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NASA SOUNDING ROCKET SURVEY FOR FUTURE DEVELOPMENT

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October 1966

Goddard Space Flight Center
Greenbelt, Maryland

SUPPORT REQUIREMENTS SURVEY
FOR THE NASA
NATIONAL SOUNDING ROCKET PROGRAM
OCTOBER 1966

BACKGROUND INFORMATION

SOUNDING ROCKET BRANCH
SPACECRAFT INTEGRATION AND
SOUNDING ROCKET DIVISION

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

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INTRODUCTION

Table I is a tabulation of currently used vehicles, those under development, and those under study. Note that a maximum payload length is not specified for those vehicles under study. For each vehicle type, availability of telemeter DOVAP and recovery systems and the current permissible launch sites are shown. Requirements for systems and launch sites not now available should be listed on the questionnaire.

Chart I shows graphically the performance capabilities of the vehicle-payload systems listed in Table I. Vehicles A through H are those rocket systems under study. The Aerobee 350 and Astrobee 1500 are in development, and will be operational in the near future.

Chart II displays the external configurations of the rockets currently stocked or on order. Note the payload dimensions are the maximum currently allowable.

Chart III is an outline drawing of those vehicles under study, and also includes the two vehicles under development for comparison.

Chart IV describes various control and point systems which are now available or under development for Aerobees and other vehicles.

The Questionnaire covers only major points. Please use the "remarks" section to describe your requirements fully.

The Questionnaire Notes include definitions, a key to abbreviations, and all instructions for completing the Questionnaire.

Further information may be obtained by writing or contacting the following GSFC individuals at:

NASA Goddard Space Flight Center
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Greenbelt, Maryland 20771

Project Manager and Key Contact	Mr. Karl R. Medrow	301-982-4813
Current Vehicles and Launch Sites	Miss E. C. Pressly	301-982-5633
Vehicles – Development and Study	Mr. E. F. Sorgnit	301-982-4865
T/M, Instrumentation and Rocket Position Determining Systems	M. E. E. Bissell	301-982-5871
Control Systems	Mr. W. A. Russell	301-982-4894
Mechanisms, Structures, and Launcher Systems	Mr. G. E. MacVeigh	301-982-4893

Table I
Tabulation of Vehicle Payload Systems

	Launch Site Availability	Systems Now Available for This Rocket: Telemetry	DOVAP RADINT	Payload Recovery
OPERATIONAL VEHICLES				
Boosted Arcas # Stages - 2 P/L Diameter - 4.5" P/L Max Length - 80" Net Payload Weight Range 5 to 16 lbs. Weight 5 lbs 12 lbs 16 lbs Altitude 90 km 80 km 68 km	Not Restricted	FM/FM	No	Land
Nike Cajun # Stages - 2 P/L Diameter - 6.5" P/L Max Length - 80" Net Payload Weight Range 25 to 85 lbs. Weight 25 lbs 50 lbs 85 lbs Altitude 160 km 140 km 125 km	Not Restricted	FM/FM PPM/AM	Yes	Land
Nike Apache # Stages - 2 P/L Diameter - 6.5" P/L Max Length - 80" Net Payload Weight Range 25 to 85 lbs. Weight 25 lbs 50 lbs 85 lbs Altitude 200 km 175 km 150 km	Not Restricted	FM/FM PPM/AM	Yes	Land
Nike Tomahawk # Stages - 2 P/L Diameter - 9" P/L Max Length - 72" Net Payload Weight Range 50 to 150 lbs. Weight 50 lbs 100 lbs 150 lbs Altitude 400 km 310 km 250 km	Not Restricted Except WSMR	FM/FM PPM/AM	No	Land (Planned)
Aerobee 150 # Stages - 2 P/L Diameter - 15" P/L Max Length - 145" Net Payload Weight Range 100 to 350 lbs. Weight 100 lbs 250 lbs 350 lbs Altitude 330 km 200 km 160 km	Wallops Island Ft. Churchill White Sands Mobile Tower Facility	FM/FM PPM/AM	Yes	Land Sea
Javelin # Stages - 4 P/L Diameter - 19" P/L Max Length - 29" Net Payload Weight Range 50 to 150 lbs. Weight 50 lbs 100 lbs 150 lbs Altitude 1200 km 850 km 670 km	Wallops Island Ft. Churchill Pacific Missile Range NATAL (Planned)	FM/FM PPM/AM	No	No
UNDER DEVELOPMENT (See Questionnaire Notes for Further Explanations)				
Astrobee 1500 # Stages - 2 P/L Diameter - 20" P/L Max Length - 58" Net Payload Weight Range 50 to 300 lbs. Weight 50 lbs 140 lbs 300 lbs Altitude 3000 km 2000 km 1200 km	Wallops Island Pacific Missile Range	FM/FM PPM/AM	No	No
Aerobee 350 # Stages - 2 P/L Diameter - 22" P/L Max Length - 198" Net Payload Weight Range 150 to 1000 lbs. Weight 150 lbs 500 lbs 1000 lbs Altitude 500 km 350 km 240 km	Wallops Island White Sands (Planned)	FM/FM PPM/AM	No	Land (Planned)
UNDER STUDY	(PLANNING INPUTS REQUESTED)			
Vehicle A 100 km Rocket # Stages - 1 P/L Diameter - 9" Net Payload Weight Range 50 to 100 lbs. Weight 50 lbs 75 lbs 100 lbs Altitude 110 km 100 km 90 km	Probably Unrestricted	FM/FM PPM/AM	No	Yes
Vehicle B Light Payload 200 km Rocket # Stages - 1 P/L Diameter - 10" Net Payload Weight Range 50 to 100 lbs. Weight 50 lbs 75 lbs 100 lbs Altitude 200 km 180 km 160 km	Probably Unrestricted	FM/FM PPM/AM	Yes	Yes
Vehicle C Heavy Payload 200 km Rocket # Stages - 1 P/L Diameter - 13" Net Payload Weight Range 80 to 250 lbs. Weight 80 lbs 175 lbs 250 lbs Altitude 200 km 140 km 110 km	Probably Unrestricted	FM/FM PPM/AM	Yes	Yes
Vehicle D Moderate Payload 500 km Rocket # Stages - 1 P/L Diameter - 17" Net Payload Weight Range 175 to 500 lbs. Weight 175 lbs 300 lbs 500 lbs Altitude 430 km 350 km 270 km	Wallops Island Ft. Churchill Natal White Sands (Probable)	FM/FM PPM/AM	No	Yes
Vehicle E Very Heavy Payload 500 km Rocket # Stages - 2 P/L Diameter - 27" Net Payload Weight Range 500 to 1500 lbs. Weight 500 lbs 1000 lbs 1500 lbs Altitude 700 km 500 km 350 km	Wallops Island White Sands (Probable for heavier payloads)	FM/FM PPM/AM	No	No
Vehicle F 1000 km Rocket # Stages - 2 P/L Diameter - 10" Net Payload Weight Range 40 to 100 lbs. Weight 40 lbs 60 lbs 100 lbs Altitude 1000 km 930 km 800 km	Wallops Island Ft. Churchill Natal	FM/FM PPM/AM	No	No
Vehicle G 5000 km Rocket # Stages - 3 P/L Diameter - 18" Net Payload Weight Range 15 to 150 lbs. Weight 15 lbs 50 lbs 150 lbs Altitude 8500 km 5000 km 2500 km	Wallops Island Pacific Missile Range	FM/FM PPM/AM	No	No
Vehicle H 20,000 km Rocket # Stages - 4 P/L Diameter - 18" Net Payload Weight Range 15 to 150 lbs. Weight 15 lbs 50 lbs 150 lbs Alt. 30,000 km 20,000 km 9,000 km	Wallops Island Pacific Missile Range	FM/FM PPM/AM	No	No

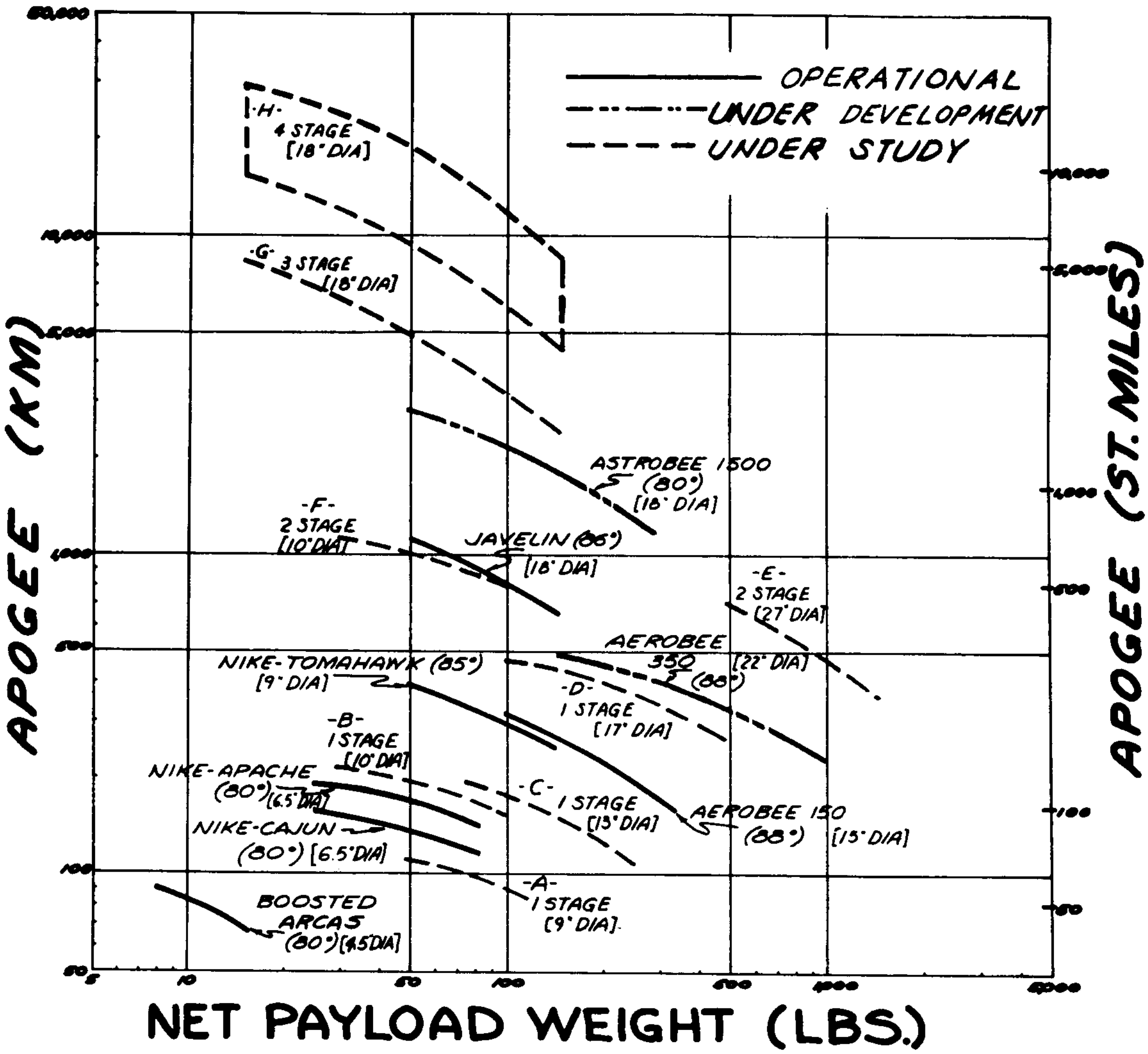

CHART 1—Sounding Rocket Altitude Performance

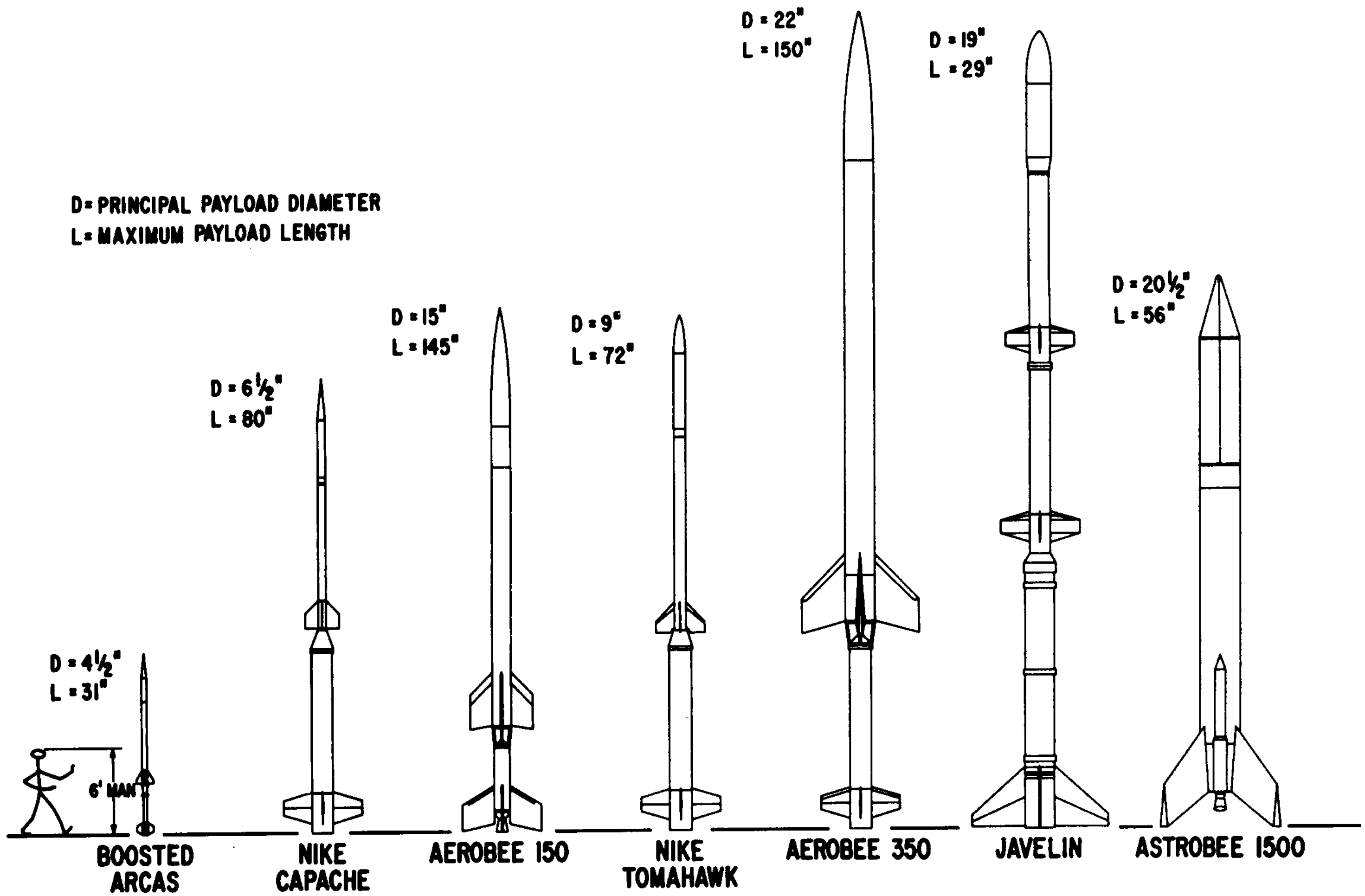

CHART II–NASA Sounding Rocket Vehicles

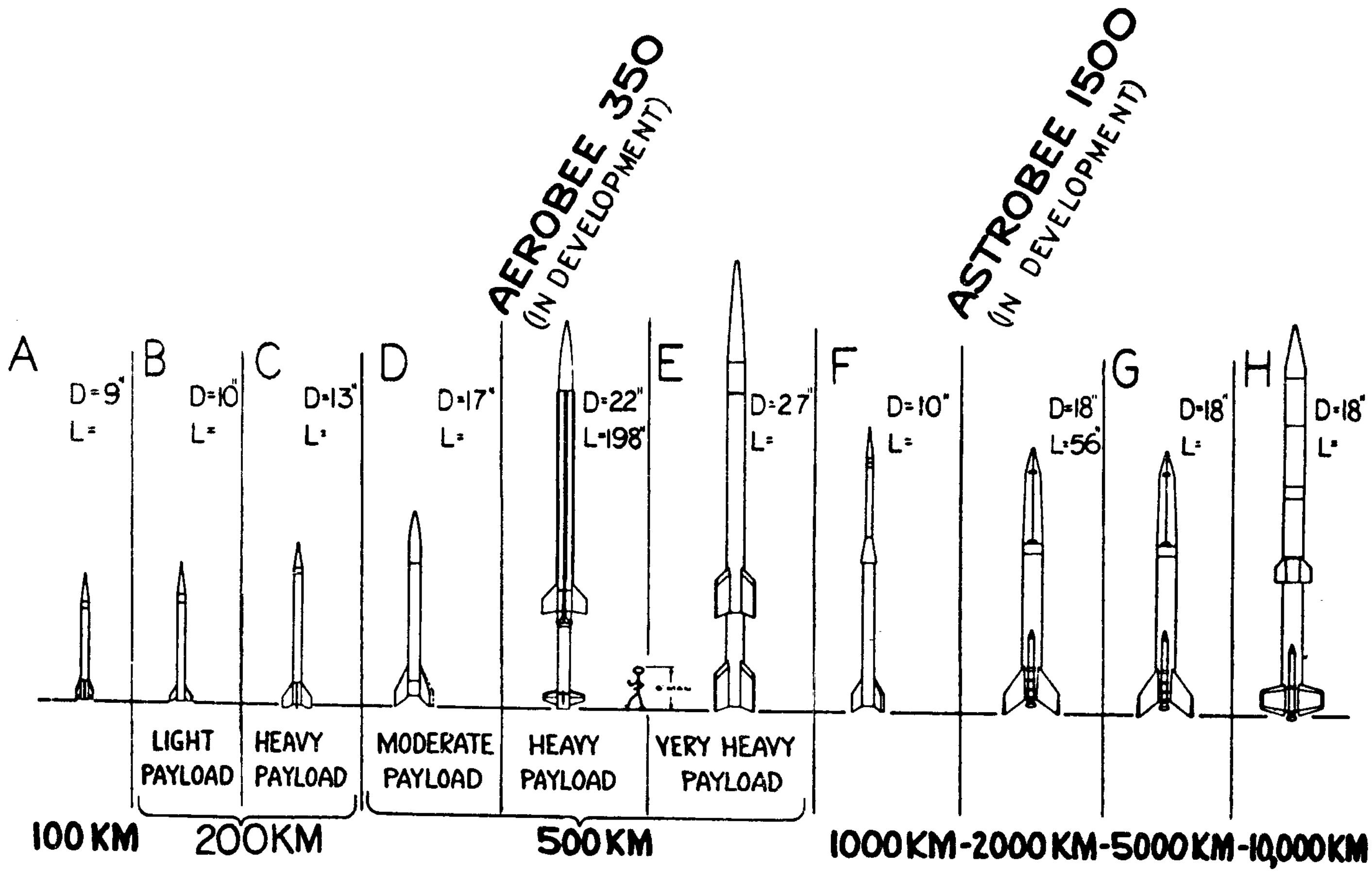

CHART III—Sounding Rockets - Vehicles Under Study

Control System	Cognizant Agency (Manufacturer)	Mode Of Operation
1. STANDARD IACS (Inertial Attitude Control System) (a) With roll stabilized gyro platform (RSP) (b) With gyros strapped down	NASA-GSFC (Space-General)	3 axis-gyro referenced cold gas jet controllec inertially programmed open loop system. Usec for 3 axis coarse stabilization of entire rocke to any desired orientation and for scanning programs. Has programmable multi-target capability.
2. STRAP, STELLAR (Stellar Tracking Rocket Attitude Positioning)	NASA-GSFC (GSFC-Space Gen.)	Uses IACS (System 1) to orient rocket longitudinal axis within 3 degrees of a target star. Control in pitch and yaw is then switched to a startracker and system homes on star using auxiliary (low thrust) jet system. Several stars may be investigated in one flight.
3. STRAP, SOLAR	NASA-GSFC (GSFC-Space Gen.)	Simplified version of system #2 whereby system slews to a solar capture using a modified control system #1(b). After solar capture system switches to a low thrust system for fine limit cycle.
4. FINE ATTITUDE CONTROL SYSTEM (FACS)	NASA-GSFC (Space-General)	Operates similar to STRAP system #3 but uses advanced design IACS. Can use either a solar or stellar tracker. Multiple stellar targets may be programmed on one flight.
5. SPARCS (Solar Pointing Aerobee Rocket Control System)	NASA-AMES RESEARCH CENTER (Lockheed Aircraft Corporation)	A fine pointing control system to point the separated rocket payload section longitudinal (roll) axis at the sun.
6. SOLAR POINTING CONTROL	Ball Bros. Res. Corp. (BBRC)	Two axis solar pointing system (3rd axis uncontrolled) which points a payload boom (which will accept a 40# experiment) at the sun
7. Univ. of Colorado SOLAR POINTING CONTROL	Univ. of Colorado	Similar to 6
8. SPCS-1	AURA (KITT PEAK NAT'L OBS.) (Ball Bros. Res. Corp.)	Three axis gyro referenced 1st stage to orient separated rocket payload within 4-degrees of desired stellar target, then control is switched to a stellar tracker in two axes and system homes on stellar target using auxiliary low thrust jet system. Only one stellar target per flight may be investigated.
9. RACER IACS (with roll stab. gyro platform)	Space Gen. Corp.	Same as 1 except stops at desired orientation.
10. WHITTAKER ACS FOR SPINNING ROCKETS	Whittaker Corp.	Two axis (rocket continues to roll) gyro referenced system using one or two jets firing normal to the longitudinal axis to point longitudinal axis of rocket or payload along a programmer vector
11. SKYLARK ACU (British STAGE I	Royal Aircraft Est. (RAE) (Elliott Bros. Ltd.)	Three axis solar referenced cold gas jet controlled system which points the longitudinal axis of the payload (after separation from the rocket) at the sun. Magnetometer is used for 3rd axis control reference.
12. SKYLARK ACU (British) STAGE III	Same as 11	Same as #11 except is being adapted to point at moon with lesser accuracy and stability.

Rocket Availibility	Fine Guidance Error Sensor (Closed Loop Systems)	Operational Status	Approximate Length and Weight	Expected Pointing Accuracy
Aerobee 150-150A Veronique (French) Aerobee 350	None	Operational	Aerobee 150 15" long 60 lbs. Aerobee 350 7" long 75 lbs.	(a) RSP — Better than 3° (From programmed position) due to gyro drift and aligning, programming, and launch angle correction errors. (b) Strapped Down — Better than 5"
Aerobee 150-150A Available for Aeorbee 350 in FY '68	GSFC Startracker ITT Startracker	Operational	15" long 94 lbs.	Pitch-Yaw: 30 arc seconds (Due primarily to tracker payload alignment problems observed) Roll: ±2°
Aerobee 150-150A	GSFC Solar Tracker	In final stages of development. First flights scheduled for fall '66.	8.75 long 68 lbs.	Pitch-Yaw: Determined primarily by payload to tracker alignment accuracy capability Roll: ±2°
Aerobee 150-150A Aerobee 350	GSFC Solar Tracker ITT Startracker	Under development. Final packaging design under way. 1st flight scheduled for May '67	10" long 75 lbs.	Same as 3
Aerobee 150-150A	To be specified or developed by contractor	First flight expected in fall 1967	8" long 37 lbs.	Pitch-Yaw: Better than 15 arc seconds Roll: ±2 degrees
Aerobee 150-150A	BBRC Fine & Coarse Eyes	Operational	130 lbs	±1 arc minute in two axes
Aerobee 150-150A	Similar to 6	Operational		Similar to 6
Aerobee 150-150A	To be specified by contractor	Under development. 1st flight scheduled for May 1967	Uses conical section of cone cylinder nose cone and approx. 8 inches of cylindrical insert. Approx. 100 lbs. including rocket separation system	Pitch Yaw: Better than 30 arc seconds Roll: Gyro controlled
Aerobee 150-150A	None	Operational	13" long 65 lbs.	Better than 3°
Nike Tomahawk, Nike Javelin, and other small rocket vehicles	Can be used with an Electro Optics Solar Sensor to correct gyro reference for solar pointing mission.	Operational	15" long 21 lbs.	Better than 4°
Skylark (British) Black Brant V (Canadian)	BBRC Fine & Coarse Eyes	Operational	15" long 91 lbs.	Pitch-Yaw: 10 arc minutes Roll: ±5 degrees
Same as 11	RAE Solar Tracker RAE Magnetometer on extendible strut	Developed. 1st flight scheduled for late '66	17" long 96 lbs.	Pitch-Yaw: 20 arc seconds Roll: ±2 degrees

CHART IV-

Prepared: September 1966
William A. Russell, Jr., Code 721.1
NASA-GSFC

Limit Cycle Noise and Frequency	Approx. Cost $	Notes
±1/4 degree in all axes @ 1/5 cps (±1/8 degree @ 1/5 cps available)	60K (with RSP) 50K (Strapped Down)	By addition of "Valve Modulation" circuitry the limit cycle rates can be reduced to less than .05°/sec. in all axes.
Pitch-Yaw: ±20 arc seconds @ 1/2 cps Roll: ±1/4° @ 1/5 cps	92K	Stellar target must be brighter by one visual magnitude than other stars or planets in the startracker acquisition field of view (approximately eight degrees square).
Pitch-Yaw: ±10 arc seconds @ 1/2 cps Roll: ±1/4° @ 1/5 cps	68K	
Pitch-Yaw: ±10 arc sec. @ 1/2 cps Roll: ±1/4° @ 1/5 cps	137K (Solar) 157K (Stellar)	
Pitch-Yaw: ±4 arc sec. @ 4 arc sec/sec. Roll: ±1/4° @ 1/4 deg./sec.	50K	Has capability of using control gases to minimize experiment contamination problems. Freon, nitrogen, helium, and argon are the current options. Can also raster scan the solar image. Can be used in conjunction with System 1(b) to obtain 3-axis stabilization. This system has also been used with less complex rate gyro controlled "cross spin stabilization system," which allows vehicle to spin under the two axis pointing control but takes out rocket precession (coning) by firing gas jets in the pitch and yaw planes of motion to null rate gyro sensors.
±1 arc minute at 2.5 cps	65K with field services	
Similar to 6		
Pitch-Yaw: ±15 arc sec. @ 2-1/2 cps	100K	
±1/4 degrees @ 1/5 cps	60K	Simplified version with strapped down gyros has been flown through system is configured to take gyro roll stabilized platform.
Pitch-Yaw: +1 degree p-p @ 1/3 cps Roll: Spinning	25K	
Pitch-Yaw: ±20 arc seconds @ 2-1/2 cps Roll: ±1/2°	45K	Can also raster scan the solar image.
Pitch-Yaw: ±1.5 arc seconds @ 5 cps Roll: ±30 arc seconds	45K	

[redacted]

SOUNDING ROCKET QUESTIONNAIRE

Name ______________________________ Date __________

Address ______________________________

Rocket Type ______________ Scientific Discipline ______________

Anticipated Source of Funding ______________________________

General: Use numbers or checks as appropriate. Refer to Questionnaire Notes, Charts and Tables. Include information on all approved flight projects in addition to future requirements.

	FY 1967	FY 1968	FY 1969	FY 1970	FY 1971
1. No. Rockets Anticipated					
2. Launch Site Desired					
a. Wallops Island					
b. Ft. Churchill					
c. White Sands					
d. Pacific Missile Range					
e. Natal, Brazil					
f. Other ______					
3. Telemetry & Instrumentation					
a. PPM/AM					
b. FM/FM					
c. PCM (under study)					
d. Other ______					
4. Rocket Position Determining System					
a. DOVAP					
b. RADINT					
c. SSD					
d. AME/DME/VME (under study)					
e. RADO					
f. Other ______					

5. Aerobee Attitude Control System (150 & 350)

	FY 1967	FY 1968	FY 1969	FY 1970	FY 1971
a. Open Loop (IACS)					
b. Closed Loop (STRAP/FACS)-Solar					
c. Closed Loop (STRAP/FACS)-Stellar					
d. SPARCS					
e. Other ____________					

6. Non-Aerobee Attitude Control Systems

7. Payload Recovery Systems

	FY 1967	FY 1968	FY 1969	FY 1970	FY 1971
6. Non-Aerobee Attitude Control Systems					
a. Land					
b. Sea					
c. Air Grab					

8. Miscellaneous Questions

a. Data accuracy requested: (1) Telemetry ____________
(2) Tracking ____________

b. Data reduction requested: Yes _____ No _____

c. Attitude Control System Accuracy: ____________

d. Special requirements for vehicle coning, acceleration, spin rate, etc.: ____________

e. Requirements for special structural and mechanical assemblies: ____________

REMARKS

Return to: NASA
Goddard Space Flight Center
Code 721
Greenbelt, Md. 20771

QUESTIONNAIRE NOTES

General: Use numbers or checks as appropriate. Refer to the Charts and Tables. Include information on all approved flight projects in addition to future requirements. Use one questionnaire for each rocket type.

Question 2. Launch Site Desired

Launch Site Availability - (Chart I)

Not restricted means that a capability exists at Wallops, White Sands, Fort Churchill, Pacific Missile Range and Natal to launch the particular rocket; and the range boundaries are such that approval to launch may be expected to be granted.

Planned means active work is underway to accomplish a capability in this area.

Mobile tower facility - a 50-foot mobile tower suitable for launching Aerobee 150's. The facility includes all systems necessary to service the propulsion unit.

Note!! (1) Operational ranges also exist in Sweden, Pakistan, Argentina, India, Norway and Sardinia as part of the International Sounding Rocket Program. They are equipped with Nike rail launchers and some have limited capabilities in the radar, DOVAP and telemetry ground station areas. Another such range is being planned for Spain.

(2) ARCAS flights may also be made from these ranges, or from almost any location with a nominal amount of preparation.

(3) Nike boosted vehicles have also been flown from Point Barrow, Ascension and Surinam.

(4) NASA has conducted flight operations at Woomera.

(5) The Air Force Range at Eglin has the capability to launch Aerobee 150's and a variety of smaller solids.

(6) Nike Apaches and ARCAS were flown from the Wallops Mobile Facility, a small aircraft carrier in 1965.

Question 3. Telemetry and Instrumentation

PPM/AM (Pulse Position Modulation/Amplitude Modulation) - This technique satisfied a majority of users requiring medium frequency response telemeter. Development projects at some sites permit the digitization of this data at the ground stations as well as providing an analog record. The airborne unit is also qualified to withstand the rocket environment as well as to allow some design leeway in data handling capabilities.

FM/FM (Frequency Modulation/FM Sub-Carrier) - This is the standard range telemetry system including the standard IRIG sub-carrier channels. The listing shown indicates the Instrumentation Section has developed a package capable of withstanding the environment of the rocket. Basic portions of the system have been standardized and the user requirements are readily satisfied by custom modification.

PCM - Pulse code modulation including digital.

Question 4. Rocket Position Determining Systems

DOVAP (Doppler Velocity and Positioning) - is a multi-station system which provides data output in the form of a magnetic tape record of relative doppler frequencies as received by widely separated stations. (Fort Churchill has the only remaining station of this type and it is being phased out.) The data from each station must be laboriously reduced by hand.

RADINT (Radio-Doppler-Interferometer) - This is a complete tracking system providing data recording, data digitization, processing and digital data transmission into computer facilities.

SSD (Single Station Doppler) - is a partial RADINT system covering operation through data recording. The data may be hand reduced or processed to digital by playback through a RADINT system.

AME - Angle Measuring Equipment.

DME - Distance Measuring Equipment.

VME - Velocity Measuring Equipment.

Note the Instrumentation Section has under study a scheme of using a telemeter channel or an extremely small transponder to be carried in the rocket. It is anticipated this system would supplement RADAR and possibly be the only means of trajectory measurements at remote sites without RADAR capability.

RADO (Radio Doppler Only) - as a partial DOVAP system. This uses the doppler frequency as measured by a single station plus the additional information of launcher coordinates and splash azimuth as supplied from separate sources to provide trajectory via computer comparison with mathematical model trajectories. Trajectory data are accurate to within ±250m at 150 Km range.

Question 5. Aerobee Attitude Control Systems

General: Chart IV lists: (1) all of the control systems used to date on NASA Aerobee (Standard IACS, the Ball Brothers and Colorado Solar Pointing Controls, Stellar STRAP); (2) other NASA Aerobee control systems under development (FACS, Solar STRAP, SPARCS); and (3) several other systems of possible interest (RACER, SKYLARK ACU, Whittaker ACS for spinning rockets, Ball Brothers SPCS-1).

Open Loop (IACS) - This is the standard inertial control system, see Item 1, Chart IV.

STRAP - This system (Items 2 and 3, Chart IV) is an interim one which switches an IACS from open loop gyro to closed loop tracker control after target acquisition.

FACS - This system (Item 4, Chart IV) is under development, and may replace STRAP, starting in FY 68.

Fine Guidance Error Sensors for STRAP/FACS - Solar and stellar trackers, which when used with STRAP, FACS or SPARCS will yield the vehicle pointing characteristics shown on Chart IV, are available and are furnished by NASA.

SPARCS - (See Item 5, Chart IV) - This is a special system being developed solely for solar pointing missions. It will be simpler, lighter, and more accurate than a solar STRAP or FACS. It points a separated payload using its own gas supply. SPARCS will be available for FY 68.

Question 6. Non-Aerobee Attitude Control Systems

List future requirements for systems not shown on Chart IV.

Question 7. Payload Recovery Systems

Land recovery systems are used at White Sands and Fort Churchill. Wallops is sea recovery only. At other ranges special arrangements need to be made to accommodate recovery. Air grab systems have not been used in this program.