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FINAL EIS - NASA SOUNDING ROCKET
PROGRAM

FINAL ENVIRONMENTAL IMPACT STATEMENT

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
OFFICE OF SPACE SCIENCE

SOUNDING ROCKET PROGRAM

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Abstract: The NASA OSS Sounding Rocket Program is responsible for the launch of approximately 80 science and applications payloads per year. These launches are for NASA programs and those of other U.S. government agencies, private industry, universities, foreign countries, and international organizations. NASA launches occur or have occurred from 34 sites located throughout the world. Nine of these receive substantial use. Payloads launched by this program contribute in a variety of ways to control and betterment of the environment (e.g., solar studies). Environmental effects caused by the research vehicles are limited in extent, duration, and intensity and are considered insignificant. There are no short-term alternatives to the current family of sounding rocket vehicles. The possibilities for changes in the family including new stage and sounding rocket developments, are continuously reviewed. Although measurements using high-altitude aircraft and balloons are possible at lower altitudes and using satellites at much higher altitudes, the specific region of the atmosphere between about 40 and 200 km cannot be reached in any of other way. Sounding rockets can be launched simultaneously from several points and can be used in response to time related phenomena.

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SUMMARY

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Responsible Federal Agency: National Aeronautics and Space Administration
(NASA), Office of Space Science (OSS),
Sounding Rocket Program

1. (X) Administrative Action () Legislative Action
2. The NASA OSS Sounding Rocket Program is responsible for the launch of approximately 80 science and applications payloads per year. These launches are for NASA programs and those of other U. S. government agencies, private industry, universities, foreign countries, and international organizations. NASA launches occur or have occurred from 34 launch sites located throughout the world. Nine of these receive substantial use.
3. Payloads launched by this program contribute in a variety of ways to the control and betterment of the environment (e.g., solar studies). Environmental effects caused by the research vehicles are limited in extent, duration, and intensity and are considered insignificant.
4. There are no short-term alternatives to the current family of sounding rocket vehicles. The possibilities for changes in the family including new stage and sounding rocket developments, are continuously reviewed. Although measurements using high-altitude aircraft and balloons are possible at lower altitudes and using satellites at much higher altitudes, the specific region of the atmosphere between about 40 and 200 km cannot be reached in any other way. Sounding rockets can be launched simultaneously from several points and can be used in response to time-related phenomena.
5. Comments on the 1971 Draft Statement were received from:

 Environmental Protection Agency
 Peter Hunt Associates.

These comments and NASA's reply to Peter Hunt Associates are included in Appendix F. The EPA comments are incorporated into the body of the greatly revised statement.
6. Draft Statement published April 21, 1971.
 Final Statement published July, 1973.

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PROGRAM DESCRIPTION

The National Aeronautics and Space Administration (NASA) Office of Space Science (OSS) Sounding Rocket Program provides research vehicles and operations for the automated suborbital upper atmosphere and space research missions of OSS, the NASA Office of Applications (OA), the NASA Office of Aeronautics and Space Technology (OAST), other government organizations [e.g., National Oceanographic and Atmospheric Administration (NOAA), Department of Defense (DOD), and Atomic Energy Commission (AEC)], universities, private industry, foreign governments, and international organizations. This responsibility is met by the Sounding Rocket Program^{(1)*} and appropriate sounding rocket research and development activities which support current and expected future requirements.

Disciplines Under Investigation

The NASA Sounding Rocket Program supports research efforts principally in the fields of solar physics, galactic astronomy, magnetospheric physics, high energy astrophysics, aeronomy, and meteorology. Specifically included in the program are rockets to map the parameters of the earth's atmosphere between about 40 and 200 km; to study pressure, temperature, and density of the ionosphere; to measure ionosphere electric currents; and to study auroras and airglow. The interrelations of these parameters and their dependence on solar heating, solar flares, geomagnetic storms, trapped radiation fluctuations, and meteor streams are also being investigated through sounding rockets to supplement the knowledge obtained from balloons, aircraft, satellites, and ground observations.

* References thus indicated are listed in Appendix A.

Special situations occur where time-coordinated vertical measurements are required at a number of locations or where data from vertical cross-sections are required to supplement data from horizontal cross-sections. The development of attitude stabilization systems, particularly for the Aerobee, makes the Sounding Rocket Program uniquely suitable for conducting exploratory astronomical observations in the X-ray, ultraviolet, and radio regions of the electromagnetic spectrum which are not observable from the earth's surface.

Vehicles

Through the development of vehicles and subsystems necessary to satisfy experimenter requirements, NASA has, over the years, evolved a family of sounding rocket vehicles that provides the range of capabilities necessary to perform the desired sounding rocket missions.

The NASA sounding rocket vehicle family provides experimenters with the capability of economically sending about 4.5 to 450 kg payloads to altitudes as high as about 1200 km. Provisions can be made for payload recovery and highly accurate payload pointing.

Outline sketches of the basic family of NASA sounding rocket vehicles are presented in Figure 1, while Figure 2 shows their performance capabilities. Table 1 provides a general summary of data for each of the NASA sounding rocket vehicles.

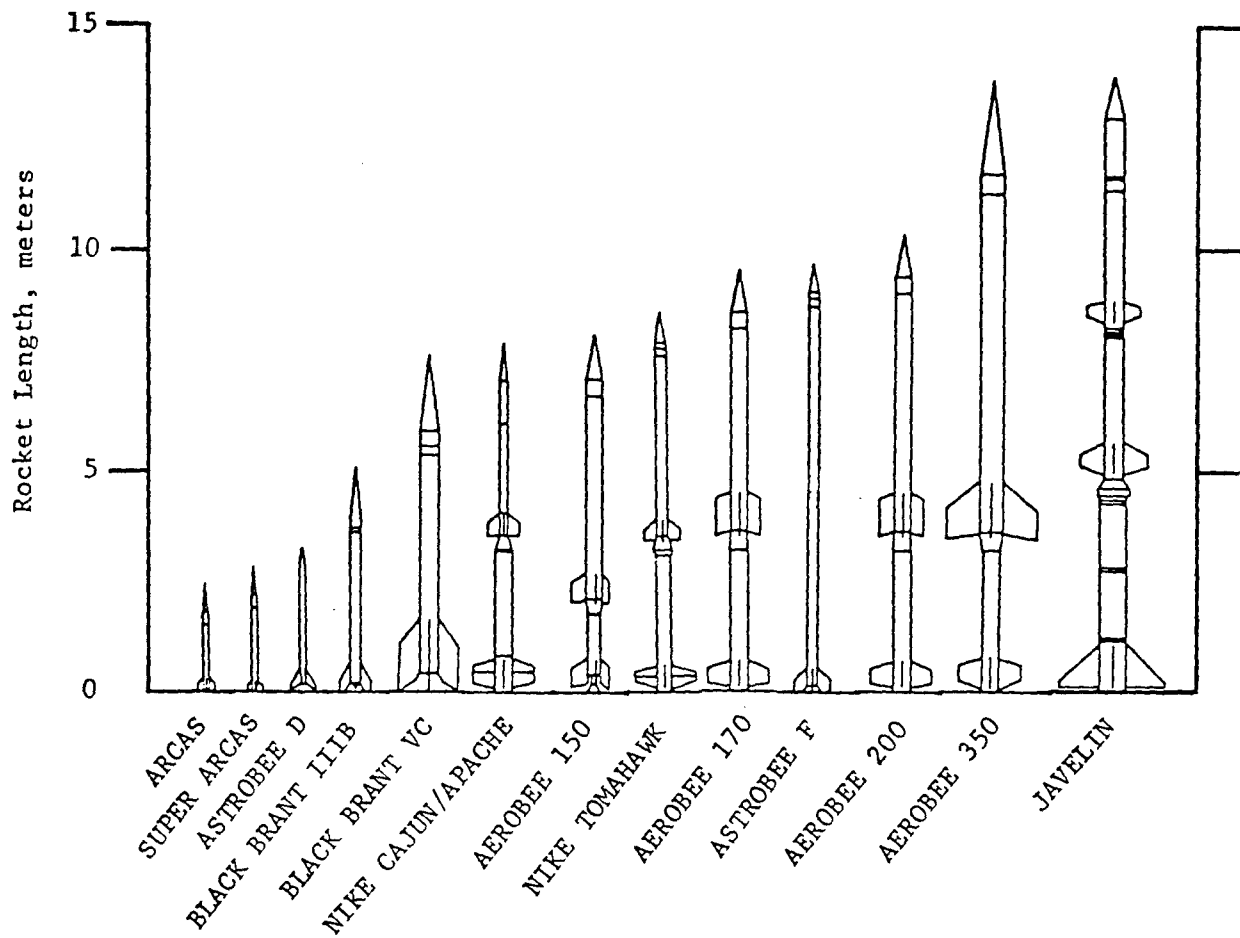


FIGURE 1. NASA SOUNDING ROCKET VEHICLES

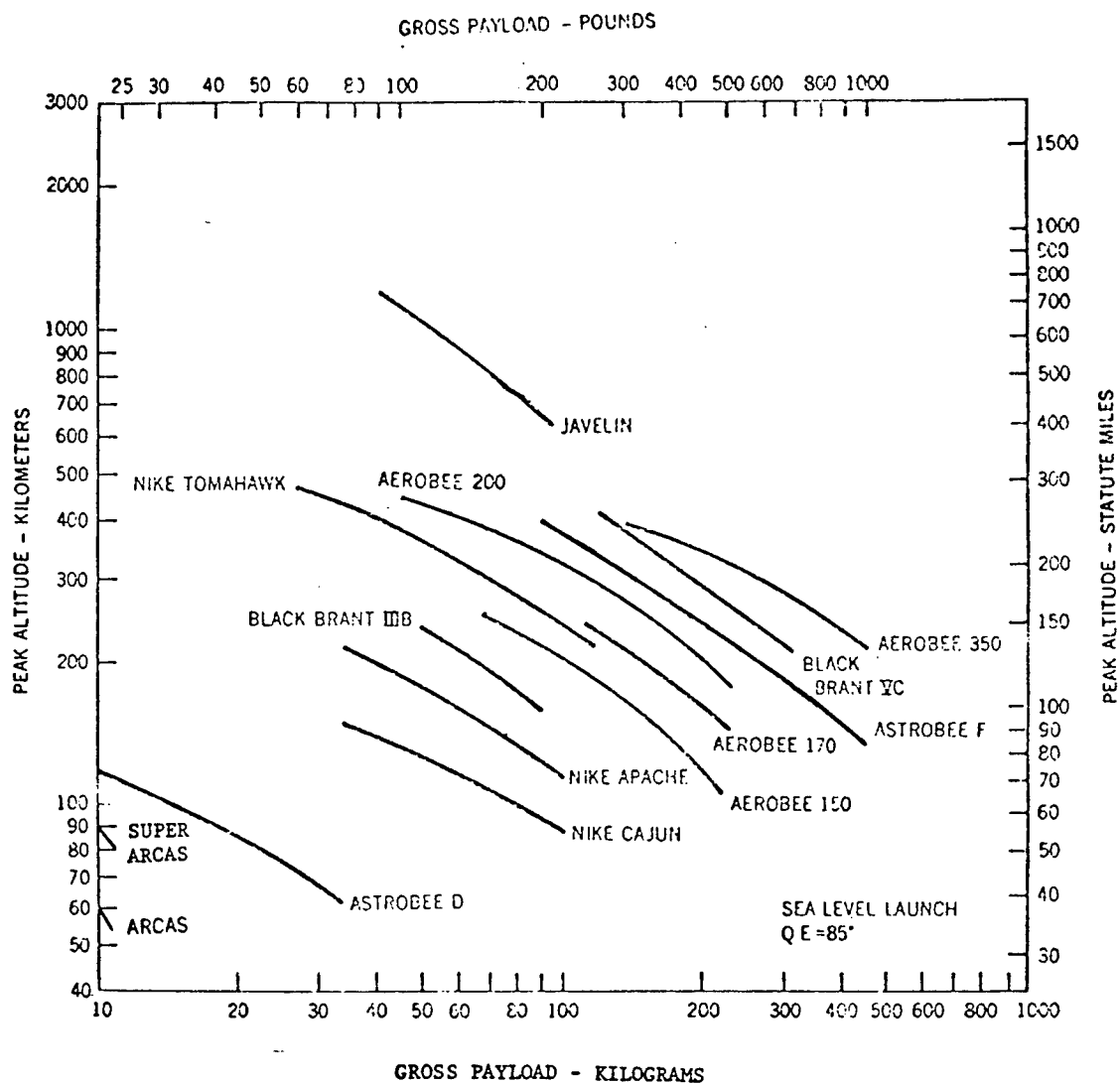


FIGURE 2. PERFORMANCE CAPABILITIES FOR
NASA SOUNDING ROCKETS

TABLE 1. SOUNDING ROCKETS CURRENTLY
USED IN THE NASA SOUNDING
ROCKET PROGRAM*

Vehicle	Type of Propellant	Quantity of Propellant (kg)	Average Total Vehicle Mass (kg)	Average Thrust Levels at Zero Altitude (Newtons)	Maximum Dimension (meters)	
					length ^(a)	diameter ^(b)
Arcas			34	1,374	2.4	0.11
Stage 1	AP/PVC/A1	18.5				
Super Arcas			42	1,446	2.7	0.11
Stage 1	AP/PVC/A1	23.7				
Astrobee D			92	15,840	3.6	0.15
Stage 1	HTFB	60.5				
Black Brant IIIB			360	43,700	5.5	0.26
Stage 1	AP/FU/A1	227				
Nike-Cajun			750	204,920	9.2	0.42
Stage 1	NG/NC	340				
Stage 2	AP/PS/A1	54				
Nike-Apache			770	204,920	9.2	0.42
Stage 1	NG/NC	340				
Stage 2	AP/PVC/A1	59				
Nike-Tomahawk			910	204,920	9.6	0.42
Stage 1	NG/NC	340				
Stage 2	AP/PBAN/A1	175				
Aerobee 150			970	77,395	10.4	0.38
Stage 1	KP/AS	118				
Stage 2	IRFNA/AFA	485				
Astrobee F			1,350	168,579	10.4	0.38
Stage 1	HTFB	996				
Aerobee 170			1,360	204,920	12.8	0.42
Stage 1	NG/NC	340				
Stage 2	IRFNA/AFA	485				
Aerobee 200			1,500	204,920	13.2	0.42
Stage 1	NG/NC	340				
Stage 2	IRFNA/AFA	582				
Black Brant VC						
Stage 1	AP/FU/A1	998	1,520	75,730	8.1	0.43
Aerobee 350			3,440	204,920	15.3	0.80
Stage 1	NG/NC	340				
Stage 2	IRFNA/AFA	1,966				
Javelin			3,400	401,770	14.6	0.58
Stage 1	NG/NC	930				
Stage 2	NG/NC	340				
Stage 3	NG/NC	340				
Stage 4	NG/NC	206				

* Information found in this table was assembled from a multitude of sources. Reference 1 was the predominant source.

(a) Length varies with the payload shroud and may be different than shown for some configurations.

(b) Diameter does not include fins.

AFA	= aniline-furfuryl alcohol
A1	= aluminum
AP	= ammonium perchlorate
AS	= asphalt
HTFB	= hydroxy terminated polybutadiene
IRFNA	= red fuming nitric acid inhibited with hydrofluoric acid (HF)
KP	= potassium perchlorate
NC	= nitrocellulose
NG	= nitroglycerine
PBAN	= polybutadiene-acrylic acid-acrylonitrile
PS	= polysulfide
FU	= polyurethane
PVC	= polyvinylchloride

The performance data shown in Figure 2 are for an 85 degree elevation angle (QE), sea level launch as a function of gross payload mass. Performance different from that shown in Figure 2 would result from changes in payload geometry, protrusions such as antennas, and variation in launch elevation. Gross payload mass includes the mass of the nose cone, any cylindrical extension, telemetry, attitude control system (ACS), recovery package, and the experimental payload.

In the period 1961-1972 these vehicles were launched by NASA at an average rate of about 130 per year. Current projections indicate an average NASA launch rate of about 80 per year for the period 1973-1980.

Within the United States a large number of government agencies are flying, or have flown, sounding rockets. In addition to the NASA, the primary agencies launching sounding rockets today are: Air Force Cambridge Research Laboratory (AFCRL), Naval Research Laboratory (NRL), Atomic Energy Commission (AEC Sandia), Kitt Peak National Observatory (KPNO), and the Defense Atomic Support Agency (DASA).

International Programs

The purpose of the Sounding Rocket Program, as related to International Cooperative Programs, is to stimulate scientific interest and technical competence of other countries. In order to stimulate interest, NASA provides sounding rocket flight opportunities for the participation of scientists and agencies of other countries in experiments and observations which will increase man's understanding and use of his spatial environment, and supports operating requirements for launching and observation of sounding rocket flights.

During the past decade, about twenty countries have joined with NASA in cooperative projects resulting in the launching of more than 500 rockets from ranges in the United States and abroad. In all cases, the scientific data are shared and the results published in the open literature. The basic components of a NASA sounding rocket program are the scientific payload, sounding rocket, launch facilities and services, and ground equipment for command, telemetry, and tracking. Division of responsibilities in international cooperative projects with Brazil, Norway, India, and other countries has varied to reflect the respective interests and capabilities of the cooperating parties in the specific project.

In most cases, foreign scientists propose experiments to NASA. If there is NASA interest in the scientific investigation, then a cooperative project is designed and arrangements made with NASA providing the sounding rockets and the cooperative agency providing both the scientific payload and range services. Occasionally, payloads are cooperatively furnished by U. S. and foreign scientists.

In 1966, in another type of relationship, NASA scientists initiated an X-ray astronomy program requiring a launch from the Brazilian equatorial range into the South Atlantic anomaly. In this case, NASA provided both the scientific payload and an Aerobee sounding rocket. Brazilian space authorities prepared and operated the launch range.

Launch Sites

The location of sounding rocket ranges has been determined mainly by logistic and safety requirements. In some cases, such as that of the auroral site at Fort Churchill, ranges have been constructed specifically to undertake research on special scientific problems. A number of scientific investigations involving coordinated launchings of sounding rockets from several sites have been carried out, beginning during the International Geophysical Year (IGY). During IGY, World Days were set aside for coordinated launchings of sounding rockets. Synoptic scientific investigations have been proposed and worldwide cooperative flights have been undertaken. It has been from studies of this nature that the advantages derived from the simultaneous or coordinated sounding-rocket investigations at various geographical sites have been established. It is now possible to investigate problems in meteorology and aeronomy by means of simultaneous or consecutive flights (from the same or several launch sites). The study of solar-terrestrial relations and the effects of latitude variations are typical examples.

The distribution of sounding rocket sites has become all the more important in the correlation of observations obtained from satellites with observations of phenomena which vary with altitude. The capacity for undertaking such comparisons depends on the geographical distribution of sounding rocket launch facilities and the state of development of these facilities.

Sounding rocket vehicles have been launched from 43 sites around the world shown in Figure 3. Thirty of these sites are listed in Table 2; twelve of these are under the control of the United States. Table 3⁽²⁾ indicates that, during the 1959-1972 period, over 37 percent of the launches were made from Wallops Station and over 90 percent of the launches were made from nine launch sites plus shipboard. The nine launch sites, Wallops Station, White Sands, Fort Churchill, Point Barrow, Thumba, Andoya, Natal, Sweden (now Kiruna, formerly Kronogard), and Fairbanks (Poker Flat), described in some detail in Appendix C, account for over 90 percent of all NASA sounding rocket launches.

TOTAL IMPACT OF THE PROGRAM

The potential environmental impact of the National Aeronautics and Space Administration, Office of Space Science, Sounding Rocket Program activities is summarized in Table 4. No significant impact is expected from current or future activities.

In terms of global or even national significance, the contributions of the NASA sounding rocket launches to environmental pollution are insignificant and many orders of magnitude below those of other sources of such pollution.

Conversely, the scientific information derived from payloads launched by these rockets has made significant contributions⁽²⁸⁾ to the understanding, prediction, and use of the environment, and, thus, ultimately to its betterment. Future activities are expected to contribute even more to the understanding of man's environment.

LEGEND	
ROCKET CLASSIFICATION	
CLASS	ROCKET (TYPE)
A	ARCAS
B	CAPACHE (APACHE & CAJUM)
C	TOMAHAWK
D	JAVELIN
E	BLACK BRANT III & V
F	AEROBEE 150, 170, 200
G	AEROBEE 350
H	ASTROBEE D & F
I	ASTROBEE 1500

FIGURE 3. WORLDWIDE SOUNDING ROCKET LAUNCH SITES

TABLE 2. LAUNCH SITES FOR SOUNDING ROCKETS

<u>Location</u>	<u>Coordinates</u>
Argentina	
Chamical	30.5 S, 66 W
Ascension Island (British)	7.57 S, 14.22 W
Australia	
Woomera	21.0 S, 137 E
Brazil	
Natal	5 S, 35 W
Rio Grande Beach	32.02 S, 52.05 W
Canada	
Fort Churchill	58.8 N, 94.3 W
Resolute Bay	74.6 N, 95.0 W
France (South America)	
French Guiana	5 N, 53 W
India	
Thumba	8.5 N, 77 E
Italy	
Sardinia	39.6 N, 9.5 E
Kenya	
San Marco Platform	2.9 S, 40.2 E
Norway	
Andoya	69.3 N, 16 E
Netherlands (S. Amer.)	
Dutch Guiana,	
Surinam	5 N, 55 W
New Zealand	
Karikari	34.47 S, 173.27 E
Pakistan	
Sonmiani (Karachi)	26 N, 67 E
Spain	
Arenosilia	38.07 N, 4.23 W
Sweden	
Kronogard	66 N, 18 E
Kiruna	68 N, 21 E
United States	
White Sands, N.M.	32.5 N, 106.5 W
Cape Kennedy, Fla.	28.2 N, 80.6 W
Wallops Station, Va.	37.8 N, 75.5 W
Eglin AFB, Fla.	30.4 N, 86.7 W
Point Mugu, Calif.	34.1 N, 119.1 W
Kauai, Hawaii	21.9 N, 159.6 W
Kwajalein, Marshall Islands	8.8 N, 167.7 E
Tonopah, Nevada	38.0 N, 116.5 W
McMurdo Sound, Antarctica	77.9 S, 166.6 E
Pt. Barrow, Alaska	71.3 N, 156.8 W
Keweenaw Peninsula, Michigan	47.5 N, 87.7 W
Poker Flat, Alaska	64.6 N, 147.5 W

TABLE 3. LAUNCH SITES USED, 1959-1972, FOR NASA
SOUNDING ROCKET LAUNCHES IN DESCENDING
ORDER OF FREQUENCY*

Launch Site	Number of Launches	Cumulative	
		Number of Launches	Percent of Launches
Wallops Station, Virginia (U.S.)	625	625	37.4
White Sands, New Mexico (U.S.)	295	920	55.1
Fort Churchill, Canada	276	1196	71.6
Point Barrow, Alaska (U.S.)	73	1269	75.9
Thumba, India	52	1321	79.1
Andoya, Norway	49	1370	82.0
** Shipboard	47	1417	84.8
Natal, Brazil	43	1460	87.4
(Kronogard and Kiruna), Sweden	39	1499	89.7
Fairbanks (Poker Flat), Alaska	20	1519	90.9
French Guiana	17	1536	91.9
Karachi, Pakistan	16	1552	92.9
Ascension Island, South Atlantic (British)	12	1564	93.6
Kauai, Hawaii (U.S.)	11	1575	94.3
Arenosilia, Spain	10	1585	94.9
Camp Tortaquerro, Puerto Rico (U.S.)	9	1594	95.4
Pacific Missile Range, Point Mugu, Calif. (U.S.)	8	1602	95.9
Foxmain, Canada	8	1610	96.3
Karikari, New Zealand	7	1617	96.8
Woomera, Australia	7	1624	97.2
**Koroni, Greece	7	1631	97.6
Eglin Air Force Base, Florida (U.S.)	6	1637	98.0
Northwest Territories, Canada	5	1642	98.3
Resolute Bay, Canada	5	1647	98.6
Coronie, Surinam	4	1651	98.8
Ft. Greeley, Alaska (U.S.)	3	1654	99.0
Barter Island, Alaska (U.S.)	3	1657	99.2
Sardinia, Italy	3	1660	99.3
Chamical, Argentina	2	1662	99.5
Keweenaw Peninsula, Michigan (U.S.)	2	1664	99.6
Panama	2	1666	99.7
Antigua	2	1668	99.8
Primrose Lake, Canada	2	1670	99.9
San Marco Platform, Kenya	2	1671	100.0

* Reference 2.

** Shown on Figure 3, but not listed as a current launch site in Table 2.

TABLE 4. SUMMARY OF POTENTIAL ENVIRONMENTAL IMPACT
OF NASA OSS SOUNDING ROCKET PROGRAM

Area of Concern	Type of Event or Activity		
	Normal Launch	Accident or Failure	Development and Test
Air Quality	Effects limited to the immediate vicinity of the launch pad.	Effects limited to the immediate vicinity of the launch pad.	No significant effect
Water Quality	No significant effect	Limited ocean volume (about 75 meters radius) possibly subjected to aniline-furfuryl alcohol concentrations above the maximum allowable concentrations for failures of a fully loaded Aerobee 350. No measurable effects for other vehicles listed in Table 1.	No significant effect
Noise	No significant effect	No significant effect	No significant effect
Reentry Debris	No significant effect	No significant effect	No significant effect
Environmental Enhancement	Upper atmospheric research makes positive contributions	Not applicable	Not applicable
Commitment of Resources	No significant commitment of scarce or limited resources	No significant commitment of scarce or limited resources	No significant commitment of scarce or limited resources

The commitment of resources to this program is very modest and is not of major significance to the national economy. The program is not a major consumer of any scarce or limited resource.

Currently, there are no significant development activities in the NASA Sounding Rocket Program related to vehicles, stages, or chemical propulsion motors. The NASA Sounding Rocket Program is managed by NASA Headquarters through the Goddard Space Flight Center and Wallops Station.

Sounding rockets have been launched from many locations on the earth, including from shipboard. Significant use has been made of about thirty sites (as listed in Table 2) in the course of conducting the NASA Sounding Rocket Program.

ACTIVITIES WHICH MAY RESULT IN ENVIRONMENTAL IMPACT

The activities which result from the operation of NASA OSS Sounding Rocket Program are:

- Advanced Studies
- Research and Development
- Sounding Rocket Manufacture
- Sounding Rocket and Component Testing
- Launches of Scientific Payloads.

Possible environmental effects which might result from these activities include:

- Air Quality
- Water Quality
- Noise
- Impact of Spent Stages and Payloads
- Population Shifts (due to manpower needs for the programs)
- Liquid Waste
- Solid Waste
- Pesticides.

Of the above possible environmental effects, the first four are considered to be of greatest potential significance and will be considered in greater detail in subsequent sections of this Environmental Impact Statement. No population shifts of significance are expected to result from current or planned future activities. The solid waste generated by these activities is generally valuable and is usually recovered. The liquid wastes generated by these activities are minor and have no

significant effect on the environment. Use of pesticides is at most only incidental to the manufacture, test, and launch of sounding rockets. Consequently, population shifts, solid wastes, liquid wastes, and pesticides will not be considered further.

The advanced studies, most research and development activities, manufacturing, and most testing, are relatively clean and quiet operations and do not directly produce significant environmental effects. However, such activities do consume power, steel, aluminum, paper, etc., and thus, may have some secondary impact on the environment. This secondary impact is difficult to quantify, but probably does not differ grossly from that resulting from the employment of an equal number of people in other activities. Consequently, it will not be considered further.

Some research and development activities and testing, particularly those related to rocket propulsion systems, result in the handling and consumption of propellants and, thus, may affect air and water quality and generate noise. Propellant consumption in current research and development activities is minor. The impact of these activities is considered in the subsequent sections of this Statement.

The actual launch and flight of sounding rockets are the major activities which may cause some temporary perturbation in the environment. In addition to normal rocket launch and flight, the effect of possible abnormal launch and flight conditions will be considered in the following sections. The vehicle trajectory, launch date, launch time, and other parameters are adjusted, as necessary, to meet safety requirements. Examples of trajectory plots and corresponding impact points for representative sounding rockets considered in this Environmental Impact Statement are shown in Appendix B.

AIR QUALITYSource and Nature of Emissions

All current and expected future sounding rocket vehicles will be powered by chemical rocket engines. These engines operate by the combustion of a fuel and self-contained oxidizer. The types of fuels and oxidizers are listed in Table 1. The products of combustion exhausted from the rocket nozzle may include compounds and molecular fragments which are not stable at ambient conditions, or which may react with the ambient atmosphere. The detailed composition of rocket exhaust gases is based on thermochemical calculations.

The substances emitted by rocket engines may be derived from the nominal propellant, from additives to the propellant, from impurities in the propellant, or from the engine itself (e.g., ablative components). Major chemical species emitted by rocket engines are:

Water
Carbon Dioxide
Carbon Monoxide
Hydrogen Chloride
Nitrogen
Hydrogen
Aluminum Oxide

Of the major constituents, carbon monoxide and hydrogen chloride are generally recognized as air pollutants and may present a toxicity hazard. In the upper atmosphere, water and carbon dioxide may be

considered as potential pollutants due to their low natural concentration, and their possible influence on the earth's heat balance and on the ozone and electron concentration.*

In a normal launch, the exhaust products are distributed along the vehicle trajectory. Due to the acceleration of the vehicle, and the staging process, the quantities emitted per unit length of trajectory are greatest at ground level and decrease continuously. In the event of a failure during powered flight, the vehicle may explode or a stage may fail to ignite. In addition, Aerobee's liquid rocket engines can be shut down if a problem develops with the vehicle. Little information is available concerning the products formed or the extent to which the propellants are consumed if an explosion were to occur.

From 1961 through June, 1972, approximately 97 percent of the 1527 NASA sounding rocket launches were successful.⁽⁴⁾

Research, development, and test activities result in the consumption of propellants other than in flight. At the present time, research, development, and test activities result in the consumption of significantly less propellants than normal launches.

Impact on the Environment

Potential air pollutants from NASA Sounding Rocket Program activities may arise from the following situations. The pollutant involved is also indicated.

* NASA is conducting investigations on the effects of combustion products on the upper atmosphere. These investigations are being coordinated with the DOT and NOAA.⁽³⁾

<u>Situation</u>	<u>Pollutant</u>
Engine Test	Combustion Products
Launch	Combustion Products
On-pad Accident	Propellants, Combustion Products
In-flight Failure	Propellants, Combustion Products

Table 5 lists the propellants and the related combustion products of primary concern, together with some reported and estimated human exposure criteria. Data on exhaust product compositions of NASA sounding rockets are summarized in Table D-1, Appendix D.

Table 6 briefly describes dispersion characteristics within selected atmospheric layers. Table 7 lists the combustion products of concern emitted into these layers. Note that quantities of CO_2 and H_2O are tabulated for the higher altitudes, due to the concern that these materials may have an influence on the Earth's heat balance or on the ozone or electron concentrations at high altitudes.

Normal Launch

Ground Level Effects. Ground level concentrations of the pollutants resulting from sounding rocket launches have been estimated using a multi-point source atmospheric diffusion model which assumes a buoyant rise of the exhaust cloud.⁽¹¹⁾ The dispersion from each point source is based on the instantaneous point source equation described by Turner.⁽¹²⁾ Figures 4 and 5 present the results of these calculations for the combustion products CO and HCl using three atmospheric stability criteria (slightly unstable, neutral, and slightly stable). The exposure criteria shown on Figures 4 and 5 for controlled populations are the industrial Threshold Limit Values (TLV's) (considered conservative for short duration, infrequent exposures) and the criteria for exposure from ordinary operations for uncontrolled populations (See Table 5).

Substance	Controlled Populations (a)		Uncontrolled Populations (b)				
	TLV, ppm	Emergency Limits (6) 10 min. 30 min. 1 hr.	Short-Term		Exposure from		
			10 min.	30 min.	Ordinary Operations, ppm 10 min. 30 min. 1 hr.	Exposure, ppm 10 min. 30 min. 1 hr.	Emergency
HCl	5	30	20	10	4(d)	2(d)	3(d)
CO	50	50	25	200	2(d)	30(e)	125(8)
Al ₂ O ₃ (mg/m ³)	10	50	(10)	(10)	--	--	--
AlCl ₃	10(f)	--	--	--	--	--	--
FeCl ₂ (mg/m ³)	1	--	--	--	--	--	--
IRFNA	2	--	--	--	--	--	--
Aniline	5	--	--	--	--	--	--
Furfuryl Alcohol	5	--	--	--	--	--	--

(a) Controlled populations consist of persons with known medical histories, subject to periodic health checks, and generally under the control of the responsible agency. Such persons are normally employees with jobs that may result in exposure to known contaminants.

(b) Uncontrolled populations consist of persons with unknown medical histories, not subject to periodic health checks, and not generally controlled by the responsible agency. The general public is included in this classification.

(c) No short duration exposure criteria for controlled populations appear applicable for ordinary launch operations. Threshold Limit Values (TLV's) are time weighted concentrations for 7 or 8 hour work days and a 40-hour work week, except that the value for HCl is also considered a ceiling value not to be exceeded. (5) TLV's are thought to be conservative for short duration exposures of controlled populations for relatively infrequent normal operations.

(d) While there are no criteria for short-term exposure of uncontrolled populations to HCl which have official standing, the values quoted here have been proposed by a responsible organization after careful study of the problem. See Reference 7.

(e) Based on 1.5 percent carboxyhemoglobin in 1 hour exposure. See Reference 8.

(f) Based on hydrolysis to HCl. In subsequent discussion, AlCl₃ is considered only in terms of its contribution to HCl levels.

TABLE 6. DISPERSION CHARACTERISTICS WITHIN
SELECTED ATMOSPHERIC LAYERS*

Atmospheric Layer; Altitude Range	Temperature Structure	Wind Structure	Characteristic Mixing Rate
Below nocturnal inversion 0-500 m	Increase with height	Very light or calm	Very Poor
Below subsidence inversion 0-1500 m	Decrease with height to inversion base	Variable	Generally fair to inversion base
Troposphere 0.5-20 km	Decrease with height	Variable; increase with height	Generally very good
Stratosphere 20-67 km	Isothermal or increase with height	Tends to vary seasonally	Poor to fair
Mesosphere-Thermosphere Above 67 km	Decrease with height	Varies seasonally	Good

* Adapted from References (13) and (14).

Note: To convert to feet, multiply meters by 3.28

TABLE 7. QUANTITIES OF POTENTIAL POLLUTANTS EMITTED
INTO SELECTED ATMOSPHERIC LAYERS

Atmospheric Layer Altitude Range	Nocturnal Inversion 0-500 m		Subsidence Inversion 0-1500 m		Troposphere 0.5-20 km				Stratosphere 20-67 km				Mesosphere-Thermosphere Above 67 km			
					Emission, kg											
	HCl	CO	Al ₂ O ₃	HCl	CO	Al ₂ O ₃	HCl	CO	Al ₂ O ₃	HCl	CO	Al ₂ O ₃	HCl	CO	Al ₂ O ₃	H ₂ O
Research Vehicle																
Arcas	0.503	0.590	0.871	1.032	1.204	1.785	3.716	4.336	6.427	--	--	--	--	--	--	--
Super Arcas	0.564	0.658	0.975	1.182	1.379	2.044	4.405	5.139	7.618	0.403	0.501	0.743	--	--	--	--
Astrobees D	1.370	5.641	5.424	2.262	9.313	8.954	3.624	14.917	14.342	--	--	--	--	--	--	--
Astrobees F	36.266	39.171	61.798	39.527	52.183	74.308	40.462	166.552	160.135	26.807	110.344	106.092	--	--	--	--
Black Brant IIIB	2.977	3.213	5.67	6.549	8.836	12.474	40.484	54.621	77.112	--	--	--	--	--	--	--
Nike Cajun	0	53.34	0	0	114.88	0	11.96	94.25	0.60	--	--	--	--	--	--	--
Nike Apache	0	53.34	0	0	114.88	0	11.92	104.90	22.45	--	--	--	--	--	--	--
Nike Tomahawk	0	82.06	0	0	143.60	0	35.00	105.44	67.92	--	--	--	--	--	--	--
Black Brant VC	29.1	26.7	35.4	50.1	67.5	95.4	139.7	188.5	266.1	19.8	26.7	37.7	--	--	--	--
Aerobee 150	0	34.77	0	0	49.98	0	0	94.01	0	0	36.44	0	--	--	--	--
Aerobee 170	0	63.76	0	0	85.51	0	0	151.01	0	0	54.91	0	--	--	--	--
Aerobee 200	0	63.76	0	0	85.51	0	0	151.01	0	0	65.25	0	--	--	--	--
Aerobee 350	0	206.28	0	0	284.64	0	0	448.51	0	--	--	--	0	14.88	0	18.88 11.90
Javelin	0	188.40	0	0	392.50	0	0	491.30	0	0	25.14	3.78	19.69	8.45	0	50.09 7.53 39.23 16.85

Note: To convert to pounds, multiply kilograms by 2.20.

To convert to nautical miles, multiply kilometers by 0.540.

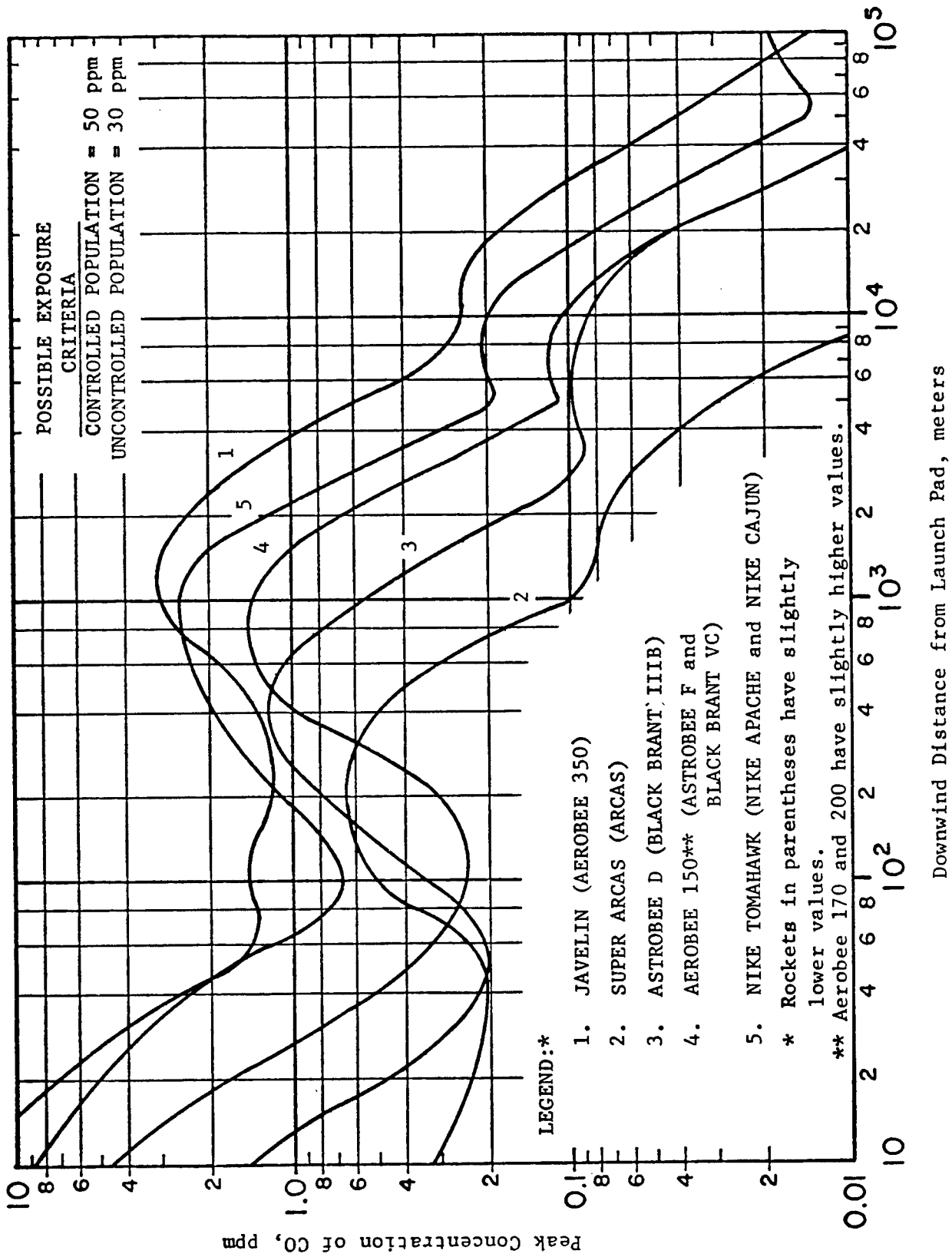


FIGURE 4. ESTIMATED PEAK CO CONCENTRATION DOWNWIND OF LAUNCHES

Note: Curves for each research rocket include the maximum concentration for three atmospheric stability classes.

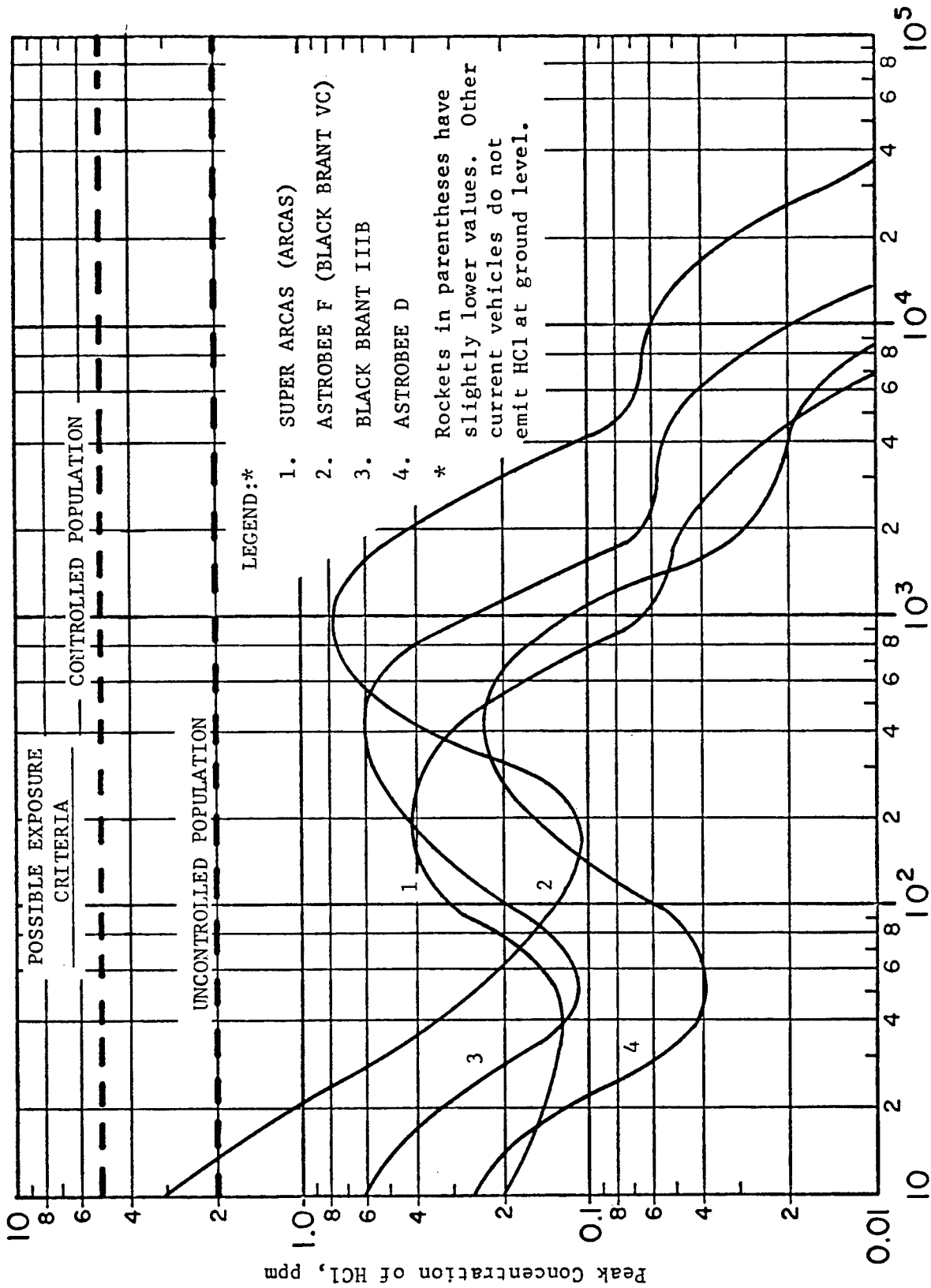


FIGURE 5. ESTIMATED PEAK HCl CONCENTRATION DOWNWIND OF LAUNCHES

Note: Curves for each research rocket include the maximum concentration for three atmospheric stability classes.

It should be noted that the distance scales on Figures 4 and 5 are the maximum distances at which the stated concentrations would be expected. Lines of constant peak concentration enclose an approximately elliptical area with the major axis equal to the plotted downwind distances.

Upper Atmospheric Effects.

Water: In the stratospheric layer, the sounding rocket emitting the largest amount of water is the Aerobee 200. The exhaust cloud spread required before the H_2O concentration falls to the ambient value given in the U. S. Standard Atmosphere was estimated. At 25 km altitude the effects of the cloud would blend into the ambient background by the time the cloud had expanded to an area of 995 m^2 . At 60 km altitude the cloud would have to expand to about 0.80 km^2 to reach an equilibrium with ambient H_2O concentrations.

The effect of water vapor (or any other exhaust emission as will be shown subsequently) from a sounding rocket upon the ozone concentration can be considered as negligible because of the small area covered by the exhaust cloud. The rocket may create a small hole in the ozone layer but the photochemical processes taking place in the atmosphere will replenish quickly the supply of ozone in that volume.

The potential effect of H_2O on the Earth's heat balance, together with the effect of CO_2 , is discussed in the next section.

Carbon Dioxide: Estimates of the area in the stratosphere into which an Aerobee 200-produced cloud* would have to expand before the carbon dioxide density would reach that of the ambient air were made as in the case of water vapor. For CO_2 at 25 km the cloud must expand to 365 m^2 before the CO_2 would reach ambient levels. At 60 km the cloud would drop below ambient levels of CO_2 concentration after it expanded to 0.015 km^2 .

The principal concerns regarding large increases of CO_2 and H_2O in the upper atmosphere and above are related to the effects these constituents would have on the global radiation balance, through absorption or scattering of incoming or outgoing radiation. The above estimates of the area required for diffusion of H_2O and CO_2 to background levels indicate that emissions of these compounds will have negligible effects.

The estimated cumulative yearly emissions resulting from the launch of NASA sounding rockets (predicated on the projected average launch frequency through 1980) are given in Table 8. The total estimated amounts of HCl , CO , Al_2O_3 , H_2O , and CO_2 that would be deposited in the various layers of the atmosphere in one year are given in this table. The emissions from a Titan IIIIE/Centaur launch are also shown in Table 8 for comparison purposes. A comparison of the total projected annual emissions of the NASA Sounding Rocket Program with a single Titan IIIIE/Centaur launch illustrates the small scale of the Sounding Rocket Program. The minor nature of the impacts of the Titan IIIIE/Centaur program has been

* Worst case.

TABLE 8. ESTIMATED YEARLY RELEASES^(a) OF CO, HCl, Al₂O₃, H₂O, AND CO₂ INTO THE VARIOUS ATMOSPHERIC LAYERS

Research Rocket	Estimated Flights/Year (b)	Atmospheric Layers														
		0-500 m			0-1500 m			0.5-20 km			20-67 km			Above 67 km		
		HCl	CO	Al ₂ O ₃	HCl	CO	Al ₂ O ₃	HCl	CO	Al ₂ O ₃	HCl	CO	Al ₂ O ₃	H ₂ O	CO	CO ₂
Arcas	4	2.0	2.4	3.5	4.7	5.5	7.1	17.6	20.6	25.7	1.7	2.0	--	.02	.01	--
Super Arcas	7	3.9	4.6	6.8	8.3	9.7	14.3	30.8	36.0	53.3	30.1	35.1	5.2	.04	.01	--
Astrobees D	7	9.6	39.5	38.0	15.8	65.2	62.7	25.3	104.4	100.4	--	--	--	--	--	--
Astrobees F	4	145.0	156.7	247.2	158.1	208.7	297.2	161.8	666.2	640.5	107.2	441.4	424.4	.02	.13	--
Black Brant IIIB	4	11.9	12.9	22.7	26.2	35.4	49.9	161.9	218.5	308.4	--	--	--	--	--	--
Nike Cajun	7	--	373.4	--	--	804.2	--	83.7	687.8	4.2	--	--	--	--	--	--
Nike Apache	7	--	373.4	--	--	804.2	--	83.4	734.3	157.2	--	--	--	--	--	--
Nike Tomahawk	11	--	902.7	--	--	1579.6	--	385.0	1159.8	747.1	--	--	--	--	--	--
Black Brant VC	2	58.2	53.4	110.8	100.2	135.0	190.8	99.4	377.0	532.2	39.6	53.4	75.4	8.6	10.5	--
Aerobee 150	11	--	382.5	--	--	549.8	--	--	1034.1	--	--	400.8	--	320.6	508.8	--
Aerobee 170	5	--	318.8	--	--	427.5	--	--	755.0	--	--	274.6	--	219.6	348.5	--
Aerobee 200	8	--	510.1	--	--	684.0	--	--	1208.0	--	--	522.1	--	417.6	662.4	95.2 150.9
Aerobee 350	2	--	412.5	--	--	569.3	--	--	897.0	--	--	--	--	--	--	--
Javelin	1	--	282.6	--	--	588.8	--	--	737.0	--	--	37.7	3.8	12.7	29.6	75.2 25.3 58.9
Totals	80	230.6	3,825.5	429.0	313.3	6,466.9	622.0	1,048.9	8,635.7	2569.0	178.6	1,767.1	508.8	979.2	1,560.0	0 194.2 7.5 120.5 209.8
Titan IIIB/Centaur ^(c)		9,800	17,510	16,190	14,920	26,540	21,600	47,170	83,000	68,280	24,040	43,320	34,800	18,800	19,700	0 3,060 -- 47,450 20,400

(a) All units are in kg and, for the sounding rockets, give the total release for a typical year.

(b) Based upon past launch frequencies and new program developments.

(c) From Reference 15. These data are for one Titan launch.

shown previously.⁽¹⁵⁾ The information contained in this document shows that the NASA Sounding Rocket Program has essentially no effect upon the environment.

Hydrogen Chloride: Hydrogen chloride emissions could have an effect on the ionization level in the upper atmosphere. If a change in ionization level is to have an effect on radio wave transmission (the only effect known to be of importance), there would need to be an emission of HCl in layers above approximately 90 km (the nominal base of the E layer of the ionosphere). No research rockets in the program deposit HCl above 60 km. Therefore, there will be no problem with the ionization level.

Engine Tests

Engine tests differ from launches in that all of the propellant is consumed at ground level. However, the high temperature of the exhaust gases causes them to rise in a buoyant plume. The downwind concentrations of the exhaust gases are dependent on the height of this buoyant rise, and any elevation contributed by the persistence of the exhaust jet.

Ground test firings of the Aerobee 350 sustainer are probably the critical case for the vehicles considered here. Using the method suggested by Reference 16, a buoyant rise of 353 meters was calculated. Using this value as the cloud rise, peak downwind concentrations were estimated by the multi-point source dispersion model previously described.⁽¹¹⁾ The maximum downwind concentration of CO predicted was 2.7 ppm, well within suggested exposure limits.

Calculations indicate that ground test firings of the Astrobee F and Black Brant VC can produce CO concentrations of 2.2 and 0.6 ppm, respectively, at 2 km from the test site. Corresponding HCl concentrations would be 1.8 and 1.2 ppm. Tests are made by the manufacturers of the various motors at their own test facilities.

Tests of motors other than the Astrobee F and Black Brant VC used by the research vehicles would have smaller effects due either to the smaller motor sizes or to the lower concentrations of pollutants in the exhaust.

Engine tests are performed at relatively remote sites, and access to the sites is controlled. Suitable precautions are taken to insure the safety of the test crew, including remotely controlled operations and the use of protective equipment.

Abnormal Launches and Accidents

On-pad accidents, either a cold spill of liquid propellant (no fire) or a fire involving solid propellant motors, and early in-flight failures might produce significant ground level concentrations of toxic materials.

The volatilities of IFRNA, aniline, and furfuryl alcohol are sufficiently low that a serious hazard is not created by cold spills. Under ordinary meteorological conditions, the concentration of aniline and furfuryl alcohol downwind of a cold spill will fall below a probable public emergency exposure criterion of 5 ppm (Table 5 and Reference 5) within 60 m.

Calculations of the downwind concentrations of HCl and CO due to an on-pad fire involving NASA sounding rockets, using buoyant rise and the multi-point source dispersion model described previously, are summarized in Figures 6 and 7. These data indicate that the resulting exhaust cloud will not create a hazardous situation outside a limited control area. Aborts or failures occurring within the first 2 seconds of flight involving complete burning of the propellant would produce less effect than would on-pad fires.

Summary of Sounding Rocket
Effects on Air Quality

Emissions into the upper troposphere are rapidly diluted by turbulent mixing and wind shear in that layer. No local or global ground level concentrations of significance will result. Emissions into the stratosphere, the mesosphere, and the thermosphere will not result in detectable ground level concentrations.

HCl and CO emissions from the individual research rocket launches present hazardous conditions only very close to the launch pad. This hazard is very modest and, even under the most unfavorable meteorological conditions, the hazard is estimated to be confined to the controlled areas.

There is no significant effect on the upper atmosphere from research rockets launched by NASA. Current activities are many orders of magnitude below activities which would be expected to produce detectable changes in the upper atmosphere.

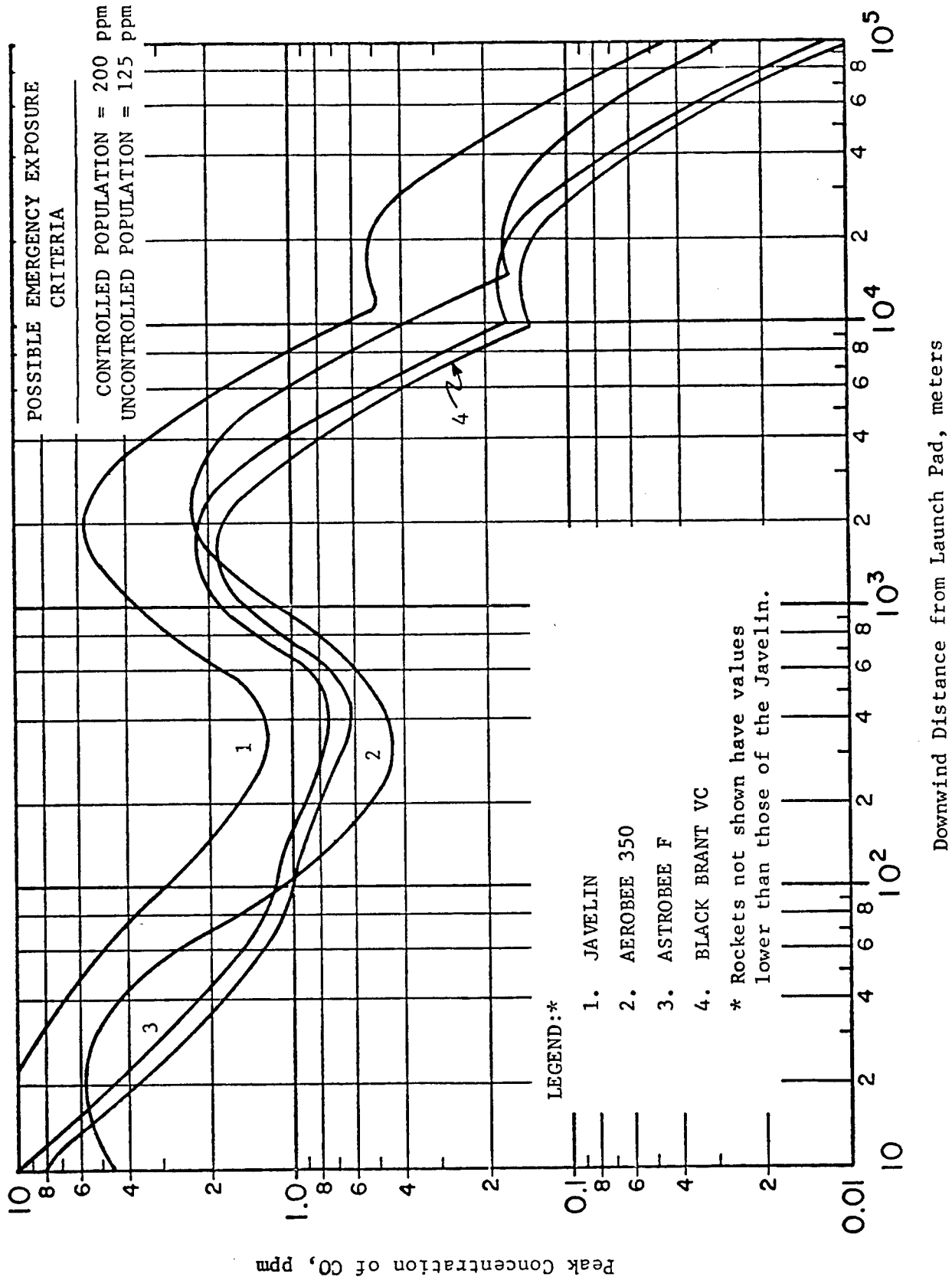
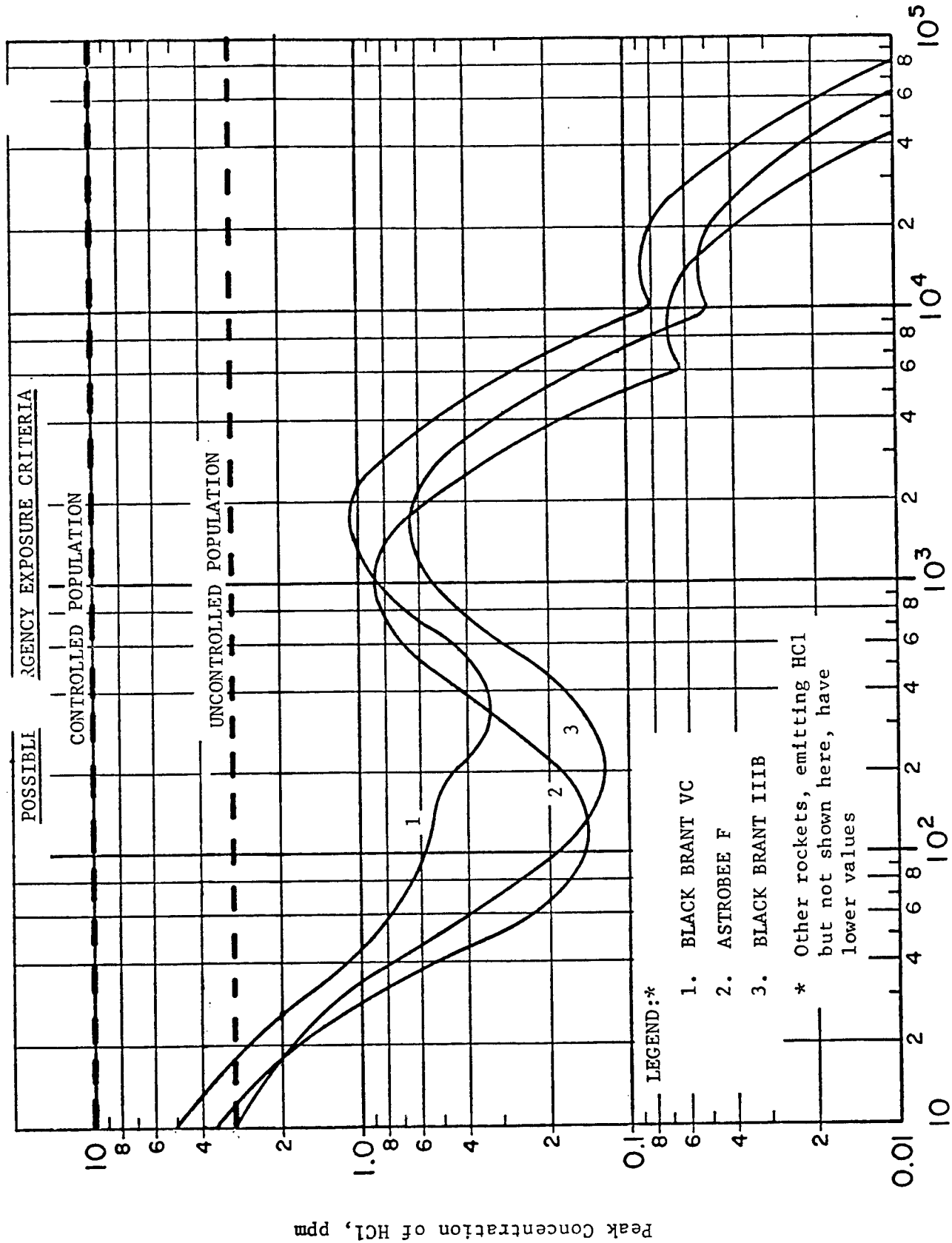


FIGURE 6. ESTIMATED PEAK CO CONCENTRATION DOWNWIND OF CATASTROPHIC PAD FAILURE

Note: Curves for each research rocket include the maximum concentration for three atmospheric stability classes.



Downwind Distance from Launch Pad, meters

FIGURE 7. ESTIMATED PEAK HCl CONCENTRATION DOWNWIND OF CATASTROPHIC PAD FAILURE

Note: Curves for each research rocket include the maximum concentration for three atmospheric stability classes.

Accidents or abnormal launches of the NASA research vehicles considered here are not expected to cause air pollutant concentrations exceeding the exposure criteria except in the immediate vicinity (about 30 meters) of the launch pad where access is carefully controlled. No other effects of significance, either in the lower or upper atmosphere, are expected.

WATER QUALITYSource and Nature of Pollutants

The NASA Sounding Rocket Program may contribute potential pollutants to bodies of water in the following ways:

- On-pad accidents and propellant spills (for liquid propellants) which could result in eventual delivery of pollutants to local drainage systems.
- In-flight failures which may result in vehicle hardware and propellants falling into oceans, lakes, or streams.
- Normal flight, which results in the impact of spent stages (containing some residual propellants) and other rocket hardware into a body of water.
- Reentry and subsequent failure to recover payload.
- Normal flight or failures which could result in some quantities of propellant reaching land surfaces with the possibility of some surface or groundwater contamination.

The possibilities of water pollution are associated primarily with toxic materials which may be released to and are soluble in the water environment. For sounding rockets, the rocket propellants are the dominant source of such materials, although consideration must be given also to soluble materials originating from hardware and miscellaneous materials and to certain toxic combustion products.

Impact on the Environment

Potential sources of pollutants from sounding rockets to the water environment and the major pollutants are given below:

<u>Source</u>	<u>Potential Pollutants</u>
Hardware	Heavy metal ions (iron, copper, cadmium, silver, magnesium, titanium, vanadium, chromium, manganese, cobalt, nickel, zinc, tin, lead) and miscellaneous compounds
Solid Propellants	Ammonium perchlorate, aluminum, asphalt, nitrocellulose, nitroglycerine, plasticizer, polybutadiene, polyurethane, polysulfide, polyvinylchloride, acrylic acid
Liquid Propellants	Red fuming nitric acid inhibited with hydrofluoric acid, aniline-furfuryl alcohol (65% aniline-35% furfuryl alcohol)
Combustion Products	Hydrofluoric acid, hydrochloric acid, aluminum chloride.

Hardware

Jettisoned stages and hardware will corrode and, thus, contribute various metal ions to the water environment. In major part, such hardware consists of aluminum, steel, plastics, fiber-reinforced plastics, and electronic components. A large number of different compounds and elements are used in small amounts in sounding rocket vehicles and payloads; for example, lead and tin in soldered electrical connections, silver in silver-soldered joints, cadmium from cadmium-plated steel fittings, and copper from wiring. The rate of corrosion of such materials is slow in comparison with the mixing and dilution rates expected in a water environment, and, hence, toxic concentrations of metal ions will not result. The miscellaneous materials (e.g., battery electrolytes) are present in such small quantities that only extremely localized and temporary effects would be expected.

Propellants

Sounding rockets do not have a vehicle destruct system (Aerobee liquid propellant rockets have a radio-controlled valve to cut off the propellant flow) and, thus, any in-flight failure could result in some of the propellant reaching the aquatic or land environment. During the past 10 years, approximately 97 percent of the sounding rocket firings have been successful (Table 9). As shown in Table 8, the projected future average launch rate is approximately 80 sounding rockets/year, and some of these launches could result in quantities of propellants entering the aquatic environment.

Solid Propellants. About 80 percent of the stages used in NASA sounding rockets have employed solid propellants. Many of these solid propellants are composed of plastics or rubbers such as polyvinylchloride, polyurethane, polybutadiene, polysulfide, etc., mixed with ammonium perchlorate. The plastics and rubbers are generally considered nontoxic and, in the water, would be expected to decompose and disperse at a very slow rate.

The ammonium perchlorate found in solid propellants is contained within the matrix of rubber or plastic and will dissolve slowly. The toxicity is expected to be relatively low as computed from the data available for sodium chlorate⁽¹⁷⁾. As a worst case, toxic concentrations of ammonium perchlorate would be expected only within a few meters of the source.

TABLE 9. HISTORICAL RECORD OF SOUNDING ROCKET LAUNCHES (a)

Vehicle	Launch Record--Total Attempts/Successes (b)																Total Attempts	Total Successes	% of Success
	Calendar Year												72						
	61	62	63	64	65	66	67	68	69	70	71								
Arcas (Boosted)	--	--	--	--	13/13	9/9	16/15	7/7	8/6	4/4	12/12	10/10	79	76	96				
Aerobee 150-150A/ 170/350	8/8	20/20	30/30	26/26	29/29	29/29	35/35	39/38	34/30	36/34	27/24	29/29	342	332	97				
Javelin (ARGO D-4)	8/8	2/2	2/2	7/7	7/7	6/6	9/9	4/4	1/0	5/5	1/0	2/2	54	52	96				
Nike Cajun	23/22	37/37	20/20	38/38	43/43	43/43	35/34	37/36	27/25	25/24	45/45	6/6	379	373	98				
Nike Apache	5/5	11/11	36/36	76/76	92/92	57/56	48/44	49/48	35/35	47/44	27/25	19/17	502	489	97				
Nike Tomahawk	--	--	--	--	3/3	12/12	15/15	30/29	13/13	27/26	18/16	10/10	128	124	97				
Others and Special(d)	26/25	8/8	5/5	5/5	4/4	2/2	4/3	8/7	5/5	3/2	4/4	8/8	82	78	95				
Total Attempts	70	78	93	152	191	158	162	174	123	147	134	84	1566	1524	97				
Total Successes	68	78	93	152	191	157	155	169	114	139	126	82	1524						
Percent of Vehicle Success	97	100	100	100	100	99	95	97	93	95	94	98	97						

(a) Adapted from References (4) and (29).

(b) Figures do not include Arcas one-stage meteorological rockets.

(c) Success figures shown relate to vehicle performance only.

(d) Special vehicle test and support launches include Black Brant III and Black Brant VC.

There is a high toxicity rating⁽¹⁸⁾ associated with nitroglycerine (from double base propellants) which could cause a localized problem. For a solid propellant rocket, a "worst case" accident would involve an intact Javelin in a water environment. This is the largest solid propellant sounding rocket currently in use and carries approximately 1815 kg of double base (nitrocellulose/nitroglycerine) solid propellant, and an intact Javelin would have approximately 510 kg of nitroglycerine in the propellant grain. The concentration of nitroglycerine in the water at the impact site would be limited by the solubility of nitroglycerine (1.8 kg/m^3 at 20°C ⁽²⁴⁾) and further limited by the solubility when combined with the nitrocellulose.

Using procedures similar to those described later for liquid propellants, a maximum radius can be calculated at which a specified maximum allowable concentration (MAC) will be reached. In this case, a radius of approximately 14 meters was calculated as the extent where the MAC ($25 \times 10^{-3} \text{ kg/m}^3$ ⁽¹⁸⁾) will be exceeded. It will require approximately 30 seconds to reach this radius using a diffusion coefficient of $1 \text{ m}^2/\text{sec}$ and assuming that the nitroglycerine dissolves rapidly enough to maintain saturation at the impact site. Since the initial concentrations are limited by the solubility, these concentrations, and the radius where the concentrations will exceed the MAC, will exist for longer periods of time (approximately 1 to 2 hr) than for the case of the liquid propellants which are quickly dispersed. The lower solubility of the nitroglycerine when combined with the nitrocellulose/plasticizer was not considered in these calculations and, thus, the affected area would actually be smaller than stated, although the time factor could be considerably extended.

Liquid Propellants. The Aerobee series of rockets, as previously noted, uses inhibited red fuming nitric acid and aniline-furfuryl alcohol propellants. Spills, on-pad vehicle failures, and in-flight failures could cause a release of the propellants to the aquatic environment.

Provisions normally are made for containing on-pad spills and disposing of the spilled propellant without contaminating the water environment. The largest of these liquid propellant sounding rockets, the Aerobee 350, is launched infrequently (two launches during 1959-1969) and has only been launched from a facility (Wallops Station) which is well equipped to handle spill problems. Current plans call for 1 to 2 launches in 1973 and 2 to 3 launches in 1974. The quantity of propellant (1966 kg) involved in the Aerobee 350 can be contained and disposed of without major problems.

If the IFRNA and aniline-furfuryl alcohol were spilled simultaneously, the hypergolic reaction would ignite the propellants. The resulting fire would be expected to consume most or all of the propellant, resulting in combustion products normally handled as an air pollution problem. Similarly, an on-pad vehicle failure would normally be expected to result in a fire which would consume the propellant. The only exhaust product of potential concern to the water quality would be the HF which is considered subsequently.

When a volume of liquid propellant is suddenly released into a water body, assuming it has not ignited due to hypergolic properties, it will diffuse and disperse into the surrounding water. This process will cause a certain volume of water to be subjected to propellant

concentrations equal to or higher than the allowable concentration. Since the quantities of propellant involved with sounding rockets are relatively small and the probability of a vehicle reaching the ocean environment with a full load of propellant is also very small, it would be expected that the volume of water subjected to concentrations equal to or exceeding allowable concentrations would be negligible.

For example, consider a "worst case" situation consisting of a fully loaded Aerobee 350 impacting in the ocean and releasing approximately 1966 kg of IFRNA/aniline-furfuryl alcohol. As a classical diffusion problem^(20,21), this case can be considered as diffusion from a point source into a semi-infinite volume. Reasonable values for the MAC for aniline-furfuryl alcohol^(19,22) and nitric acid⁽¹⁷⁾ are $2 \times 10^{-4} \text{ kg/m}^3$ and 0.107 kg/m^3 , respectively. The value for the aniline-furfuryl alcohol is based on furfuryl alcohol only, because of the greater toxicity of this compound. The furfuryl alcohol used in Aerobee sounding rockets is approximately 10 percent of the total propellant mass.

Proudman⁽²³⁾ has tabulated values of typical eddy-diffusion coefficients for the mixing of sea water of different salinities. The values obtained are based on measurements taken in various bodies of water and show that there is an extremely wide variation in the coefficient, dependent on the local currents, degree of vertical mixing, salinity, and temperature gradients. The actual values range from $3.6 \times 10^{-5} \text{ m}^2/\text{sec}$ in the case of stationary vertical mixing to as high as $1 \times 10^4 \text{ m}^2/\text{sec}$ in the case of stationary mixing horizontally along the current. These values are

highly dependent upon the local conditions. A value for average sea conditions obviously lies somewhere between these extremes. Recognizing that, in most situations, the vertical diffusion is much less than the horizontal diffusion, a value of $1 \text{ m}^2/\text{sec}$ was chosen as a representative value and was used to calculate the results presented below. It must be remembered that choosing a smaller diffusion coefficient simply increases the time required for the pollutant to reach the maximum radius specified by the MAC without affecting the radius; similarly, a larger diffusion coefficient will decrease the time.

For the quantities of propellant contained in a fully loaded Aerobee 350, a radius of approximately 75 meters can be calculated as the extent where the MAC will be exceeded for an aniline-furfuryl alcohol mixture. Using the diffusion coefficient discussed above, the time required to reach this radius is about fifteen minutes. Obviously, longer times would be predicted for areas with few currents or little mixing and shorter times for areas where very strong (tidal) currents would speed the mixing process.

A similar calculation for the quantities of nitric acid involved in an Aerobee 350 shows a radius of approximately 13 meters as the maximum radius at which the MAC will be reached. The time to reach this radius using the above diffusion coefficient is about 25-30 seconds. In the case of nitric acid in the ocean, the 13-meter radius is probably a conservative estimate since, in an ocean environment, the basic qualities of the water would quickly neutralize the acid and reduce the toxicity rapidly. For a body of fresh water, the calculations would be similar except that a smaller diffusion coefficient should be used (i.e., time period to maximum radius is longer) due to the less intense currents, wave action, and surface agitation.

Products of Combustion

Some sounding rockets represent a potential threat to water quality because of the toxic nature of certain chemical species in their combustion products when dissolved in water. There is no way, however, in which the true potential of this risk can be assessed because an estimate of the fraction of the exhaust product which might reach the water as well as its likely distribution is indeterminable. However, a maximum theoretical effect can be computed on the basis that all of the active chemical species reaches the water and dissolves and dilutes to its MAC. This has been done for all NASA sounding rockets whose exhaust products contain chemical species which are significantly soluble and of a toxic nature. The affected volumes shown in Table 10 are trivial except possibly for the AlCl_3 produced by the Astrobee F and the HCl produced by the Black Brant VC. In a large body of water, this quantity of AlCl_3 would not be expected to produce any long-term effects since it would be diluted quickly and dispersed as well as decomposed to relatively innocuous compounds. In the improbable case where all of the AlCl_3 from the Astrobee F would be released into a small pond or other small body of water, considerable damage to the biota associated with that body of water could be expected. However, aluminum salts are known to hydrolyze rapidly at high dilutions, particularly in alkaline waters, forming the relatively harmless aluminum hydroxide and chloride ion. Consequently, the toxicity of this compound in natural waters may be substantially less than indicated.

TABLE 10. MAXIMUM THEORETICAL EFFECTS OF ACTIVE PRODUCTS
OF COMBUSTION WHEN DISSOLVED IN WATER

Rocket	Pollutant Species	Total Amount Produced, kg	Fraction of Total Propellant, weight percent	Maximum Allowable Concentration (MAC) (17) kg/m ³	Water Volume Required for Dilution to MAC, m ³	Size of Volume Diameter, m	Depth, m	Other Rockets Producing Lesser Amounts of Same Pollutant
Aerobee 150 - First Stage (Nike)	KCl	46.5	39.5	0.35	133	7	3	None
Aerobee 350	HF	9.8	0.5	5×10^{-2}	196	9	3	Aerobee 200(30%), Aerobee 170 and 150(25%) (b)
Astrobbee F - Second Stage	AlCl ₃	109	13.4	4×10^{-3}	27,000	107	3	Astrobbee D
Black Brant VC	HCl	189	18.9	1×10^{-3} (a)	189,000(a)	251(a)	3	Arkas, Super Arcas, Astrobbee D, Astrobbee F, Black Brant III B, Nike-Cajun, Nike-Tomahawk, Nike-Apache

(a) Based on the HCl needed to depress the pH of pure water to 4.5. Natural waters will vary greatly in their pH and buffering capacity, and hence these figures can be used only as a rough guide.

(b) Percent of pollutant emitted as compared with quantity for Aerobee 350.

For the case of the HCl produced by the Black Brant VC, the HCl would be expected to disperse quickly and be diluted and neutralized in any water body greater in size than that indicated in Table 10. Neutralization would be especially rapid in the ocean because of the basic properties of ocean water ($\text{pH} = 8.1$ to 8.3)⁽¹⁷⁾. It is the resulting pH rather than the initial concentration of HCl that governs lethality toward aquatic life. In fresh waters the pH of natural streams and ponds vary widely, depending upon the soils and vegetation of the watershed; thus, the effects on bodies of fresh water could be much greater than the effects in the ocean.

In the event that the KCl produced by the Aerobee 150 were to reach a body of water some effects could be observed. However, any body of water of significant size would quickly dilute any KCl produced to values harmless to plant and animal life.

The Black Brant VC sounding rocket produces Al_2O_3 as an exhaust product. Since aluminum oxide is essentially insoluble in water and the compound does not seem to have an appreciable toxicity⁽¹⁷⁾ for aquatic organisms, the potential effect of this reaction product on the water quality is insignificant.

It must be emphasized that the above estimates are for worst case situations. Physical mechanisms by which a significant fraction of the combustion products could be delivered to a limited body of water in concentrated form involve unlikely combinations of events. No such events are known to have occurred.

Biological Impacts

Few data are available on the effects of rocket propellants on a water environment. Since the compounds of greatest interest (nitric acid, aniline-furfuryl alcohol, nitroglycerine, etc.) are not commonly found as pollutants in a water environment, it is not surprising that they have received little study.

The toxic effects of rocket propellants on lower taxonomic groups of marine life would be undetectable after a few days because of the relatively small volume of water affected and the resiliency of most species. In the open sea, planktonic species affected would include forms such as diatoms, dinoflagellates (phytoplankton), copepods, and euphausiids (zooplankton). These forms of biota have great reproductive potentials so a possible loss of most or all of these forms in the limited areas that could be affected by a sounding rocket would be undetectable after only a short time. These forms would repopulate the area quickly after the concentrations of toxicants returned to low levels due to dispersion and dilution of the propellant by the water. The effects could be more observable in fresh water or coastal regions. In coastal regions the concentrations of larger crustaceans (e.g., crab and shrimp species) and mollusks (e.g., clam species) and the limited depths and mixing conditions leading to slower dispersion of the propellants could cause a greater environmental impact. Larval forms of these species might be susceptible to toxicants, but, again, in the case of sounding rockets, the area affected would be small and the reproductive potential for most of these animals is so large that a measurable long-term population density

effect is unlikely. Because of the generally small size of fresh water lakes, ponds, and streams, the introduction of large quantities of propellants into such bodies could cause considerable local impact. However, the propellant quantities involved in sounding rockets are small (See Table 1) and most launch sites are located in ocean or desert areas (See Table 11).

For the case of phytoplankton population in the ocean, growth is generally regulated by such ecological factors as temperature, light, and standing stocks. Nutrients such as phosphates, nitrates, silicates, etc., are normally abundant enough in marine waters that they do not exercise a limiting influence on primary productivity. Even assuming that the phytoplankton would be removed totally from a small volume of water by some toxic compound, the phytoplankton from surrounding areas would repopulate the affected area as soon as the compound ceased to poison the water involved. Since reproductive rates are quite high for most species of phytoplankton, it would require only a few days for recovery to their original densities.

Zooplankton reproductive rates are similar and standing stocks are generally large so they also would be expected to repopulate rapidly an area exposed to the effects of sounding rocket propellants. Thus, it appears that there would be little likelihood of noticeable effect on photoplankton or zooplankton from an introduction of sounding rocket propellant into the sea.

TABLE 11. LAUNCH SITE CHARACTERISTICS AS
RELATED TO POTENTIAL FOR WATER
QUALITY DEGRADATION

<u>Location</u>	<u>Water Body Affected by Launch</u>
Argentina	
Chamical	None (Land site)
Ascension Island (British)	South Atlantic
Australia	
Woomera	None (Land site)
Brazil	
Natal	Atlantic Ocean
Rio Grande Beach	" "
Canada	
Fort Churchill	Hudson Bay
Resolute Bay	Arctic Ocean
France (South America)	
French Guiana	Atlantic Ocean
India	
Thumba	Laccadine Sea (Arabian Sea)
Italy	
Sardinia	Tyrrhenian Sea (Mediterranean)
Kenya	
San Marco Platform	Formosa Bay (Indian Ocean)
Norway	
Andoya	Norwegian Sea
Netherlands (S. Amer.)	
Dutch Guiana, Surinam	None (Land site)
New Zealand	
Karikari	Pacific Ocean
Pakistan	
Sonmiani (Karachi)	Sonmiani Bay (Arabian Sea)
Spain	
Arenosilia	None (Land site)
Sweden	
Kronogard	None (Land site)
Kiruna	None (Land site)
United States	
White Sands, N.M.	None (Land site)
Cape Kennedy, Fla.	Atlantic Ocean
Wallops Station, Va.	" "
Eglin AFB, Fla.	Gulf of Mexico
Point Mugu, Calif.	Pacific Ocean
Kauai, Hawaii	" "
Kwajalein, Marshall Islands	" "
Tonopah, Nevada	None (Land site)
McMurdo Sound, Antarctica	McMurdo Sound
Pt. Barrow, Alaska	Arctic Ocean
Keweenaw Peninsula, Michigan	Lake Superior
Poker Flat, Alaska	None (Land site)

Ultimate Fate of Water Pollutants

Propellants introduced into an ocean environment will undergo chemical alterations caused by the dissolved salts or gases in the water or by being metabolized by the various life forms. In this way, nitric acid would be expected to be neutralized quickly, converted to nitrates, and metabolized by plant life. Other propellant components would also be expected to degrade and disperse into relatively innocuous materials. Currently, at best only generalized information is available concerning the degradation and metabolization of propellants; information specifically pertinent to the marine environment is almost nonexistent. However, the question of "ultimate fate" as such is probably not as important as is the rate at which the pollutants could be expected to degrade. For some compounds (e.g., nitric acid, hydrochloric acid), the rate of degradation could be comparable to the rate of spreading or diffusion. At the other extreme, solid propellants probably would not degrade for a number of years because of their chemical stability.

Summary of Sounding Rocket Effects on Water Quality

In general, water quality is not expected to be affected significantly from the operation of the NASA Sounding Rocket Program. Even in the situation of a "worst case" involving the impact of a fully loaded vehicle (probability of occurrence being near zero) in the ocean environment, the volume involved is small and the effects are not persistent; i.e., the toxicants will disperse and degrade to values below the MAC within a very short time. The maximum environmental effect upon the water quality

and life processes would be experienced if there were a near-shore (shallow water) or freshwater impact of one of these fully loaded vehicles. This is not regarded as a likely event; but, even in this case, the small quantities of propellant involved would not produce any permanent impact on the environment. For inshore marine areas and small freshwater lakes, the immediate effects would be more drastic than those for a deep-water impact because of the smaller volume, shallower water, lack of currents, etc., to disperse the toxic materials quickly. However, since the area involved would be small and the reproductive potential for most of the plants and animals involved is so large, a measurable long-term population density effect is unlikely.

NOISE

Source and Nature

Large rocket motors can be relatively powerful sources of noise. The major source of this noise appears to be the interaction of the exhaust jet with the atmosphere. Both the acoustic power emitted and the frequency spectrum of the noise are affected by the size of the motor and the specific impulse, as well as by design details.

For operational motors, the acoustic power emitted is approximately proportional to the thrust, and hence, the sound pressure level at a fixed distance is approximately proportional to the square root of the thrust.

The noise generated by sounding rockets may be described as composed predominantly of low frequencies, of short duration, and of relatively infrequent occurrence.

Because of their small size, relative to space launch vehicles and some military missiles, little attention has been given to the noise generated by sounding rockets. Consequently, it is necessary to extrapolate the results of field measurements of larger rocket motors. Of these, the first stage of the Scout launch vehicle (thrust of about 400,000 N) is most comparable to that of sounding rockets.

Figure 8 is a frequency-intensity spectra taken at three distances from a Scout launch. In general, the higher frequencies are attenuated more rapidly with distance than are the low frequencies. The low frequencies are less harmful to human hearing and are less annoying than the high frequencies⁽²⁵⁾. Figure 9 is an average intensity-time relationship at a distance of 1500 meters from a Scout launch. The entire event, measured within 20 dB of the peak intensity, lasts less than 20 seconds. At distances greater than that corresponding to Figure 9, the duration of the event is greater, but, of course, the peak intensities are lower.

Figure 10 is a plot of the distance from the launch site at which a specified overall sound pressure level (OSPL) is reached as determined by the thrust of the rocket motor. Shown on the figure are the distances at which 120 dB would occur for five space launch vehicles or military missiles, including one liquid propellant system. Because the observed OSPL depends in part on the geometry and topography of the launch site and on the meteorological conditions prevailing, the plotted points are based on the upper bounds of the observed OSPL-distance relationships.

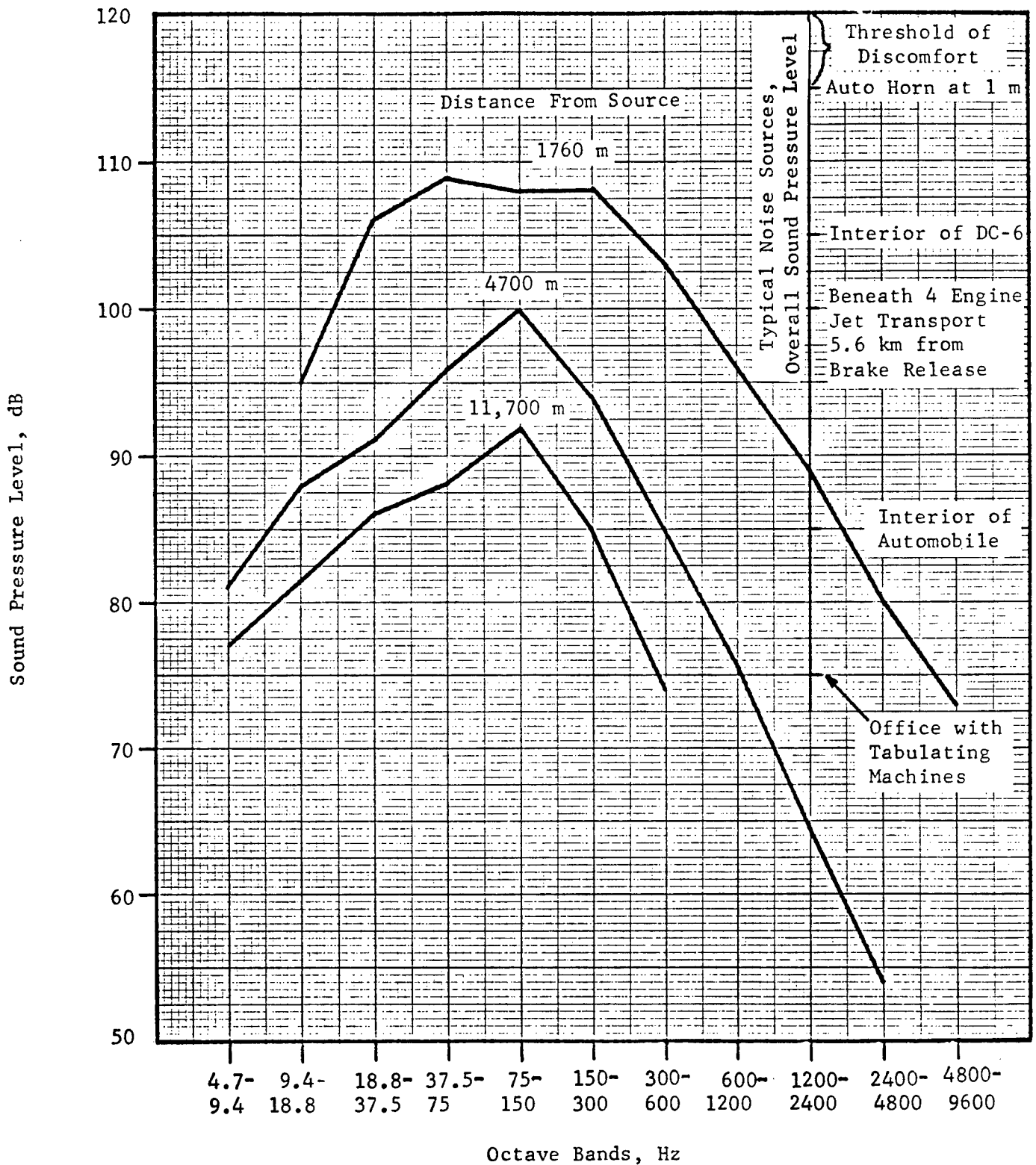


FIGURE 8. MAXIMUM FREE-FLIGHT SOUND SPECTRA FOR A SCOUT LAUNCH⁽²⁶⁾

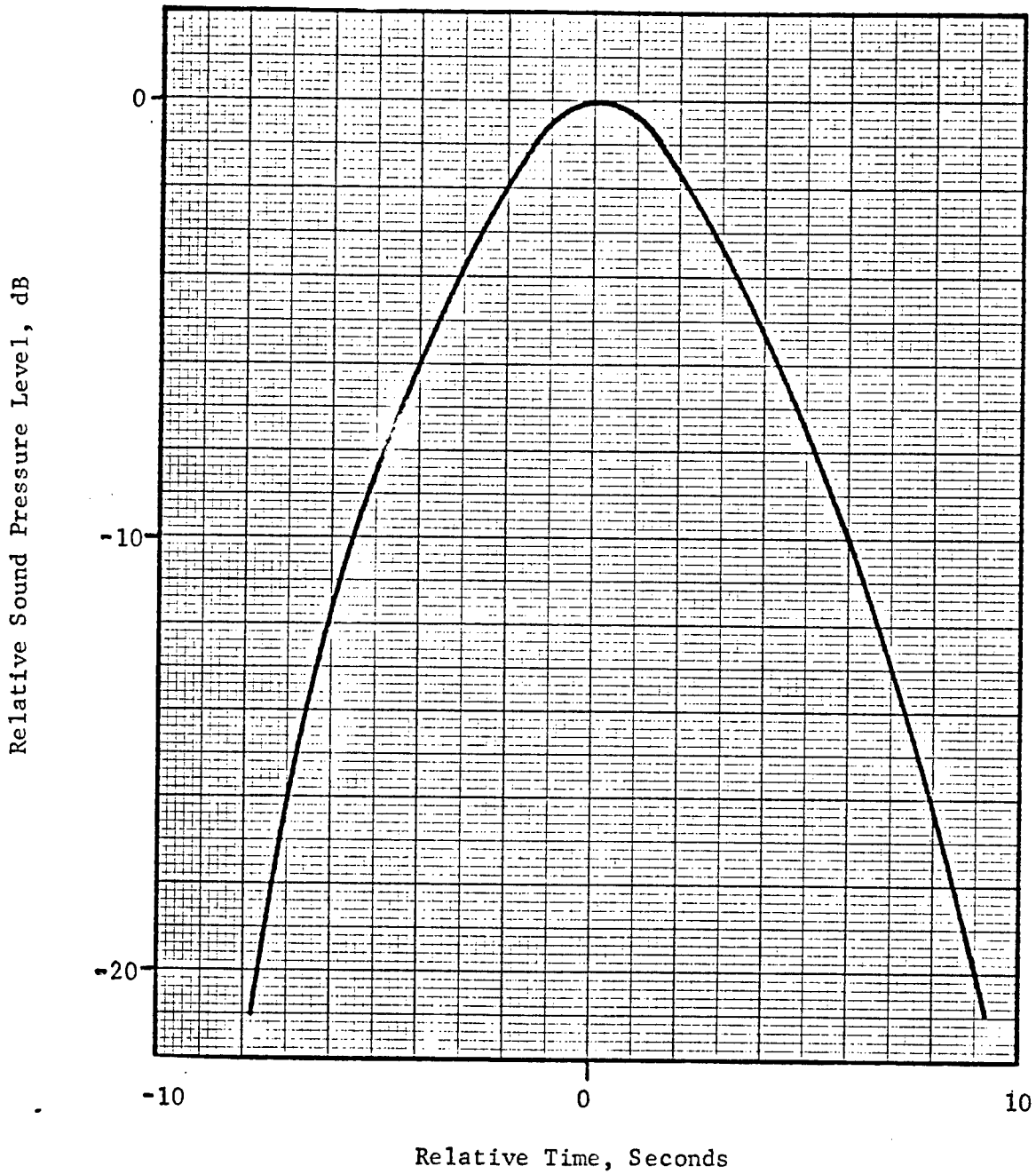
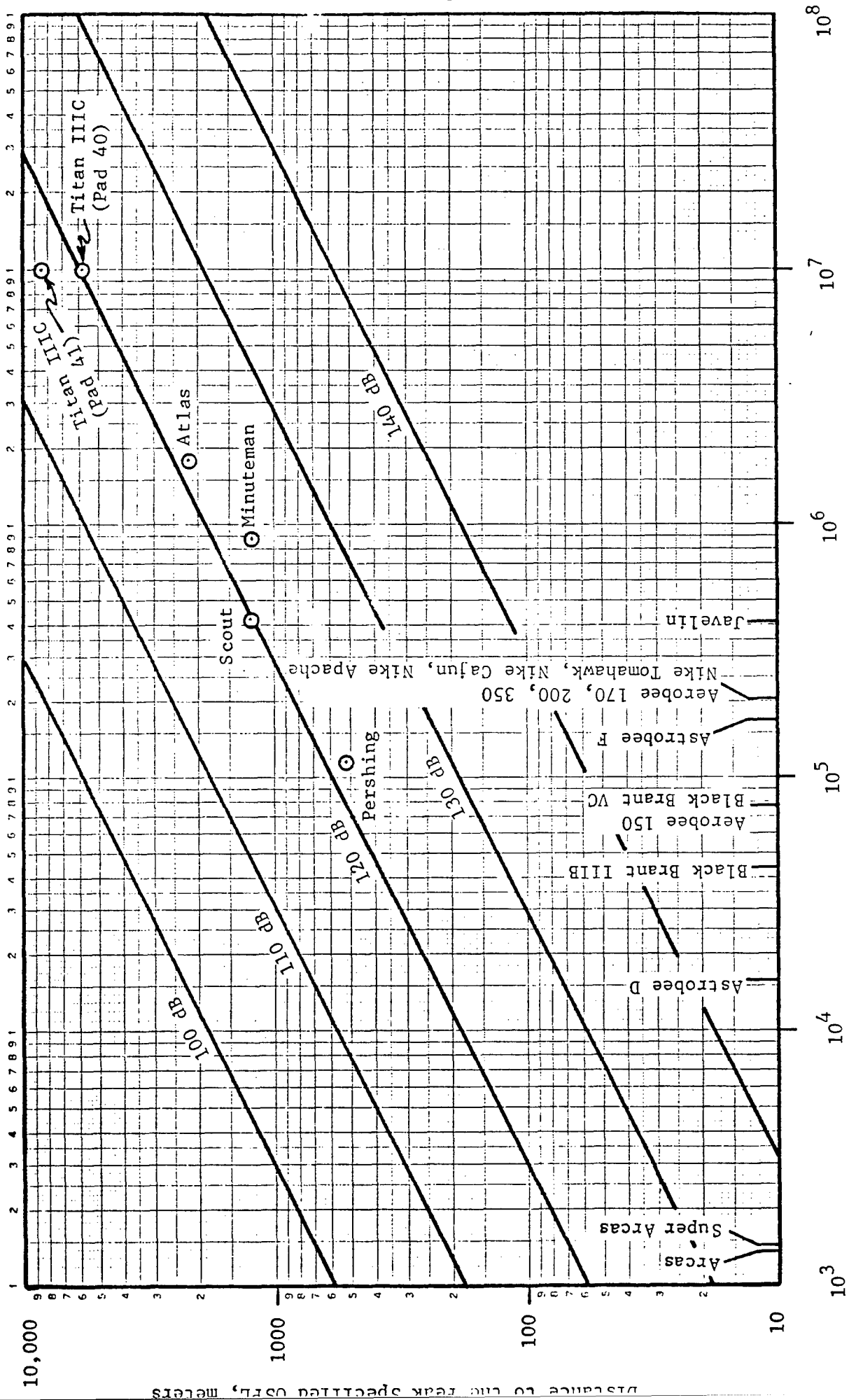


FIGURE 9. TYPICAL TIME DURATION OF THE NOISE PRODUCED BY A SCOUT LAUNCH AT A DISTANCE OF 1500 METERS (26)



Thrust at Sea Level, Newtons

FIGURE 10. DISTANCES FROM THE LAUNCH SITE TO SPECIFIC OVERALL PEAK SOUND PRESSURE LEVELS
Based on observed upper bound SPL. Adapted from Reference (26).

Impact on the Environment

Noise can affect the environment, with perhaps its most important effects on man. Noise can also have an effect on structures, animals, and plants. For the size of rocket motors considered here, noise levels sufficient to cause structural damage would occur only very close to the launch site, at distances less than 400 meters for the largest motor. Damage to plants might occur at noise levels similar to those causing structural damage, although no such damage from rocket launches is known to have been observed. The effects of noise on domestic animals and wildlife might be expected to be similar to those on man: hearing damage at sufficiently high noise levels, and various psychological effects such as annoyance or excitement and pleasure. The fact that several Osprey regularly nest within 100 meters of the Rocket Launch Area at Wallops Station indicates that the noise problem has minimal effect on wildlife.

Table 12 shows a set of tolerance limits. The Damage Risk Values are thresholds beyond which hearing damage might occur. In the absence of specific information, the limits of Table 12 may be presumed to apply to domestic animals and wildlife in addition to humans.

TABLE 12. NOISE LEVELS FOR DAMAGE RISK AND ANNOYANCE ^(25,27)

Hearing Damage Risk Values	Annoyance Threshold	Damage to Structures Threshold
130 dB, 10 seconds		
125 dB, 30 seconds		
120 dB, 60 seconds	90 dB (A)	130 dB (frequencies lower than 37 Hz)

Comparing the risk values of Table 12 with Figure 10, it is evident that no appreciable risk to either hearing or structures exists at distances ranging from about 20 meters for Arcas to about 400 meters for Javelin. There is no difficulty in excluding personnel from such close approaches to a launch. Potentially annoying sound levels may exist at distances from about 2 km to perhaps 40 km; however, due to the short duration of the noise, the low frequencies, and the infrequent occurrence, the annoyance is minimal.

It may be noted that a four-engine jet aircraft 150 meters overhead can produce noise levels approaching or exceeding those of a rocket launch at the closest approach normally permitted by uncontrolled or unprotected personnel. Also, unmuffled motorcycles, construction noise (compressors and hammers), and some rock-and-roll bands closely approach these noise levels.

IMPACT OF SPENT ROCKETS AND PAYLOADS

In the normal launch of a sounding rocket, one or more rocket stages and often the payload will impact, intact, in the ocean or unpopulated land area. To avoid endangering, to any appreciable extent, any property and any living plant or animal species, including man, the location of the impacts is carefully planned. Since the flight path of sounding rockets is influenced by atmospheric winds, careful consideration is given to wind velocities before any launch. The impact range of a given rocket and its dispersion about the predicted impact points are important since they may be the limiting factor in the ability to launch a particular vehicle from a specific site. For example, at the present time vehicles like the Javelin are not launched at the White Sands Missile Range (WSMR) for this reason.

The impact areas are carefully selected. If it is an ocean area, ship traffic is restricted so that there will be no hazard to property or people. Aircraft and radar surveillance is exercised over these areas when sounding rocket launches are planned. In the case of land areas, exclusion is practiced and the areas are under surveillance during periods of activity.

When spent stages or payloads impact in the ocean, no recovery is attempted. The potential effects are covered under water quality. When spent stages or payloads impact on land, it is planned that this occurs in nonproductive areas. For example, White Sands is a desert area and only wasteland surface is disturbed. In northern areas, for example Fort Churchill, any launch over land will impact on the tundra. Because the rocket is fin stabilized, it is pointed nose down on impact.

The only evidence of the impact is a small hole in the tundra indicative of the spot below which the rocket has buried itself. Normally, no recovery is attempted so, without additional disturbance, the location of the impact is soon obliterated by natural processes.

In some sounding rocket programs, however, the payload (experiment package) and/or some portion of the rocket will be recovered. The NASA Sounding Rocket Program is currently utilizing parachute recovery systems to support Nike Apache, Nike Cajun, Aerobee 150, Aerobee 170, Aerobee 200, and Aerobee 350 operational vehicles. Additional systems are nearing operational status to support the requirements of the Black Brant IIIB, Black Brant VC, and Nike Tomahawk vehicles.

Four types of launchers are used for the NASA Sounding Rocket Program. They are the (1) tube launcher, (2) zero length launcher, (3) rail launcher, and (4) tower launcher. The first three are easily transportable. Although the fourth, the tower launcher, is normally a permanent fixture at an established rocket launching range, there is a portable launch tower available for the Aerobee 150. The tower launcher is utilized for launching the higher performance vehicles to minimize impact dispersions.

From 1959 to the present time, over 1600 sounding rockets have been launched in the conduct of experiments by NASA. As evidence of the effectiveness of the precautions observed, no casualties, injuries, or property damage are known to have resulted from impact of stages, payloads, or fragments. Based on worldwide experience to date, the extent of the hazard from sounding rocket experiments is considered negligible.

ALTERNATIVES

As indicated previously, the sounding rocket vehicle activities which currently contribute to potential environmental impact are limited to the launch of scientific payloads. There are no significant development programs currently underway which relate to sounding rocket vehicles or their propulsion.

Two types of alternatives logically can be considered for the Sounding Rocket Program as it relates to this Environmental Impact Statement. First, alternative methods for obtaining the same information are discussed. Second, propulsion or vehicle alternatives within the Sounding Rocket Program are considered. A third alternative might appear to be the cessation of the program itself; however, although this would eliminate any related potential impact, it is not worthy of serious consideration. The achievements realized from the Sounding Rocket Program in the past⁽²⁸⁾ far outweigh the extremely small environmental impacts which have been discussed in other portions of this statement.

The alternatives to using sounding rockets for measurements below about 40 km in the atmosphere consist of using aircraft and balloons for certain types of experiments. In general, however, the scientific advantages, low cost, and minimal environmental effect of sounding rockets make them a desirable vehicle and it is for these reasons they are used. Above 200 km, satellites can be used to carry instruments for the measurement of various phenomena. Each of these vehicles (balloons, aircraft, sounding rockets, and satellites) has unique performance characteristics and each is used to exploit these. However, aircraft and satellites would normally result in greater impact on the environment if used in place of sounding rockets.

The unique characteristics of sounding rockets which allow them to be launched quickly to observe fleeting phenomena, simultaneously from many locations on earth, or in a timed and carefully controlled sequence cannot be matched by any other method. Satellites are the only other devices which can provide a stabilized, oriented spacecraft capable of conducting sophisticated scientific experiments, unencumbered by the major effects of the earth's atmosphere, gravity, or other environment during the coasting or free fall portions of the trajectory. Sounding rockets have much lower cost and less harmful environmental effects than satellites.

In the second category, the use of alternative propellants might eliminate some potential (but clearly minor) hazards. Some rockets use solid propellants which emit HCl. Other solid propellant formulations might be developed which would reduce or eliminate the HCl in the combustion products. However, such alternative motors would be expected to lead to increases in other objectionable emissions such as CO.

The aniline-furfuryl alcohol mixture used as fuel in the Aerobee liquid propellant sounding rocket engines has certain objectionable features described previously. These engines might be replaceable by LOX/kerosene or LOX/LH₂ engines, for example. Such substitutions would change combustion product compositions only slightly with the

most significant difference being the elimination of CO with the use of the LOX/LH₂ system. Further, effects of spilled propellant in a water environment essentially would be eliminated. There would be no effect on noise. Although no specific estimate has been made, past experience in developing space launch vehicles indicates the costs of such an alternative would be significant. Also, the convenience and simplicity obtained from using storable propellants would be lost if a cryogenic system were adopted.

In view of the very limited environmental effect of the current sounding rocket vehicles, no further consideration of any of the above alternatives is recommended at this time.

THE RELATIONSHIP BETWEEN THE LOCAL SHORT-TERM USES OF THE
ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT
OF LONG-TERM PRODUCTIVITY

In fulfilling its responsibility, the NASA OSS Sounding Rocket Program has followed a philosophy that has always emphasized safety, reliability, and economy in conducting experiments, both in near-space and in the near and far reaches of the atmosphere.

This program provides a relatively inexpensive approach to partial satisfaction of man's need to better understand, utilize, predict, protect, and control his life-sustaining and, sometimes, hostile environment.

It is impractical here to itemize all known and potential environmental benefits (28) generated by past or planned sounding rocket activities, but the general value can be expressed simply as follows. Scientifically, more has been learned about our immediate environment and that of the solar system in the last two decades than in all previous decades combined. The space program has made a large contribution to the knowledge gained. Such knowledge is fundamental to any realistic endeavor to protect the environment. In the immediate, practical sense, slow but noticeable improvement is being made in our ability to utilize this recently acquired capability for such functions as communications and meteorology. The NASA Sounding Rocket Program makes a unique contribution in the total effort to provide mankind with an operational capability to measure, monitor, and manage environmental conditions and natural resources from a local to a global scale.

Virtually all NASA sounding rocket experiments represent passive payloads which in themselves have no environmental effect aside from that associated with the launch and impact (or recovery) process. The launch and impact processes represent only minor transient effects. On the other hand, many of these experiments make contributions to the betterment of mankind.

IRREVERSIBLE AND IRRETRIEVABLE
COMMITMENTS OF RESOURCES

The materials which make up a sounding rocket at launch are largely irretrievable once the launch process is initiated. However, they are replaced relatively easily and, in general, are replaceable from domestic resources with relatively insignificant expenditure of manpower and energy.

By far the largest mass of materials making up a sounding rocket is the propellant. Propellants have been enumerated and defined previously; they are common chemicals. Resources and energy required for their production are insignificant in comparison with, for example, the resources and energy required to produce 1 million barrels of jet fuel per week, the current production rate for private, commercial, and military jet aircraft. Considered as the equivalent mass of jet fuel, the average yearly consumption of rocket propellants by sounding rockets would support only one 747 flight from Washington, D. C., to San Francisco, California.

After propellants, the next largest amounts of materials are iron and aluminum. Other materials include plastics and glass, as well as other metals such as nickel, chromium, titanium, lead, zinc, copper, etc.* There may be small amounts of silver, mercury, gold, and platinum. The quantities of materials of various kinds which are utilized are insignificant in comparison with those used in one year of production (10,000,000) of automobiles, for example. The average yearly mass of flight hardware employed by the Sounding Rocket Program for the past 12 years is equivalent to only 31 automobiles.

Perhaps the best available measure of the commitment of resources to the NASA Sounding Rocket Program is the annual rate of dollar expenditures on the program. This is expected to average approximately \$20M/yr through 1980. By far the largest fraction of these expenditures is for wages and salaries. These expenditures represent a relatively small fraction of the national economy. As illustrated by this and the other examples given, no commitment of any individual resource of major significance to the national economy exists.

* The composition of "typical" sounding rocket inert components can be estimated as 78.2% steels, 20.2% Al, 0.4% Ti, and 1.2% miscellaneous.

APPENDIX A

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REFERENCES

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- (27) Regier, A. A., Mayes, W. H., and Edge, P. M., Jr., "Noise Problems Associated with Launching Large Space Vehicles", Sound, No. 6, pp 7-12, 1962.
- (28) Newell, Homer E., Jr., Sounding Rockets, McGraw-Hill Book Company, Inc., New York, 1959.
- (29) Medrow, Karl R., "Compendium Summary-NASA Sounding Rocket Program", Sounding Rocket Division, Goddard Space Flight Center, Greenbelt, Maryland, January 16, 1973.
- (30) Rice, E. E., "Propellant and Exhaust Product Composition Data for 14 NASA Sounding Rockets", Battelle-Columbus Laboratories Report No. BMI-SG-ICM-73-1, March 16, 1973.

APPENDIX B

SAMPLE TRAJECTORIES

SAMPLE TRAJECTORIES

Figures B-1 through B-5 present the relationships between ground range and altitude for six sounding rockets which are considered representative of the entire family of fourteen considered in this Environmental Impact Statement. Also shown on these figures are burn out altitudes of spent stages, parachute deployment altitude, and the corresponding impact range.

The ground range-altitude plots shown in this Appendix should be regarded as representative examples. Variations in payload mass and launch angle can influence the trajectories. Nearly every mission launched is unique in some sense, and vehicle trajectories are designed to satisfy the unique requirements of the mission. For every launch, trajectories are calculated at a level of detail impossible for the generalized treatment required here. Full consideration is given to the location of the impact points of jettisoned hardware and to the path followed by the instantaneous impact point. When necessary, trajectories are modified to control the impact point of jettisoned hardware and to control the path of the instantaneous impact point.

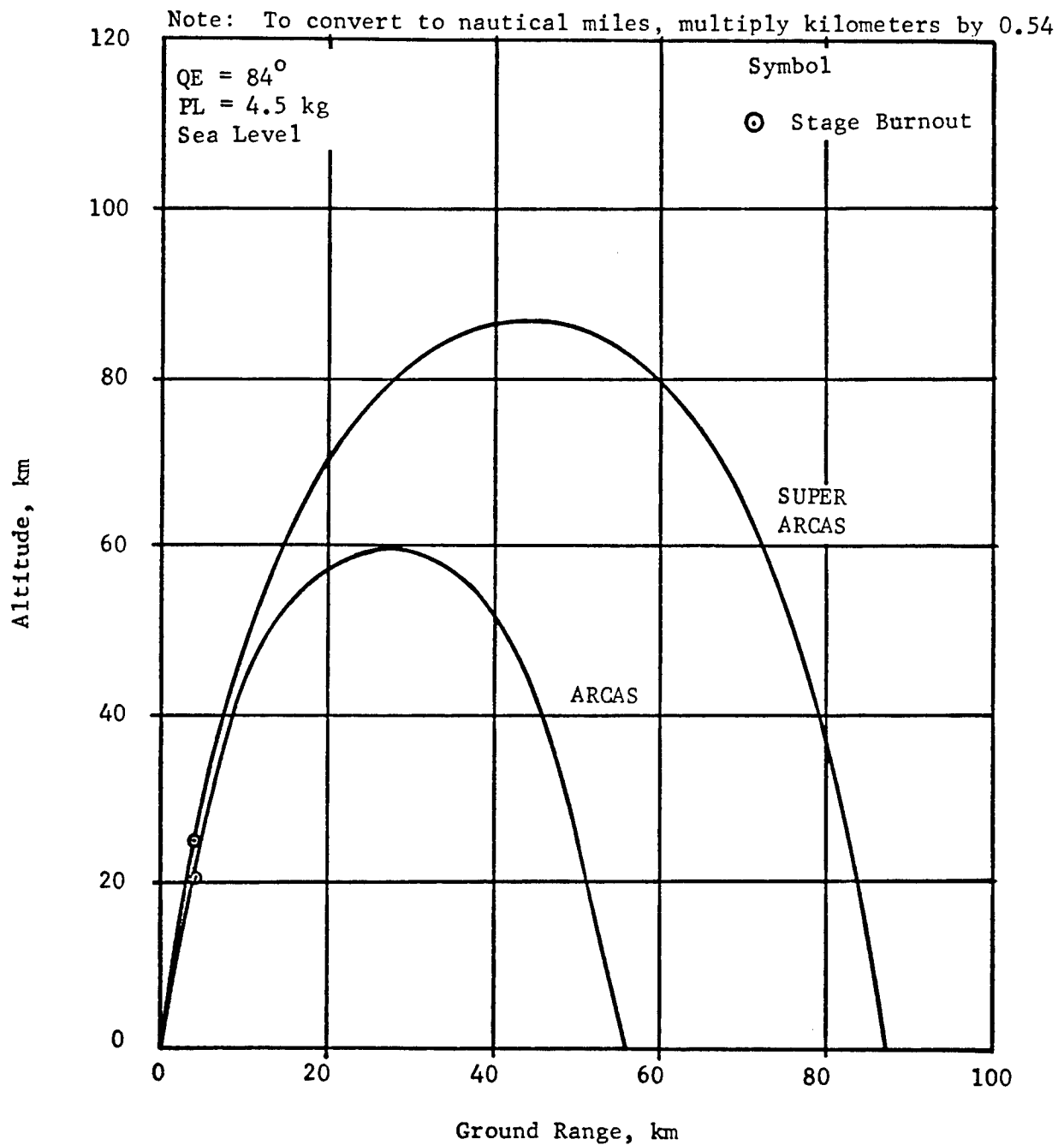


FIGURE B-1. SAMPLE TRAJECTORIES FOR ARCAS AND SUPER ARCAS

Note: To convert to nautical miles, multiply kilometers by 0.54

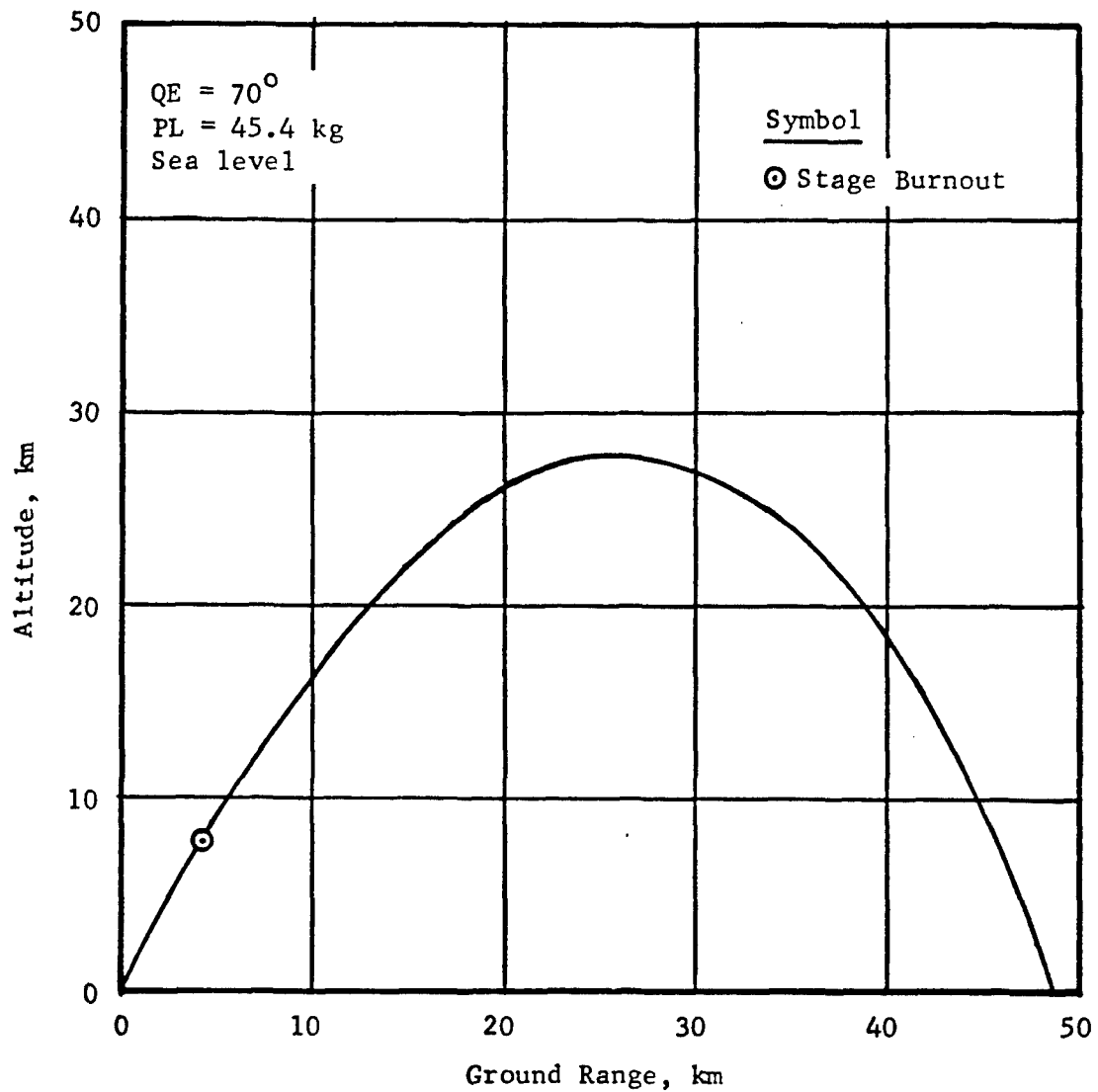


FIGURE B-2. SAMPLE TRAJECTORY FOR ASTROBEE D

Note: To convert to nautical miles, multiply kilometers by 0.54

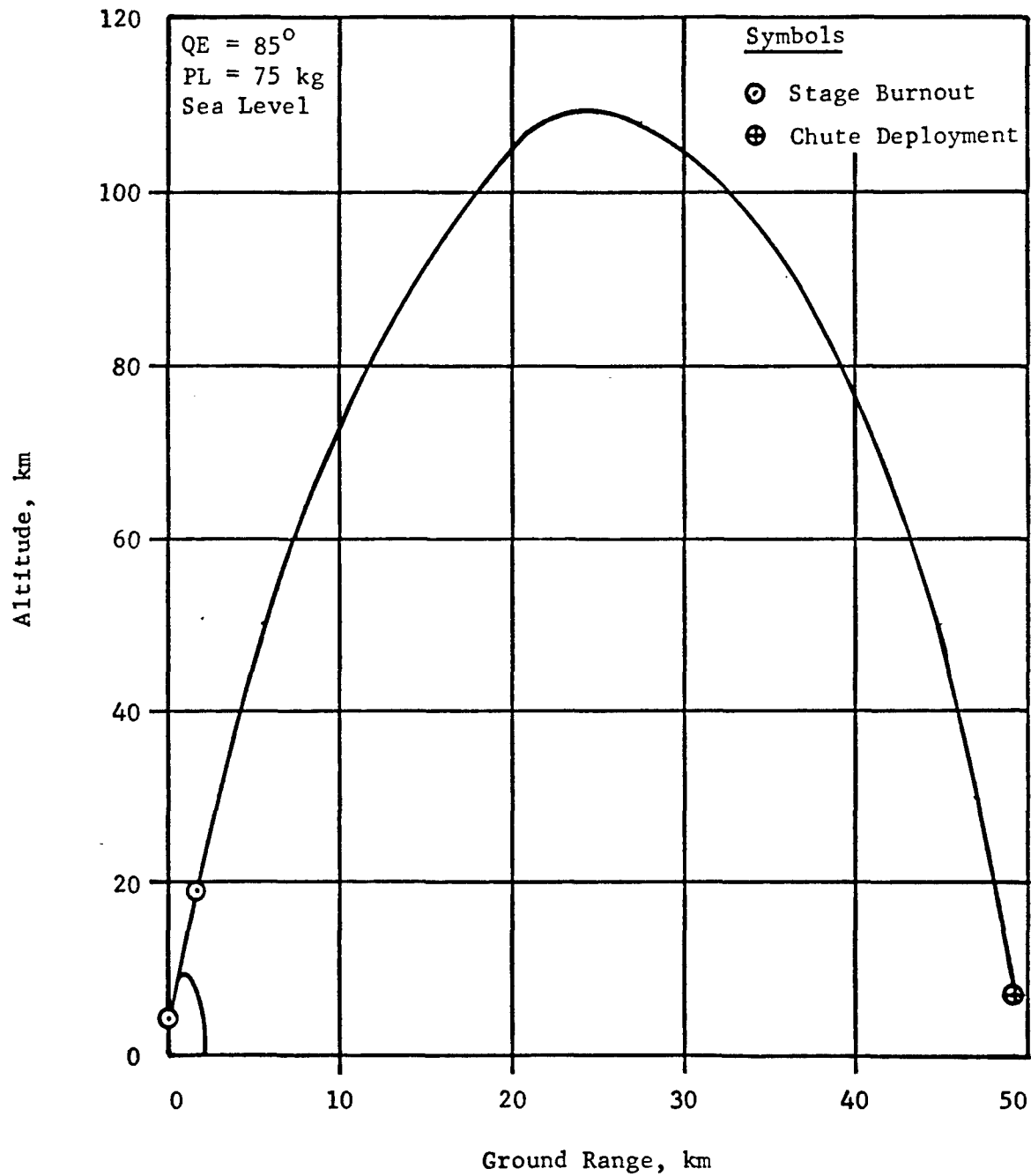


FIGURE B-3. SAMPLE TRAJECTORY FOR NIKE-APACHE

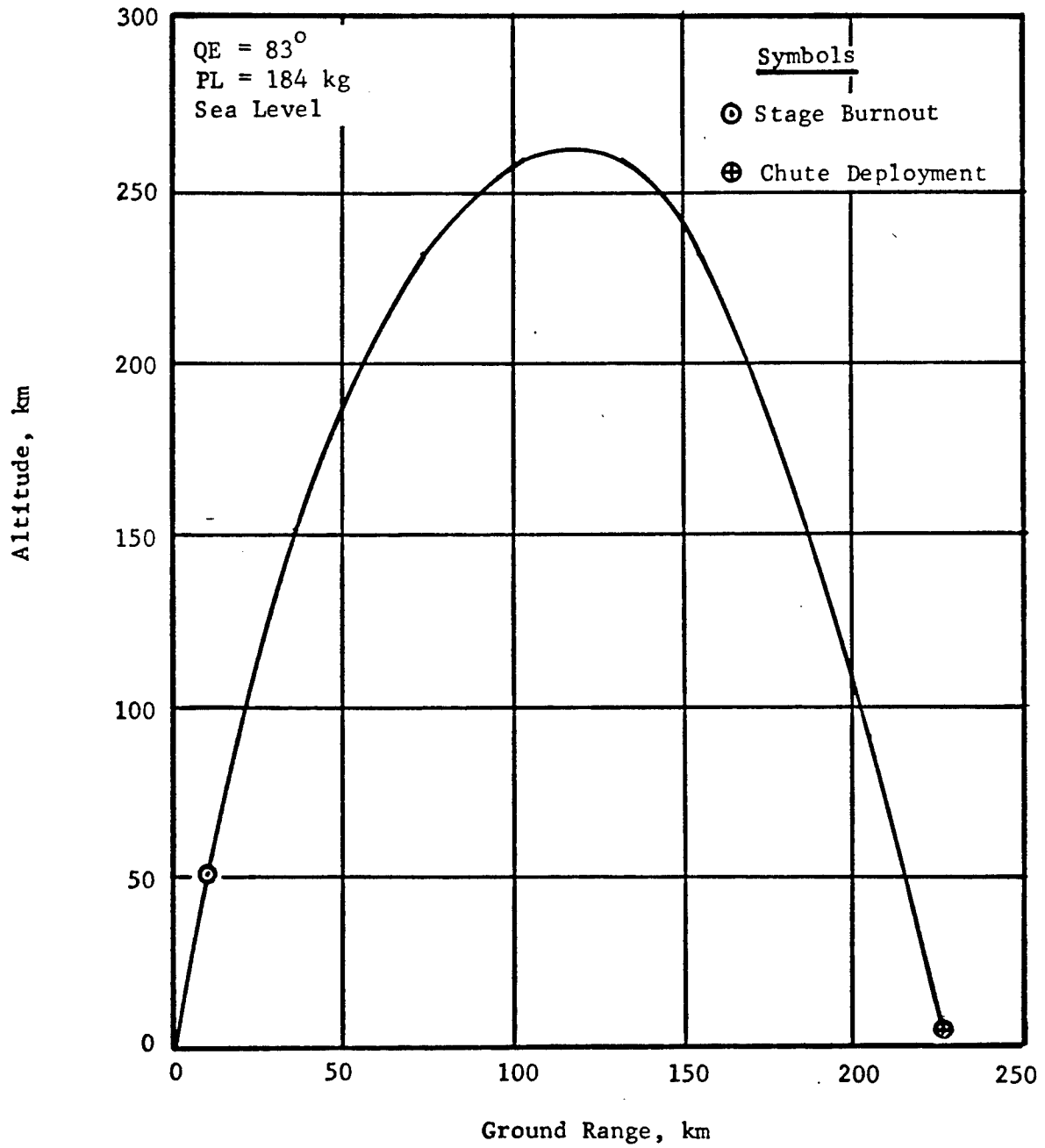


FIGURE B-4. SAMPLE TRAJECTORY FOR ASTROBEE F

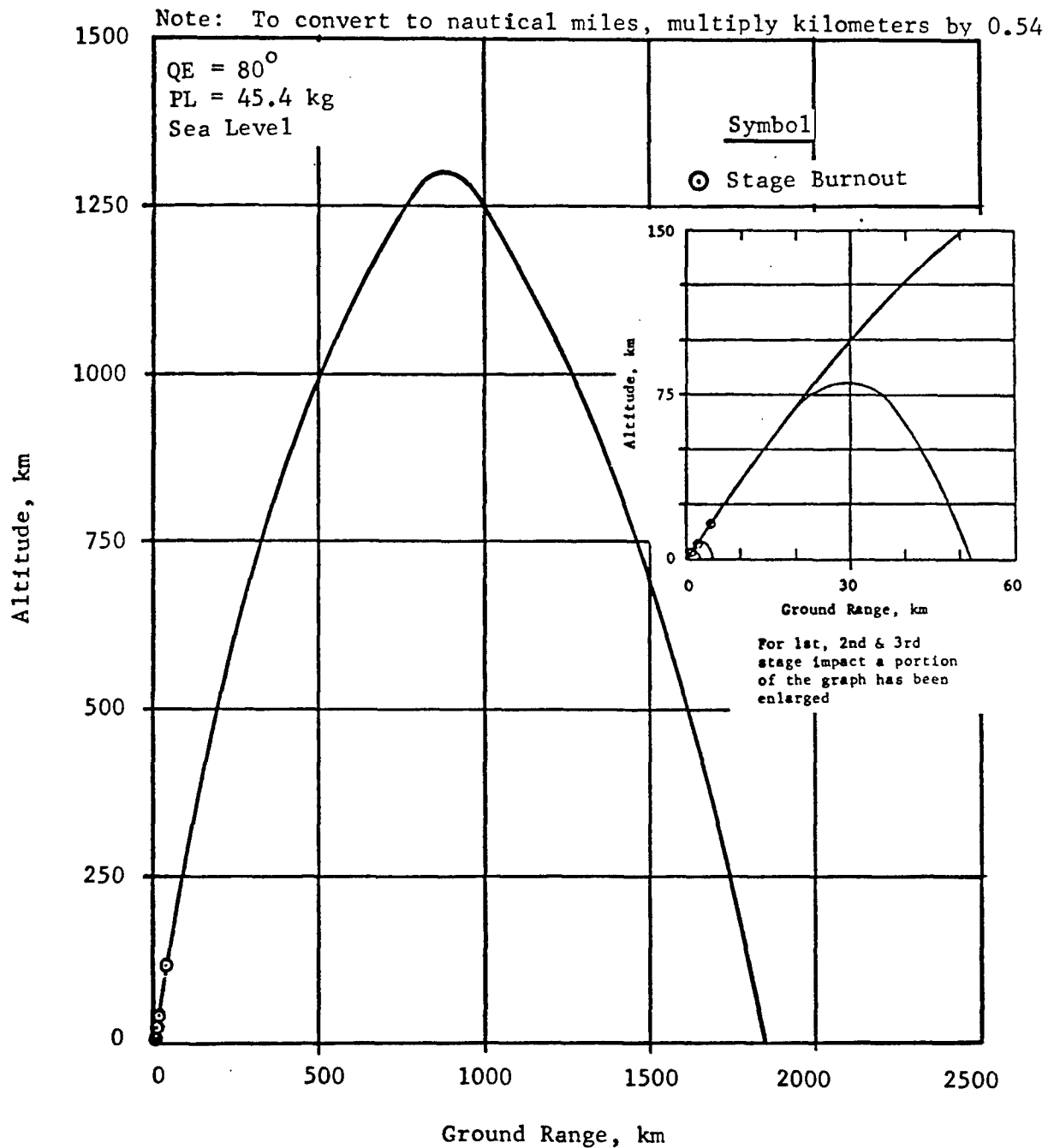


FIGURE B-5. SAMPLE TRAJECTORY FOR JAVELIN

APPENDIX C

LAUNCH SITE MAPS

APPENDIX C

LAUNCH SITE MAPS

Figures C-1 through C-14 are range and launch site maps of nine of the launch sites employed by the NASA Sounding Rocket Program. During the 1959-1972 period, approximately 90 percent of the NASA sounding rockets were launched from these sites (See Table 3). The sites depicted are Wallops Station, Virginia (U.S.A.); White Sands, New Mexico (U.S.A.); Fort Churchill, Canada; Point Barrow, Alaska (U.S.A.); Thumba, India; Andoya, Norway; Natal, Brazil; Kiruna, Sweden; and Fairbanks, Alaska (U.S.A.).

For each launch site, distances between the launch pads and the facility boundary, and the nearest community are indicated or can be estimated from the distance scales provided.

In general, press sites, as such, do not exist at these launch facilities so that it is difficult to determine the closest permitted approach of uncontrolled personnel to the launch pad during a launch. Although press representatives and other viewers may be uncontrolled in the sense of medical histories and periodic health examinations, their movements are controlled by the responsible agency and they may be provided with and required to use protective equipment. The nearest facility boundary represents the closest possible approach of completely uncontrolled persons.

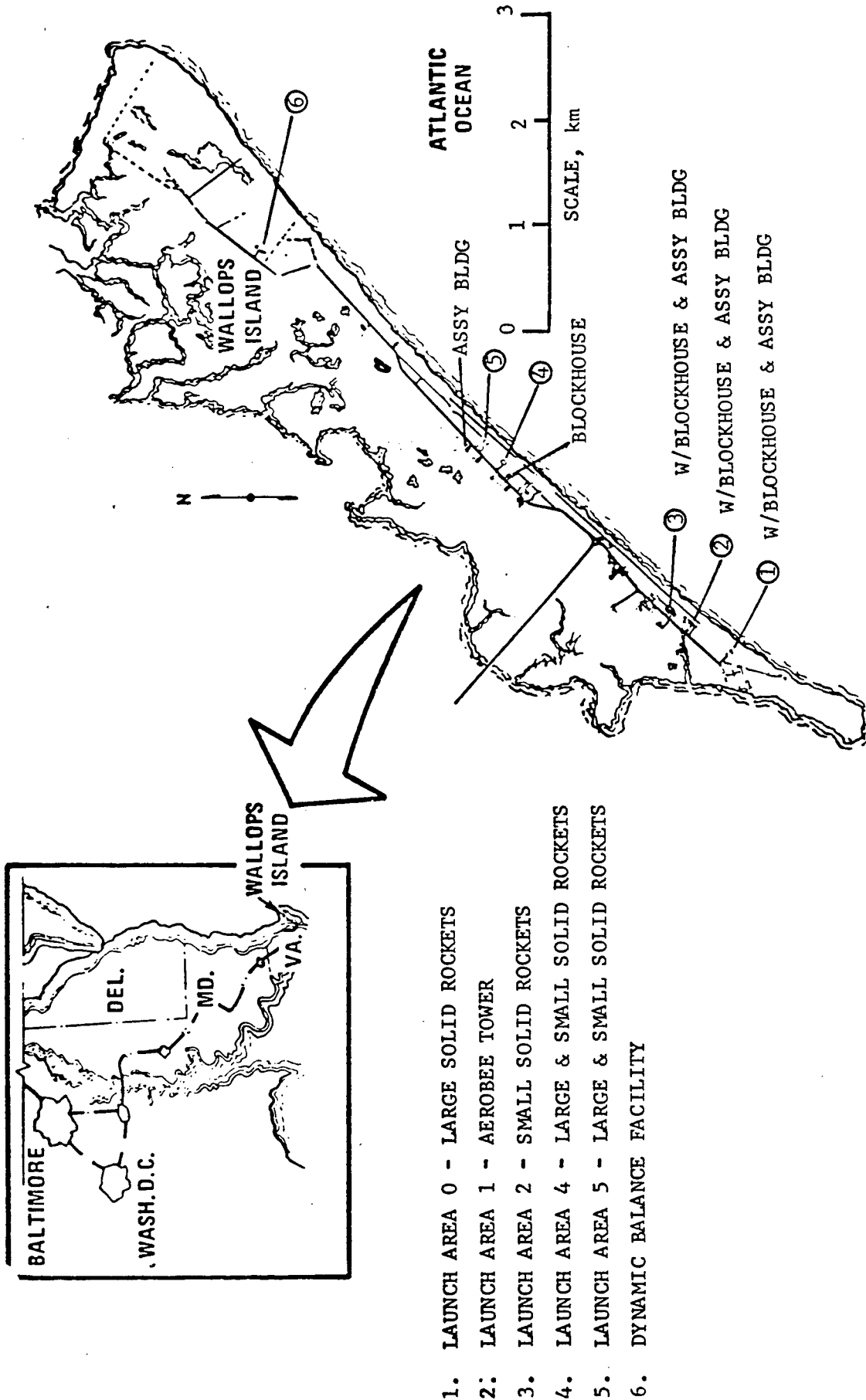


FIGURE C-1. MAP OF WALLOPS STATION

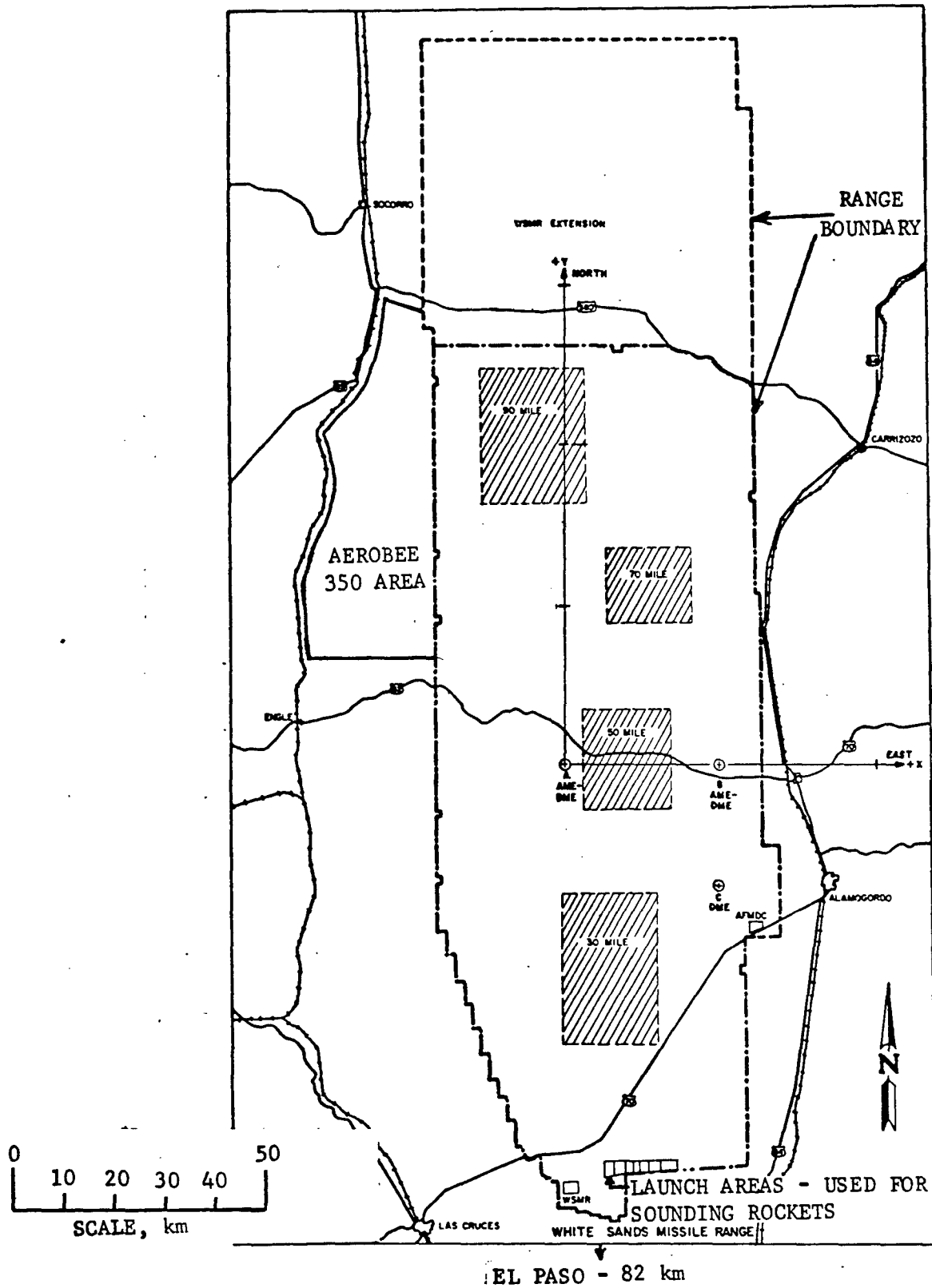


FIGURE C-2. WHITE SANDS LAUNCH FACILITY AND RANGE

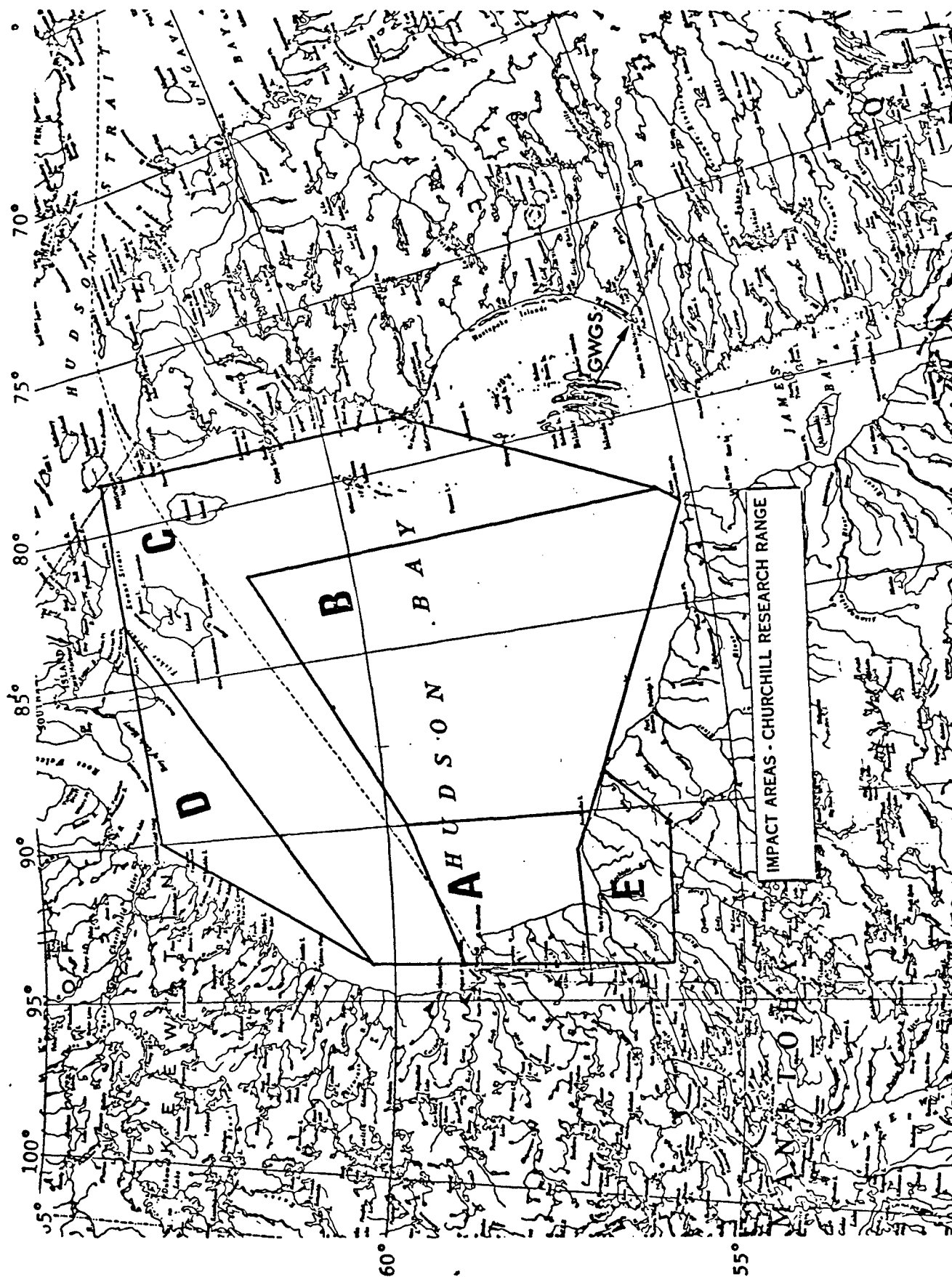
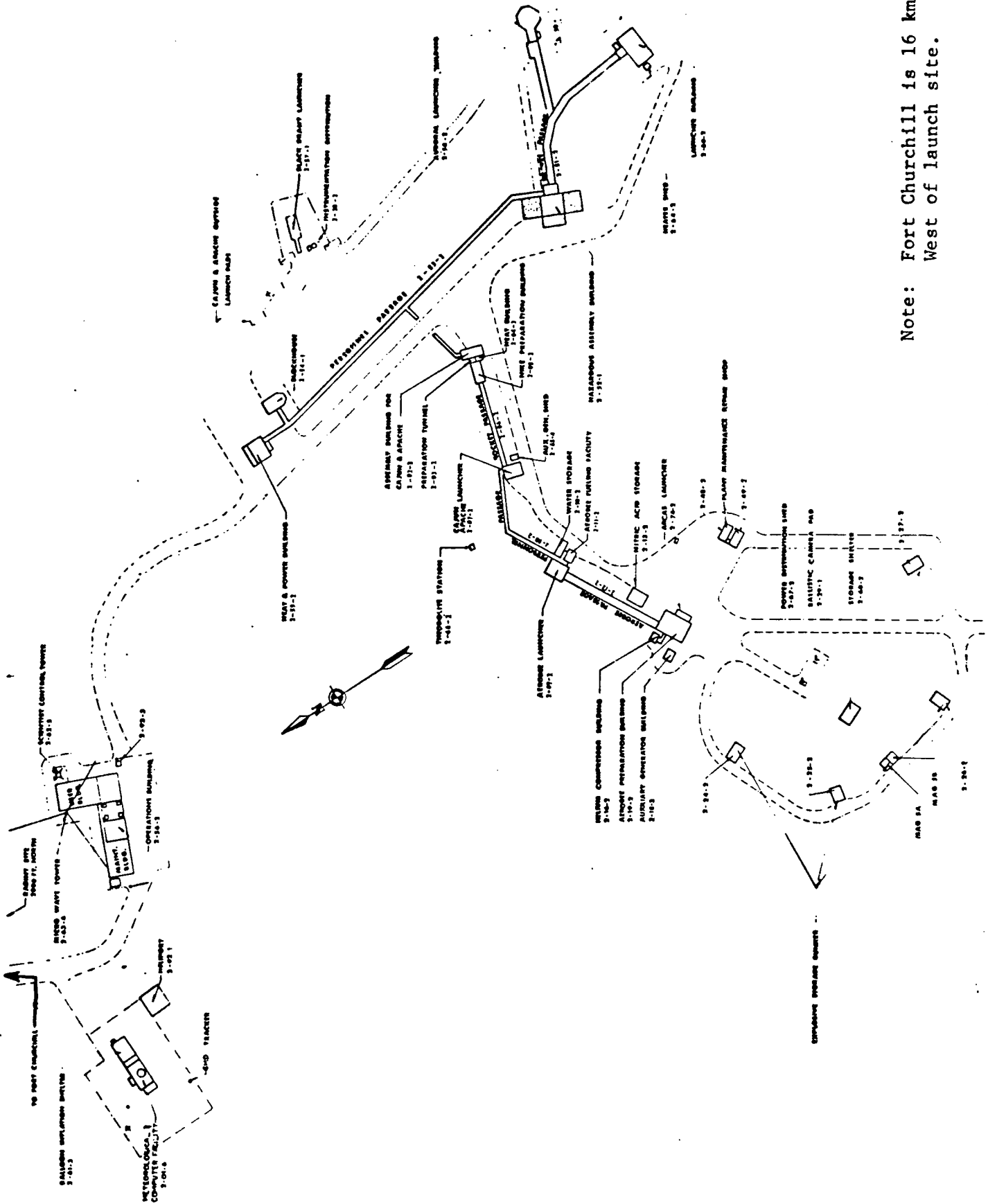


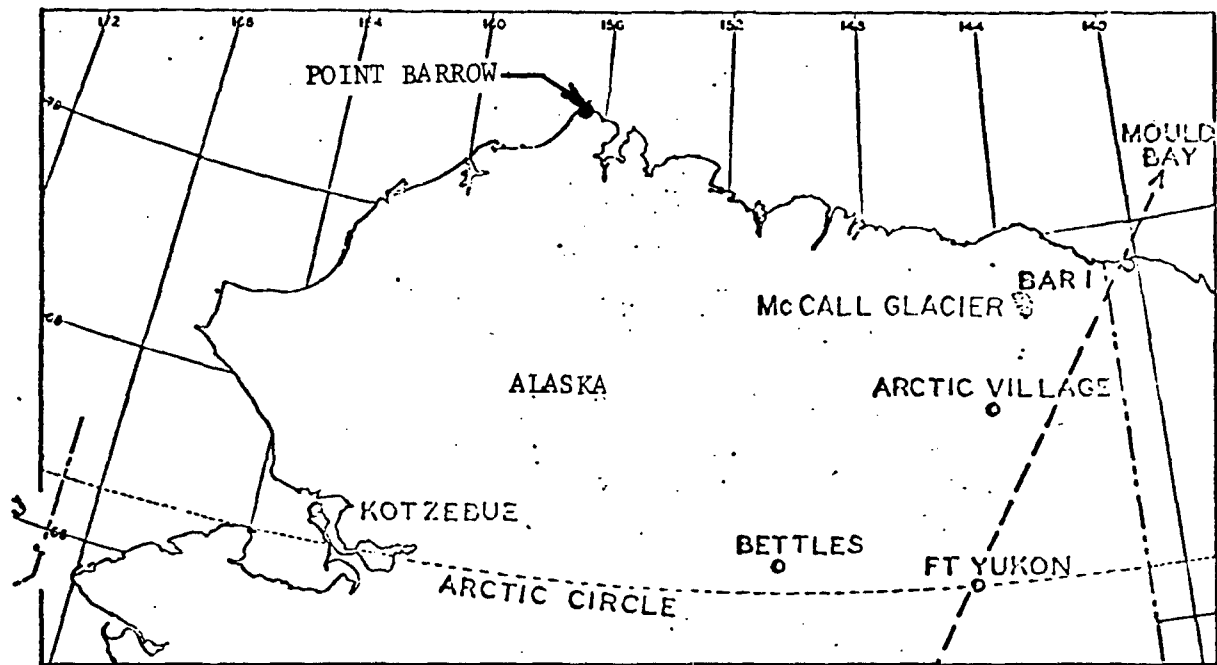
FIGURE C-3. LOCATION OF FORT CHURCHILL RESEARCH RANGE

(See also Figure C-4)



Note: Fort Churchill is 16 km West of launch site.

FIGURE C-4. LAUNCHING SITE OF FORT CHURCHILL RESEARCH RANGE



The broken line indicates the geomagnetic meridian 257°

FIGURE C-5. LOCATION OF POINT BARROW LAUNCH FACILITY

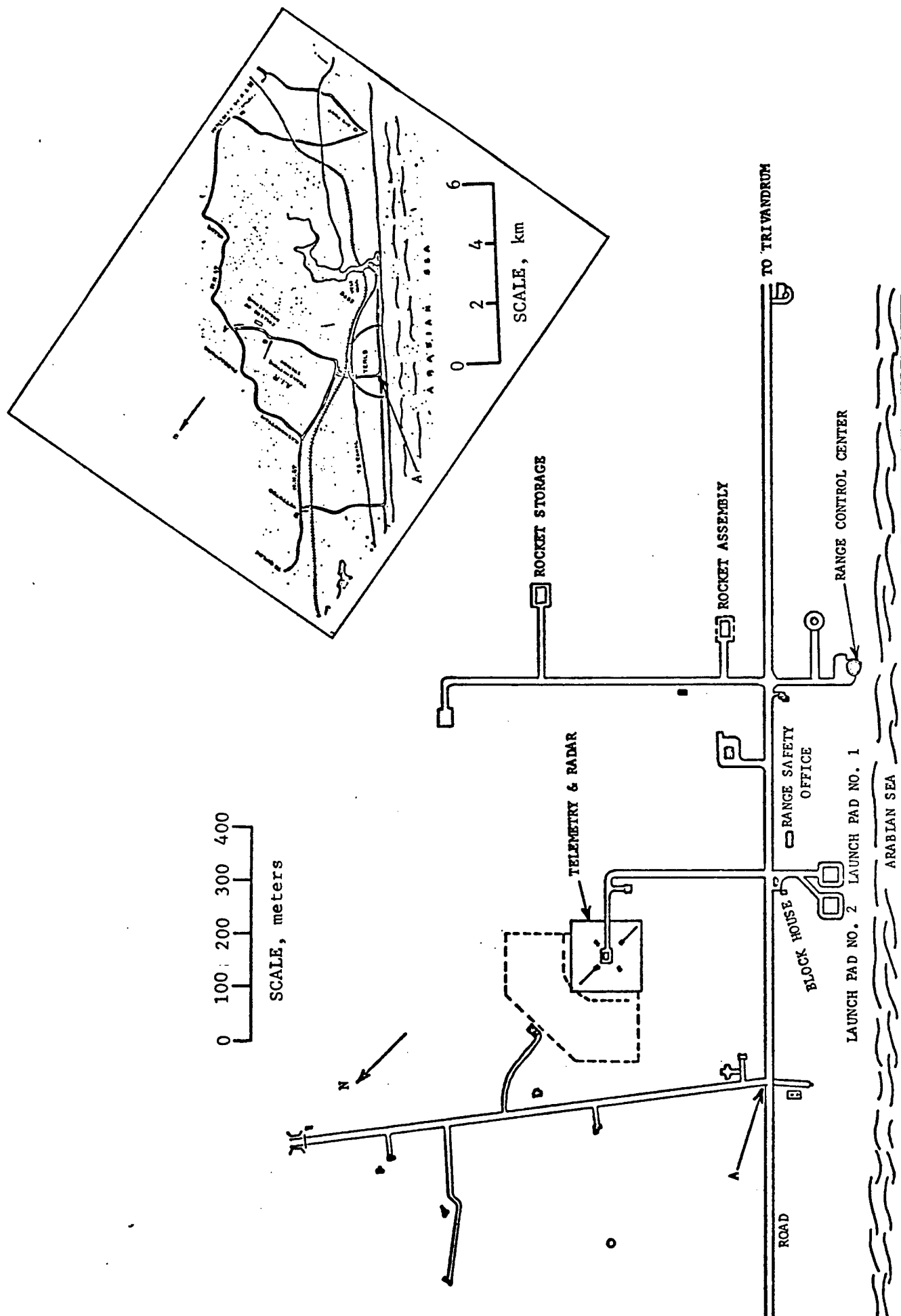


FIGURE C-6. THUMBA EQUATORIAL ROCKET LAUNCHING STATION (TERLS)

FIGURE C-7. ANDOYA ROCKET RANGE

(See also Figure C-8)

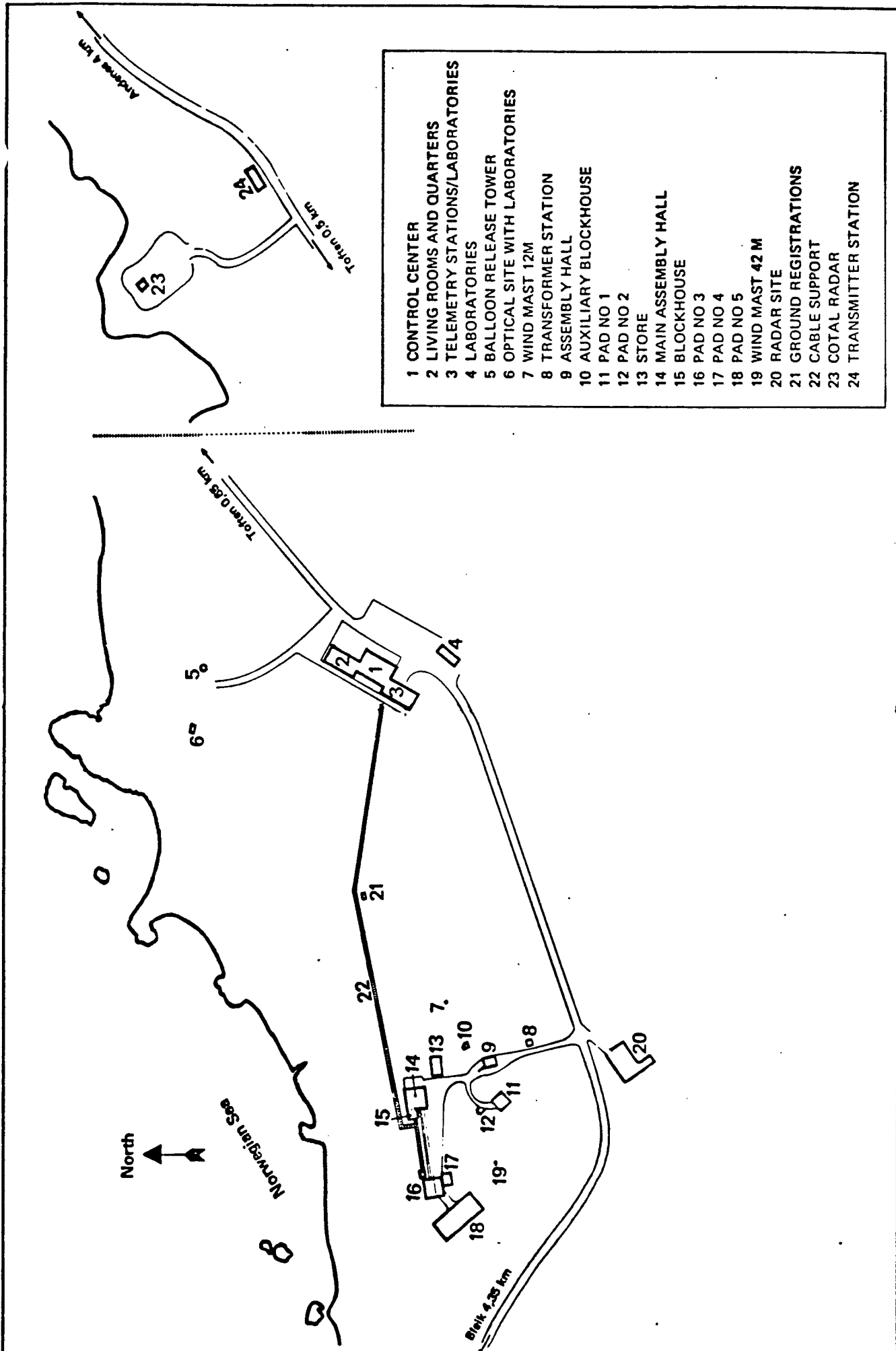


FIGURE C-8. ANDOYA ROCKET RANGE LAUNCH SITE

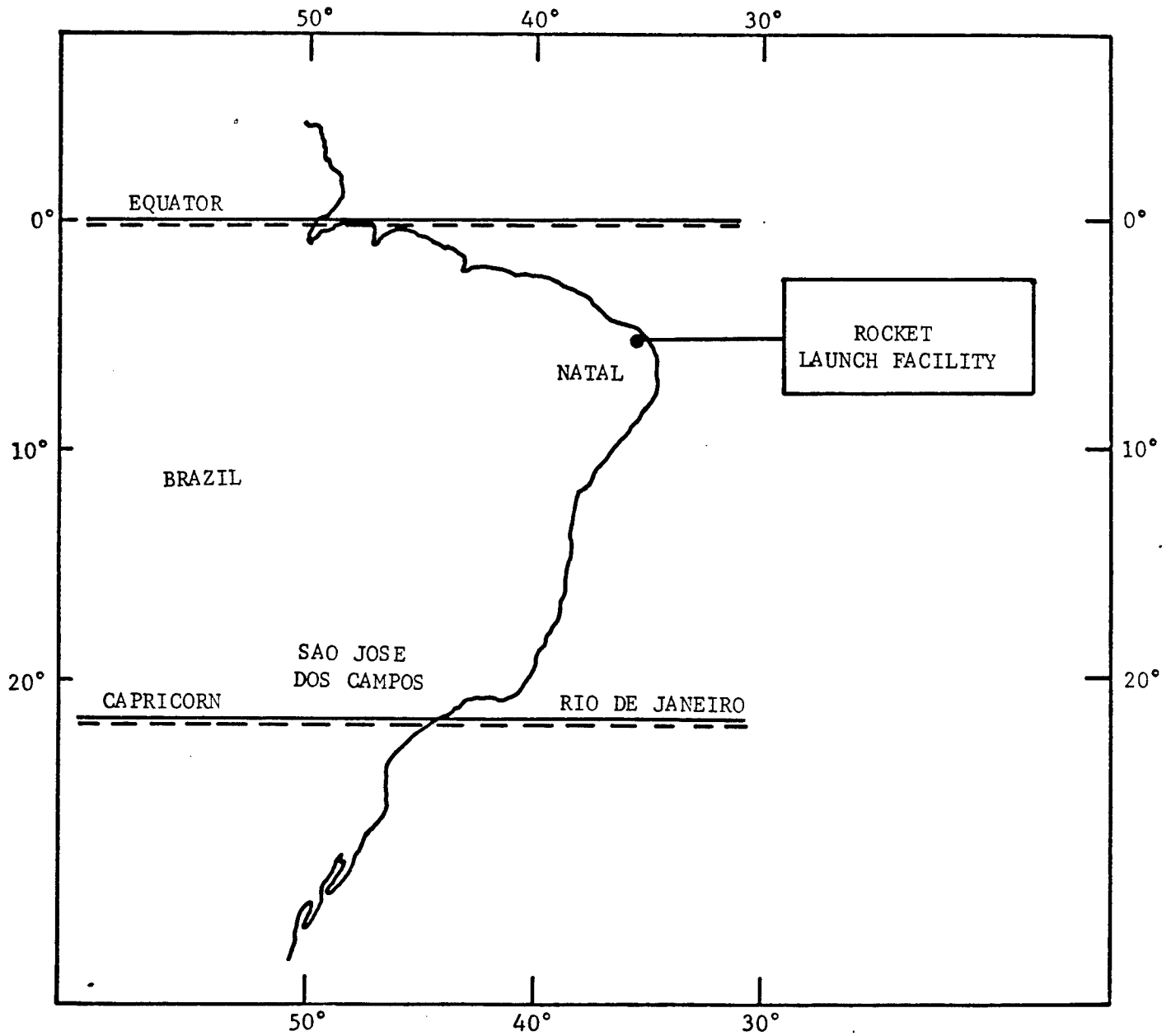


FIGURE C-9. LOCATION OF NATAL LAUNCH FACILITY

(See also Figures C-10 and C-11)

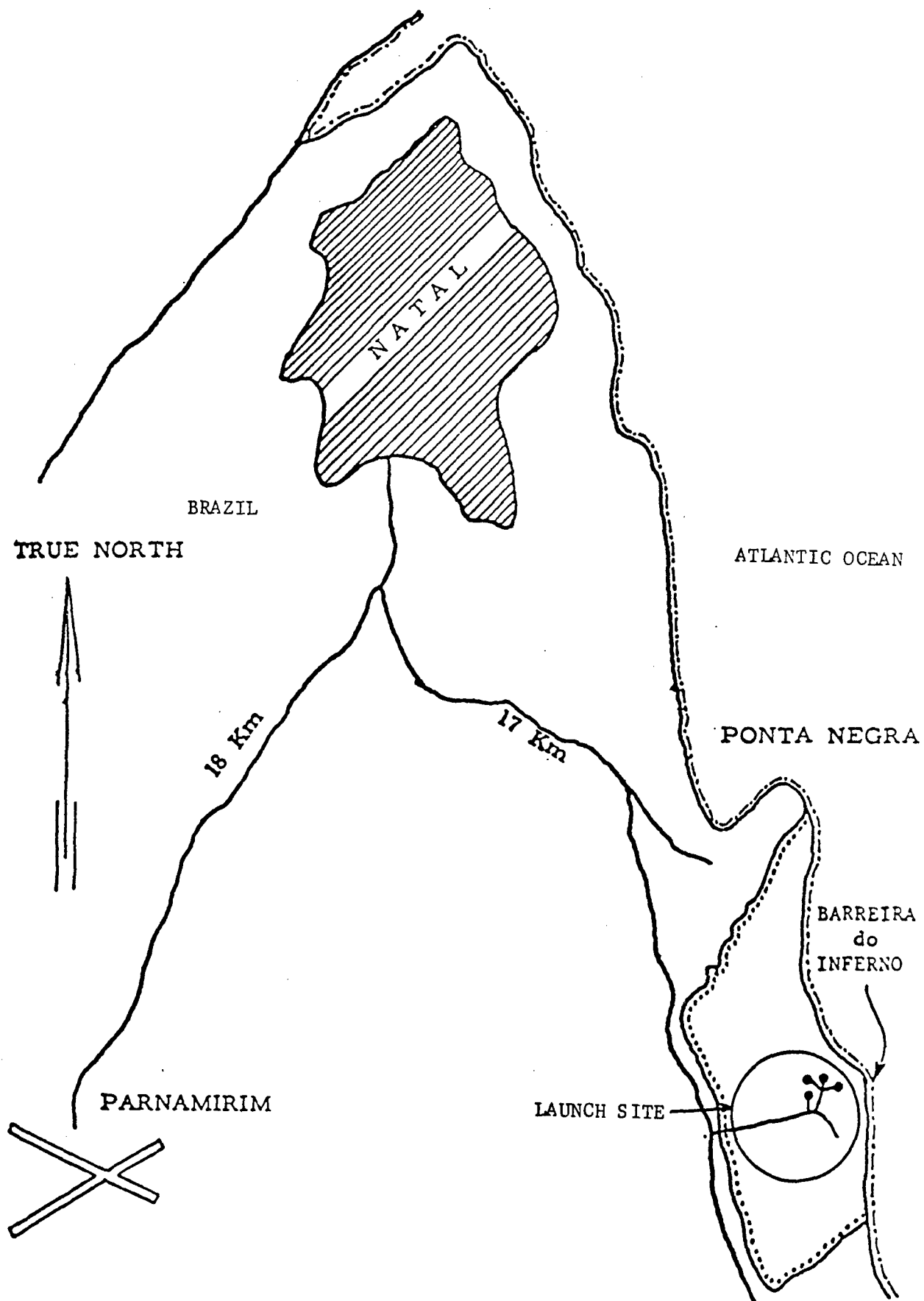


FIGURE C-10. LOCATION OF NATAL LAUNCH FACILITY

1. NIKE PAD
2. ARCAS, HASP, AND TEST
ROCKET PAD
3. RESERVE PAD
4. AEROBEE TOWER
5. UNIVERSAL LAUNCH PAD

TRUE
NORTH

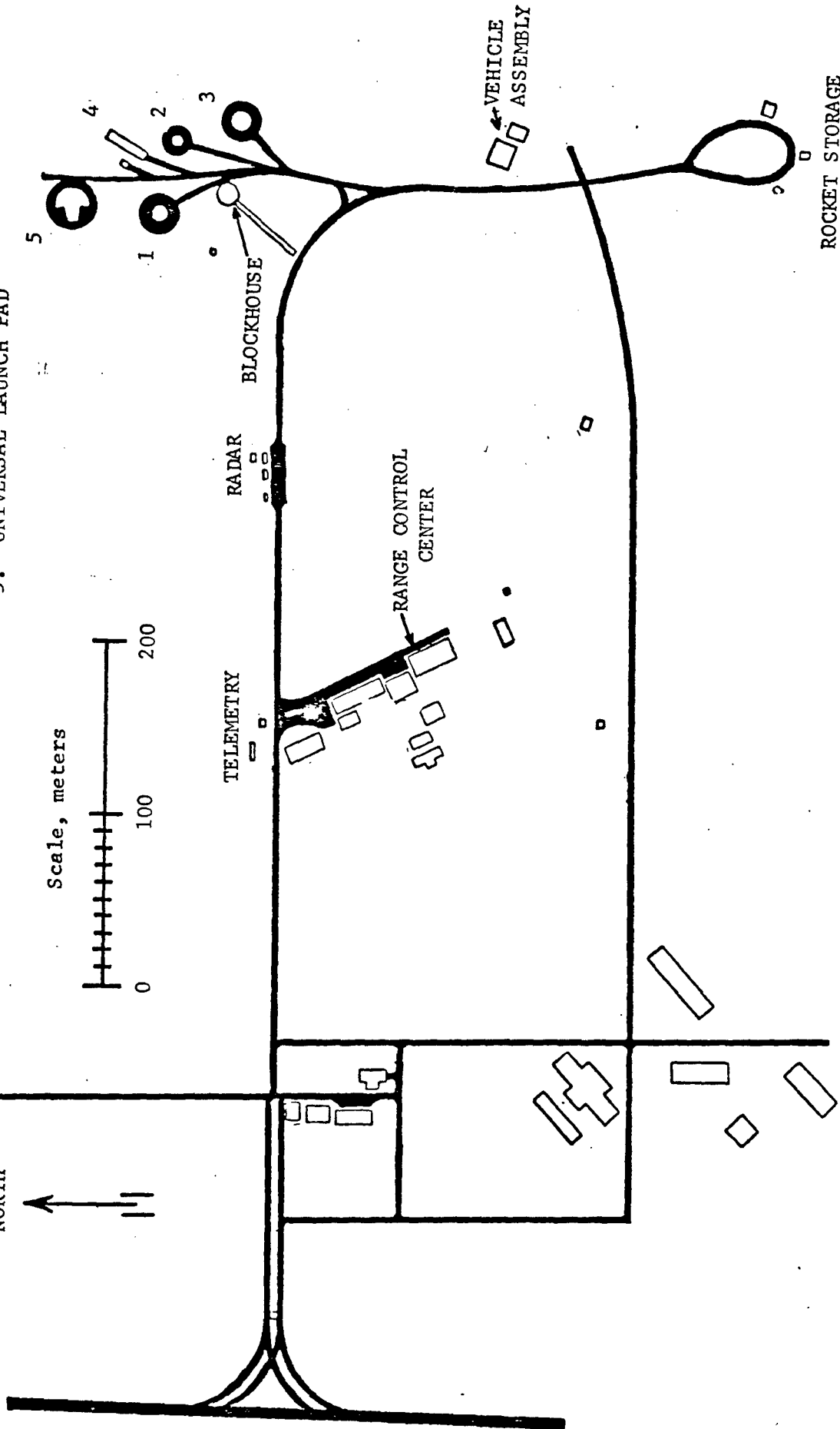
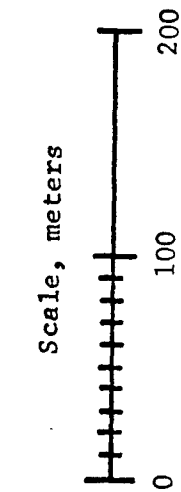


FIGURE C-11. NATAL LAUNCH FACILITY

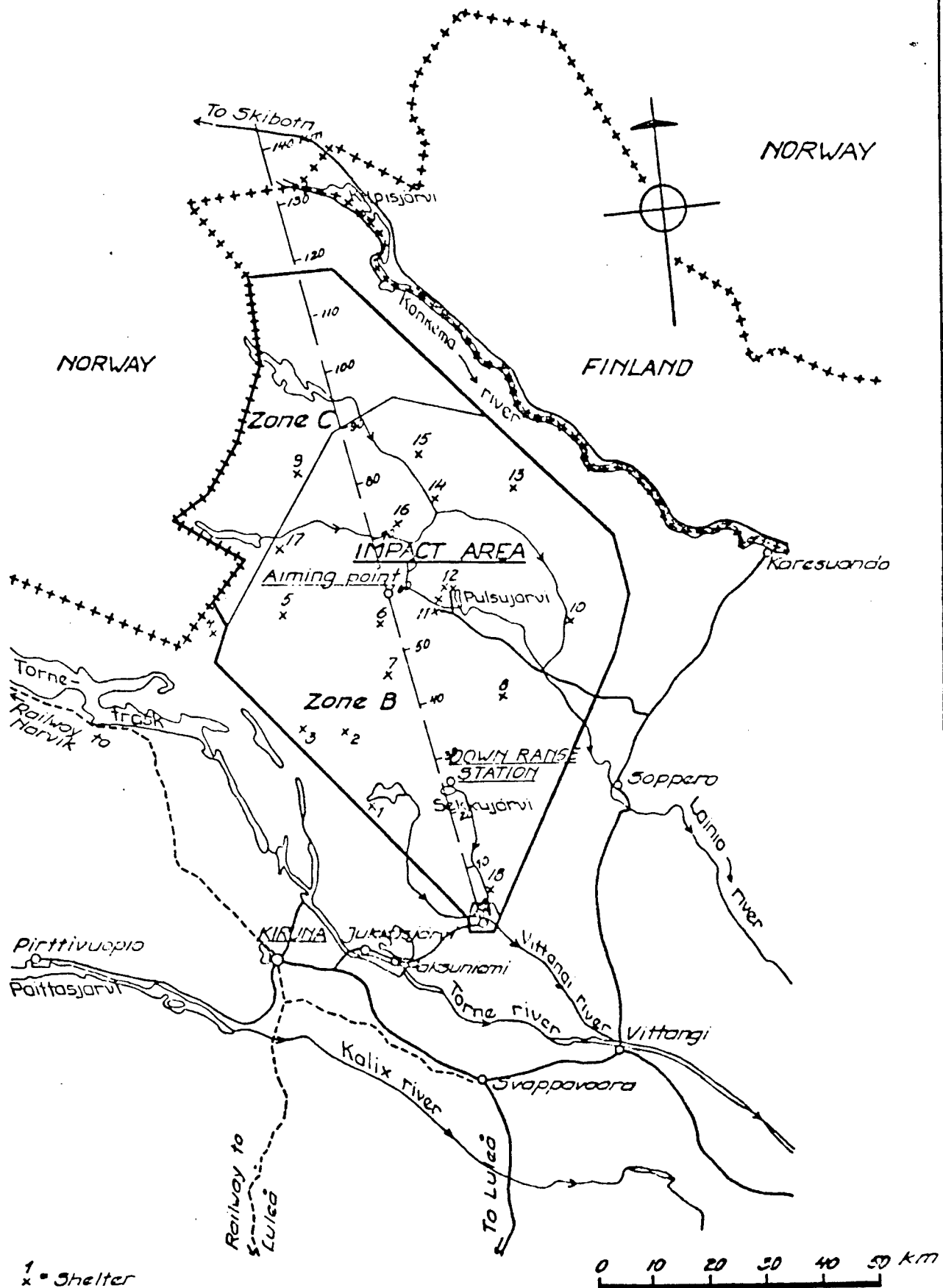


FIGURE C-12.. KIRUNA ROCKET RANGE

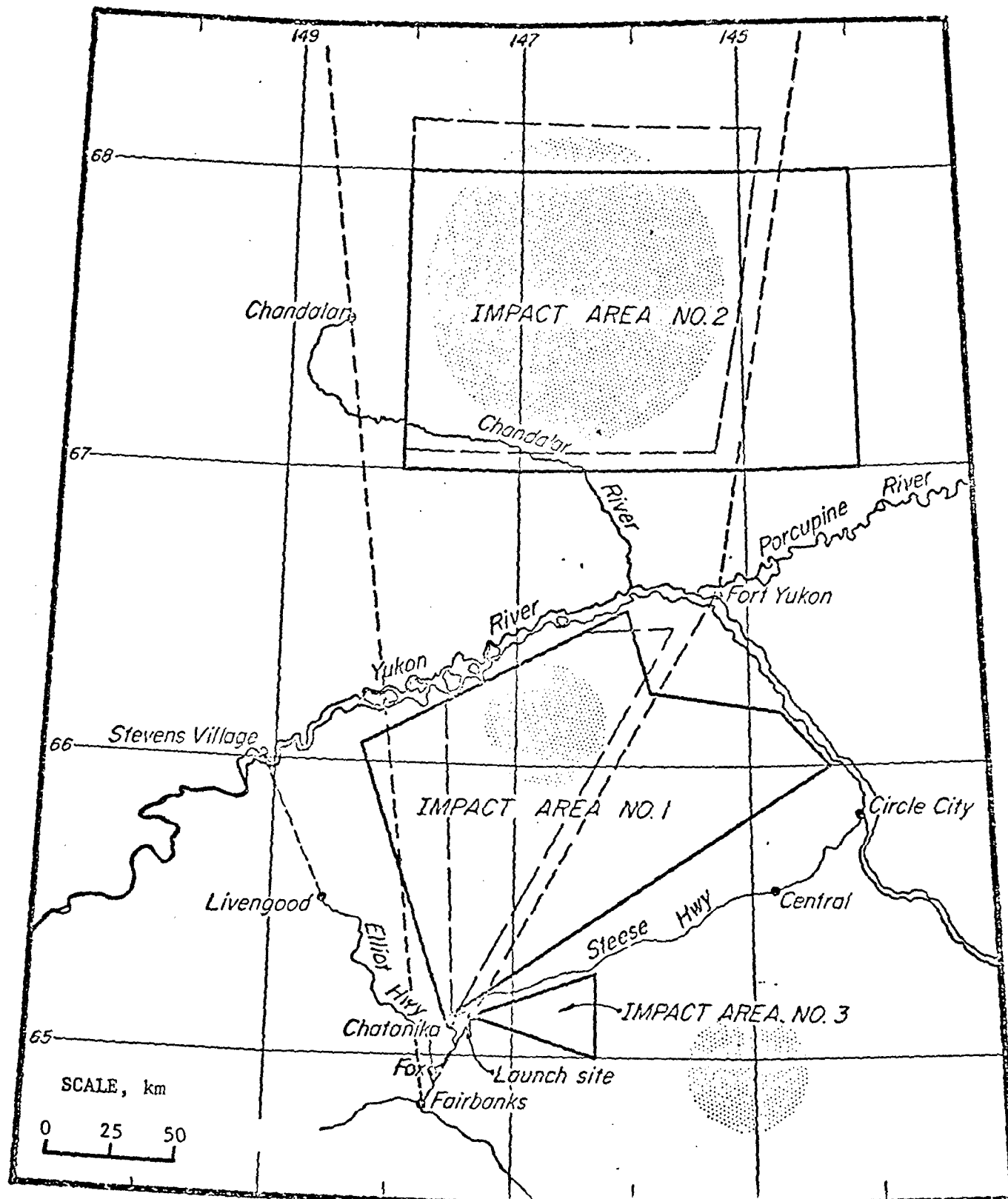


FIGURE C-13. POKER FLAT ROCKET RANGE

(See also Figure C-14)

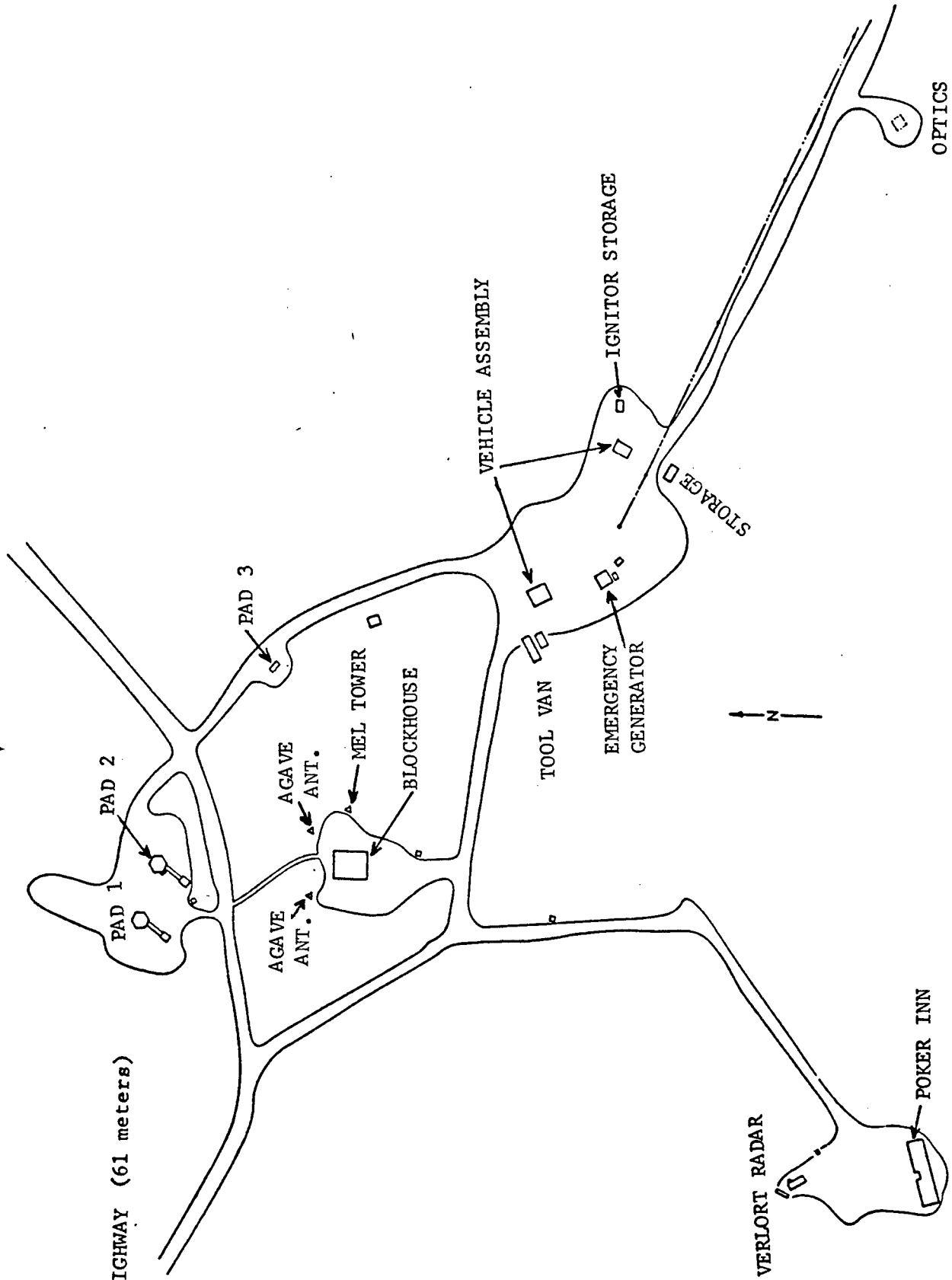


FIGURE C-14. POKER FLAT ROCKET RANGE

APPENDIX D

SOUNDING ROCKETS EXHAUST PRODUCTS

APPENDIX D

SOUNDING ROCKETS EXHAUST PRODUCTS

Data on exhaust products for fourteen NASA sounding rockets are presented in Table D-1. The "Other" category includes small amounts of species whose environmental effects are negligible. References to the many data sources and a discussion of the methods used in reducing the data to the form shown are given in Reference 30.

TABLE D-1. SOUNDING ROCKET PROPELLANT EXHAUST PRODUCTS

Vehicle	Stable Exhaust Product, mass percent														Other
	CO ₂	CO	H ₂ O	H ₂	HCl	HF	KCl	N ₂	H ₂ S	Al ₂ O ₃	AlCl ₃	FeCl ₂	S	Pb	
Arcas															
Stage 1	0.10	26.60	0.25	3.08	22.80	--	--	7.02	--	39.43	--	--	--	--	0.72
Super Arcas															
Stage 1	0.10	26.60	0.25	3.08	22.80	--	--	7.02	--	39.43	--	--	--	--	0.72
Astrobee D															
Stage 1	0.01	34.00	0.002	3.77	8.26	--	--	7.56	0.31	32.69	13.37	--	--	--	0.03
Astrobee F															
Stage 1	2.87	21.57	8.87	2.13	19.97	--	--	8.20	0.18	34.03	--	1.96	--	--	0.22
Stage 2	0.01	34.00	0.002	3.77	8.26	--	--	7.56	0.31	32.69	13.37	--	--	--	0.03
Black Brant IIIB															
Stage 1	5.0	25.5	4.1	3.0	18.9	--	--	7.5	--	36.0	--	--	--	--	--
Nike Cajun															
Stage 1	35.48	42.21	6.66	2.46	--	--	--	12.34	--	--	--	--	--	--	--
Stage 2	27.06	7.38	21.56	0.68	22.15	--	--	9.02	9.27	1.12	--	--	0.94	--	0.82
Nike Tomahawk															
Stage 1	35.48	42.21	6.66	2.46	--	--	--	12.34	--	--	--	--	--	--	--
Stage 2	1.15	25.01	3.89	2.71	19.94	--	--	8.02	--	38.69	--	--	--	--	0.59
Nike Apache															
Stage 1	35.48	42.21	6.66	2.46	--	--	--	12.34	--	--	--	--	--	--	--
Stage 2	1.65	24.64	5.26	2.66	20.06	--	--	7.97	--	37.78	--	--	--	--	--
Black Brant VC															
Stage 1	5.0	25.5	4.1	3.0	18.9	--	--	7.5	--	36.0	--	--	--	--	--
Aerobee 150															
Stage 1	21.1	33.2	3.6	1.6	--	--	39.5	--	--	--	--	--	--	--	1.0
Stage 2	33.0	26.0	20.8	0.8	--	0.5	--	18.9	--	--	--	--	--	--	--
Aerobee 170															
Stage 1	35.48	42.21	6.66	2.46	--	--	--	12.34	--	--	--	--	--	--	--
Stage 2	33.0	26.0	20.8	0.8	--	0.5	--	18.9	--	--	--	--	--	--	--
Aerobee 200															
Stage 1	35.48	42.21	6.66	2.46	--	--	--	12.34	--	--	--	--	--	--	--
Stage 2	33.0	26.0	20.8	0.8	--	0.5	--	18.9	--	--	--	--	--	--	--
Aerobee 350															
Stage 1	35.48	42.21	6.66	2.46	--	--	--	12.34	--	--	--	--	--	--	--
Stage 2	33.0	26.0	20.8	0.8	--	0.5	--	18.9	--	--	--	--	--	--	--
Javelin															
Stage 1	35.48	42.21	6.66	2.46	--	--	--	12.34	--	--	--	--	--	--	--
Stage 2	35.48	42.21	6.66	2.46	--	--	--	12.34	--	--	--	--	--	--	--
Stage 3	35.48	42.21	6.66	2.46	--	--	--	12.34	--	--	--	--	--	--	--
Stage 4	28.55	36.45	12.26	1.46	--	--	--	12.88	--	5.48	--	--	--	2.90	--

APPENDIX E

GLOSSARY

APPENDIX E

GLOSSARY

dB	- decibel, one-tenth of a bel. (The sound-pressure level in decibels is equal to $20 \log_{10} (p/p_0)$, where p is the sound-pressure level of a given sound and p_0 is an arbitrary sound pressure level usually taken to be 0.0002 dynes/cm.)
dBA	- A-weighted sound level in dB. (A weighted sound-pressure level in dB corresponding to the frequency response characteristics of the human ear.)
g	- gram
Hz	- hertz, cycles/second
IRFNA	- inhibited red fuming nitric acid
kg	- kilogram
km	- kilometer
l	- liter
m	- meter
mg	- milligram
N	- Newton, kg-m/sec^2
PL	- payload
ppm	- parts per million
QE	- quadrant elevation, degrees
TLV	- threshold limit value

APPENDIX F

COMMENTS ON DRAFT STATEMENT BY EPA
AND PETER HUNT ASSOCIATES

ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

Mr. Ralph E. Cushman
Special Assistant
Office of Administration
National Aeronautics and Space
Administration
Washington, D.C. 20546

Dear Mr. Cushman:

Enclosed is this Agency's comments on the "Draft Environmental Statement for Physics and Astronomy Sounding Rocket, Balloon and Airborne Research Programs."

This Agency supports the efforts of the National Aeronautics and Space Administration in its various research projects designed to further the total knowledge of the atmosphere and atmospheric processes. Of particular importance to the Environmental Protection Agency is the effect such knowledge will have on the understanding of air and water pollution problems. To this end, we appreciate the opportunity to assist you in this endeavor.

If we can be of further service, please contact Mr. Jack Anderson of our office.

Sincerely,



George Marienthal
Acting Director
Office of Federal Activities

Enclosure

Comments on the Draft Environmental Statement for (the) Physics and Astronomy Sounding Rocket, Balloon and Airborne Research Programs

In general, the draft statement lacks the detail, on the equipment and procedures to be employed in the project, to make a valid environmental impact assessment. We believe the following additional information should be included:

- 1) Details on all launch vehicles and/or aircraft to be used. Discussion of the flight paths and trajectories (including maps), types and quantities of fuel used, and operational altitudes of each vehicle.
- 2) Description of the nature, operational characteristics, and possible environmental impacts of the equipment to be employed.
- 3) Any experiments involving tracers or planned release of substances into the atmosphere should be described in detail. Information on the physical and chemical nature of these substances as well as the quantities to be released at various altitudes and the probable environmental fate of each, should be discussed.
- 4) Plans for possible dumping or accidental spillage of unburned fuel in the event of an aborted launch should be described. Particularly important is the likelihood of contamination of surface water. Consideration should be given to:
 - a) The probability of an aborted rocket launch.
 - b) The quantities of unburned fuel involved.
 - c) The possible effect of the fuel or reaction products thereof on water quality and marine life.
 - d) The geographical regions or bodies of water likely to be affected.

Peter Hunt Associates

4-793-3859

832 PALMER ROAD
BRONXVILLE, N. Y. 10708

May 24, 1971

Ralph E. Cushman
Special Assistant
Office of Administration
N.A.S.A.
Washington, D.C.

Dear Mr. Cushman:

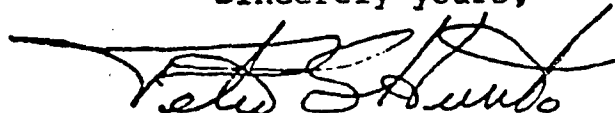
In the recent, May issue, of the 102 Monitor it was noted that N.A.S.A. has released a Draft Environmental Impact Statement on a program of Physics and Astronomy Soundings. As a final statement in the report of that release was a comment on the potential pollution from certain chemicals such as sodium, lithium, cesium etc.

As I am sure you are aware some of N.A.S.A.'s high altitude releases ranging from radioactivity to tiny needles may have created some problems in the past. I would like to be assured that your current program does not involve similar interdisciplinary oversights.

In line with bolstering my confidence in your capacity for taking these external considerations into account I would greatly appreciate it if you would send me a copy of your related draft analysis on the release of such foreign materials and their expected environmental impact. I hope such an analysis will detail the nature, composition, date, location, altitude and velocity of the proposed contamination.

I look forward to reviewing the analysis.

Sincerely yours,

A handwritten signature in dark ink, appearing to read "Peter S. Hunt", with a stylized, sweeping flourish extending from the end of the name.

Peter S. Hunt

JUL 28 1971

Mr. Peter Hunt
Peter Hunt Associates
832 Palmer Road
Bronxville, New York 10708

Dear Mr. Hunt:

Thank you for your recent letter on the subject of the National Aeronautics and Space Administration (NASA) Draft Environmental Statement for Physics and Astronomy Sounding Rocket, Balloon and Airborne Research Programs, as abstracted on page 75 of Volume 1, No. 4 of the Council on Environmental Quality's 102 Monitor.

Enclosure 1 is the full text of our draft environmental statement which is now being put in final form in accordance with the new guidelines issued by the President's Council on Environmental Quality (CEQ) (Enclosure 2) and our internal Management Instruction NMI 8800.7A which became effective on 30 June 1971 (Enclosure 3).

For the past decade NASA has been keenly aware of possible environmental effects of its programs, and has continued to reduce to a minimum any possible short term adverse impact of these programs. Indeed, we try to assure that our programs contribute to the enhancement of the environment through increased understanding of that environment. The specific program to which you refer will increase our understanding of the behavior of the upper atmosphere and should contribute to our understanding of weather phenomena and the interaction of the earth's atmosphere with the solar energy flux.

In carrying out its responsibilities for space research and applications and the advancement of aeronautics and space technology as described in the basic act establishing the National Aeronautics and Space Administration of 1958, a number of programs are involved which may contribute to the near term and future projected enhancement of the global environment. The Physics and Astronomy Sounding Rocket Program is just one of these. The CEQ Monitor to which you refer also summarizes the Tiros Operational Meteorological Satellite Program to provide systematic global cloud cover observations; the Nimbus Program to develop the next generation of operational meteorological satellites; the Global Atmospheric Research

Program to establish the physical and mathematical basis for long-range weather predictions on a global basis; the Earth Resources Aircraft Program to develop multispectral sensors and other remote sensors for use in aircraft and space laboratories; and the Earth Resources Technology Satellite Project to test orbiting spacecraft to conduct experiments that will test the utility of the application of space-borne sensors to natural and cultural resources problems. This last program will furnish a wealth of data to the user community, the federal, state and local organizations charged with earth resources responsibilities in such areas as agriculture, forestry, geology, hydrology, oceanography, land use planning, and environmental management.

As you can see, the sounding rocket research in Physics and Astronomy is just one of the several tasks we use in our broadly based Space Science and Applications Program. In addressing your specific concerns in this particular program area, the following data are provided:

NASA has not released either radioactive material or needles at high altitudes in any of our programs, nor do we intend to do so in any of our planned programs.

Sounding rockets are the only means of obtaining data below 150 km, where satellites cannot survive, and of providing vertical profiles of geophysical parameters which are complementary to satellite observations. Sounding rockets are a flexible, timely, and cost-effective means of providing space flight opportunities and, as such, constitute an invaluable component of a balanced program in space research.

Inexpensive vehicles are utilized to carry a wide variety of scientific instruments developed for studies in the disciplines of aeronomy, energetic particles and fields, ionospheres and radio physics, galactic and radio astronomy, and solar physics.

Sounding rockets provide timely opportunities for: conducting test flights of instrumentation being developed for spacecraft, studying scientific phenomena in the exploratory phase and taking advantage of unique opportunities (eclipses, novae, flares etc.).

In a typical year, the Office of Space Science and Applications (OSSA), Physics and Astronomy Programs, launches approximately 100 rockets to conduct investigations in the disciplines of planetary atmospheres, particles and fields, ionospheric and radio physics, astronomy, and

solar physics. Approximately 92% of these rockets carry scientific instrument payloads; only about 8% carry barium, sodium, or other chemical payloads. Chemical payload weights average approximately 20 pounds per rocket and are released at various altitudes from approximately 100 to 1000 km for study of upper atmosphere winds, temperature density and electrical fields. Chemical releases made from Wallops Station, Virginia, during the past year for example consisted of 13 pounds of barium-salt, 2.2 pounds of sodium, 2.2 pounds of lithium, and 39.6 pounds of barium-copper oxide. As stated in the draft impact statement, these amounts are insignificant compared to the natural influx of material from meteoroids.

Finally, let me assure you that the interaction of the worldwide scientific community participating in the program does indeed provide for effective cooperation and planning of this very important program.

We appreciate this opportunity to publicize the benefits to mankind that the National Space Program has already contributed during the past decade, including our broad-based programs in environmental research, development and space applications. I trust that this brief background will give you and your associates a broader understanding of our program and allow you to share with us as a citizen and taxpayer our pride in leading the global effort in the international cooperative efforts to apply the tools of the space age to the study, understanding, long-term stabilization and enhancement of our total environment.

Sincerely yours,

John E. Naugle
for Homer E. Nowell
Associate Administrator

3 Enclosures

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OFFICIAL FILE COPY

CONCURRENCES							
OFFICE CODE	SP/Daniel s 50-	S/Naugle		EP/Cohen	C. Cohen		SCX
INITIALS	<i>D. V. Schmitt</i>	<i>CV</i>		<i>NBC</i>			<i>2/1/71</i>
DATE	<i>7/26/71</i>	<i>7/26/71</i>	<i>230/71</i>	<i>7/28/71</i>	<i>7-20-71</i>		<i>7/21/71</i>

NASA FORM 1267 OCT. 66 PREVIOUS EDITIONS MAY BE USED.