represents elements conducted by the science team

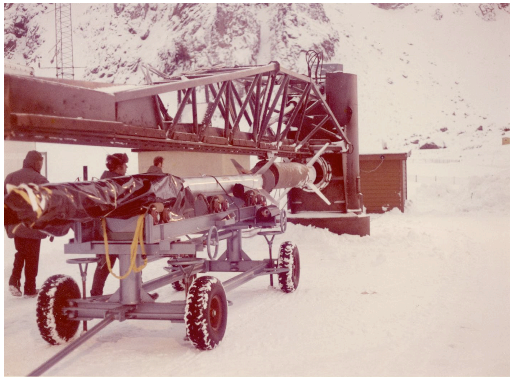
Blue/White are combined efforts

Foreign Ranges have overall safety authority for operations on their ranges and thus present during vehicle processing. They may help move motor, but they do not assist with the preparation. **NSROC obtains a TAA to cover this defense service.**

Motor Processing

Motors are processed in dedicated processing facilities separate from where the payloads are processed. Usually only the motor technicians, vehicle technicians and safety personnel are present during processing.

Staging Operations



Staging operations in Norway (1977)

Staging operations in Puerto Rico (1992)

Staging operations in Woomera, Australia (1987)

Staging operations in Kwajalein (2004)

Typical rocket on the rail at White Sands
Missile Range

(during launcher elevation)

Payload Recovery Operations

- White Sands Missile Range (Domestic)
  - All payloads are recovered for reuse
- Norway
  - No recovery since impact takes place in the ocean or on the remote Northern ice pack
    - Payloads are destroyed on impact and/or sink
    - Finding the impact site is extremely difficult
  - Most missions involve high flying vehicles and extensive heating is experienced upon reentry
- Sweden
  - Missions typically involved payloads that have boom systems which makes recovery problematic
  - Payloads free-fall from space and impact in desolate region
    - Payloads unusable after impact
  - Recovery would likely be attempted in the event of a failure
- Australia
  - All payloads to date have been recovered

Expended Rocket Motor Recovery

- Expended rocket motors are not recovered unless there is an environmental reason
  - Recovery may be attempted in the event of a vehicle failure (for land impact)
  - Recovery of a sounding rocket motor from the ocean has never been attempted
- Expended motors consist of burned fuel residue, burned rubber insulation, casing, nozzle, and fins
- Upper stage ignition modules are destroyed on impact

FY08 Planning Manifest

	Mission	Launch Date	Site	PI	TAA Required	TAA Submitted	TAA Approved
1	36.241	Oct	WSMR	Rabin	0		
2	41.075	Nov	WFF	Smith	0		
3	36.225	Nov	WSMR	Chakrabarti			
4	36.XXX	Nov	WSMR	McCandliss	3	0	0
5	36.223	Nov	WSMR	McCammon			
6	35.036	Dec	Andoya	Kletzing	4	4	4
7	40.018	Dec	Andoya	Kletzing			
8	36.221	Dec	WSMR	Moses	2	0	0
9	35.021	Jan	Andoya	Kintner	2	2	2
10	36. 240	Feb	WSMR	Woods	2	0	0
11	36.226	May	WSMR	Bock	2	0	0
12	36.213	June	WSMR	Davis			
13	36.219	June	WSMR	Hassler			
14	36.235	July	WSMR	Harris			
15	36.239	Sept	WSMR	Korendyke			
	41.XXX	Spring	WSMR	Erdman			

FY09 Planning Manifest

	Mission	Launch Date	Site	PI	TAA Required	TAA Submitted	TAA Approved
1	36.XXX	Oct-Dec	WSMR	Nordseick			
2	41.076	Jan	PFRR	Lehmacher	3	0	0
3	41.077	Jan	PFRR	Lehmacher			
4	41.078	Jan	PFRR	Lehmacher			
5	41.079	Jan	PFRR	Lehmacher			
6	21.139	Jan	PFRR	Bounds	3	0	0
7	36.242	Jan	PFRR	Bounds			
8	40.XXX	Jan	PFRR	Lynch			
9	36.207	Jan	WSMR	Cruddace			
10	36.XXX	Spring	WMSR	Bock			
11	36.XXX	April	WSMR	McCandliss			
12	41.XXX	July	WFF	Goyne			
13	36.XXX		WSMR	Hassler			
14	36.XXX		WSMR	Kankelborg			
15	36.XXX		WSMR	Judge			

FY10 Planning Manifest

	Mission	Launch Date	Site	PI	TAA Required	TAA Submitted	TAA Approved
1	36.XXX	Oct	WSMR	Nordseick			
2	36.XXX	Nov	WSMR	Green			
3	36.XXX	Jan	PFRR	Bailey			
4	36.XXX	July	WSMR	Kankelborg			
5							
6							
7							
8							
9							
10							
11							
12							

Potential Future Foreign Operations

- Norway
  - Continued auroral research
  - High potential for missions in next two to five years
- Australia
  - Potential support for Air Force Research Laboratory (AFRL) hypersonics testing
  - Moderate potential for missions in one to five years
- Sweden
  - Moderate potential for missions in next two to five years

Export Control Plan

The NASA Sounding Rocket Program is committed to
compliance with U.S. Export Control Laws and Regulations

- NASA will obtain export licenses for rocket vehicles and payloads
- Support equipment will be exported consistent with 22 CFR 126.4(a)
- Foreign nationals from 22 CFR 126.1 Countries will not participate in these programs
- The NSROC contractors will obtain Technical Assistance Agreements (TAA's) for all defense services performed in foreign countries
- The NSROC contractors will obtain TAA's for all missions involving foreign national science team members
  - In the event that a TAA can not be obtained foreign nationals will not be allowed to witness defense services (controlled via a Technology Control Plan)

Motor Shipments

- Rocket motors are placed in separate certified shipping boxes which are then place in a 20’ container
  - A DOT seal is placed on the container when commercial shipping is used
  - Individual motor containers will be sealed with a tamper seal
- When secure storage for the entire shipping container is not possible, the foreign range personnel will break the external seal
  - The individual sealed motor containers will be placed in the secure hazardous storage facility
- The motor containers are opened (seals broken) by NSROC personnel upon arrival at the range
- Rocket motor ignition systems are shipped separately (with the payload hardware)

MTCR Category I; Item 1

Category	Item	Description
I	1	COMPLETE DELIVERY SYSTEMS
	1.A.1.	Complete rocket systems (including ballistic missile systems, space launch vehicles, and sounding rockets) capable of delivering at least a 500 kg "payload" to a "range" of at least 300 km.
		Black Brant IX ; Black Brant X ; Black Brant XI ; Black Brant XII Stages shipped in separate containers. Upper stage ignition systems are shipped separately as part of the payload shipment. Complete rocket system never shipped as a complete assembly.
	1.B.1.	“Production Facilities" specially designed or modified for the systems specified in 1.A.
		Rocket motors are not produced at the Wallops Sounding Rocket facility, but payload hardware is built and motors are processed.
	1.E.1.	"Technology", in accordance with the General Technology Note, for the "development", "production" or "use" of equipment or "software" specified in 1.A., 1.B., or 1.D.
		Applies to SRs providing defense services for the above

MTCR Category I; Item 2

I	2	COMPLETE SUBSYSTEMS USABLE FOR COMPLETE DELIVERY SYSTEMS
	2.A.1.	Complete subsystems usable in the systems specified in 1.A., as follows:
	2.A. 1.a.	Individual rocket stages usable in the systems specified in 1.A.;
		Talos, Taurus, Black Brant VC, Terrier, Nihka
	2.A. 1.c.	Solid propellant rocket motors or liquid propellant rocket engines, usable in the systems specified in 1.A., having a total impulse capacity equal to or greater than 1.1 x 10^6 Ns;
		Black Brant VC, Talos, Taurus, Terrier Mk70

Notes:

- **Recovery systems do not use specially designed electronics. The parabay cover consist of an aluminum plate and AvCoat thermal coating. 2.A.1.b not applicable.**

MTCR Category I; Item 2

2.A.1.d.	Guidance sets', usable in the systems specified in 1.A., capable of achieving system accuracy of 3.33% or less of the "range" (e.g. a 'CEP' of 10 km or less at a "range" of 300 km), except as provided in the Note below 2.A.1. for those designed for missiles with a "range" under 300 km or manned aircraft;
	S-19 Boost Guidance (1-sigma dispersion is ~2.5% based on apogee altitude, ~6km 1-sigma radius for SR trajectory) S-19 in the full guidance mode can reduce dispersions even further (function not used by the Sounding Rocket Program)
2.D.3	“Software”, specially designed or modified for the “use” of ‘guidance sets’ specified in 2.A.1.d
	S-19 Boost Guidance Software (used only at White Sands Missile Range)
2.E.1.	"Technology", in accordance with the General Technology Note, for the "development", "production" or "use" of equipment or "software" specified in 2.A., 2.B. or 2.D.
	Applies to rocket motors (2.A.) used in conjunction with the sounding rocket program – key word “use”

Notes:

- Thrust vector control not used thus 2.A.1.e does not apply to sounding rockets
- 2.B does not apply because the program does not produce the rocket motors. “Specially Designed” does not apply

Back-up

Sounding Rocket Motors

Motor	Total Impulse (N-sec)
Talos	2,258,090
Black Brant	2,250,018
Terrier MK70	1,648,097
Taurus	1,610,900
Nihka	817,785
Orion	< Nihka

Guidance

- ACS
  - Cold gas systems do not have the control authority to guide the vehicle
  - Exoatmospheric reorientation of the final stage is possible, but impact dispersion is on the order of 33 km (50/50 circular bivariant dispersion needs to be ~9.7 km)
  - Concusion: Not Category I
- S-19
  - Systems are only used at White Sands Missile Range
  - For an 85 deg QE flight (typical for a SR flight) dispersion w/ an S-19 is ~ 6km
  - Reducing QE to achieve 300 km impact range w/ 500 kg would tend to reduce dispersion
  - While the NSRP does not employ the full capability of the S-19 system, it is capable of full guidance for 40 seconds
  - Conclusion: Category I