SC-RR-71 0354

HAVE SINEW-1 PREFLIGHT REPORT

A. C. Bustamante
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ABSTRACT

This report contains the preflight description of the HAVE SINEW-1 reentry test flight.

Key words: aerospace nuclear safety,
radioisotope, tantalum

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HAVE SINEW-1 PREFLIGHT REPORT

Introduction

General

The AEC Headquarters, Space Nuclear Systems Division, and the Department of Defense, Deputy Director Research and Engineering, Assistant for Space Technology, jointly have established a cooperative interagency arrangement for suborbital reentry flight tests of AEC payloads pertaining to radioisotopic heat sources for nuclear space programs. The tests are to be conducted by designated Air Force and AEC field offices.

The tests as planned will be flown on the Air Force Inland Test Range, Green River, Utah, with impact on White Sands Missile Range (WSMR), New Mexico, using the standard Athena four-stage booster vehicle. The program tentatively consists of two flights: one on August 6, 1971 (designated HAVE SINEW-1), and one tentatively in the second quarter of CY 1973 (designated HAVE SINEW-2). This preflight report pertains only to the HAVE SINEW-1 flight test.

The payload will consist of six radioisotopic heat sources and one dummy source which will be ejected as independent reentry bodies. Simulated nuclear fuel will be used, and tracer amounts of tantalum-182 will be contained in each heat source to aid in radiometric detection and recovery after impact.

Payload Agencies

The AEC will provide all six heat sources that will constitute the payload on HAVE SINEW-1. The responsible AEC agencies are:

1. Space Nuclear Systems Division
Space Electric Power Office, SEPO
U. S. Atomic Energy Commission, Washington, D.C. 20545
Director, Space Nuclear Systems Division, SEPO Safety Branch
2. Sandia Laboratories
P. O. Box 5800
Albuquerque, New Mexico 87115
3. Albuquerque Operations Office, U. S. Atomic Energy Commission,
Albuquerque, New Mexico 87115; Director, Space and Special Projects
and Operational Safety Divisions

The AEC as the range user will plan, manage, and conduct all aspects of the payload in accordance with Air Force payload guides (Atlantic Research Corporation Document No. 220-PR-056, Volume I, Standard Athena, dated December 1969). Specifically:

1. Provide payloads for the tests, including design and fabrication of all payload components and associated test hardware.

2. Accomplish payload integration with booster interface and provide pretest and posttest analyses associated with the payload.
3. Support AF/SAMSO with respect to all payload information and analyses to assure compatibility between AEC and Air Force hardware and requirements.
4. Prepare a brief Safety Analysis Summary on the use of radioisotopes in the test heat sources and provide copies to the Air Force.
5. Provide postimpact airborne search and detection capability using infrared and radiometric techniques; these techniques will be integrated with AF/WSMR search and recovery operations.

Flight Objectives

The objectives of HAVE SINEW-1 are to provide information on instrumentation reliability for reentry and impact and to determine suitability and confidence in the postimpact detection and recovery of payloads to enhance the success of HAVE SINEW-2. The R&D flight parameters (19,700 fps and -41.5 degree angle) represent some, but not all, accident environment models. The flight will provide a low cost preliminary checkout of key factors having an impact on the HAVE SINEW-2 test and will test some accident models. This test will also serve to verify the safety aspects of reentry from space of radioisotope heat sources for nuclear space programs commensurate with interagency safety requirements. This will be done by subjecting characteristic instrumented and passive heat sources to actual reentry environments and earth impact and by obtaining data on heating rates, body motion (yaw, pitch, and roll), and survivability. Direct data obtained and postrecovery analysis must correlate with or supplement calculations and ground test results. Recovery on WSMR after impact is essential to the mission, since data will be contained on a tape recorder within the instrumented heat source and will not be telemetered during flight.

Flight Test Description

Launch Vehicle

The HAVE SINEW-1 payload was initially scheduled to be flown "piggy-back" aboard the Athena H launch vehicle. As program development proceeded, reliability considerations resulted in a decision to shift this payload to an Athena D launch vehicle (standard Athena). With the switch to the Athena D booster, the HAVE SINEW payload was assigned the status of primary booster payload.

The Athena D booster (Figure 1) is a four-stage launch vehicle developed for the Air Force by Atlantic Research Corporation. The first and second stages are fired upward to boost the payload above the earth's atmosphere. After apogee the third and fourth stages are fired downward to accelerate the payload to velocities approximating 20,000 feet per second at reentry angles in the range of -20 to -40 degrees. The nominal HAVE SINEW-1 reentry initial conditions are 19,700 feet per second at a reentry angle of -41.5 degrees. Further information on the Athena D launch vehicle and details of its performance characteristics may be obtained from References 1 and 2.

ATHENA MISSILE

Figure 1. Standard Athena configuration

The HAVE SINEW-1 payload is carried in a specially fabricated Alternate Payload Support Adapter (APSA) which is attached to the fourth-stage motor. The APSA is a structure which provides a series of rubber-lined cradles arranged around the periphery of a cylinder. The HAVE SINEW-1 payload configurations rest in these cradles and are held in place with a rubberized nylon retaining strap encircling the APSA. The fourth-stage motor-APSA structure is spun at 3.5 revolutions per second during the fourth-stage burn period. Following fourth-stage motor burnout, a signal is provided to actuate two bolt cutters which sever the payload retaining band. The payload configurations are then free to separate from their APSA cradle and reenter as independent bodies.

Mission Profile and Sequence of Events

The Athena D mission profile is a high reentry angle ballistic trajectory originating at the Green River Launch Site (GRLS) in Utah and terminating at the White Sands Missile Range (WSMR) in New Mexico. During payload reentry, the payload will separate at an altitude of 300,000 feet (msl). At this altitude, each of the heat sources will reenter as an independent body with a reentry velocity of 19,700 fps and a reentry angle of -41.5 degrees. All the heat sources (Units 1 through 6) are designed to survive the reentry heating environment resulting from these reentry conditions, and they should experience very little ablation and remain intact until impact. At the time of impact, the graphite heat shield on the heat sources will be cracked and should shed from the internal can or capsule, and the radioactive tracer ^{182}Ta , which will be fastened to the inner container, should be exposed. All the heat sources, except for the two Pioneer heaters, should impact within a common area (Figure 2). Airborne radiometric and infrared detection support will be provided by the EG&G ARMS aircraft.

A typical flight profile and sequence of boost and reentry events is presented in Figure 3. The event times are approximate since the finalized trajectory will not be available until 60 days prior to the scheduled launch.

Payload

Description

The AEC payload will consist of six radioisotopic heat sources (Figure 4); an instrumented heat source (Unit 1), a Transit heat source (Unit 2), a Pioneer heat source (Unit 3), a Dart minithruster (Unit 4), two Pioneer heaters (Units 5 and 6), and a dummy payload (Unit 7). The payload will be housed in an alternate payload support adapter (APSA) (Figure 5). The radioactive material with which this report is concerned is housed in each of the heat sources (no radioactive material in Unit 7). Table I gives the physical property data for the HAVE SINEW-1 payload.

Instrumentation

The instrumented unit shown in Figure 6 will be used to obtain thermal and motion data on a right circular cylinder configuration. The unit will be instrumented with a 3-axis rate gyro to obtain angular rates about the pitch, yaw, and roll axes. In addition, 11 thermocouples will be placed at various locations on the unit in order to obtain its temperature distribution. These locations are shown in Figure 7. Some of the important characteristics of this instrumented heat source (payload No. 1) are described in Table II.

Figure 3. Flight profile and sequence of events

Figure 4. Heat source configurations

Figure 5. Payload in APSA

TABLE I

Physical Property Data for HAVE SINEW-1 Payload

Unit Number	Weight (lbs.)	Center of Gravity (inches)	Imbalance		Moments of Inertia (lb. -in. ²)		
			Static (in. -oz.)	Dynamic (lb. -in. ²)	Roll	Pitch	Yaw
① Instrumented	35	0.01 Y&Z 0.07 X		0.0259	175	540	540
② Transit	13	Geometric center		0.008	27	62	62
③ Pioneer	11	Geometric center		0.004	12.6	29.4	29.4
④ Dart	5	Geometric center		0.0016	5.9	6.84	6.84
⑤ Pioneer Heater	0.12	Geometric center		0.158x10 ⁻⁶	0.0114	0.04	0.04

NOTE: Moments of inertia are about each units center of gravity

Figure 6. Instrument package

Figure 7. Thermocouple locations

TABLE II
Instrumented Heat Source Description

Total Weight	35.0 lb
Ballistic Parameter (Hypersonic Cont.) Side on Stable)	46
Terminal Velocity at 6000 Feet Altitude ...	324 fps
Maximum Deceleration Load	90 g
Reference Trajectory: Velocity = 19,700 fps, $\gamma = -41.5$ deg	
Instrumentation:	
a. Three axis rate gyro: Pitch ± 3600 deg/sec Yaw ± 3600 deg/sec Roll ± 1800 deg/sec	
b. VCO	
c. Commutator	
d. Tape recorder	
e. 11 Thermocouples	

Detailed Functional Operations -- The functional operation during flight commences with the activation of payload No. 1 at approximately 20 seconds prior to payload release. The payload is activated by a "Positive Turn-On" control circuit. A series of acceleration sensing switches (Rolamites) and MC824 fuse switches is used. Only third stage acceleration is sensed by a 13.5 g biased Rolamite switch. At third stage burnout, 0 g is sensed, which activates all the instrumentation. A redundant system, the "Start Sequencer," is incorporated to sense third stage ignition via another 13.5 g biased Rolamite which activates the onboard gyro and a 10 second delay timer. After the elapsed time, all the instrumentation, including the tape recorder, is turned on. The "Positive Turn-On Control" and "Start Sequencer" are shown schematically in Figure 8 and the power control and distribution diagram for payload No. 1 is shown in Figure 9. A typical Athena D axial acceleration versus time curve is shown in Figure 10. The major activity points are indicated on this curve (Figure 10) and refer to the description in Table III.

Ordinance associated with payload No. 1 consists of two MC824 fuse switches contained within the payload. The initiation of these switches is shown in Figures 8 and 9. The remaining internal circuitry associated with payload No. 1 is shown in Figures 11 through 14.

Temperatures at various locations in the payload are measured with thermocouples and thermistors over a range of 70° to 4200°F. Rates of motion are measured with a 3-axis rate gyro.

Payload No. 1 contains no sources of EMR. However, there are EMR sensitive components within the payload. Since payload No. 1 has no external wires, no external shielding is required.

Figure 8. Start sequencer and positive turn-on control schematic

○ Denotes terminals on Printed Circuit Board #1. All diodes noted are located on Printed Circuit Board #1.

Figure 9. Power control and distribution diagram for payload No. 1

Figure 10. Axial load factor vs time Athena D vehicle

TABLE III

Sequence of Events Flow Chart for Athena D Configuration

Positive Turn-On Control

- a. Launch and first stage burn - Rolamite B will toggle.
- b. Second stage ignition and burn - Rolamite B may toggle.
- c. Third stage ignition.
  - Point #1 - Rolamite B to +g closure.
  - Point #2 - Rolamite C to +g closure and latch.
  - Point #3 - Rolamite B to 0 g closure - MC824 #1 fuse switch fired. +28V dc applied to instrumentation package for positive turn-on for entire package. Tape recorder on.

Start Sequencer

- a. Launch and first stage burn. No activity.
- b. Second stage ignition and burn. No activity.
- c. Third stage ignition.
  - Point #2 - Rolamite A to +g closure and latch - instrumentation package internal turn-on sequence initiated.
  - Point #4 - 10 sec time delay - tape recorder turn-on (backup).

Note that in the overall sequence of events the positive turn-on control starts the tape recorder. The start sequencer delay timer is used as a back-up system to start the tape recorder.

If the event point #2 (+13.8 g) was not achieved during third stage burn due to low thrust levels, it would occur during fourth stage burn. The same sequence of events would take place after point #2 but at the expense of a late tape recorder turn-on time.

Power, Control and Signal Pins

- O-A - 0V REF to CB2-f
- O-B - +12V to CB2-C
- O-C - +28V to VCO's
- O-D - and Commutator
- O-E - +28V to Tape Recorder
- O-F - Thermistor Ref. No. 3
- O-G - Therm. Ref. No. 3
- O-H - Therm. Ref. No. 3
- O-I - to Commutator Ch 13
- O-J - Therm. Ref. No. 2
- O-K - to Commutator Ch 14
- O-L - VCO No. 5 Input
- O-M - Therm. Ref. No. 1
- O-N - to Commutator Ch 15
- O-O - -15V to CB2 - B
- O-P - +1V Ref. to CB2 - b
- O-Q - +4V Ref. to CB2 - h
- O-R - D.M. Select to CB2 - A
- O-S - D.M. Output to CB2-D
- O-T - +28V to Gyro
- O-U - Gyro 1 Out + VCO No. 2 Input
- O-V - Gyro 2 Out + VCO No. 3 Input
- O-W - Gyro 3 Out + VCO No. 4 Input
- O-X - Commutator Channel No. 1 Input
- O-Y - D.M. Clock and Reset Input

Thermocouple and Commutator Pins

- O O a - Thermo. & Comm. Ch 2
- O O b - Thermo. & Comm. Ch 3
- O O c - Thermo. & Comm. Ch 4
- O O d - Thermo. & Comm. Ch 5
- O O e - Thermo. & Comm. Ch 6
- O O f - Thermo. & Comm. Ch 7
- O O g - Thermo. & Comm. Ch 8
- O O h - Thermo. & Comm. Ch 9
- O O i - Thermo. & Comm. Ch 10
- O O j - Thermo. & Comm. Ch 11
- O O k - Thermo. & Comm. Ch 12

Commutator Spare Pins

- O O - m - Commutator Ch 16
- O O - n - Commutator Ch 17
- O O - p - Commutator Ch 18
- O O - r - Commutator Ch 19
- O O - s - Commutator Ch 20

Figure 11A. Printed circuit schematic Athena reentry payload CB1

R1	-	5K	1/8W	5%	
R2	-	27K	1/8W	5%	
R3	-		1/8W	1%	
R4	-	300Ω	1/8W	0.5%	
R5	-	2K	1/8W	5%	
R6	-	10K	1/8W	5%	
R7	-	300Ω	1/8W	5%	
R8	-	5K	1/4W	5%	
R9	-	200Ω	1/4W	5%	
R10	-	50Ω	1/8W	5%	
R11	-	10Ω	1/8W	5%	
R12	-	910Ω	1/2W	5%	
R13	-	910Ω	1/2W	5%	
R14	-		1/8W	5%	
R15	-		1/8W	5%	
R16	-	3.6K	1/8W	5%	
R17	-	2.4K	1/8W	5%	
R18	-	5.360K	1/8W	1%	
R19	-	1K	1/8W	1%	
R20	-	133Ω	1/8W	1%	
R21	-	30K	1/8W	5%	
R22	-	1K	1/8W	5%	
R23	-	27K	1/8W	5%	
R24	-	3.9K	1/8W	5%	
R25	-	2.4K	1/8W	5%	
R26	-	10K	1/8W	5%	
R27	-	10K	1/8W	5%	
R28	-		1/8W	5%	- used, if needed
R29	-	1K	1/4W	5%	
R30	-	0.5Ω	3W	1%	
C1	-	1.0 MFD	100 VDC	Mylar	
C2	-	0.1 MFD	50 VDC	Ceramic	
C3	-	40.0 MFD	30 VDC	Tantalum	
C4	-	5.6 MFD	35 VDC	Tantalum	
C5	-	5.6 MFD	35 VDC	Tantalum	
C6	-	0.001 MFD	50 VDC	Ceramic	
C7	-	0.1 MFD	50 VDC	Ceramic	
C8	-	0.1 MFD	50 VDC	Ceramic	
D1	-			IN3981	
D2	-			IN3981	
D3	-			IN3981	
D4	-			IN3981	
D5	-			IN3981	
D6	-			IN3022B	
D7	-			IN100	
D8	-			2N1595SCR	
D9	-			IN3981	
D10	-			IN3981	
D11	-			IN752	
D12	-			IN3981	
D13	-			IN3981	
D14	-			IN3981	
Q1	-			2N494B	
Q2	-			2N2907	
Q3	-			CD4004	- RCA COS/MOS Binary Counter
Q4	-			NC521	- GI Voltage Regulator
Q5	-			2N4342	
Q6	-			2N4342	
Q7	-			2N2222	
Thermistor Reference #1					Fenwoil GA51L3
Thermistor Reference #2					Fenwoil GB42JMI
Thermistor Reference #3					Fenwoil GB42JMI
S1	-			MC824	Fuse Switch

Figure 11B. Parts list printed circuit board - CB1 Athena reentry payload

Payload Printed-Circuit Board-CB1

External Checkout and Control Cable

Connector - LJT-13-98P

Figure 12. Wiring diagram, Athena reentry payload

IDENTIFICATION	DESCRIPTION
CB1	PAYLOAD PRINTED CIRCUIT BOARD
CB2	DATA MONITOR PRINTED CIRCUIT BOARD
TAPE RECORDER	BORG WARNER, MOD R-101-3018, 3 1/2 IPS, 28VDC - 200 ma
COMMUTATOR	FIFTH DIMENSION, MOD. LA-22EM-227, SOLID STATE, LOW-LEVEL DIFFERENTIAL INPUT
GYRO	JS TIME PART NO 401450, 1 AXIS RATE, BUILT TO SANDIA SPEC
VCO 1	IED SUB-CARRIER OSCILLATOR, MOD. C50-1237A, 3.375 KHZ CENTER FREQUENCY
VCO 2	SAME AS ABOVE
VCO 3	SAME AS ABOVE
VCO 4	SAME AS ABOVE
VCO 5	SAME AS ABOVE
VCO 6	SAME AS ABOVE
REF 3	THERMISTOR REFERENCE JUNCTION FEYNWALL GB423M1
P1	CONTINENTAL MM34-2255K
P2	CONTINENTAL MM34-2255K
P3	CANNON M081-3PH001
P4	SAME AS ABOVE
P5	SAME AS ABOVE
P6	SAME AS ABOVE
P7	SAME AS ABOVE
P8	SAME AS ABOVE
P9	CANNON M081-37PH001
P10	SAI445-10 (LJT-13-98P)

INTERNAL BATTERY
 CB3
 ROLAMITE-1
 ROLAMITE-2
 ROLAMITE-3

GULFON BUTTON CELL VDD 12V0 250, 2 EA
 START SEQUENCER & POSITIVE TURN-ON CONTROL PC. BOARD
 TC450 MODIFIED ROLAMITE G-SW
 TC450 MODIFIED ROLAMITE G-SW
 TC481 MODIFIED ROLAMITE G-SW

PYROTECHNIC COMPONENT DESCRIPTION
FUSE SWITCH - MC 824 - SANDIA DEVICE
NO-FIRE CURRENT 1.4 AMP MAX
ALL-FIRE CURRENT 5 AMP MIN
FUNCTION - ME 2.34 SEC
FUSE WIRE RESISTANCE 2.02-3.04MS
Based on a nominal fire voltage of 100V @ 125 Joules

Figure 13. Payload/Athena interface component distribution and cable routing diagram Athena-reentry payload

- A - D.M. Select to CB1-R
- B - -22V Supply to CB1-M
- C - +12V Supply to CB1-B
- D - D.M. Output to CB1-S
- a - VCO 2 Output + Tape Channel No. 6
- b - +1V Ref. to CB1-N
- c - VCO 3 Output + Tape Channel No. 10
- d - Commutator Output
- m - VCO 1 Input + VCO 6 Input
- e - VCO 4 Output + Tape Channel No. 12
- f - 0.V. Ref. to CB1-A
- g - VCO 7 Output + Tape Channel No. 4
- h - +4V Ref. to CB1-P
- j - VCO 5 Output + Tape Channel No. 8
- k - VCO 6 Output + Tape Channel No. 7

Figure 14. Data monitor printed circuit schematic
Athena reentry payload CB2

Prelaunch operations are indicated in Figure 15. Details of the indicated tests are included in Appendix A of Reference 3. The payload is in the "off" condition prior to launch.

Time	Test Sequence		
	PLCA Checkout	Test Sequence A	Battery Charge
Pre-Shipment to Green River	Yes	Yes	Yes
Post-Shipment to Green River	Yes	Yes	Yes
CST in missile assy area ①	No	No	No
SST on launcher ①	No	No	No
FACT ①	No	No	No
Elevated test ①	No	No	No
Payload removal from APSA ②	Yes	Yes	Yes
Payload installation on APSA ③	No	No	No
① Payload mounted on APSA. ② Payload transported to Sandia assy building. ③ Payload installed T-8 hours.			

Figure 15. HAVE SINEW-1 payload test schedule

Payload No. 1 does not contain telemetry and consequently has no antenna properties. The thermocouple information is scanned by an electronic commutator which modulates a voltage controlled oscillator and is recorded on magnetic tape using an FM mode. Data from the rate gyro are similarly recorded on three additional tracks of the tape (Figure 16).

Figure 13. Signal systems block diagram HAVE SINEW-1

Radioisotopes

Physical Form and Characteristics - ^{182}Ta Source and Thorium Dioxide (Thoria) --
 Pieces of tantalum material will be shaped and configured for each of the heat sources
 as described below and shown in Figure 17.

Heat Source	Tantalum Configuration	Size
Unit 1 Instrumented	Round sheet	Diameter = 1.00 in. Thickness = 4 mils
Unit 2 Transit	Wire ring	Ring diameter = 2.470 in. Wire diameter = 25 mils
Unit 3 Pioneer	Wire ring	Ring diameter = 2.470 in. Wire diameter = 25 mils
Unit 4 Dart	Round sheet	Diameter = 0.250 in. Wire diameter = 4 mils
Unit 5 Pioneer Heater	Foil sheet	0.75 x 0.75 x 0.002 in.
Unit 6 Pioneer Heater	Foil sheet	0.75 x 0.75 x 0.002 in.

Figure 17. Physical forms for ^{182}Ta

The tantalum material will be irradiated at the Omega West reactor facility at Los Alamos, New Mexico. Once the tantalum is irradiated, it becomes the radionuclide ^{182}Ta . The characteristics of this radioactive material are given below:

Base Material	Tantalum
Radionuclide	Tantalum-182
Gamma Energies of Radiation in MeV	0.100, 0.175, 0.260, 1.12, 1.22
Major Observed Radiation	Gamma
Radiation Level Dose	1 mR/hr at 1 meter/mCi
Half Life	115 days

In addition to radioactive material tantalum-182, each of the heat sources except for Unit 1 will have thorium dioxide ThO_2 (thoria) as a fuel simulant. The radiation dose of thoria, which is a powder form, is very low, approximately 0.027 mR/hr at 1 meter per millicurie. The characteristics of this radioactive material are:

Base Material	Thoria
Radionuclide	Thorium-232
Mode of Decay: (Energies in MeV)	Alpha (α) 4.01, 3.95 Gamma (γ) 0.059
Major Observed Radiation	Alpha and Gamma
Radiation Level Dose*	0.027 mR/hr at 1 meter/mCi
Half Life	1.39×10^{10} years

Each of the heat sources will have approximately 100 millicuries of tantalum-182, and the flight date level of activity present inside and outside of the heat sources from ^{182}Ta and ThO_2 is shown in Table IV.

Physical Location -- The ^{182}Ta source and the ThO_2 simulant will be located inside the heat sources as shown in Figure 18. For heat source Units 1, 2, 3, and 4, the tantalum material will be fastened to the capsule, and for Units 5 and 6 the tantalum sheet will be wrapped around the capsule. The ThO_2 powder will be in each of the heat sources, with the exception of the instrumented heat source, and will be contained inside a fuel capsule as shown in Figure 18.

---

* NOTE: The radiation level for Thorium-232 is based on experimental measurement.

① INSTRUMENT UNIT (MOTION & THERMAL)

All dimensions are in inches

② TRANSIT HEAT SOURCE

VIEW B-B

④ HEAT SOURCE, DART THRUSTER (LASL)

VIEW D-D

③ PIONEER HEAT SOURCE

VIEW C-C

⑤ PIONEER HEATER
⑥ IDENTICALLY EQUAL TO ⑤

SCALE: 4/1

Figure 18. Location of tantalum material in heat sources

Radioactivity Levels

Heat Source Configuration	Activity* Level Inside Heat Source From			Activity Level Outside Heat Source From		
	¹⁸² Ta (mCi) **	Thorium Simulant (mCi)	Total (mCi)	¹⁸² Ta (mCi)	Thorium Simulant (mCi)	Total (mCi)
Unit 1 Instrumented	121	--	121	100	--	100
Unit 2 Transit	118	0.232	118.23	100	0.162	100.16
Unit 3 Pioneer	118	0.176	118.18	100	0.123	100.12
Unit 4 Dart	118	0.094	118.09	100	0.065	100.07
Unit 5 Pioneer Heater	109	0.00028	109.	100	0.000196	100.
Unit 6 Pioneer Heater	109	0.00028	109.	100	0.000196	100.
		Total	693.5 mCi		Total	600.35
			≈ <u>694</u>			≈ <u>601</u>
			Maximum = 694 + 10%			Maximum = 601 + 10%

* This is the activity level presence on the flight date.
** mCi = millicuries.

Purpose for Radioactive Material on the Payload -- The object of using ^{182}Ta on this flight is to aid in the recovery of the heat sources through the use of an airborne radiation detector. Recovery is mandatory for the HAVE SINEW-1 payload, since heat source Unit 1 will have its flight data recorded on tape and it is necessary to recover the tape in order to obtain the data. In addition, as a result of the physical size of the other heat source units, the probability of recovery of these units would be low without a radioactive tracer. The activity of each ^{182}Ta source is sufficient to assure airborne detection by established search techniques and equipment. Experience has shown that there is a very high probability of locating the sources in all normal and postulated accident situations.

Various other radioactive materials were considered as tracers for aiding in recovery. The three main parameters that governed the selection of the radioactive materials were: (1) safety (half-life), (2) availability, and (3) detectability. Based on these parameters, the choice was narrowed to two radionuclides: tantalum-182 and cobalt-57. Of these two, ^{182}Ta was selected because of its shorter half life of 115 days compared to 270 days for ^{57}Co and also because of its higher detectability. Table V compares point source detectabilities for ^{182}Ta and ^{57}Co . The signal to background ratios given in the last line of Table V show that a ^{57}Co source must be more than 100 times more active than a ^{182}Ta source in order to compare in detectability.

The purpose of using thorium in heat source Units 2 through 6 is to thermally and physically simulate some of the properties of the active fuel (^{238}Pu) that will be used in the actual radioisotopic systems.

TABLE V

Comparison of Point Source Detectabilities at
600 Feet Distance of Closest Approach
(100 mCi source)

		^{57}Co	^{182}Ta
E_Y = Photopeak Energy (MeV)		0.12	1.2
Factors affecting signal	α = Fraction of disintegrations giving E_Y	0.8	0.7
	λ = mean free path in air (ft)	250	600
	$e^{-\frac{600}{\lambda}}$ ft = attenuation factor at 600 ft = distance of closest approach	0.082	0.37
	A = effective detector area (shielded by aircraft)(cm^2)	400	500
	$S = \alpha e^{-\frac{600}{\lambda}}$ A = signal count rate	260	1300
Factors affecting Background	$\frac{dN}{dEdt}$ = Background count rate distribution at E_Y (From naturally occurring isotopes in soil measured at 300 ft altitude)	700	7
	ΔE = Width of photopeak at E_Y = window width used when scanning area	0.02	0.07
	B = $\frac{dN}{dEdt} \Delta E$ = Background count rate accepted by window	14	0.49
	S/B = Ratio signal-to-background	19	2700

Aerothermodynamic Characteristics

Aerodynamic Characteristics

The importance of payload recovery to the success of the mission places a heavy emphasis on trajectory estimates. Such estimates are in turn dependent upon an accurate knowledge of the vehicle's aerodynamic force and moment characteristics. Right cylindrical configurations which are of concern here have several possible trim points. These are not all stable orientations, however. Without a knowledge of the initial angular rates at separation, it is extremely difficult to predict the orientation or type of motion experienced by these bodies during reentry. Therefore, it was decided to consider those motions or orientations which result in minimum and maximum range.

Right cylindrical configurations with coincident geometric and mass centroids have stable modes of motion or trim attitudes for which the net aerodynamic force integrated over a cycle of motion acts in the drag direction. Integrated over a cycle of motion, no net lift and side forces act. Under the condition of zero lift and side forces, the minimum range trajectory results from that orientation which gives the highest integrated drag force over the trajectory length. This condition results from the side-on mode of motion. This mode of motion is one of the possible stable attitudes considered to have a good probability of occurrence. Conversely,

the maximum range trajectory results from that orientation which provides the lowest integrated drag force over the trajectory distance. The end-on mode of motion leads to this condition. Although this orientation is ordinarily not an aerodynamically stable attitude, its probability of occurrence is enhanced considerably by the 3.5 rps roll rate possessed by the payloads at separation. Between these two extremes is a large group of possible modes involving angular or tumbling motions, some of which are considered to have a high probability of occurrence. Representative of this group with respect to range and thermal performance is the end-over-end tumbling mode of motion. In addition to the side-on and end-on modes, this is the third mode of motion selected for analysis.

Payload separation from the APSA is nominally scheduled to occur at 300,000 feet altitude. At this altitude, all five payload configurations have not yet entered the continuum flow regime. Therefore, the aerodynamic drag coefficient for each configuration, in each of the three modes of motion considered, was evaluated for both the free molecular and the hypersonic continuum flow regimes. For the free molecular flow regime, the drag coefficients are based on the theory of Sentman.^{4,5} A combination of modified Newtonian theory⁶ and experimental drag data⁷ was used to evaluate the hypersonic continuum drag coefficients. Between these two regimes a faired curve was computed as a function of altitude according to the procedure outlined by Spahr.⁸ The resulting high Mach number drag data are presented in Figures 19a through 23a for configurations 1 through 5, respectively. Listed in each figure for each mode of motion is the ballistic coefficient ($W/C_D A$) based on free molecular flow and also the value for hypersonic continuum flow. The ballistic coefficients for Units 1 through 4 are similar, while the values for Units 5 and 6 are significantly lower.

All six payload units decelerate to subsonic Mach numbers prior to earth impact. Thus, the Mach number influence on the drag coefficients must be accounted for. Data from a variety of drop test programs supported by AEC/SNS were compiled and combined with basic experimental data⁷ on cylindrical configurations to evaluate the subsonic drag coefficients. The drag coefficient variation with Mach number for configurations 1 through 5 is illustrated in Figures 19b through 23b.

Reentry Trajectories

Initial Conditions -- Payload separation from the fourth stage motor/APSA structure occurs upon release of the payload retaining band following burnout of the fourth-stage motor. This event is scheduled to occur at a nominal altitude of 300,000 feet. At this point, the nominal velocity vector is 19,700 feet per second on a reentry flight path angle of -41.5 degrees and an azimuth of 152 degrees.

The nominal 3.5 rps roll rate of the APSA imparts to each payload at separation a tangential velocity component lying within a plane normal to the longitudinal axis of the APSA. The direction of this component within the plane is determined by the angular location of each payload on the APSA and by the roll orientation of the APSA at band release. For the purposes of this study the roll orientation of the APSA at band release is considered to be random. This velocity component results in an incremental change in the reentry flight path angle and/or azimuth for each payload. The magnitude of the tangential velocity component and the resulting incremental shift in the flight path/azimuth angle are presented in Table VI for each payload configuration.

a.

b.

Figure 19. HAVE SINEW Unit No. 1
Ref. area = LD

a.

b.

Figure 20. HAVE SINEW Unit No. 2
Ref. area = LD

a.

b.

Figure 21. HAVE SINEW Unit No. 3
Ref. area = LD

a.

b.

Figure 22. HAVE SINEW Unit No. 4
Ref. area = LD

a.

b.

Figure 23. HAVE SINEW Units No. 5 and 6
Ref area = LD

TABLE VI

	CONFIGURATION				
	1	2	3	4	5
Velocity (ft/sec)	16.7	20.6	20.6	19.8	24.9
Angle (deg)	0.044	0.055	0.054	0.052	0.066

The magnitudes of this velocity component and angle increment are such that their effect on the nominal trajectory initial conditions are negligible. The primary result of this velocity component is to effect a separation distance among the six payloads which increases linearly along the trajectory.

Trajectory Environments -- The velocity and altitude history for configurations 1 through 5 are shown in Figures 24a through 28a, respectively. Figures 24b through 28b illustrate the thermal environment, in the form of the stagnation point reference heating rate and the integrated heat load, experienced by the same configurations. The stagnation point reference heating rate is the rate experienced by a 1-foot radius sphere on the same trajectory.

These figures illustrate the similarity in the trajectories, time to impact, and the thermal environment experienced by Units 1 through 4. These units have a time to impact from separation of 100 to 140 seconds, depending upon the type of motion they experience. Because of their significantly lower ballistic coefficient, Units 5 and 6 decelerate at a higher altitude, resulting in a greater time to impact and a less severe thermal environment. The time to impact from separation for Units 5 and 6 is 260 to 290 seconds.

The stagnation point heating rates experienced by Units 1 through 4 are significantly higher than levels achieved by typical radioisotopic heat sources on orbital decay reentry trajectories and are comparable to the levels achieved during some of the less severe launch abort reentries. The total trajectory heat load, however, is an order of magnitude lower than is experienced during a heat source orbital decay-type reentry.

The similarity in the reentry trajectories is further illustrated in Figures 29, 30, and 31. These figures depict the altitude versus range for all five configurations for end-on, side-on, and end-over-end tumbling modes of motion, respectively. It is evident that between 300,000 and 100,000 feet altitude the trajectories for all five configurations approximate a straight line. Beyond this point, Units 5 and 6 are first to separate from the group, and they assume an essentially subsonic vertical fall from approximately 80,000 feet. Units 1 through 4 remain relatively closely grouped to below 50,000 feet where they enter the subsonic vertical fall condition.

As was mentioned in the preceding section, the roll rate at payload separation introduces an incremental shift from the nominal in the flight path and azimuth angles for each payload unit. The effect is to cause each unit to fly a trajectory which is shifted slightly in flight path and/or azimuth angle from the nominal trajectory. Over the straight line section of the trajectories, these six trajectories then approximate a conical reentry corridor whose apex is at the separation point and whose base lies in a plane normal to the nominal trajectory at 100,000 feet. The radius of the base circle of this cone at 100,000 feet, within which all six trajectories pass, is calculated from the maximum angle shift to be 300 feet. Below 100,000 feet altitude, the separation distance between the individual trajectories commences increasing sharply as the individual payload flight path angles steepen.

a.

b.

Figure 24. HAVE SINEW Unit No. 1
Athena D launch

a.

b.

Figure 25. HAVE SINEW Unit No. 2
Athena D launch

a.

b.

Figure 26. HAVE SINEW Unit No. 3
Athena D launch

a.

b.

Figure 27. HAVE SINEW Unit No. 4
Athena D launch

a.

b.

Figure 28. HAVE SINEW Units No. 5 and 6
Athena D launch

Figure 29. HAVE SINEW payload; Athena D launch

Figure 30. HAVE SINEW payload; Athena D launch

Figure 31. HAVE SINEW payload; Athena D launch

Impact Dispersions -- The dependence of data retrieval upon postimpact recovery of the payload units places great importance on the estimation of the payload impact dispersion area. The impact dispersion pattern is illustrated in Figure 32. The latitude-longitude scales shown here are only approximate since the payload separation point in space had to be approximated. At the time the payload reentry trajectories were calculated, the booster trajectory from launch was not available. However, the relative impact location among the six units for the three motions remains valid. As the final estimate of the booster trajectory and the separation point become available, the total impact pattern may be shifted in latitude and longitude as required.

The estimated impact locations are marked by symbols for each unit for each of the three modes of motion, based upon the estimated separation point and the nominal trajectory initial conditions. It should be mentioned that the symbols marking impact locations for Units 2, 3, and 4 were shifted slightly off the nominal ground track (in the normal direction) simply for the sake of clarity. The data indicate, as was suggested earlier, that the longer range for each unit results from the end-on mode of motion while the side-on mode results in the shorter range. The exception to this situation is Unit No. 4. The mode of motion has a minimal effect on the range and impact location for Unit 4; this results from the $L/D \approx 1$ for Unit 4. The impact locations for Units 1 through 4 are grouped relatively close together. Units 5 and 6, as a result of their significantly lower ballistic coefficient, are estimated to impact 6 to 7 nautical miles uprange of the other units.

The two elongated ellipses shown in Figure 32 encircling Units 1 through 4, and separately Units 5 and 6, define the overall impact zones for Units 1 and 5, respectively. These impact zones result from the consideration of the tolerances on initial trajectory conditions at payload separation. For the Athena D missile system, initial reentry condition tolerances are defined as ± 200 feet per second in velocity and ± 2 degrees in flight path angle at the performance specification altitude of 250,000 feet.

No tolerance on azimuth was specified. A value of ± 1 degree from the nominal heading was arbitrarily assumed. Since the impact locations of Units 2, 3, and 4 are so closely grouped with Unit 1, the influence of these tolerances has been evaluated for Units 1 and 5 only. The extreme downrange impact location for each unit is defined by the maximum reentry velocity, minimum reentry angle (most shallow) condition applied to the end-on trajectory. Conversely, the minimum velocity, maximum reentry angle (steepest) initial condition coupled with the side-on mode of motion defines the extreme uprange impact location. These two extremes, coupled with the crossrange extremes defined by the minimum and maximum heading angles, define the total impact zone illustrated. For Unit 1 the impact zone covers an area approximately 9 by 2 nautical miles in extent. The impact zone for Units 5 and 6 is approximately 7 by 2 nautical miles centered 6-1/2 nautical miles uprange of the Unit 1 area.

Figure 32. HAVE SINEW impact dispersion
Athena D launch

In addition to the influence of aerodynamic characteristics and the initial trajectory conditions, which have been considered above, impact dispersions will also be affected by winds in the reentry region. This effect has been estimated for the HAVE SINEW-1 flight. Statistical data on winds to 100,000 feet altitude over WSMR⁹ are available on a bi-monthly basis. The data are presented in the form of a range of wind speeds and headings as a function of altitude within which falls 63 percent of all winds for the month being considered. Wind profiles for the months of July and September were applied to the nominal reentry trajectories of Units 1 and 5. The prevailing wind direction for the month of July results in a shift of the nominal impact location along an azimuth of 285 degrees. For Unit 1 the magnitude of the shift is approximately 0.25 nautical mile. Units 5 and 6, because they spend a greater length of time at the lower subsonic velocities, experience a shift of approximately 0.5 nautical mile. Between July and September the prevailing wind direction undergoes an almost complete reversal so that the September winds shift the impact locations along an azimuth of 90 degrees. For Unit 1 the magnitude of the shift is approximately 0.5 nautical mile and for Units 5 and 6 it is 0.75 nautical mile.

Heat Shield Ablation

Estimates of the heat shield ablation experienced by Units 1 and 3 on the HAVE SINEW-1 reentry trajectory were computed using the Charring Material Ablation (CMA) computer code. This computer program is an implicit finite-difference computational procedure for computing the one-dimensional transient response of a material which can ablate at one boundary and which can decompose in depth. The HAVE SINEW-1 payloads all have heat shields representative of the crystalline graphite materials. In this class of materials, the ablation process occurs as an oxidation reaction at the material surface. In the HAVE SINEW-1 reentry environment, the oxidation reaction may be confined to the kinetic or reaction rate controlled regime or may proceed from the kinetic to the diffusion controlled regime depending upon the type of motion or orientation of the individual payload. The oxidation characteristics of POCO graphites (characteristic of these heat shields) are not yet defined for the kinetic regime nor even the temperature levels at which transition from the kinetic to the diffusion regime occurs. In addition, the CMA code used here is restricted to consideration of the diffusion controlled oxidation reaction only. Therefore, the ablation calculation used here permitted the diffusion controlled oxidation reaction to proceed throughout the subsonic section of the trajectory to impact. In this respect, the ablation calculation represents a conservative (perhaps ultra) approach to the estimate of total surface recession.

As was indicated above, the CMA code is restricted to a one-dimensional energy balance through the ablator thickness coordinate. By utilizing the iterative technique described below, a first order improvement to the one-dimensional analysis is obtained. By running successively the CMA code and a two-dimensional or a three-dimensional thermal analyzer program (such as CINDA), one is able to evaluate the heat losses which the ablator nodes experience orthogonally to the thickness (CMA) coordinate. Inputting to the CMA code an equivalent radiation heat loss permits one to account for the magnitude of orthogonal heat losses from the ablator nodes on successive iterations. One or two iterations generally suffice to achieve convergence and, thus, accountability of orthogonal heat losses in the ablation analysis.

The ablation analyses for Units 1 and 3 were conducted for the side-on mode of motion trajectory. Both stable (nonrolling) and rolling motions in the side-on orientation were investigated. For Unit 3, the side-on stable orientation was considered to be with the flat face of the hexagon forward (facing the velocity vector). Figure 33 shows both the surface recession rate and the total surface recession as a function of time for Unit 1. The same parameters are illustrated in Figure 34 for

Figure 33. HAVE SINEW Unit No. 1; Athena D launch

Figure 34. HAVE SINEW Unit No. 3; Athena D launch

Unit 3. The total calculated surface recession is approximately 70 mils for Unit 1, while Unit 3 experiences approximately 90 mils recession. It should be noted that for the stable motion more than 50 percent of the calculated recession occurs during the subsonic flow section of the trajectory. Thus, if the diffusion controlled oxidation reaction becomes quenched early in the subsonic flow regime, the total surface recession will be significantly less than the calculated total illustrated in the two figures. For the side-on rolling motion, the illustrated data may be more representative of an upper bound to the heat shield recession. Calculated heat shield temperatures indicate the oxidation reaction may be confined to the kinetic regime for rolling and/or tumbling motions. If this proves to be the case, the heat shield recessions experienced on the HAVE SINEW-1 reentry trajectory may be entirely negligible.

Thermal Response

Thermal Models -- In defining the mathematical thermal analog to be used for representing Unit 1, consideration was given to the use of the resulting data, to the probable modes of motion, and to the surface heating rate distributions. The usual heat source aerothermal safety analysis is concerned with assessing the integrity of the radioisotopic fuel containment design under all plausible aerothermal environments that can be foreseen for the heat source. With respect to heat shield ablation, thermal gradients, and heat shield thermal stresses in cylindrical configurations, the side-on stable (nonrolling) mode of motion presents the most severe environment for heat source integrity. This frequently results in consideration of radial and circumferential coordinates and neglect of the axial coordinate in modeling cylindrical configurations. The HAVE SINEW-1 reentry environment, however, does not present a particularly severe environment with respect to heat source integrity. Increased heating rates near the ends of cylindrical configurations and the presence of thermocouple instrumentation near the ends make it desirable to consider the axial coordinate in modeling Unit 1. As a result of the initial roll rate imparted to each payload unit at separation, the side-on stable mode of motion was estimated to have a low probability of occurrence. The presence of a roll rate allows the heating distribution in the circumferential direction to be averaged and serves to minimize gradients in this direction. Therefore, a two-dimensional (radial and axial) thermal model of a one-half body length, 15-degree circumferential segment of Unit 1 was defined. This model is appropriate for side on rolling and tumbling motions. In addition, this model is estimated to provide a good approximation for the end-on mode since the surface heat input and the internal heat storage within the aft half length of the body are considered negligible.

Figure 35 illustrates the thermal model defined to represent Unit 1. Correspondence between the nodal network and Instrumentation Unit components is tabulated in Table VII. Initially, the three interfaces between these four components were assumed to be thermally contiguous. This assumption provided a conservative approach to the estimate of both heat shield thermal gradients and the temperature rise of the internal instrumentation package. In addition, assembly procedures call for oversize initial fabrication of the insulation cylinder, to be followed with hand sanding to achieve a light press fit during final assembly. Some additional analyses were conducted incorporating an air filled 7.5-mil radial gap between the insulation and the steel instrumentation case, however.

Figure 35. Unit 1 thermal model

TABLE VII

Nodal Network - Instrumentation Unit Component Equivalence		
Nodes 1 through 64		POCO AXF-5Q graphite heat shield
Nodes 65 through 96		Fibrous carbon insulation
Nodes 97 through 99		4130 steel instrumentation case
Nodes 100 and 101		Lumped instrumentation

Figure 36 illustrates a cross section of the Pioneer Heat Source (Unit 3). As was mentioned previously, the unit supplied for the HAVE SINEW-1 flight had thorium fuel simulant substituted for the radioisotopic fuel. As a result of the aerothermal safety analysis conducted for the Pioneer thermoelectric generator program, a two-dimensional thermal model of the Pioneer heat source already existed at Sandia Laboratories.¹⁰ This model incorporates the radial and circumferential coordinates since this safety analysis was concerned with demonstrating heat source integrity in the side-on stable mode of motion. This Pioneer thermal model was modified for the Unit 3 thermal analysis by deleting the radioisotopic fuel heat generation and by considering all material interface gaps to be air filled. The resulting nodal configuration is illustrated in Figure 37.

Figure 36. Cross section of Pioneer heat source

Figure 37. Nodal model of Pioneer heat source

An extensive compilation of data on the heating rate distribution over the surface of an $L/D = 2.05$ circular cylinder is presented in Reference 11. The heating rate distribution along the side of the cylinder for unit length Reynolds numbers of 0.68×10^6 , 1.0×10^6 , and 1.5×10^6 are shown in Figures 38, 39, and 40, respectively. Figure 41 illustrates the data over the end surface of the cylinder. However, the particular configuration tested had a recessed section of the end face and a protruding lip at the maximum radius of the end face. Therefore, a comparison of the data for this end face was made with other unpublished data for a flat ended cylinder. The data for the flat ended cylinder is also presented in Figure 41. It is evident that the recessed end and the protruding lip have distorted the end face heating distribution, particularly near the outer edge. In the end-on mode of motion, the heating input over the entire end face has been modified. Therefore, the data representative of the flat end face was used together with the $Re/ft = 1.5 \times 10^6$ data for the side wall from Figure 40 to define the heating rate distribution to Unit 1.

Heating rate distributions for Unit 3 were taken from data obtained from a wind tunnel test of the hexagonal prism configuration conducted at the NASA Langley 20-inch Mach 6 facility. A discussion of the test plan and data reduction procedures together with a presentation of the Pioneer heat source heating rate distributions is made in Reference 12.

Payload initial temperatures at separation were assumed to be a uniform 100°F through both Units 1 and 3.

Figure 38. Heating rate distribution to side of cylinder

Figure 39.

Heating rate distribution
to side of cylinders

Figure 40.

Heating rate distribution
to side of cylinder

Figure 41. Heating rate distribution to end of cylinder

Temperature Histories -- The temperature history for Unit 1 in the end-on mode of motion is illustrated in Figure 42. Shown are the temperatures for the corner of the heat shield (node 37), the outer and inner surfaces of the heat shield at the stagnation point (nodes 64 and 61), the outer and inner surfaces of the insulation at the center of the end face (nodes 96 and 93), and the steel instrumentation case (node 99). It is evident that the maximum heat source temperature occurs at the corner of the heat shield. Temperature rise at the instrumentation case is estimated to be only 10 degrees. None of the temperatures appear high enough to give cause for concern.

Figure 42. HAVE SINEW Unit No. 1
Athena D launch

Similar data for Unit 1 in the side-on rolling and the end over end tumbling plus rolling modes of motion are presented in Figures 43 and 44, respectively. The results of the analysis indicate that the thermal response of Unit 1 in the side-on rolling and the tumbling modes presents a less severe material thermal environment than does the end-on motion.

The results of the thermal analyses for Unit 3 are presented in Figures 45 and 46 for side-on stable and side-on rolling modes of motion, respectively. Here, temperature data for the outer surface of the heat shield adjacent to a hexagonal corner (node 5), for the platinum rhodium cladding on the fuel capsule (node 57), for the fuel capsule T-111 strength member (node 65), and for the outer thorium fuel simulant material (node 85) are illustrated. As in Unit 1, none of the Unit 3 temperatures are severe enough to be cause for concern.

A comparison of the temperature response of Units 1 and 3 for the side-on rolling motion (Figures 43 and 46) indicates that, for similar modes of motion, Unit 1 temperatures are less severe than Unit 3 temperatures. The thermal margin of the Unit 1 instrumentation package appears to be sufficient that even stabilization of the unit in the side-on nonrolling orientation does not seem to preclude satisfactory operation of the data recording system.

Although thermal analyses were not conducted for each of the five payload configurations, the results obtained for Units 1 and 3 provide no basis for concern with respect to the thermal response of Units 2, 4, 5, and 6.

Figure 43. HAVE SINEW Unit No. 1
Athena D launch

Figure 44. HAVE SINEW Unit No. 1
Athena D launch

Figure 45. HAVE SINEW Unit No. 3
Athena D launch

Figure 46. HAVE SINEW Unit No. 3
Athena D launch

Thermal Stresses -- No quantitative analysis of the HAVE SINEW payload heat shield thermal stresses has been completed for the Athena D trajectory. A preliminary thermal stress analysis was conducted earlier for Unit 1 flying the Athena H reentry trajectory in the end over end tumbling mode of motion. This analysis was conducted in part for the purpose of evaluating the influence of the longitudinal temperature gradient on the heat shield thermal stresses. The results of this analysis indicated that, for the Athena H trajectory, the Unit 1 maximum heat shield tensile stress was approximately 25 percent of the material's ultimate tensile strength. The analysis further indicated that for this case the longitudinal temperature gradient resulted in a compressive stress at the inner surface of the heat shield. The longitudinal temperature gradient, by introducing a compressive stress, thus contributes to a net reduction in the critical maximum heat shield thermal stress, since peak tensile stress occurs at the inner surface of the heat shield.

A comparison of the thermal response for the Athena D and Athena H trajectories provides a qualitative evaluation of the Unit 1 thermal stresses for the Athena D trajectory. The heating rates for the two trajectories are nearly equivalent, with the peak reference stagnation point heating rate for the Athena D trajectory being 98 percent of the rate for the Athena H trajectory. The rise in the heating input is steeper and the peak heating rate is reached sooner for the Athena D trajectory as a result of its considerably steeper reentry angle. However, in spite of this shortened time scale, the radial temperature gradient is reduced by approximately 14 to 23 percent for the Athena D trajectory. This would indicate that a corresponding reduction in the heat shield thermal stress might be expected for the Athena D trajectory.

Conclusions

An analysis of the reentry aerothermal performance of the HAVE SINEW-1 payload was prepared for the nominal reentry trajectory which will be provided by the Athena D launch vehicle. This analysis provided the following conclusions with respect to the reentry performance of the six HAVE SINEW-1 payload units.

1. Payload Units 1 through 4 are expected to remain relatively closely grouped throughout the trajectory to impact. The estimated impact dispersion area resulting from consideration of the tolerances on the aerodynamic characteristics and on the reentry conditions at the performance specification altitude is an elongated ellipse measuring 9 by 2 nautical miles for Units 1 through 4. For Units 5 and 6, the impact dispersion area is a 7 by 2 nautical mile elongated ellipse centered 6.5 nautical miles uprange of the dispersion area for Units 1 through 4. The data that are available on nominal wind conditions over the range indicates that the wind influence on the impact zone is not sufficient to significantly extend the search pattern to be flown by the ARMS recovery aircraft.
2. Ablation calculations performed for Units 1 and 3 indicate that heat shield total surface recessions pose no problem for the HAVE SINEW-1 flight. Recovery of heat shield fragments of sufficient size may provide the opportunity to gain some insight into the behavior of POCO graphite in the post heat pulse subsonic flow regime and in the kinetic oxidation regime.
3. The estimated thermal response for Unit 1 indicates that, for characteristic motions involving roll, the temperature rise experienced by the instrumentation package will be only a few degrees. The resulting thermal margin affords confidence that the data recording system should operate satisfactorily even in the event this unit

stabilizes in the side on nonrolling orientation. Estimated thermal response indicates that temperature levels throughout Units 1 and 3 are compatible with material thermal capabilities. Although no quantitative thermal response calculations were completed for Units 2, 4, 5, and 6, the calculations that were completed for Units 1 and 3 do not provide any basis upon which to anticipate thermal problems with Units 2, 4, 5, or 6.

4. No quantitative heat shield thermal stress calculations were completed for the Athena D reentry trajectory. However, an extrapolation of calculated stress levels for the Unit 1 heat shield on the Athena H reentry trajectory was made based upon the respective radial temperature gradients for each trajectory. The results indicate the maximum heat shield tensile stress for Unit 1 in the end over end tumbling mode of motion is 20 to 25 percent of the material ultimate strength.

Environmental Test Program

The environmental test program was responsible for proving the compatibility of the SNAP isotopic heat sources and the Athena rocket system; it also covered the impact and recovery of the SNAP payloads. The final outline for environmental tests was:

1. Drop tests at Tonopah Test Range,
2. Vibration tests for all aspects and about all axes of flight,
3. Payload spin and separation tests in high altitude chamber, and
4. Payload mounting with tracers installed.

The objective of the environmental test program was to achieve a design for the payloads and payload supporting hardware which would give the highest confidence in a successful flight.

Drop Test Program

Two test units simulating Unit 1 were prepared by Sandia Laboratories for drop tests on Sandia's test range at Tonopah, Nevada. Unit A (dummy) consisted of a steel weight which simulated the instrumentation, balsa wood to simulate the carbon insulator, and an ATJ graphite shell. Unit B consisted of an instrument package with pre-recorded tape on the tape recorder, a flight quality carbon insulator, and an ATJ graphite shell. The weight, center of gravity, and moments of inertia were designed to match those of Unit 1. The overall dimensions of the right circular cylinders were 6.75-inch OD and a 13.41-inch length.

The primary purpose of the drop tests was to verify the ability of the tape recorder to survive impact without damage or alteration to the data stored on the tape. Secondary purposes were to obtain impact velocity for Unit 1 and to determine the ability of the instrumented unit to shed its graphite shell and carbon insulator upon impact.

Both test units were dropped from a C-47 aircraft at an altitude of 17,500 feet (msl) (approximately 12,000 feet above terrain). The impact velocity for Unit 1 as determined from range radar data was 325 ft/sec. Postmortem examination of Unit B revealed only minor damage to the instrumented unit. The strength member or protective steel case for the instruments was slightly out of round. Also, two internal mounting screws sheared on impact. The prerecorded tape, of primary interest, was played back with no signs of damage or alteration, and the recovered tape recorder was still operable. Figures 47 through 53 show Unit B as photographed by the recovery team. The results of these tests were considered satisfactory by the project group.

Figure 47. Unit B after impact

Figure 48. Unit B after impact

Figure 49. Unit B after impact

Figure 50. Unit B after impact

Figure 51. Unit B after impact

Figure 52. Unit B after impact

Figure 53. Unit B after impact

Vibration Tests

These tests were performed at the vibration facility in Sandia Laboratories Technical Area 3.

The vibration test criteria were obtained from the Athena H* payload planning document prepared by Atlantic Research Corporation, the contractor to the USAF on the Athena rocket systems. The vibration output from the third stage rocket motor of the Athena H was chosen to be used for the input of the vibration spectrum. The payloads were mounted as in flight condition in the APSA (alternate payload support adapter). Each payload cradle in the APSA is lined with a half-inch of silicone rubber which acts as a vibration damper for the payloads.

Figure 54 shows the vibration spectrum used for each axis of random vibration. The payloads and the APSA were instrumented with ten accelerometers. The location of these accelerometers is shown in Table II of the Appendix. The APSA structure with dummy payloads was vibrated in the X-axis, then in the Y-axis and finally in the Z-axis. On the Z-axis run, an instrumented package replaced dummy Unit 1. This instrumented package was monitored and operated during vibration.

Vibration Spectrum	
10 to 20 Hz	6 db/octave increasing
20 to 87 Hz	0.005 g ² /Hz
87 to 300 Hz	6 db/octave increasing
300 to 1000 Hz	0.06 g ² /Hz
1000 to 2000 Hz	6 db/octave decreasing
Random vibration in three orthogonal axes.	
Two minutes minimum in each axis.	

Figure 54. Vibration test--HAVE SINEW

The Z-axis run was performed a second time with flight units replacing the dummy units. The flight units were removed from the APSA and examined for signs of physical damage. No damage was evident on any unit. The units were then taken to Sandia Technical Area 1 where a more complete examination confirmed the early assessment of no physical damage.

Figures 55, 56, and 57 show the APSA and payloads as vibrated in the X, Y, and Z axes. A complete report on the vibration tests is attached as the Appendix. The test results were determined to be satisfactory by the project group.

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* The Athena H environment was used since at the time the scheduled booster for HAVE SINEW-1 was the Athena H.

Figure 55. X-axis vibration test setup

Figure 56. Y-axis vibration test setup

Figure 57. Z-axis vibration test setup

Spin and Separation Tests

The spin and separation tests were performed in Sandia Laboratories high altitude spin chamber. A series of six tests was performed using the APSA structure with both dummy and flight payloads.

The primary purpose of this test series was threefold:

1. Determine effects of missile spin on payloads,
2. Observe the APSA, retaining belt and bolt cutters, and
3. Observe payload separation with hi-speed cameras.

As seen in Figures 58, 59, and 60, this facility is a 26-foot diameter steel sphere. This sphere was evacuated to a pressure equivalent to approximately 220,000 feet. The APSA structure was mounted on the spin table which is located at the top of the pedestal near the centroid of the sphere. This spin table is driven by an air turbine, and the rotation rate is varied by controlling the inlet pressure to the turbine. The ribbon parachute was installed as a protective device to prevent damage to the facility and payloads.

Figure 58. High altitude spin chamber

Figure 59. High altitude spin chamber

Figure 60. High altitude spin chamber

The payload retaining belt is a dacron fabric covered with a coating of Butyl N; it is a continuous loop with no joints or seams. The strap is doubled and jointed with a turnbuckle which passes through two bolt cutters.

Six high speed cameras were mounted in the facility. Four cameras were mounted around the horizontal centerline 90 degrees apart, and two cameras were mounted overhead at the top of the chamber. These cameras were to record events such as: payload movements, proper strap tension, bolt cutter operation, separation of payloads from cradles, payload separation velocities, and potential hazards to payloads during separation. The film rate on these cameras was 400 and 600 fps. A real time TV monitor was used as an aid in testing.

Proper belt tension was a design goal to be checked on this test series. Preventing payload movement without crushing or damaging payloads while spinning at maximum rpm required considerable design analysis. Bridges to absorb belt loading were used on Units 2 and 7, and a nylon strap guide was used on Unit 3.

A series of six tests was performed for this test program. Tests 1, 2, and 3 were conducted using actual flight payloads. The test sequence is outlined in Figure 61. Run 6 was the complete spin sequence for the Athena H flight from launch to separation of payloads. Run 3 used only one bolt cutter to demonstrate release system operation with only one cutter functioning.

All units were examined after testing for indications of damage. No damage to any unit was detected.

Figure 61. Spin test plan

The high speed camera coverage of these tests yielded good results. The sequence of events occurred as planned. No indications of potential failures were evident. Proper strap tension on the payload retaining belt was achieved. Operation of the bolt cutters, flyaway of the retaining belt, and bridges and payload separations show up well on the film coverage. The test results were determined to be satisfactory by the project group.

Installing and Handling Payloads

Payloads with the tantalum-182 tracers installed presented a problem of radiation safety. Therefore, it was necessary to develop procedures for handling and installing payloads in the APSA. After the initial writing of procedures, a set of handling equipment was designed and fabricated. A series of tests was then performed to determine the proper methods for handling and installing payloads in the APSA. These tests were necessary for developing timing and procedures for handling radioactive payloads. Exposure time for the handling crew was to be as short as possible without endangering personnel or payloads.

The APSA was installed in a structure which simulated the position of the APSA in the Athena on the launcher and in the lowered position as it would be for actual payload installation. Handling equipment designed to increase the distance between the installer and the source was tested. Temporary restraining straps used to hold payloads in place during the assembly were installed as part of the procedure. Health physics personnel monitored time and distance from radiation sources for each

person involved. Dummy radioactive sources and payloads were used in this test series. All events and times were monitored and recorded so as to improve current and develop better methods of payload handling. The final procedure which evolved from this test series was incorporated in the Operations Special Test No. 4124-71-031.

Figures 62, 63, and 64 show the test setup and some equipment. The results were determined to be satisfactory by the project group.

Figure 62. Test Setup

Figure 63. Installing payload

Figure 64. Installing payload

Safety Considerations

Safety considerations are presented for the following mission phases.

1. Maximum allowable radiation.
2. Irradiation of tantalum material and transportation of ^{182}Ta to GRLS.
3. Installation of radioactive sources into payload units.
4. Installation of radioactive source into payload Unit 1.
5. Placement of payload Units 2 through 6 on the alternate payload adapter (APSA).
6. Recycle after a No-Launch condition.
7. Pad abort.
8. Abort of mission during Athena boost and flight.
9. Recovery plan and accountability procedure.

Maximum Allowable Radiation

Sandia Laboratories Radiation Protection Officer (RSO) will establish a "controlled area" to ensure that no individual receives radiation in excess of the maximum allowable dose limits as specified in Title 10, Code of Federal Regulations, Part 20. "Controlled area" means any area, the access to which is controlled by the contractor (Sandia) for purposes of protecting individuals from exposure to radiation and radioactive material.

Irradiation of Tantalum Material and Transportation of ^{182}Ta to Green River

The tantalum material will be irradiated at the Omega West reactor facility at Los Alamos, New Mexico, approximately one week before the scheduled launch date. The tantalum sources will then be placed in a DOT approved shipping container and delivered to Sandia Laboratories in Albuquerque via a government vehicle. The container will then be shipped by commercial carrier to Green River, Utah.

Installation of Radioactive Sources Into Payload Units 2 Through 6

The tantalum sources will be taken to the building in Assembly Area 6 at the Green River launch site. This building will be secured by a Sandia combination lock. The area will be posted with signs which read "CAUTION RADIOACTIVE MATERIALS." The sources will be stored in the shipping container. The combination of the lock will be known only to the Sandia Radiation Officer, a representative from Sandia Scientific Group, and the Utah Launch Facility security group.

Installation of the tantalum sources into payload Units 2 through 6 will start at T-660 minutes and will be performed at the building in Assembly Area 6. The detailed procedures that Sandia personnel will follow during this installation are outlined in Reference 13, Appendix A. During the installation, the Sandia Radiation

Protection Officer (RSO) will monitor the activities according to the safety procedures outlined in Reference 13, Appendix B. During and after the above installation, the following safety considerations will be involved.

1. The two qualified Sandia technicians who will do the source loading will be constantly monitored for radiation safety by the Sandia RSO.
2. The Sandia personnel required to work inside the posted radiation areas will adhere to the Sandia radiological monitoring requirements.
3. All personnel within the designated radiation area will be required to wear film badges and dosimeters.
4. A gamma survey meter with a range of at least 50 R/hr will be used to indicate the radiation levels in the radiation area.
5. Individual radiation exposure records will be maintained in accordance with White Sands Missile Range procedures.
6. The area surrounding the payload in which exposure would exceed the maximum radiation limits of 100 mR/40 hr week (2.5 mR/hr) will be designated as a "Radiation Area." This will be a circle with an approximate radius of 15.5 meters around the payload (Figure 65). The exact distance of this line will be established by the use of an instrument. The radiation area will be conspicuously posted with signs bearing the radiation control symbol and the words "Caution Radiation Area." Included on the signs will be the actual measured radiation levels, type of radioisotope, an estimate of its activity, and the date for which the activity was calculated.

Figure 65. Radiation area

A High Radiation Area is defined as "any area, accessible to individuals, in which there exists radiation at such levels that an individual could receive in any one hour a dose to the whole body in excess of 100 mrem." This area will be a circle with an approximate radius of 2.4 meters (Figure 65). All work by Sandia personnel inside the "high radiation area" will be under the control of the designated RSO.

7. Should an emergency situation arise involving the radioactive material (fire, explosion, source spill, etc.), the following shall apply:
  - a. Evacuate the area and allow only emergency personnel to enter.
  - b. Care for any injured.
  - c. Call the Base Fire Department if fire or explosion occurs.
  - d. Notify the Sandia RSO, H. D. Christiansen.
  - e. Notify the Green River - White Sands Missile Range health physics group (phone 678-3210).

The times involved for this operation are shown in Figure 66.

Figure 66. Times involved for installation of tantalum-182 tracers

Installation of Radioactive Source Into Payload Unit 1

Installation of the tantalum source into payload Unit 1 will start at T-480 minutes and will be performed when this unit is on the alternate payload support adapter (APSA) at the launch pad. The detailed procedures that Sandia personnel will follow for performing this operation are outlined in Reference 13, Appendix C. As described above, the Sandia Radiation Protection Officer (RSO) will monitor the activities according to the safety procedures outlined in Reference 13, Appendix B. During this installation, the safety considerations which will be involved are the same as those described above. The times involved for the completion of this operation are shown in Figure 66.

Placement of Payload Units 2 Through 6 on the Alternate Payload Support Adapter (APSA)

After the installation of the radioactive source into payload Unit 1 has been completed (T-450 minutes), Units 2 through 6 will be transported from Assembly Area 6 to the launch pad for placement on the alternate payload support adapter (APSA). Placement of these payload units should commence at T-435 minutes; the detailed procedures for this operation are outlined in Reference 13, Appendix C. As described above, the Sandia Radiation Officer (RSO) will monitor the operation according to the safety procedures outlined in Reference 13, Appendix B. During this activity, the safety considerations which will be involved are the same as those stated previously. The times involved for this operation are shown in Figure 66.

Recycle After a No-Launch Condition

In the event of a "no-launch" condition, which requires that the payload be detached from the booster or that extensive work be performed on the booster within the designated "Radiation Area," the following operations will be performed.

1. Atlantic Research Corporation personnel will remove the Athena H nose heat shield.
2. Sandia personnel will remove payload Units 2 through 6 from the APSA and place them in their shipping containers.
3. Depending on the circumstances for the no-launch condition, Sandia personnel will either:
  - a. Remove tracer material from Unit 1 and then remove the unit from the APSA, or
  - b. Remove Unit 1 with tracer material from the APSA and place it in a shipping container.

During the above operations, the safety considerations listed previously will apply. The times involved for this operation are shown in Figure 67. The detailed procedures are outlined in Reference 13, Appendix D.

NO LAUNCH CONDITION

Figure 67. Times involved for the removal of payload units

Pad Abort

In the event the Athena booster explodes or burns on the pad, two possible situations that could occur are:

1. The tantalum material could be scattered throughout the area, with the pieces still intact; or
2. Some of the tantalum material could be exposed to a propellant fire or rocket motor exhaust.

For situation 1, the area will be surveyed by the Sandia Radiation Protection Officer and WSMR health physics personnel before other personnel are allowed to re-enter the area. An attempt will be made to recover the tantalum material.

In the event that the tantalum material is contained within a propellant fire or rocket exhaust (situation 2), it is very unlikely that the material would be vaporized because of its physical properties (melting point 5425°F, boiling point, and vapor pressure). However, the propellant fire and rocket exhaust environments are chemically highly reactive, and under these conditions it is necessary to consider the vaporization of the reaction products rather than that of the starting material. Tantalum and its alloy (TaC) oxidize readily and, at high temperature, at a catastrophic rate. The vapor species would probably be oxide or suboxides of tantalum. Under this situation, it is possible that vapor species of tantalum could be present in a launch abort (Reference 13, Appendix E).

Abort of Mission During Athena Boost and Flight

In the event the Athena booster is command destructed by the WSMR Safety Officer during first stage burn, the radioactive material should impact in an intact condition. In case this should occur, it is of interest to know what the probability would be of this material impacting in a populated area (i.e., population density of more than one per square mile). Considering the normal flight corridor for the Athena vehicle, the ground area within this corridor, and the area which has a density population greater than one per square mile, it can be determined that the populated area is only 11 percent of the total corridor area; thus, there is a relatively small probability of persons coming in contact with the radioactive material.

If a mission abort occurs during boost, recovery of the radioactive material will be attempted through the use of EG&G ARMS aircraft (airborne search) and through use of a WSMR recovery team that is supported by qualified material handlers of the Air Force Weapons Laboratory (SEQ).

Any recovered radioactive material will be placed in a restricted storage area at WSMR until it is removed for shipment to Sandia Laboratories, Albuquerque, New Mexico, for disposal. The packaging and transporting of the radioactive material will be in accordance with the regulations in Chapter 0524 of the AEC Manual and Department of Transportation regulations.

Recovery and Accountability of Radioactive Materials After Impact From a Normal Mission

It is mandatory that these units be recovered. The prime recovery aid will be the EG&G ARMS aircraft (Twin Beach) which will use radiometric detection as the primary aid and infrared detection as a secondary aid. The proposed operational plan that this aircraft will use for recovery is as follows.

The search aircraft carries an array of NaI crystals for detection of γ -rays. The signals from photomultipliers viewing these crystals are summed and the pulse height analyzed with electronics on the aircraft. A pulse height window will be adjusted to register pulses falling in the photopeak portion of the lost source spectrum. This mode of operation improves the ratio of source signal to the "noise" signal from naturally occurring radioactivity in the soil. The count rate from pulses within the window will be recorded on a strip chart which responds with a wide pulse when the aircraft passes near the source.

^{182}Ta sources of 100 mCi activity should be detectable from a 600-foot distance of closest approach. A search grid flown at 300 feet altitude with 1000 feet spacings between lines guarantees a distance of closest approach less than or equal to 600 feet. The 3 by 5 mile impact area can be covered in about one hour using this search grid. This time does not include "down time" required to pin-point a source's location after its existence has been inferred from the signals received along the normal grid lines and to recover it.

The ARMS plane will be stationed at Holloman Air Force Base. Surveying can begin as soon as the aircraft receives clearance and last minute position data corrections. The search aircraft will carry a C band transponder and will be verbally vectored to the most probable impact point by the WSMR tracking radar.

The search line grid pattern will begin on a line through this point parallel to the payload trajectory. Lines at increasingly greater distances from this point will be flown until an anomalous signal appears. Several passes will then be made over the anomalous area to better define the position of the extraneous activity. Flour bag bombs will be dropped to guide helicopter and ground crews to the source position indicated by the instruments. The source position may not be defined by the aircraft to an uncertainty better than a few hundred feet in both directions. It is planned to have a helicopter and ground crew with detectors in the general recovery area.

The search grid pattern will be resumed after other aircraft have cleared the area. The first grid line flown will be a repeat of the grid line initially indicating the presence of the source. The grid line pattern will be continued until either the complete area has been covered or until all sources have been located.

In the event all sources have not been recovered after the 3 by 5 mile area has been searched, one of two alternate procedures can be followed. Either this area can be reflight along grid lines halfway between the previous lines or a larger area around the impact point can be searched.

It is estimated that there is at least a 90 percent probability of finding unshielded 100 mCi ^{182}Ta sources with the 1000-foot spacings between lines. However, depending on the geometry and orientation of the search objects, the effective strength of the source can be reduced; this indicates the desirability of flying more closely spaced lines. A better description of search object geometry, coupled with data from flights at several altitudes over a 100 mCi ^{182}Ta source, should better define the ARMS aircraft capabilities in this respect. Test flights over ^{182}Ta sources will be carried out in conjunction with the suggested preoperational survey of the most probable impact area.

In addition to the radiometric detection capability of the aircraft, it will also have sensors for infrared detection. Presently, it is estimated that the impact temperature of the payload units will be approximately 500°F, which will enhance infrared detection for a short time after impact (20 minutes).

The ARMS aircraft support will be needed at WSMR for the flight for approximately 3 days. IR and radiometric calibration checks should be accomplished at the impact site 1 day prior to each reentry and at least one postimpact day should be allowed in case extended search is required. Additionally, an airborne radiometric background survey needs to be made at WSMR 1 or 2 months prior to the first flight, and a radiation source check should also be made within the next 2 or 3 months to confirm source level response.

It is planned to have the ground search team consult with an AEC representative. This representative will have the responsibility for advising and assisting in the handling, removing, and transporting of the payloads and tantalum-182 material. Approved containers for transporting the radioactive material will be supplied by the AEC.

Comparison of Consequences and Criteria - Normal Mission

As was stated above, standard safety considerations will apply during the installation of ^{182}Ta and the placement of the payload units on the APSA. These considerations include:

1. Personnel monitoring equipment will be worn by all radioactive material operations personnel,
2. The Sandia Radiation Protection Officer (RSO) will monitor and be responsible for the radiation safety of radioactive material operations personnel, and
3. Exposure records will be kept on file in accordance with White Sands Missile Range procedures.

The radioactive material will remain intact during a normal mission. At the time of payload impact, the graphite heat shield on the payload units will be cracked and should shed from the internal can or capsule, and the radioactive tracer ^{182}Ta , which will be fastened to the inner container, should be exposed. Since each of the payload units will impact at different locations, the radiation hazard at impact is expected to be at a minimum. To locate the radioactive material, airborne radiometric and infrared detection support will be provided by EG&G ARMS aircraft. In addition, the ground recovery team will have gamma detection meters. When radioactive material is located, the material will be placed in DOT approved shipping containers and shipped back to Sandia Laboratories in accordance with DOT and AEC shipping regulations. These operations should result in minimum radiation exposure to the recovery team.

Each payload unit will contain a placard inscribed "Radioactive" to alert any unauthorized person(s) who might find an unrecovered unit.

Worst Case Consequences

Two situations were considered for worst consequences, and they are as follows.

1. A worst case would be if a launch abort occurred and the tantalum material was contained within a propellant fire or rocket exhaust and was 100 percent vaporized into a vapor plume which was dispersed by the winds to a populated area. A hazard would be created for person(s) who inhaled or ingested the tantalum vapors, and possible bodily damage could occur to the person(s), as discussed in Appendix E of Reference 13.
2. A worst imaginable radiation exposure situation would be if all the sources (693 millicuries) were deliberately picked up by a human who was unaware of their radioactivity after they had been lost as a result of either an abort or a failure to recover after impact. This is not a problem for a normal mission since the impact zone is a large remote area at WSMR with controlled access. It would only be a safety concern if the sources impacted outside of the WSMR controlled area. However, the areas along the flight path are unpopulated or very thinly populated (one person per square mile or less), and there is a good probability the sources could be detected and recovered through the use of the proven airborne radiometric detection capability that is available as part of the flight test. In any event, the government would

actively seek the source and attempt to return it to radiological control as part of the flight test procedure.

Because of the above factors, and because of the minute size of the ^{182}Ta sources (small loops of 20-mil wire), it seems unlikely that they would ever be found without the use of radiometric equipment. However, should this occur, a person could receive significant radiation doses at about the rate of 693 mR/hr at 1 meter (after picking up within a day or two of impact). Since the radioactivity would decrease by half every 115 days, the dose a person would receive would depend on the elapsed time between the day it was lost and the day it was found, as well as how long the source was kept on the person or in proximity to the person. A severe skin dose of several thousand roentgens and a whole body dose of several hundred roentgens could result under the worst circumstances.

Of the two cases considered, Case 2 is the worst possible case because, as shown in Reference 13, Appendix E, Case 1 does not exceed the maximum permissible concentration.

Safety Conclusions

Due to the physical properties of the ^{182}Ta sources and the environments to which they will be exposed, there is no significant radiological hazard as a result of pad aborts, reentry, or impact. The major hazard would be overexposure as a result of close proximity to the sources. During normal operations, exposures are controlled by shielding, exclusion areas, Health Physics procedures, etc. In accident modes, the plan is to recover the sources as soon as possible.

The object of using ^{182}Ta on the flight test is to aid in the recovery of the heat sources. The activity of each ^{182}Ta source is sufficient to assure airborne detection by established search techniques and equipment. Experience has shown that there is a very high probability of locating the sources in all normal and postulated accident situations.

The worst imaginable radiological accident would be the result of an individual deliberately placing the sources on his person or close to his person for a long period of time. Considering the small size of the sources and the unpopulated areas along the flight path, there is little possibility that this will occur. The short half life of the isotope and the fact that the government will actively search for lost sources with equipment having demonstrated airborne radiometric detection capability further reduces the hazard potential. It is therefore contended that the probability of this occurrence is sufficiently remote to justify the slight risk involved. Based on this radiological safety analysis, the normal HAVE SINEW-1 payload is considered to be safe.

Support Requirements

Instrumentation and Data Requirements

Table VII lists the instrumentation and data requirements for HAVE SINEW-1.

TABLE VII
Instrumentation and Data Requirements

Sensors	Priority	Test Objectives	Remarks
<u>Radars</u>			
WSMR FPS-16	Required (R)	P - 3.1	Track leading edge object out of a group of six payloads.
RAMPART	Mandatory (R)		Track leading edge object out of a group of six payloads.
RAM VHF	Mandatory (R)		Track leading edge object out of a group of six payloads.
AMRAD RAM UHF	Required (R)		Track leading edge object out of a group of six payloads.
HAPDAR	Desired (D)	S - 3.2	Establish track as possible.
IRVMS	Desired (D)	S - 3.2	
Radar (FPS)	Mandatory (R)	P - 3.1	To vector EG&G ARMS recovery aircraft to predicted impact areas.
<u>Optics</u>			
GLOW*	Desired (D)	S - 3.2	To provide possible trajectory data.
WSMR Ballistic Cameras	Mandatory (D)	S - 3.2	To provide tracking information from reentry to impact.
<u>Other Sensors</u>			
Rawinsonde and/or Rocketsonde	Required (R)	P - 3.1	These data should be measured to an altitude of approximately 100,000 feet and should be obtained as close to the reentry area as possible.
<u>Other Data Requirements</u>			
Computer Program Impact Prediction from Radar Data	Mandatory (R)	P - 3.1	These data will be used to predict the initial payload impact area, so that the EG&G aircraft can be vectored in.
Trajectory Listings and Plots	Mandatory (R)	P - 3.1	Data from all available radars, cameras, etc., that tracked the payload.

* If appropriate funds are available.

Recovery

Since recovery of the payload is one of the primary objectives of this flight, this type of support is of prime importance to the success of the mission. As was previously mentioned, each of the HAVE SINEW-1 payloads will contain approximately 100 millicuries of tantalum-182 wire as a tracer element to aid in postimpact radio-metric detection and recovery. The prime recovery aid will be the EG&G ARMS aircraft (twin Beech) which will use radiometric detection as the primary aid and infrared detection as a secondary aid. The proposed method that this aircraft will use in the recovery operation is as follows.

The search aircraft carries an array of NaI crystals for detection of γ -rays. The signals from photomultipliers viewing these crystals are summed and the pulse height analyzed by electronics on the aircraft. A pulse height window will be adjusted to register pulses falling in the photo-peak portion of the lost source spectrum. This mode of operation improves the ratio of the source signal to the "noise" signal from naturally occurring radioactivity in the soil. The count rate from pulses within the window will be recorded on a strip chart, which responds with a wide pulse when the aircraft passes near the source.

^{182}Ta sources of 100 mCi activity should be detectable from a 600-foot distance of closest approach. A search grid flown at 300 feet altitude with 1000-foot spacings between lines guarantees a distance of closest approach less than or equal to 600 feet. The 3 by 5 mile impact area can be covered in about 1 hour using this search grid. This time does not include "down time" required for recovery of a source and pinpointing the source's location after its existence has been inferred from the signals received along the normal grid lines.

It is desirable to have the aircraft as close to the impact area at launch time as safety precautions permit. Surveying can begin as soon as the aircraft receives clearance and last minute position data corrections. The search aircraft will carry a C-band beacon and should be vectored to the most probable impact point. The search line grid pattern will begin on a line through this point parallel to the payload trajectory. Lines at increasingly greater distances from this point will be flown until an anomalous signal appears. Several passes will be made over the anomalous area to better define the position of the extraneous activity. Flour bag bombs will be dropped to guide helicopter and ground crews to the source position indicated by the instruments. The source position may not be defined by the aircraft to an uncertainty better than a few hundred feet in both directions. It is desirable to have helicopter and ground crews with detectors in the general recovery area.

The search grid pattern will be resumed after other aircraft have cleared the area. The first grid line flown will be a repeat of the grid line on which the presence of the source was first indicated. The grid line pattern will be continued until either the complete area has been covered or all sources have been located.

In the event all the sources have not been recovered after the 3 by 5 mile area has been searched, one of two alternate procedures can be followed. Either this area can be reflight along grid lines halfway between the previous lines or a larger area around the impact point can be searched.

It is estimated that at least a 90-percent probability exists of finding unshielded 100 mCi ^{182}Ta sources with the 1000-foot spacings between lines. However, dependent on the geometry and orientation of the search objects, the effective strength of the source can be reduced; this indicates the desirability of flying more closely spaced lines. A better description of search object geometry, coupled with data from flights at several altitudes over a 100 mCi ^{182}Ta source, should better define our capabilities in this respect. Test flights over ^{182}Ta sources can be carried out in conjunction with the suggested preoperational survey of the most probable impact area. This survey should also be supported by a recovery team if the presence of extraneous sources (other than the Ta) is suspected.

In addition to the radiometric detection capability, the aircraft will also have sensors for infrared detection. Presently, it is estimated that the impact temperature of the payload units will be approximately 500°F which will enhance infrared detection for a short time after impact (20 minutes).

The ARMS aircraft support will be needed at WSMR for the flight for approximately 3 days. IR and radiometric calibration checks should be accomplished at the impact site 1 day prior to each reentry, and at least 1 postimpact day should be

allowed in case extended search is required. Additionally, an airborne radiometric background survey needs to be made at WSMR 1 or 2 months prior to the first flight and a radiation source check should also be made within the next 2 or 3 months to confirm source level response. A list of ARMS radio equipment and operating frequencies are shown in Table VIII. It is planned to have the ground search team under the consultation of an AEC representative. This representative will have the responsibility for monitoring the handling, removing, and transporting of the payloads and tantalum-182 material. Approved containers for transportation of the radioactive material will be supplied by the AEC. Photographic coverage will be supplied by WSMR.

TABLE VIII

Transmitting Equipment E-50 Beech N702B

1. DME, RCA AVQ 75 1000 watt pulse output 1041 to 1150 MHz range L-band, blade type antenna	5. Radar Altimeter, Minneapolis Honeywell APN 171 200 watt pulse 4200 to 4400 MHz Fixed, flush mounted antenna
2. VHF Communication Transmitter, RCA AVC 110 20 watt output, audio modulated 118.0 to 135.95 MHz with 50 kHz spacing Rigid blade type antenna	6. Doppler Radar, General Precision Laboratory Model AN/APN-153 10 watt output 13.325 GHz
3. Transponder, Wilcox 814B 500 watt output 1090 MHz UHF blade type antenna	7. C-Band Beacon, Motorola 500 watt, 2 ms delay RCVR 5700 MHz Transmit 5500 MHz
4. HF Transmitter, Sunair ASB-100A 500 watt output, audio modulated 100 watt output, single sideband 2000 to 18,000 kHz range Fixed wire antenna	

The prediction of the impact point for each payload will utilize the data supplied by the sensors (radar, cameras, etc.) described in Table VII. These data will be used to construct individual trajectories and impact points for each of the HAVE SINEW-1 payloads. These extrapolations will be based on parametric variations of altitude, range, and time of flight with ballistic parameter, which will be determined prior to flight.

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APPENDIX

Vibration Test of the HAVE SINEW

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R-418035

April 8, 1971

VIBRATION TEST OF THE "HAVE SINEW"

Environmental Test Report

D. O. Smallwood - 7324

Approved by D. O. Smallwood /S/
Project Leader - 7324

Approved by R. B. Abbott /S/
Test Project Leader - 7250-P

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Central Technical File - 3422-1
R. B. Abbott 7250-P

VIBRATION TEST OF THE "HAVE SINEW"

Introduction

The objective of the test was flight qualification of the "HAVE SINEW" payload package of the Athena H. The test consisted of subjecting the payload to random vibration of the following specifications in each of three orthogonal axes.

Spectrum:	10-20	Hz	6 dB/octave increasing
	20-87	Hz	0.005 g ² /Hz
	87-300	Hz	6 dB/octave increasing
	300-1000	Hz	0.06 g ² /Hz
	1-2	kHz	6 dB/octave decreasing

Duration: 2 minutes minimum in each axis

The unit was received on March 11, 1971, and testing was completed on March 13, 1971. The test was requested by J. E. Deveney, 9513, and R. B. Abbott, 7250-P, was the test project manager.

Summary

No apparent failures were noted during the testing.

Procedure and Results

Test Setup

The testing was performed in Building 6560. The equipment and fixtures used are listed in Table I. The test setup for the X-axis and Y-axis testing is shown in Figures 1-4. The setup for the Z-axis was the same as for the Y-axis except that the test unit was rotated 90°. No photos of the Z-axis setup are included in the report.

Instrumentation

The instrumentation for the test consisted of ten accelerometers as listed in Table II. For each test all accelerometers were orientated in the direction of the input vibration. The locations of the accelerometers are shown in Figures 1-4. All accelerometers were recorded for each run except for K on Run 5. Accelerometer A located on the APSA fixture was used for input control.

Test Sequence and Discussion of Results

The test sequence is listed in Table III. The X-axis test was straightforward although some difficulty in equalizing the high frequencies was noted. The input spectrum is shown in Figure 5. The response spectrums are included as Figures 6-9. During Y-axis and Z-axis tests, equalization became more difficult. At the request of the consultant, the input spectrum in the vicinity of 90 Hz was notched (see Figures 10 and 15) in an effort to reduce the response of the top plate. The accelerometer responses for these tests are included as Figures 10-19. Table IV lists the response plot figure numbers for each accelerometer and run. Runs 4 and 5 were the same except that the dummy graphite unit was replaced with a flight unit.

The random data was reduced using the RANDANT program.

TABLE I

Equipment and Fixtures

Testing Performed in Building 6560X AXIS TESTINGFixture No. F-409 and APSA Test Fixture⁽¹⁾Exciter No. 7Power Amplifier No. 7 Make MB Model T999Control Console No. 3 ☒ Remote ☐ LocalRandom Console No. 1 Make MB Model T589Data Console No. 3 ☒ Remote ☐ LocalTape Machines 4 ☒ Remote ☐ LocalY AXIS TESTINGFixture No. F-409 and APSA Fixture on Slip TableExciter No. 7Power Amplifier No. 7 Make MB Model T999Control Console No. 3 ☒ Remote ☐ LocalRandom Console No. 1 Make MB Model T589Data Console No. 3 ☒ Remote ☐ LocalTape Machines 3 ☐ Remote ☐ LocalZ AXIS TESTINGFixture No. F-409 and APSA Fixture on Slip TableExciter No. 7Power Amplifier No. 7 Make MB Model T999Control Console No. 3 ☒ Remote ☐ LocalRandom Console No. 1 Make MB Model T489Data Console No. 3 ☒ Remote ☐ LocalTape Machines 4 ☒ Remote ☐ Local

OTHER EQUIPMENT USED: _____

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⁽¹⁾Atlantic Research, Missile Systems Division, Costa Mesa, California
Drawing No. 01-50831.

TABLE II
Instrumentation of HAVE SINEW

Transducer Number ⁽¹⁾	Type	Serial Number	Calibration Date	Axis of Orientation	Location	Photograph Figure Number	Comments
A	2221M2A	NA75		Dir. of Vib.	Fixture Plate	1,3,4	Control Accel.
B	2221M2A	NB08		Dir. of Vib.	Base Plate	1,4	
C	2221M2A	VA72		Dir. of Vib.	Unit 1	1,3,4	
D	2221M2A	NA15		Dir. of Vib.	Top Plate	2,3,4	
E	2221M2A	WA15		Dir. of Vib.	3 and 4 ⁽²⁾ P/L ⁽³⁾ BH ⁽⁴⁾ , Top	2,3	
F	2221M2A	NA35		Dir. of Vib.	7 P/L BH, Top	2,3	
G	2221M2A	WA49		Dir. of Vib.	2,5, and 6 P/L BH, Top	1,4	
H	2221M2A	NB16		Dir. of Vib.	1 P/L BH, Top	1,4	
J	2221M2A	NA79		Dir. of Vib.	Unit 2	1,4	
K	2221M2A	WA01		Dir. of Vib.	Unit 3	2,3	Not used for Run 5
Transducer Code: A Accelerometer S Strain Gage M Microphone F Force Gage V Velocity Transducer P Pressure T Thermocouple D Displacement Gage							
(1) All transducers were accelerometers.				(3) P/L - payload			
(2) Unit numbers				(4) BH - bulkhead			

TABLE III

Testing Sequence for the HAVE SINEW

Run Number	Test Type	Input Axis	Input Specifications	Test Temperature	Test Date	Setup Photograph	Comments
1	Random	X	-10 dB from Run 2	Room	3/11/71	1,2	Preliminary run not recorded
2	Random	X	A	Room	3/11/71	1,2	
3	Random	Y	A	Room	3/12/71	3,4	
4	Random	Z	A	Room	3/13/71	3,4	
5	Random	Z	A	Room	3/13/71	3,4	
A: 10-20 Hz 6 dB/octave increasing 300-1000 Hz 0.06 g ² /Hz 20-87 Hz 0.005 g ² /Hz 1-2 kHz 6 dB/octave decreasing 87-300 Hz 6 dB/octave increasing Time: 2 minutes							

TABLE IV

Response Plot Figure Numbers for Test of HAVE SINEW

Transducer Number	Axis of Orientation	Location	Figure Numbers						Comments	
			Run No. 2	Run No. 3	Run No. 4	Run No. 5	Run No.	Run No.		
A	Dir. of Vib.	Fixture plate	5	15	25	35			Control accel.	
B	Dir. of Vib.	Base plate	6	16	26	36				
C	Dir. of Vib.	Unit 1	7	17	27	37				
D	Dir. of Vib.	Top plate	8	18	28	38				
E	Dir. of Vib.	-	9	19	29	39				3 and 4 ⁽¹⁾ P/L ⁽²⁾ BH ⁽³⁾ , top
F	Dir. of Vib.	-	10	20	30	40				7 P/L BH, top
G	Dir. of Vib.	-	11	21	31	41				2, 5, and 6 P/L BH, top
H	Dir. of Vib.	-	12	22	32	42				1 P/L BH, top
J	Dir. of Vib.	Unit 2	13	23	33	43				
K	Dir. of Vib.	Unit 3	14	24	34	-				

(1) Unit numbers

(2) P/L - payload

(3) BH - bulkhead

Figure 1. X-axis setup

Figure 2. X-axis setup

Figure 3. Y-axis setup

Figure 4. Y-axis setup

Figure 5. HAVE SINEW vibration test; input axis X;
accel. A fixture plate

Figure 6. HAVE SINEW vibration test; input axis X;
accel. B base plate

Figure 7. HAVE SINEW vibration test; input axis X;
accel. C unit 1

Figure 8. HAVE SINEW vibration test; input axis X;
accel. J unit 2

Figure 9. HAVE SINEW vibration test; input axis X;
accel. K unit 3

Figure 10. HAVE SINEW vibration test; input axis Y;
accel. A fixture plate

Figure 11. HAVE SINEW vibration test; input axis Y;
accel. B base plate

Figure 12. HAVE SINEW vibration test; input axis Y;
accel. C unit 1

Figure 13. HAVE SINEW vibration test; input axis Y;
accel. J unit 2

Figure 14. HAVE SINEW vibration test; input axis Y;
accel. K unit 3

Figure 15. HAVE SINEW vibration test; input axis Z;
accel. A fixture plate

Figure 16. HAVE SINEW vibration test; input axis Z;
accel. B base plate

Figure 17. HAVE SINEW vibration test; input axis Z;
accel. C unit 1

Figure 18. HAVE SINEW vibration test; input axis Z;
accel. J unit 2

Figure 19. HAVE SINEW vibration test; input axis Z;
accel. K unit 3

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