National Aeronautics and Space Administration

Sounding Rockets

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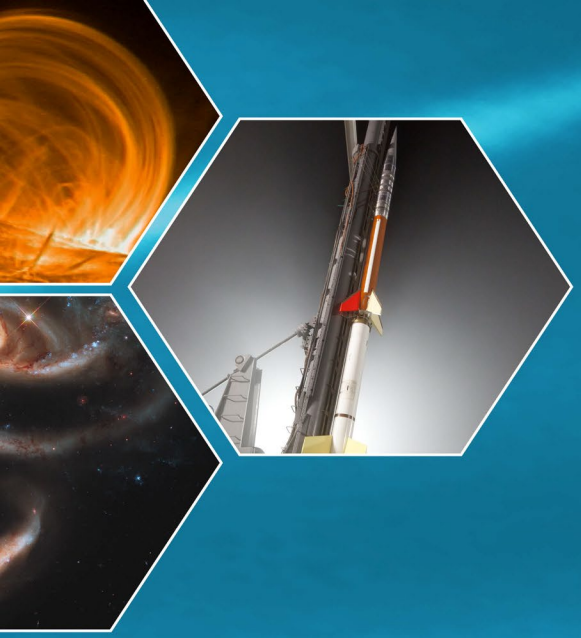
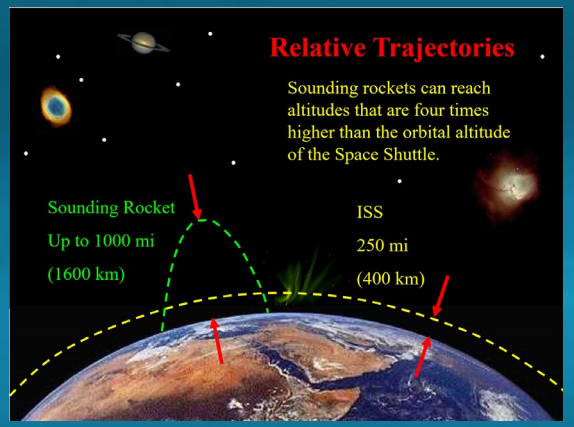
BrainLink 2024

November 21st, 2024



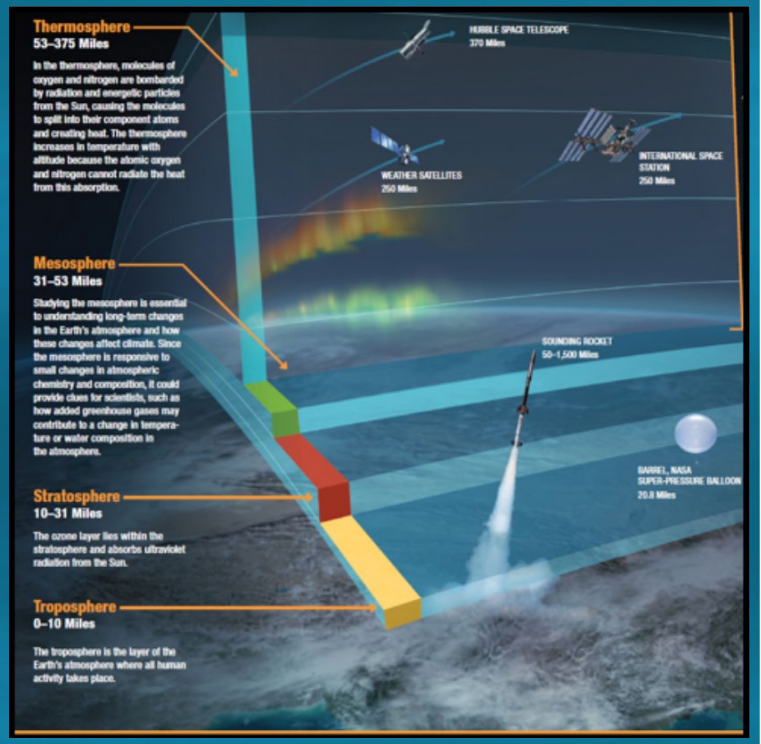
Sounding Rockets Introduction

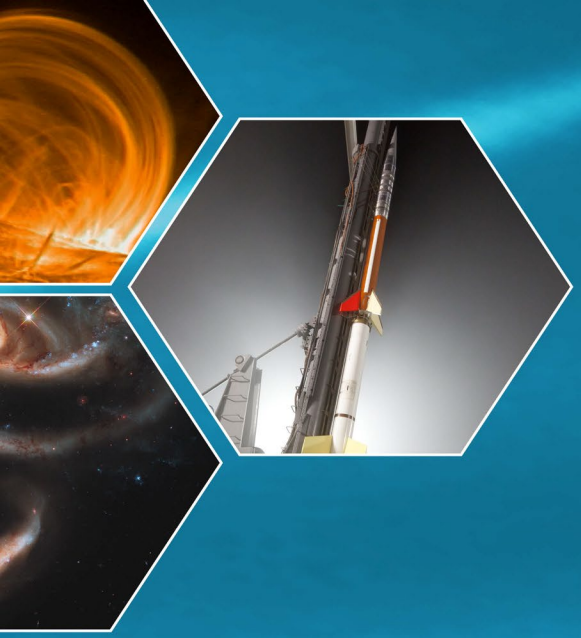
- A sounding rocket is a vehicle that carries scientific payloads on a suborbital trajectory
- Suborbital trajectories are parabolic and do not reach orbital velocities
- Sounding rockets are spin-stabilized and often unguided
- Sounding rockets carry payloads up to 2,000 pounds to sub-orbital apogee altitudes between 100 km to 1,400 km (62 – 870 miles)
  - Up to 20 minutes of ballistic flight
  - Altitudes can reach 4x higher than the ISS orbits
- Target of 85% mission assurance success
  - Enables the program to conduct cutting edge science and test new technologies and new instruments



Why Sounding Rockets?

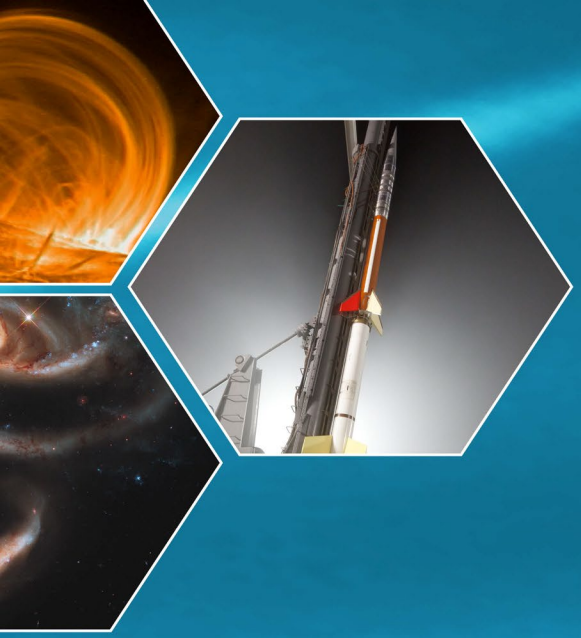
- NASA Sounding Rockets Program offers a quick-turn around and low-cost access to space for the science community
  - Utilize military surplus rocket motors
  - Accept higher technical risk
- Can place instruments directly into regions where the science is occurring for in situ measurements
  - World-wide mobile operations
- Can measure regions of the atmosphere (mesosphere and lower thermosphere) that are too low to be sampled directly by orbiting spacecraft and too high to be sampled directly by balloons or aircraft
- Excellent platform to develop, fly, and validate new science instruments that will eventually fly on a satellite
- Excellent way to train pipeline of scientists for future orbital missions





Nature of the Program

- Located at NASA Wallops Flight Facility, Virginia
- Funded by NASA Science Mission Directorate, Heliophysics Division
- Support all NASA Science Divisions: Heliophysics, Astrophysics, and other NASA Directorates, e.g. Space Technology
- Also support other U.S. Government Agencies, e.g. Department of Defense
- Frequent internal technology development missions
- Frequent Education missions (RockOn, RockSat)
- 40-50 missions in development at any given time
- 15-20 flights/year at locations around the world
- Execution: NASA Sounding Rocket Operations Contract (NSROC)



Mission Identification

- Customer Funded
  - NASA enters into an agreement with other US government and commercial entities.
  - Customer is responsible for funding all payload development and launch operations costs.
- NASA Grants
  - Individual Principal Investigators (typically from a university) apply for a NASA grant via the Research Opportunities in Space and Earth Sciences (ROSES) in two proposal categories 1) Heliophysics Low-Cost Access to Space (LCAS) and 2) Astrophysics Research and Analysis (APRA). PI's are US citizens, but foreign nationals can be Co-Investigators.
  - The NASA grant funds the development of the science instruments and science team support. The NASA Sounding Rocket Program funds the launch vehicle, payload development, and launch operation services (including range costs).
- Programmatic Developments
  - The Sounding Rocket Program funds bi-annual technology development missions.
  - The Sounding Rocket Program funds 2 annual student education missions.


Services Provided

Mission Management & Operations

- Interface to mission stake holders
- Team oversight
- Planning & Scheduling
- Progress Reporting

Engineering Support

- Electrical
- Mechanical
- Launch Vehicles & Propulsion
- Guidance, Navigation & Control
- Flight Performance
- Environmental Testing

Manufacturing

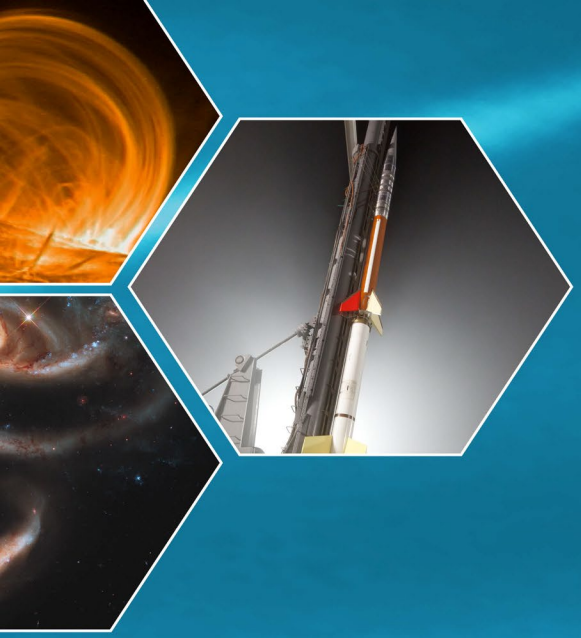
- Machine Shop
- Electrical Manufacturing
- Launch Vehicle Assembly
- Mechanical Assembly
- Quality Control
- Functional Testing

Payload systems

- Telemetry
- Power
- Recovery system
- Guidance, Navigation & Control systems
- Shutter door

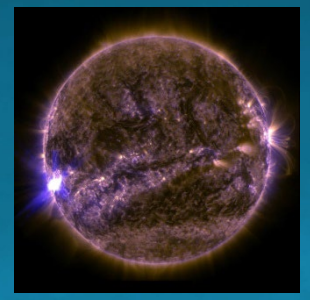
Launch Operations

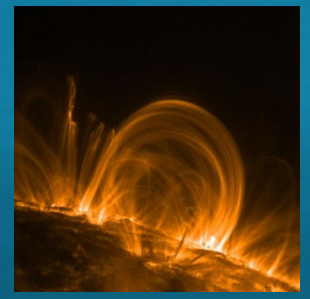
- **Vehicles**
- **Launchers**
- **Remote site operations**

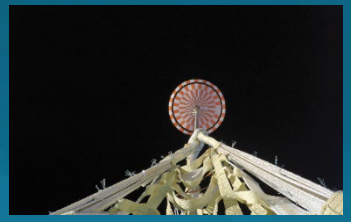


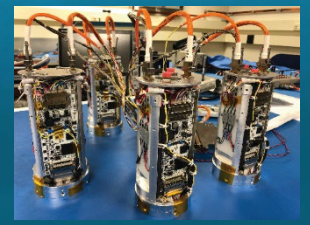
Types of Missions

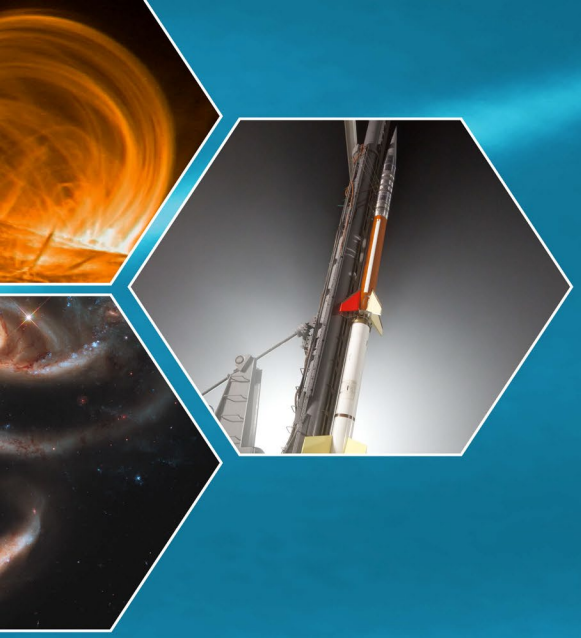
- Geospace (Plasma Physics)
- Solar Telescopes
- Astronomical Telescopes
- High Speed Aerodynamics and Propulsion
- Reentry and Descent
- Technology Development
- Educational





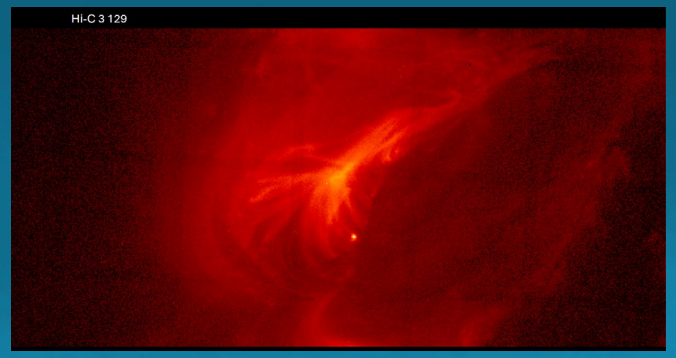



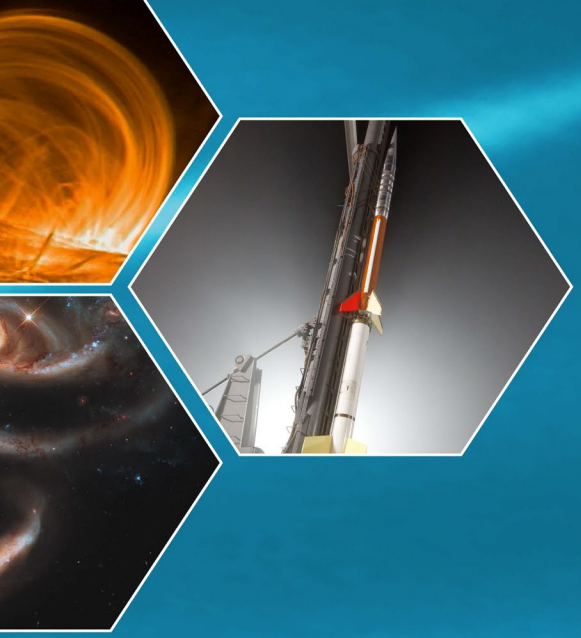




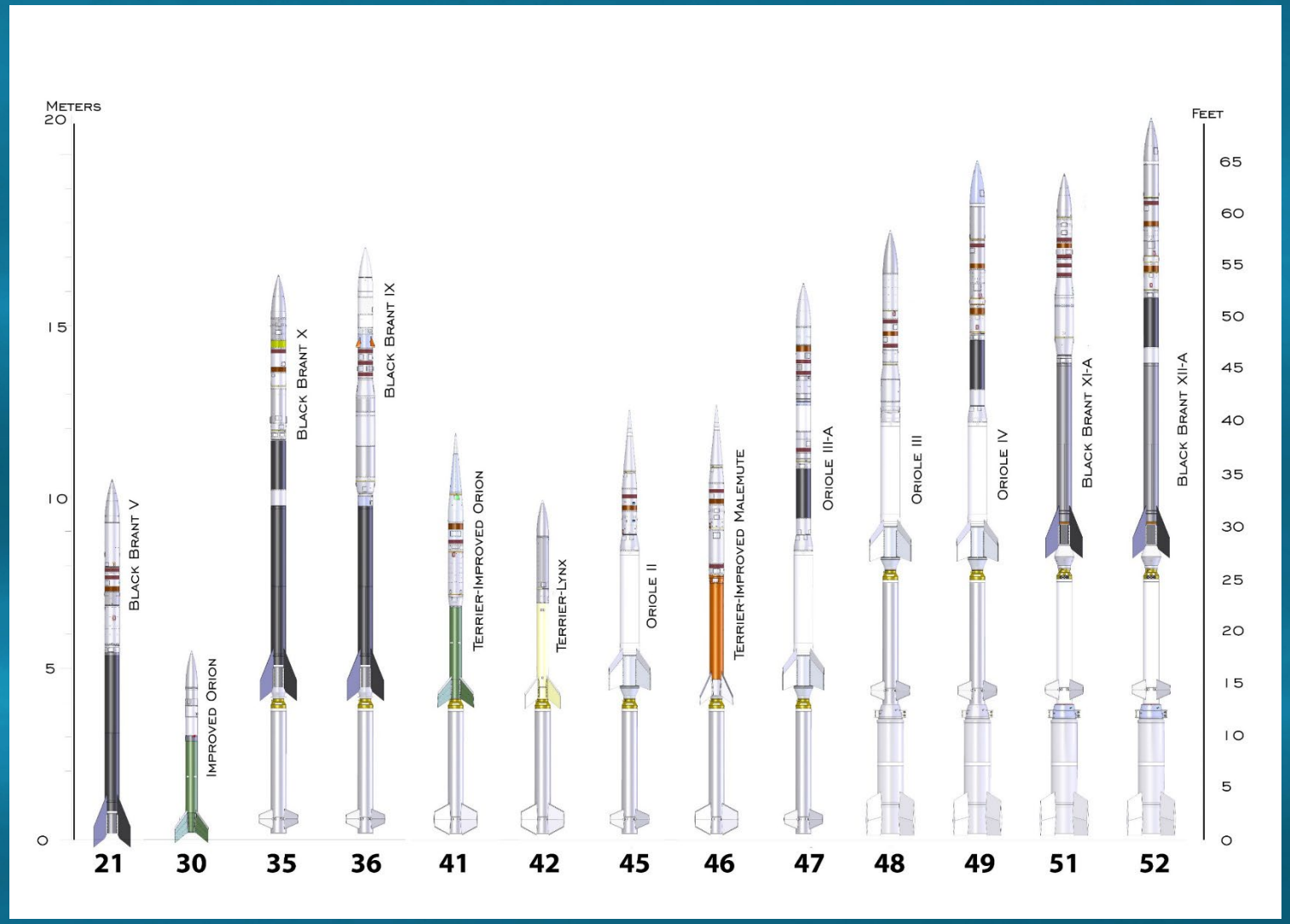
Recent Highlight Missions

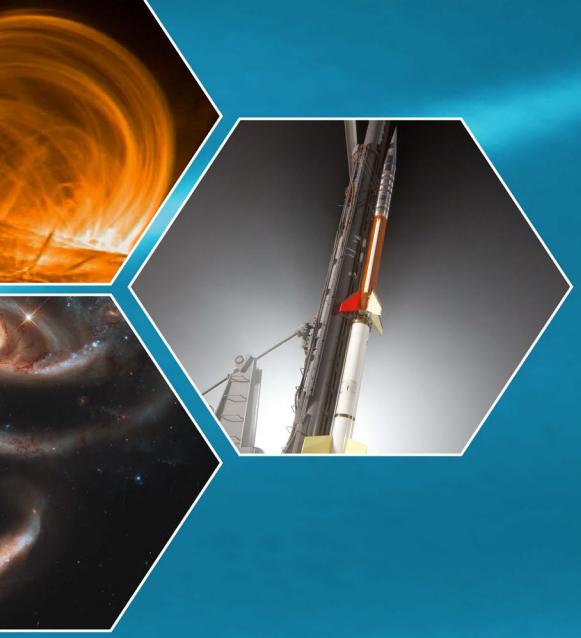
- Solar Flare Campaign – FOXSI & Hi-C Flare
  - Co-observation of M-class flare with each other and SDO from Poker Flat Research Range (PFRR) Fairbanks, Alaska
- Endurance – Svalbard, Norway
  - First successful detection of Earth's ambipolar electric field
  - Results recently published in *Nature*
- Eclipse Campaign
  - Studied ionospheric changes during eclipse – with ejected sub-payloads
  - 3 missions from WSMR Oct '23
    - Prior to peak, at peak, and after peak
    - Recovered
  - 3 missions from WFF Apr '24
    - Prior to peak, at peak, and after peak



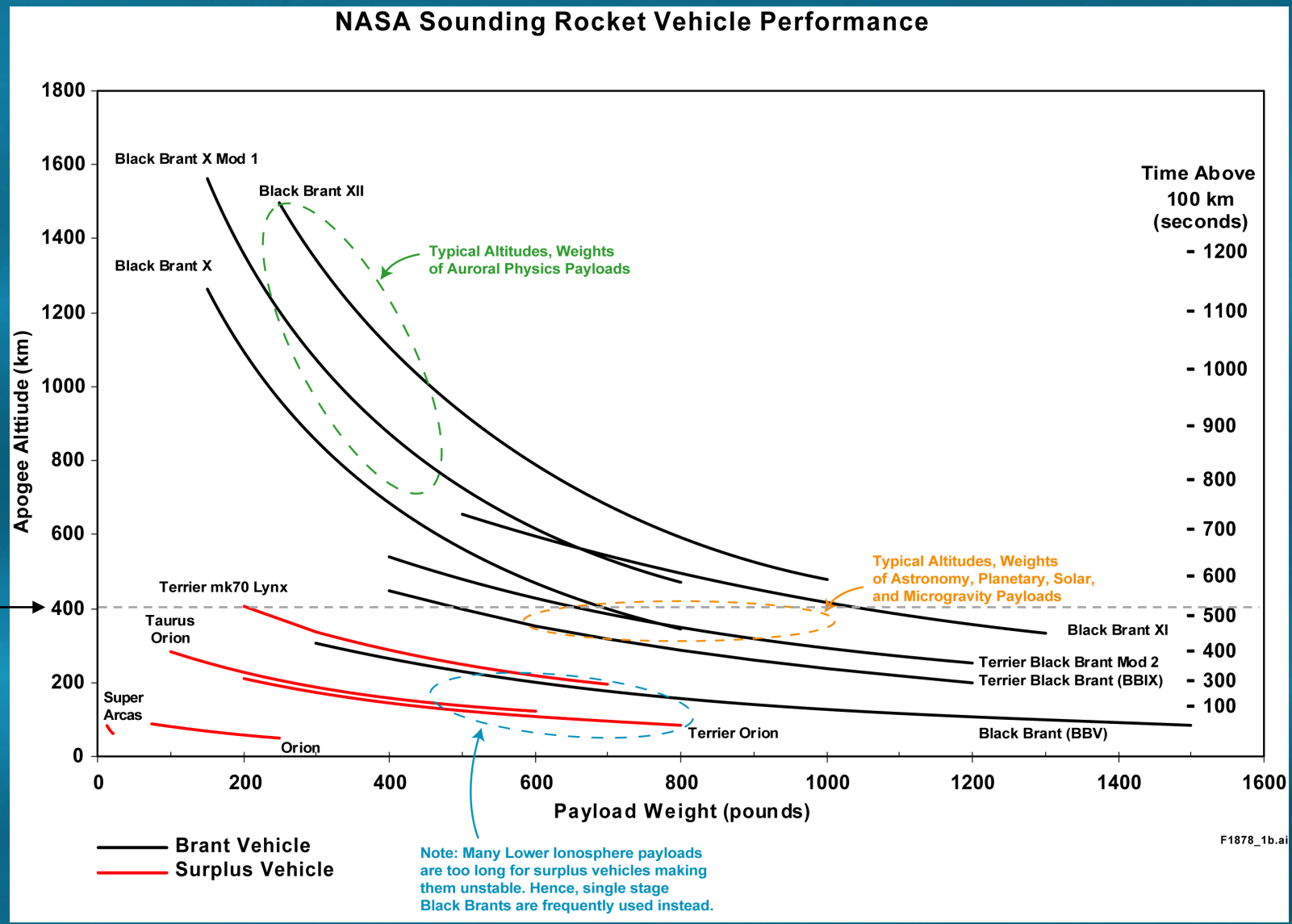


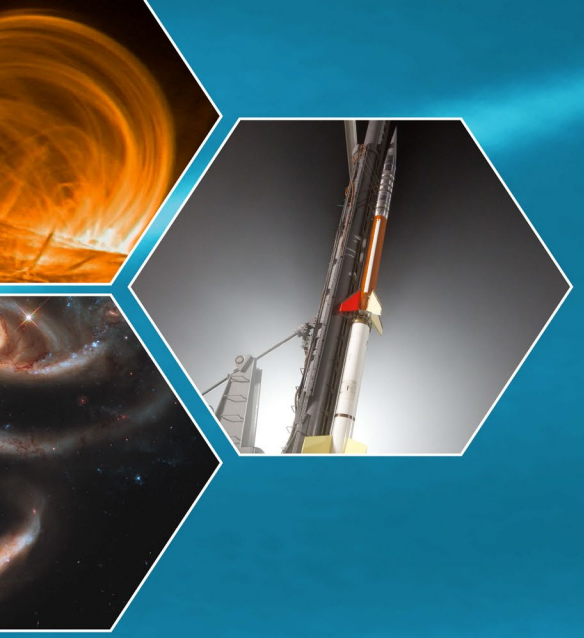
Launch Vehicles





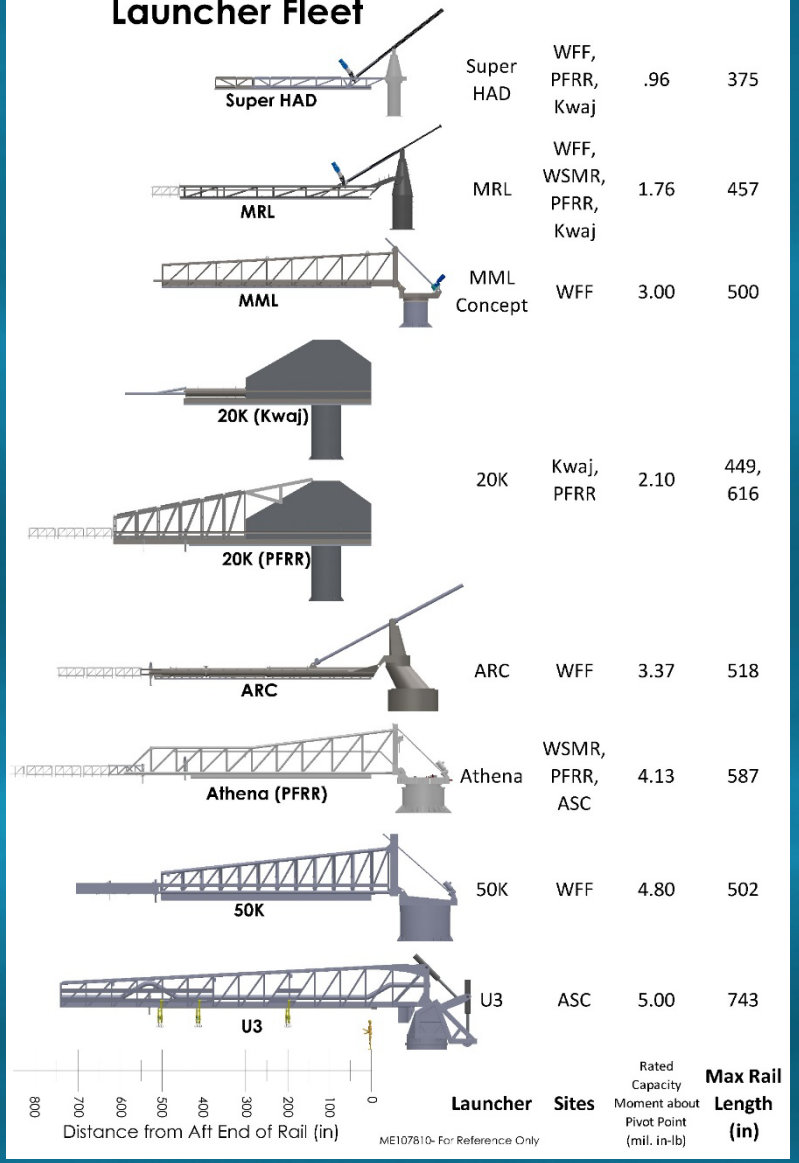
Vehicle Performance



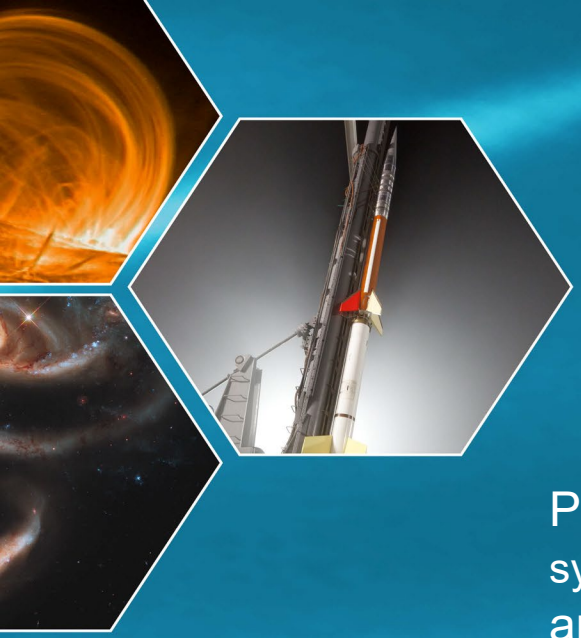


Launcher Fleet

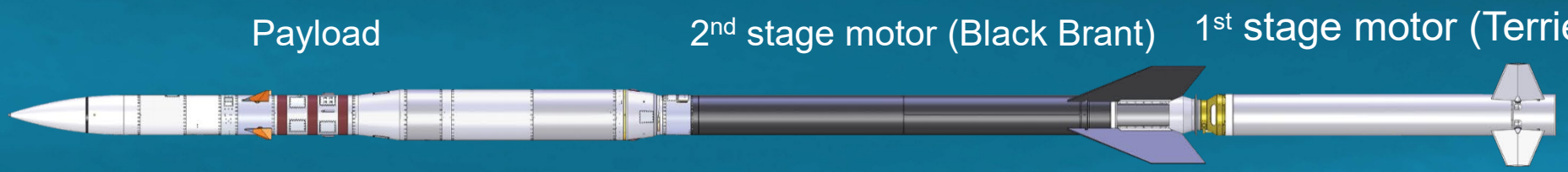
NASA's Sounding Rocket Program Launcher Fleet



Launcher	Sites	Rated Capacity Moment about Pivot Point (mil. in-lb)	Max Rail Length (in)
Super HAD	WFF, PFRR, Kwaj	.96	375
MRL	WFF, WSMR, PFRR, Kwaj	1.76	457
MML Concept	WFF	3.00	500
20K	Kwaj, PFRR	2.10	449, 616
ARC	WFF	3.37	518
Athena	WSMR, PFRR, ASC	4.13	587
50K	WFF	4.80	502
U3	ASC	5.00	743



Payload Components*



Payload support systems include recovery systems, telemetry, boost guidance systems, Attitude Control Systems, deployment mechanisms, and a shutter door among others. Mission requirements determine which support systems are used.

Parachute Recovery
The parachute recovery system houses the parachute and deployment mechanism.

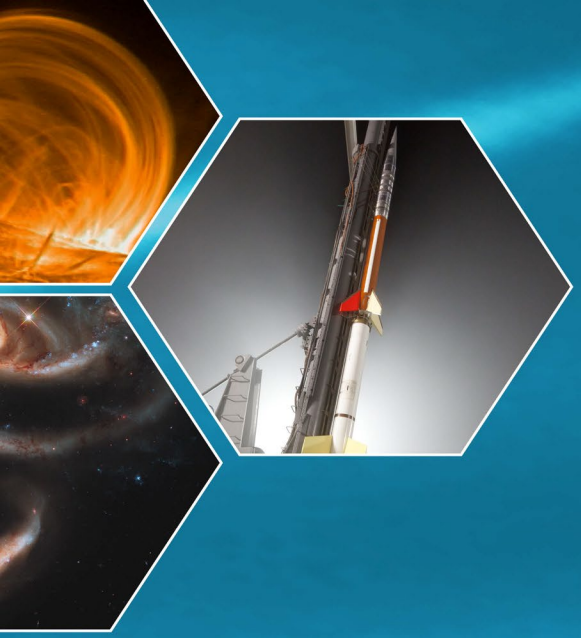
ACS
Attitude Control Systems (ACS) are used to align the payload in space.

Telemetry (TM)
The Telemetry system enables experiment data to be transmitted to a ground station.

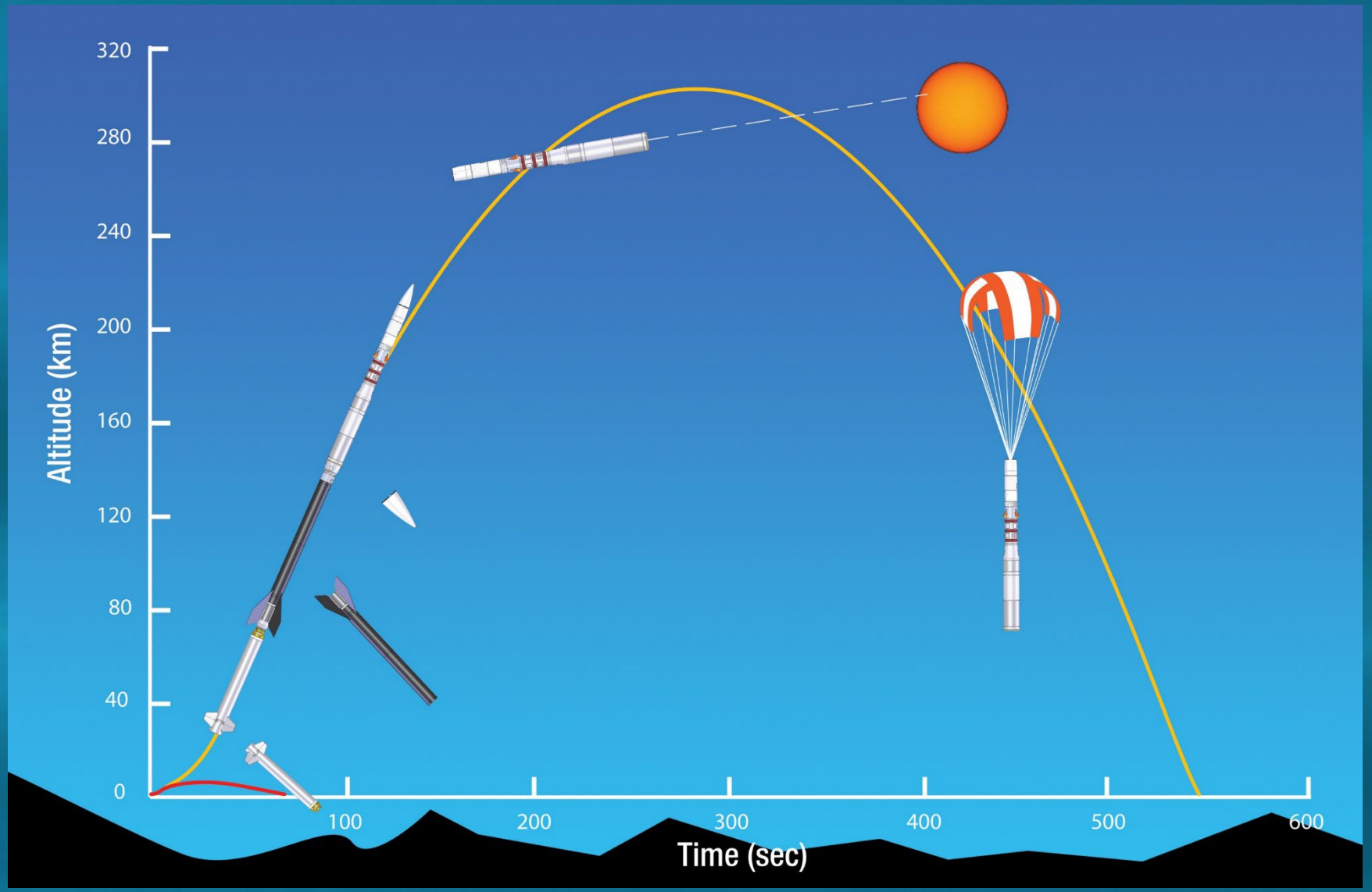
Experiment Section
This section houses the scientific instruments.

Shutter Door
Used mainly for telescope payloads, the shutter door is opened in space allowing the telescope to see the target of investigation.

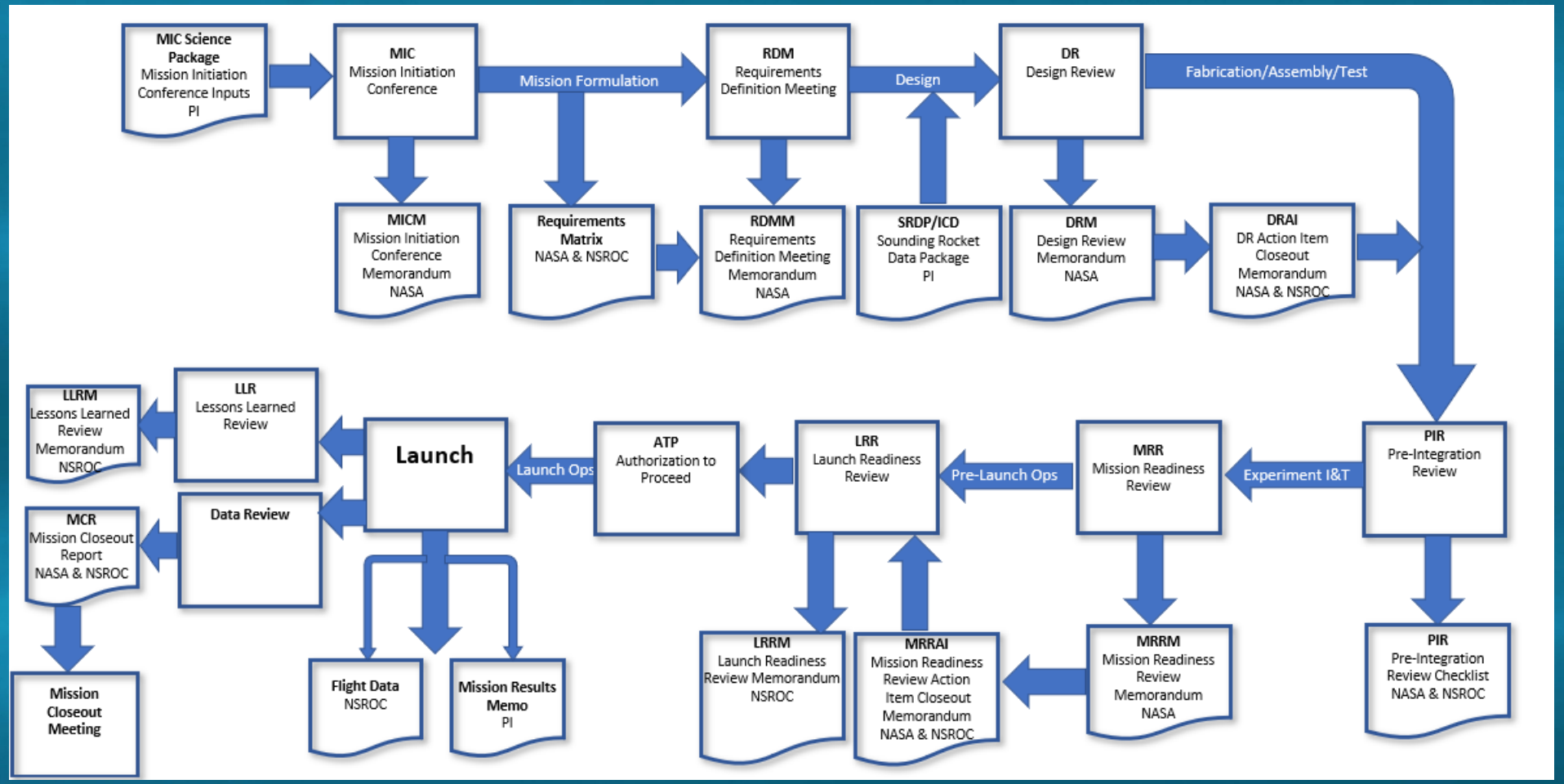
**Representative telescope payload*



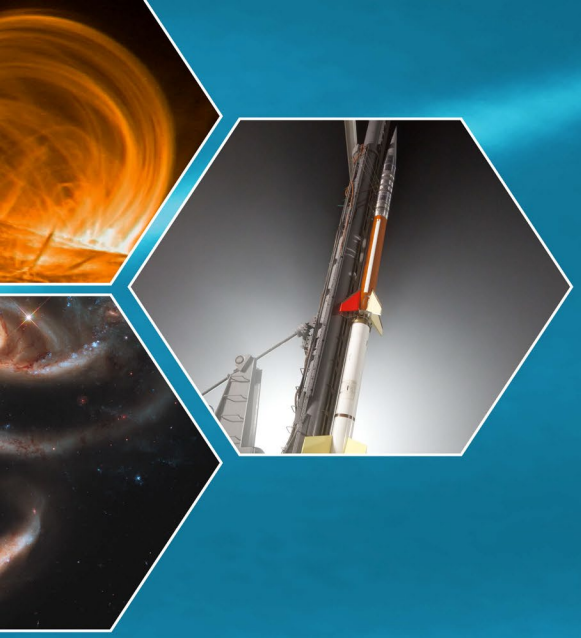
Simple Flight Profile



Sounding Rocket Mission Lifecycle

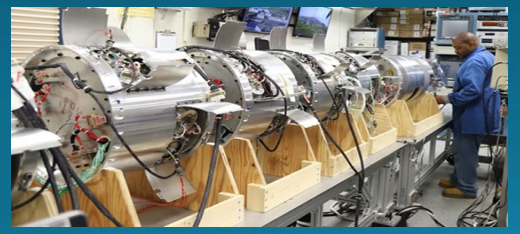


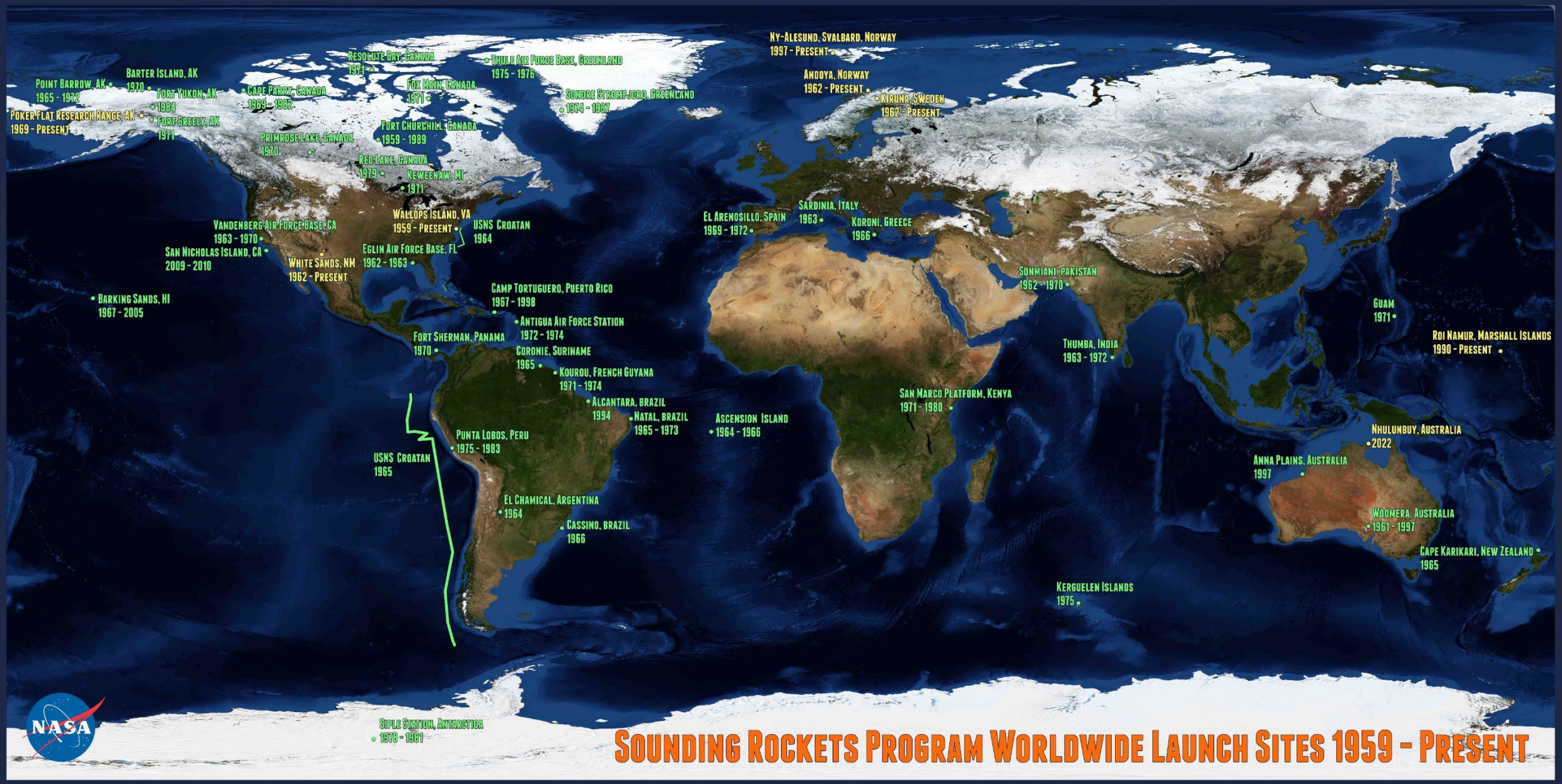
Mission lifecycle averages ~2 years



Integration and Testing

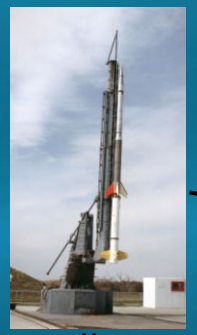
- Integration
  - Subsystem (NASA/NSROC)
  - Handshakes with instrument
  - Full payload integration
- Testing & Evaluation
  - Sequence Testing
  - GPS Outdoor
  - Magnetic Calibration
  - Electro Magnetic Interference (EMI)
  - Mass Properties
  - Vibration
  - Balance
  - Bend
  - Deployment




Point Barrow, AK
1965 - 1972
Barter Island, AK
1970
Fort Yukon, AK
1984
Fort Greely, AK
1971
Poker Flat Research Range, AK
1969 - Present
Resolute Bay, Canada
1971
Cape Parry, Canada
1969 - 1982
Fox Main, Canada
1971
Primrose Lake, Canada
1970
Fort Churchill, Canada
1959 - 1989
Red Lake, Canada
1979
Keweenaw, MI
1971
Thule Air Force Base, Greenland
1975 - 1976
Sondre Strompjord, Greenland
1974 - 1987
Ny-Alesund, Svalbard, Norway
1997 - Present
Andoya, Norway
1962 - Present
Kiruna, Sweden
1962 - Present
Wallops Island, VA
1959 - Present
USNS Croatan
1964
Vandenberg Air Force Base, CA
1963 - 1970
San Nicholas Island, CA
2009 - 2010
White Sands, NM
1962 - Present
Eglin Air Force Base, FL
1962 - 1963
El Arenosillo, Spain
1969 - 1972
Sardinia, Italy
1963
Koroni, Greece
1966
Sonmiani, Pakistan
1962 - 1970
Barking Sands, HI
1967 - 2005
Camp Tortuguero, Puerto Rico
1967 - 1998
Antigua Air Force Station
1972 - 1974
Fort Sherman, Panama
1970
Coronie, Suriname
1965
Kourou, French Guyana
1971 - 1974
Alcantara, Brazil
1994
Natal, Brazil
1965 - 1973
Ascension Island
1964 - 1966
San Marco Platform, Kenya
1971 - 1980
Thumba, India
1963 - 1972
Guam
1971
Roi Namur, Marshall Islands
1990 - Present
Punta Lobos, Peru
1975 - 1983
USNS Croatan
1965
El Chamical, Argentina
1964
Cassino, Brazil
1966
Nhulunbuy, Australia
2022
Anna Plains, Australia
1997
Woomera, Australia
1961 - 1997
Cape Karikari, New Zealand
1965
Kerguelen Islands
1975
Siple Station, Antarctica
1978 - 1981
NASA
Sounding Rockets Program Worldwide Launch Sites 1959 - Present

World-Wide Operations

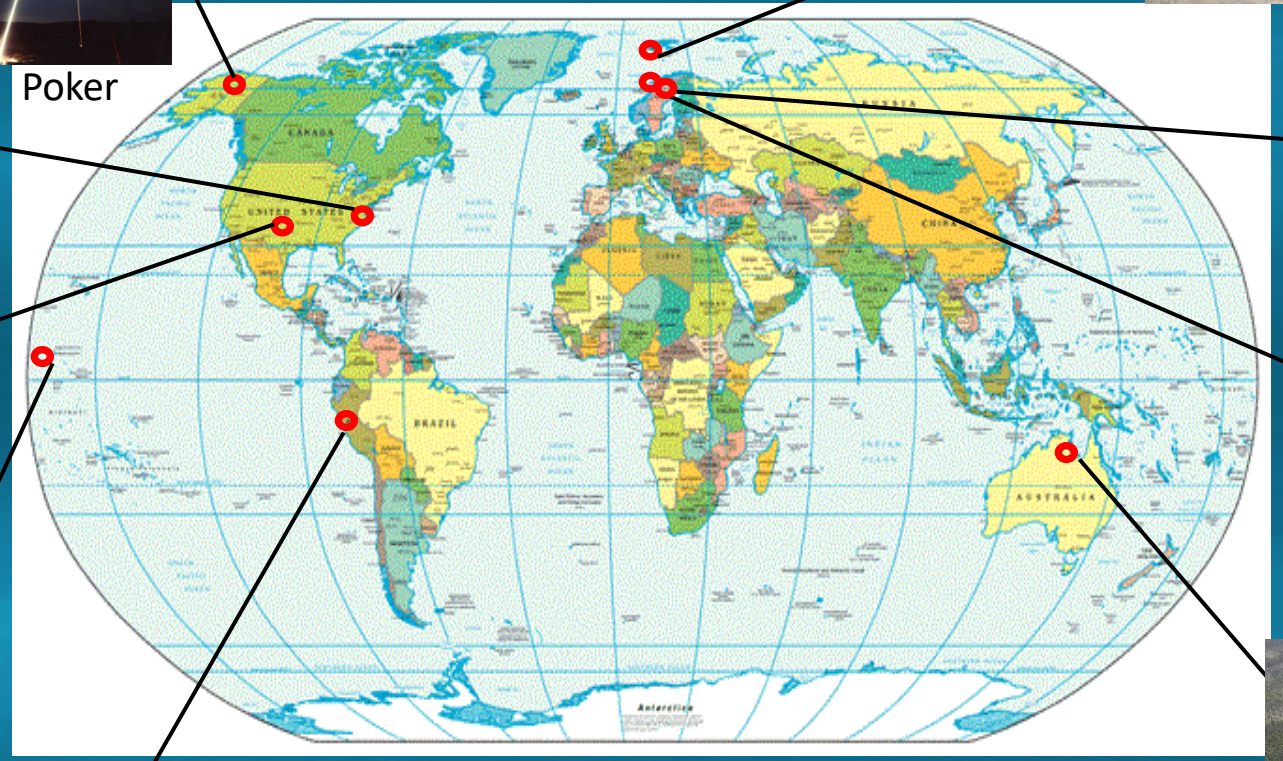
Poker



Wallops

White Sands

Kwajalein



Peru

Svalbard

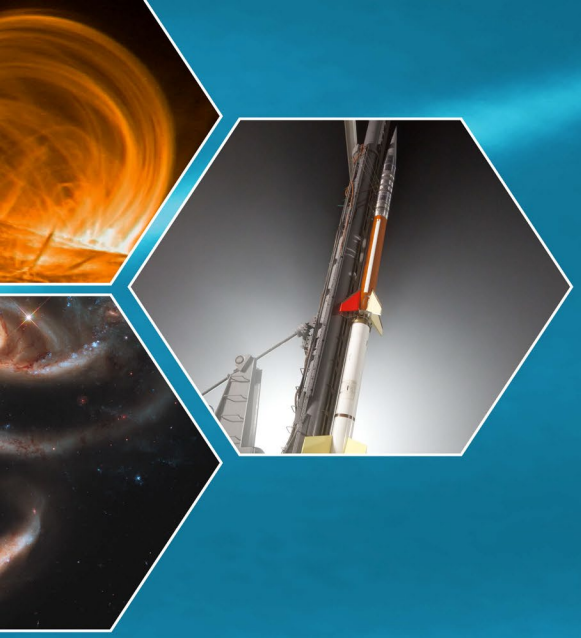
Kiruna, Sweden

Andenes, Norway

Australia

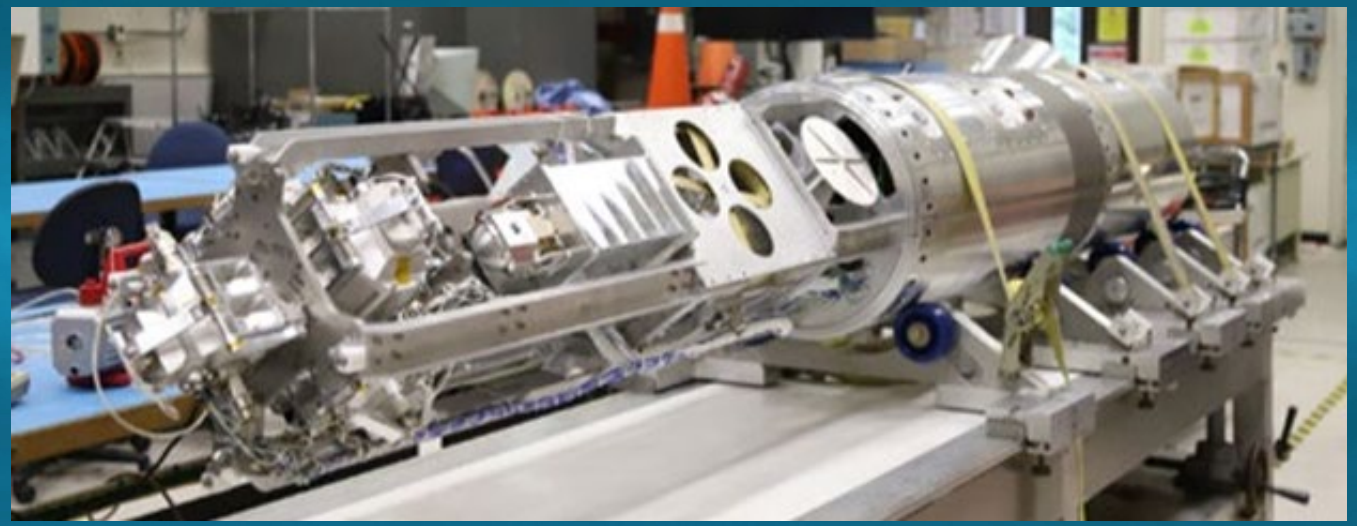
The Sounding Rocket Program

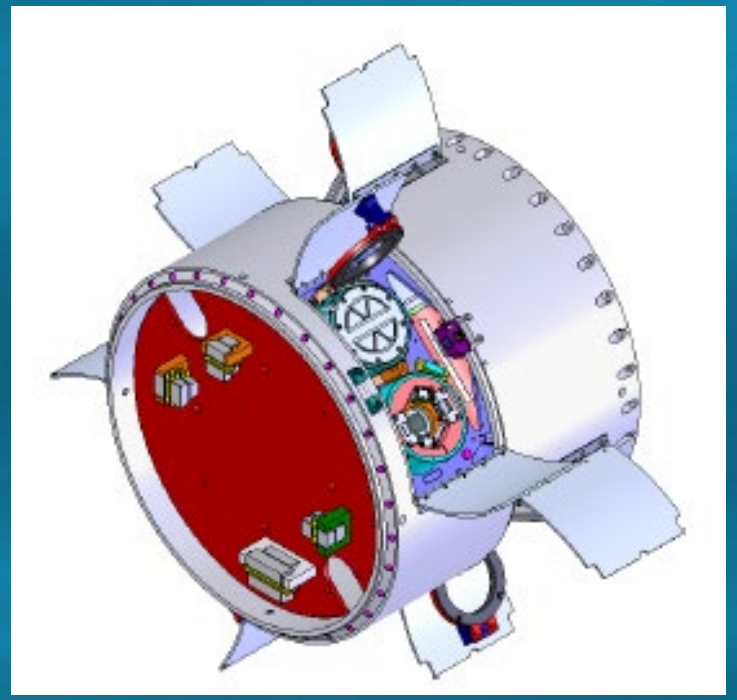
“goes to where the science is…”

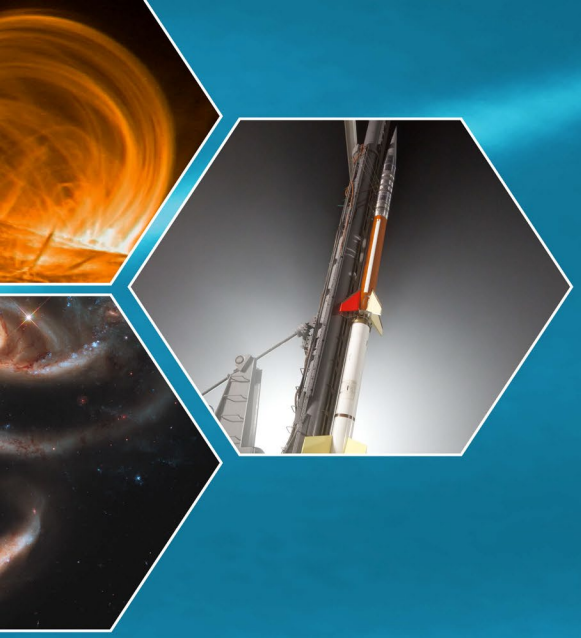


Payload Systems - Mechanical

- Experiment Mounting
  - Vacuum sections, exposed deck structures, booms
- Shutter Doors
- Crush Bumpers
- Deployments
  - Booms
  - Ejectables – Spring or rocket propelled



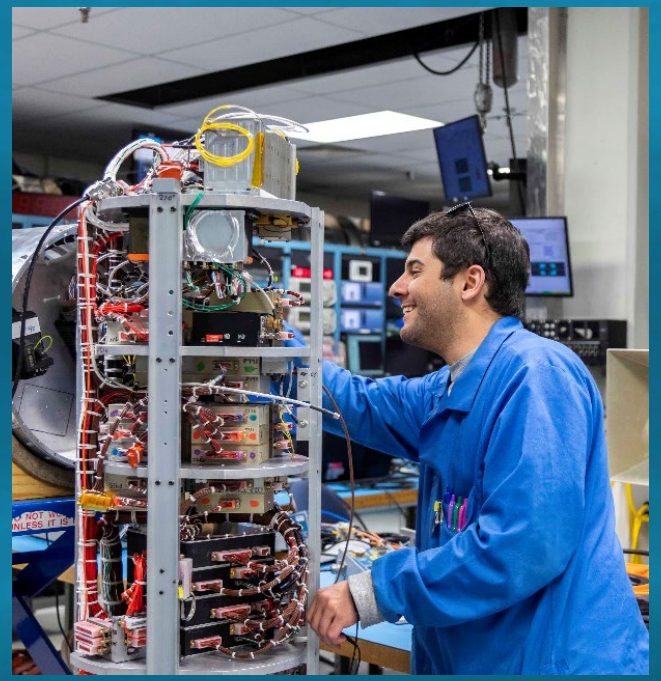


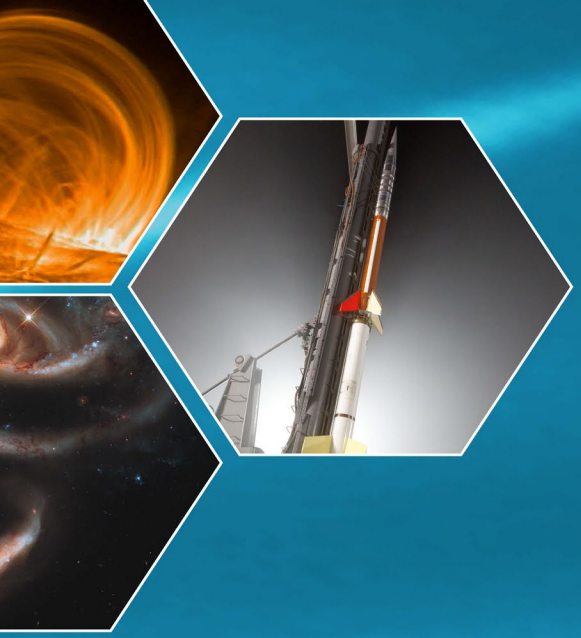


Payload Systems – Telemetry/Power

- Power
  - Unregulated battery power, switching between external power and battery
    - Various battery sizes to support range of power consumption
  - Regulated power
- In-flight events
  - Timed – relative to launch indication
  - Altitude Driven – requires navigation input
- Telemetry
  - PCM Matrix with variety of input types

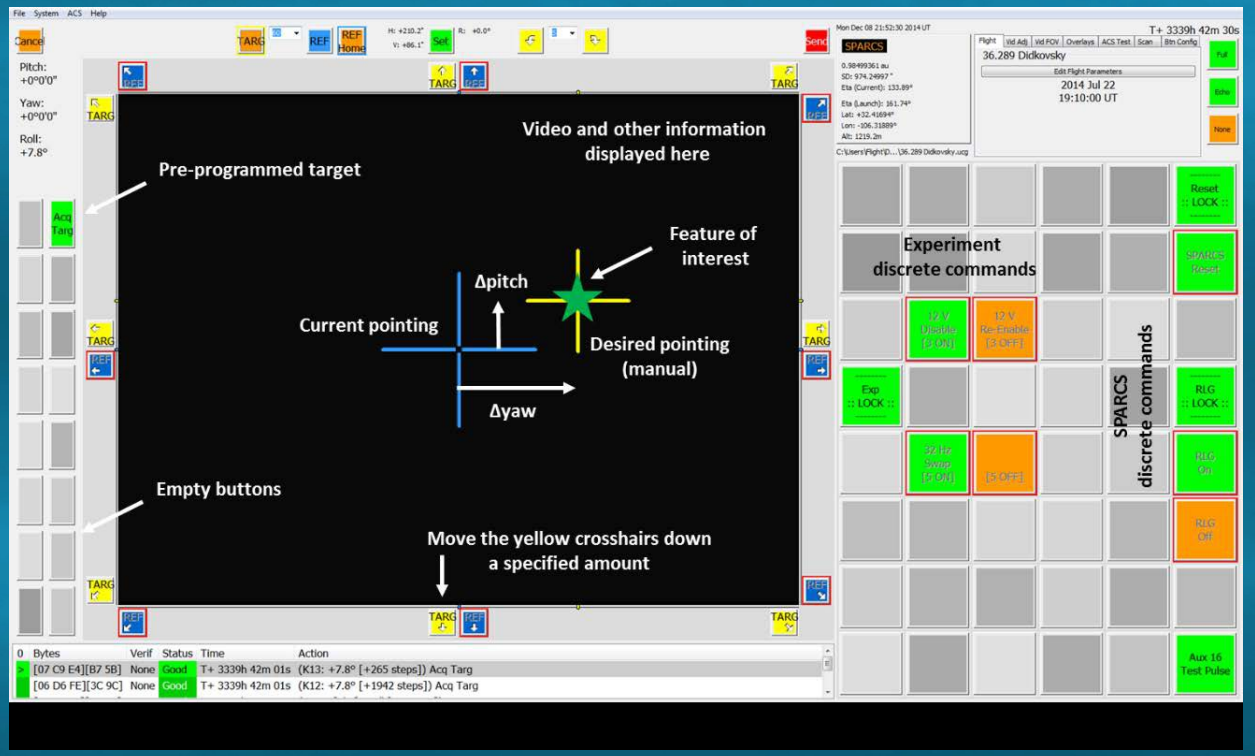
    Analog, Serial, Parallel, Asynchronous Serial, other device specific options
  - EVTM – Ethernet based
  - Baseband – Modulate an analog signal

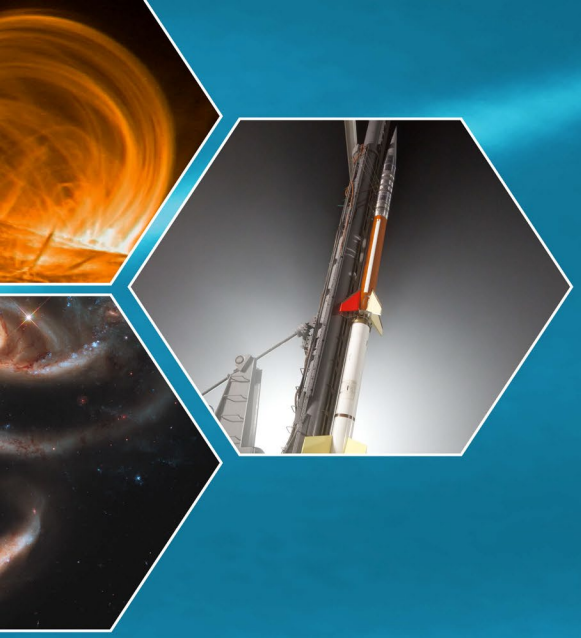




Payload Systems – Command Uplink

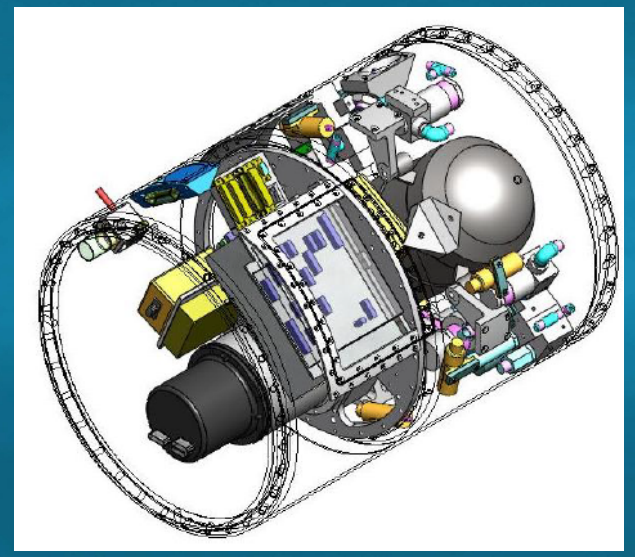
- Discrete commands – relay closures
- Experiment Serial commands
- ACS Targeting commands
  - Maneuver switching
  - Pointing refinement
  - Can incorporate science video into console display

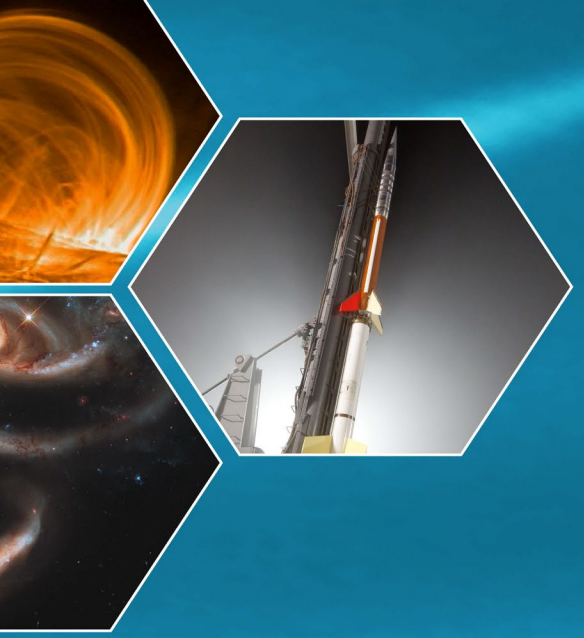




Payload Systems - ACS

- Solar Pointing Attitude Rocket Control System (SPARCS)
  - Sun pointing – sun center or offset
  - Arc-second stability
  - Can be augmented with uplink to deliver arc-second accuracy
- Celestial Attitude Control System (CACS)
  - Night sky targets
  - Arc-second stability
  - Can be augmented with uplink to deliver arc-second accuracy
- NSROC Inertial Attitude Control System (NIACS)
  - Inertial targeting – including in-flight target calculation based on trajectory
  - Supports spinning and non-spinning control
  - 2-degree accuracy
  - Stability highly dependent on payload and mission configuration
- NMACS
  - Spinning alignment to sensed magnetic field
  - 2-degree accuracy
  - Stability highly dependent on payload and mission configuration





Thank You!