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**VOLUME I
SUMMARY REPORT**

**SYSTEM FOR UPPER
ATMOSPHERIC SOUNDING (SUAS)**

■
MARCH 1969
■

PREPARED UNDER CONTRACT NO. NAS1-7911 BY



BOOZ-ALLEN APPLIED RESEARCH Inc.

FOR

**NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION**

LANGLEY RESEARCH CENTER

VOLUME I
SUMMARY REPORT

SYSTEM FOR UPPER
ATMOSPHERIC SOUNDING (SUAS)

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FOREWORD

This study was conducted for the Langley Research Center of the National Aeronautics and Space Administration by Booz, Allen Applied Research Inc., Bethesda, Maryland under Contract NAS1-7911. Mr. T.P. Wright, Jr., of the Flight Vehicles and Systems Division, was the LRC Technical Representative of the Contracting Officer. The study was initiated on February 1, 1968 and completed on January 31, 1969.

The study was under the cognizance of Mr. C.F. Riley, Jr., Vice President, of Booz, Allen Applied Research Inc. Mr. W.E. Flowers, Research Director, was the Program Manager. Principal BAARINC staff contributors were Messrs. William E. Brockman, J. Frank Coneybear, Harry L. Crumpacker II, John L. Hain, and David W. Weiss. During the course of the study, Mr. Frederick F. Fischbach of the High Altitude Research Laboratory, University of Michigan, Mr. G. Harry Stine, a private consultant, and Dr. N. Engler, University of Dayton Research Institute were engaged as consultants.

Reports produced as a result of this study are:

- Volume I - Summary Report
- Volume II - Technical Report
- Volume III - Conceptual Design
- Volume IV - Technology Development Plan
- Volume V - Program Development Plan.

Volume I is an overview of the project listing results and conclusions.

Volume II is the complete report on the project containing all of the technical analysis.

Volume III is the conceptual design which details the recommended sounding system.

Volume IV is the Technology Development Plan which is an orderly description of the remaining technical problems that need to be resolved prior to system procurement.

Volume V is the Program Development Plan which is an overall plan for the implementation of the system for Upper Atmospheric Sounding.

I. SUMMARY REPORT

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1. INTRODUCTION

This report is a condensation of the significant investigations and findings of the Conceptual Design study to develop a Synoptic Upper Atmospheric Sounding System.

The objective of the study was to perform a comprehensive analysis of alternative launch vehicles, payloads, tracking/telemetry and ancillary support to define a sounding system capable of probing the atmosphere from 30 to 100 kilometers for the purpose of obtaining measurements of wind speed and direction, temperature and pressure (or density). The recommended system should be responsive to the requirements for relatively low-cost, high reliability and simplicity of use, and be capable of synoptic operation on a world-wide basis.

The desired system accuracy is:

temperature: $\pm 2^{\circ}$ C rms at 30 kilometers
and not exceeding $\pm 5^{\circ}$ C rms at 100 kilometers

wind velocity: $\pm 5\%$ rms vector error

pressure and density measurements should be consistent with the stated temperature accuracy requirements.

operating environment: the system should be capable of synoptic operation on a worldwide basis

temperature: -40°C to $\pm 50^{\circ}\text{C}$

humidity: up to 95%

. rain: 12 inches/hour

wind: up to 60 knots in hold
and 35 knots launch

salt spray: 20% solution.

2. CONCLUSIONS

The study objectives were accomplished in that a comprehensive investigation of sensing techniques, launch techniques, and data acquisition/tracking system revealed six candidate systems having various degrees of capability to accomplish the measurements and compatibility with the stated mission requirements. All six systems received a comprehensive cost analysis.

The study revealed that sensing techniques are the most inadequate portion of a system which can measure temperature, pressure/density and horizontal winds from 30 to 100 kilometers. No

difficulties were identified in acquiring low-cost launch vehicle; the tracking system is a state-of-the-art device although expensive.

The gun-launch concept received extensive investigation and revealed its critical restriction to very low volume payloads, subjected to high acceleration during launch. The gun-launch concept is not amenable to off-design operation, i. e. , changes in payload volume or weight are essentially prohibited.

The trade-off analysis indicated that a system consisting of a launch vehicle characterized by a 2-inch diameter dart and a short-burning rocket (2-5 seconds) or a long-burning rocket (16-20 seconds) with an all-up weight of approximately 160 pounds, a payload of a 1-meter, 1/2-inch mylar passive sphere and one canister of chaff (for upper altitude horizontal winds) and a phased-array radar capable of tracking the two targets simultaneously with sufficient range and elevation accuracy to meet the desired system accuracies.

A number of development or experimental investigations are required to obtain an operational system and are discussed in depth in the Technology Development Plan (Volume IV). Some of these are:

- Development of the phased-array tracking radar

- Investigation of reliable inflation and ejection techniques for the payload

Continuation of the Falling Mass Hazard investigation

Definition of drag coefficients for the passive sphere over the necessary Reynolds number and Mach number

Rocket motor and/or dart vehicle developments to achieve a lower unit production cost

A continuing quality assurance and reliability program

Site and distribution investigation.

The launch vehicle will loft the payload to an altitude of about 130 km at apogee. The payload contains a 1-meter diameter, aluminized, 1/2 mil mylar, inflated sphere, and about 1 pound of .0006-inch diameter, aluminized plastic filaments or "chaff". The sphere will be deployed at approximately 85 km and coast to apogee, the chaff will be deployed at apogee. The interactions of the sphere and chaff, with the ambient density and winds encountered on its otherwise ballistic-trajectory, will be tracked by an extremely accurate, phased-array tracker/data acquisition system located at the launch site. These measurements will be recorded by the tracking system and will be processed at the launch site (probably) to yield density, pressure, temperature, and horizontal wind vector profiles of the atmosphere between altitudes of 30 km and about 100 km.

II. SENSOR ANALYSIS

II. SENSOR ANALYSIS

A comprehensive review was conducted to identify all pertinent sensors which have been developed, are under development or are planned for development by the meteorological community. Each sensor was evaluated as a possible element of this system. Table 1 is a listing of the sensors investigated. They were evaluated in terms of available or projected technical performance development risk, cost, and compatibility with other system elements (launch vehicle, etc.).

PAYLOAD CANDIDATES

The sensors shown in Table 2 are those found acceptable as candidates for extensive investigation for the system. They have been grouped into six payload systems which provide measurement coverage over the 30 to 100 kilometers range. These six candidates are shown in Table 3. Candidate 1 is the Passive Sphere with the minimum weight and volume requirement of any payload system. The altitude requirements for this candidate system are approximately 130 kilometers and it is not launch acceleration-limited. However,

Table 1
Sensing Techniques Studied

<u>Winds</u>	<u>Pressure</u>
Passive Sphere	Pitot & Pitot Static Gage
Grenades	Cryogenic Crystal
Parachute and Ballute	Solid-State Pressure Transducer
Chaff	
Tri-methyl-aluminum Trails	<u>Temperature</u>
Meteor Trails	Grenades
Speed of Sound	Thermistor
Ion Wind Techniques	Molecular Fluorescence
<u>Density</u>	Densitometer
Active Inflated Sphere	Speed of Sound
Active Solid Sphere	*Active Inflated Sphere
Passive Sphere	*Active Solid Sphere
Spinning Wire	*Passive Sphere
Meteor Trails	*Beta Ray Densitometer
Molecular Fluorescence	*Spinning Wire
Densitometer	*Meteor Trails
Beta Ray Densitometer	*Laser Backscatter
Laser Backscatter	*Pitot & Pitot Static Gage
Speed of Sound	Cryogenic Crystal

*

Derived from another parameter.

Table 2
Acceptable Sensing Techniques

Passive Sphere

Chaff

Spinning Wire Densitometer

Molecular Fluorescence Densitometer

Pitot System

Thermistor and Parachute

Table 3
Basic Payload Candidates*

No.	Minimum Diameter (Inches)	Description	Altitude (km)	Weight (lbs)	Volume (in ³)	Acceleration= Limit
1	1.5	Passive Sphere	125-140	3	40	None
2	2.5	Transponding Sphere	125-140	6	120	None
3	1.5	Passive Sphere & Chaff	125-140	7	90	None
4	4.0	Spinning Wire (SWD) Thermistor & Chaff	120	15	245	None
5	4.0	Molecular Fluorescence Densitometer (MFD), Thermistor, Chaff	100	16	435	100-150 g's
6	4.5	Pitot, Thermistor & Chaff	120-145	25	660	100-150 g's

*See text for altitude restrictions.

this system cannot detect horizontal winds above 80 kilometers.

Candidate 2 is the Transponder Sphere which has the altitude requirements, no acceleration limits, and approximately twice the weight of the Passive Sphere. This technique is also wind limited to about 70 kilometers. Candidate 3 is Passive Sphere plus one chaff package which will extend wind measurement to about 87 kilometers. It is approximately the same weight and volume as Candidate 2. Candidate 4, incorporating the Spinning Wire Densitometer, chaff, and a thermistor/parachute. It weighs approximately 15 pounds, has a volume of 245 cubic inches and is not acceleration-limited. Candidate 5 uses the Molecular Fluorescence Densitometer, chaff and thermistor/parachute. It weighs the same as Candidate 4 but requires 435 cubic inches of volume and is acceleration-limited. Candidate 4 requires a minimum altitude of 120 kilometers, while 5 does not require altitudes in excess of 100 km. Payload candidate 6, with the pitot probe, thermistor/parachute and chaff is the heaviest (25 pounds) and has the greatest volume requirement (660 inches). It is acceleration-limited to approximately 150 g's and has a minimum altitude requirement of 120 kilometers.

III. LAUNCH VEHICLE ANALYSIS

III. LAUNCH VEHICLE ANALYSIS

A comprehensive survey of launch concepts was conducted ranging from satellites to high-altitude guns. Table 4 is a listing of the concepts studied. Those techniques found to warrant further consideration were tested for altitude performance compability with the payload candidates, cost and development risk. Figure 1 is a diagram of launch vehicle/payload compatibility.

1. DISCUSSION OF THE FALLING MASS HAZARD

A problem of major concern for the worldwide synoptic sounding network is that of falling mass hazards associated with the launch vehicle and the payloads. Provision has been made in each of the candidate payloads for a parachute to return any hazardous payload to earth at a velocity of 15-20 feet/seconds. It thus remains to determine how best to minimize the hazard for the various launch vehicle candidates. The simplest choice from a vehicle standpoint is to provide a range area for impact of the vehicles. This is the procedure that is used in rocket test ranges today. There are at least 25 such worldwide ranges today which use the Arcas vehicle, most of which

Table 4
Launch Concepts

CONCEPT	DEFINITION
<u>Rejected</u>	
Balloon-Borne Rocket	A single or multi-stage rocket which is initially lifted to an intermediate altitude by a gas-filled balloon.
Airplane-Borne Rocket	A single or multi-stage rocket which is initially lifted to an intermediate altitude by a conventional airplane.
Gun-Boosted Ramjet	An airbreathing, ramjet powered, payload carrying projectile which receives its initial momentum from a gun.
Catapult-Boosted Rocket	A single or multi-stage rocket which is initially accelerated by a catapult device.
Satellite and Satellite-Borne Probes	A satellite used either as an in situ (low altitude) device or to carry re-entering probes.
<u>Require Further Consideration</u>	
Single-Stage Rocket	A single-stage, solid or liquid rocket, hybrids with either single or dual thrust level (Includes dart-type vehicles).
Multi-Stage Rocket	A rocket with more than one thrusting stage.
Gun-Boosted Flight Vehicle	A payload carrying projectile which is accelerated to sufficient velocity by a gun to attain the desired altitude.
Gun-Boosted Rocket	A single or multi-stage rocket which is initially accelerated by a gun.

LAUNCH VEHICLE	PAYLOADS					
	1	2	3	4	5	6
ROCKET						
DART						
GL ROCK.						
GUN						

-  - ACC. LEVELS TOO HIGH
-  - VOLUME TOO LARGE FOR 7" GUN
-  - COST SUBSTANTIALLY HIGHER THAN COMPETITIVE LV'S

1. Passive Sphere
2. Transponding Sphere
3. Passive Sphere & Chaff
4. Spinning Wire Densitometer (SWD), Thermistor & Chaff
5. Molecular Fluorescence Densitometer (MFD), Thermistor & Chaff
6. Pitot, Thermistor & Chaff

FIGURE 1. Launch Vehicle-Payload Compatibility

fire over water. However, if the grid for a synoptic sounding system were to require several hundred sites it would not be practical to provide the required land or water impact zones to minimize the falling mass risk. Several development programs have been or are currently being carried out to develop alternatives to providing large range areas.

2. CONCLUSIONS

The following general conclusions are reached with respect to launch vehicle selection:

For the passive sphere payload (#1), both the dart and gun-launched systems are cost-competitive. The gun system subjects the payload to higher acceleration and presents a greater falling mass hazard because of its high density.

For payloads 2 and 3 (transponder sphere and passive sphere plus chaff) the rocket vehicle is lighter in weight than the dart, but a competitive procurement is recommended since dart vehicle costs in the past have been somewhat lower than competitive rocket systems.

Rocket systems show a clear cost advantage for the three larger payloads. However, the gun-launched rocket has potential for the non-acceleration limited spinning wire densitometer payload, and it is recommended that design and cost studies be sponsored on this vehicle to establish its performance capabilities and cost.

The falling mass hazard problem may be severe if the proposed launch site density is high (i.e., greater than 100 worldwide sites). Frangible and consumable vehicle concepts presently in development would then have to be adapted to the vehicle designs proposed here.

3. DATA ACQUISITION/TRACKING SYSTEM

Electromechanical tracking systems have been found inadequate for this system because of limited tracking accuracy, or high cost. Two electronic systems have been found to be acceptable. The phased-array radar system to be used with the passive falling sphere, and the continuous wave (CW) tracker to be used with a falling sphere and a transponder.

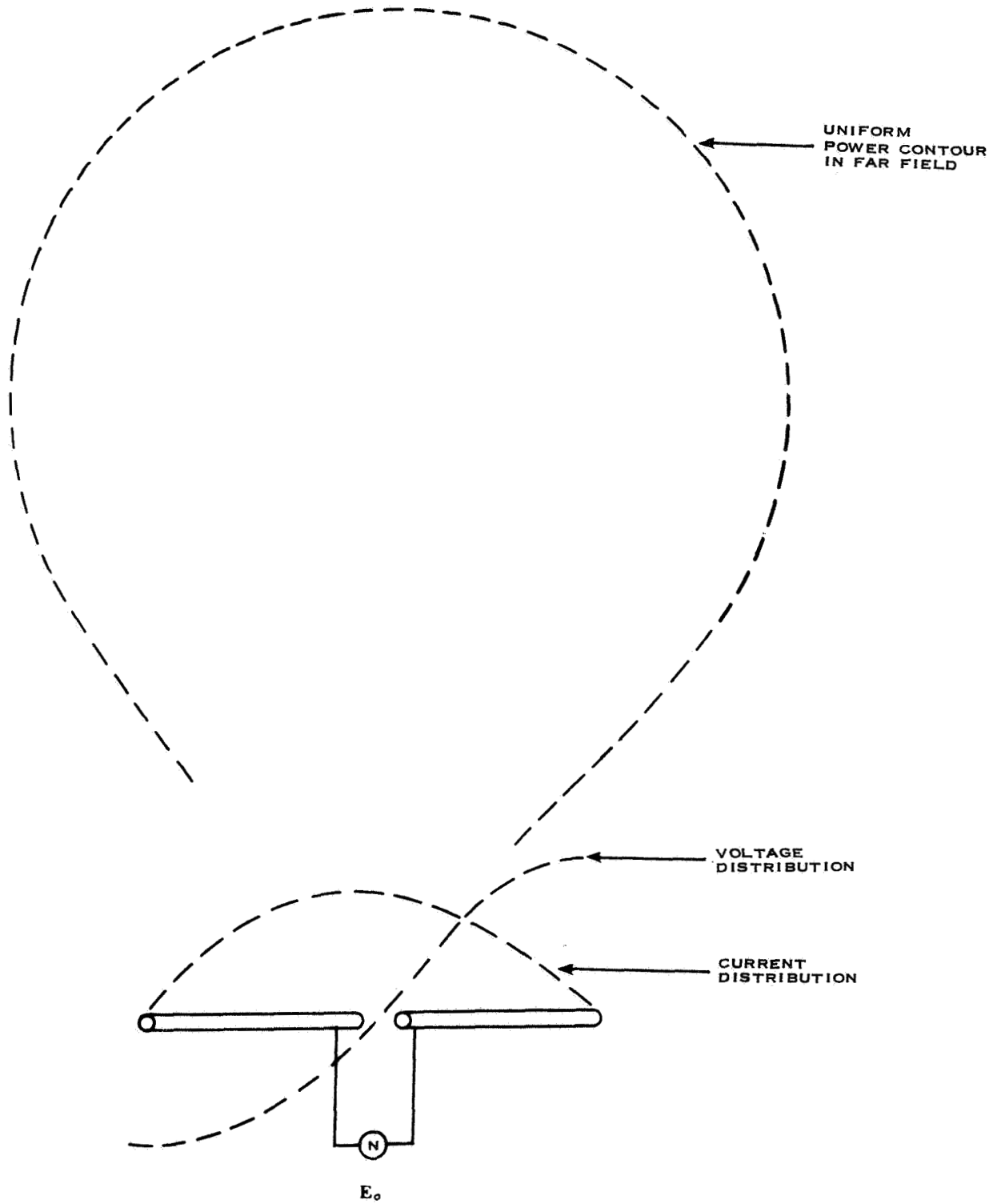
4. PHASED-ARRAY SYSTEMS

A phased-array tracker offers two inherent advantages over an electromechanical tracker. There is no moving antennae and scan patterns may be implemented in microseconds in lieu of seconds, and multiple target tracking is more readily attained. The facile acquisition capability minimizes the need for skilled operating personnel and the need for backup vehicles. The multiple target tracking capability eases the transfer of track from the launch vehicle to the inflated sphere, thus, further minimizing the need for skilled operators and backup vehicles.

A brief examination at how a phased-array system functions will show how these characteristics arise. A simple linear dipole has a relatively broad directional pattern as shown in Figure 2. Locating two or more radiating elements close to each other will result in an effective adding of their radiated power in the far field; that is, at some distance from the antennas. If all antennas are driven in phase, the effective beam width is narrowed in proportion to the number of antennas. If, however, these antennas are not driven in phase, but rather with an integral incremental phase shift, the beam will tend to retain its narrowed contour but be reoriented off the axis of the array. The amount of shift and the size of the angle steered off axis is determined by the steering frequency. The steering frequency itself is removed from the transmitter frequency thus permitting narrow band operation. Antenna reciprocity permits comparable beam forming on received signals.

Since a stable frequency synthesizer operating under the control of a digital computer can steer transmitted beams to any point within the tracker field of view at a speed limited only by the input/output capabilities of the computer, illumination of widely varying sectors can be accomplished at will, reducing the acquisition problem to a trivial one. The fact that two or more such sectors may be

FIGURE 2
Simple Dipole



illuminated in sequence at a rate which produces the effect of simultaneity permits received beams to be formed on two or more targets with simultaneous readouts. Thus, track of all components of the airborne vehicle may be maintained until positive identification of the sphere is established.

During the tracking operation some degree of adaptive control pulse spacing and real-time prediction and data smoothing will be performed by the computer. After flight termination the recorded tracking data may then be batch processed by the same computer to extract the requisite meteorological data: pressure, temperature, wind velocity, and wind direction. These data may then be formatted for facile transmission, and actually transmitted to the control center for synoptic use.

5. THE CONTINUOUS WAVE (CW) SYSTEM

If the falling sphere were to contain a transponder, then a continuous wave (cw) tracking system could be used to record the required time-position data. This system can be developed to provide adequate performance. It has the advantage of a significantly reduced R&D cost. The production cost would be about the same as the phased-array system.

The system functions in the following manner. A signal is transmitted to the falling sphere from the ground, the transponder responds. The returning signal is processed to determine the instantaneous position of the sphere. A series of such points will define the trajectory of the falling sphere.

IV. CANDIDATE SOUNDING SYSTEMS

IV. CANDIDATE SOUNDING SYSTEMS

The previous chapters have provided discussions of each of the various subsystems (sensors, launch vehicles and telemetry/tracking) that constitute the major portion of a sounding system.

This chapter describes six candidate sounding systems made up of six payloads and three launch vehicle combinations and the attendant ground equipment; i. e., telemetry/tracking system which were considered for detailed cost analysis.

These candidate systems are:

- (1) A passive 1-meter sphere, a gun projectile launch vehicle (7-inch gunbore, 3-inch subcaliber projectile), a phased-array tracking radar

The projectile containing the sphere and inflation/ejection mechanism will be launched with sufficient velocity in order that the sphere, which is inflated/ejected at 85 kilometers on the up-leg of the flight, will coast to an apogee of 120-130 kilometers. The sphere will be tracked from 85 kilometers to apogee on the down-leg to collapse near 30 kilometers. The

tracking data will provide density/pressure and temperature over the 100-30 kilometer range. Wind data will be available for the range of approximately 85-30 kilometers.

- (2) A 2-meter passive sphere with a transponder, a rocket-boosted-dart vehicle, an interferometer-type tracking system

This candidate system differs from (1) in that a transponder is available in the sphere to reduce the requirements of the tracking subsystem and (2) the launch vehicle is changed from a gun to a rocket-boosted dart.

- (3) A passive sphere, one canister of chaff, a rocket vehicle, a phased-array tracking radar

The sphere provides the same capability as in candidate (1). The chaff provides wind measurement in the 80-90 kilometer region using the same radar as to track both the chaff and the sphere.

- (4) A Spinning Wire Densitometer (SWD), a thermistor/parachute and chaff, a rocket-launch vehicle, a phased-array radar and two telemetry ground stations

This alternative uses the spinning wire densitometer to make density measurements from approximately 100 km down

to 50 km on its free-fall descent to earth. Skin tracking of the spinning wire densitometer takes place on the upward leg to apogee and the down-leg altitude versus time profile will be determined empirically; therefore, radar tracking during descent is not required. The thermistor/parachute is ejected at approximately 60 km to measure/telemeter temperature data on its retarded descent to earth. The chaff is used over the entire range (30-90 km) as in alternative (4).

- (5) A molecular fluorescence densitometer (MFD), a thermistor/parachute, chaff, a rocket-launch vehicle, a phased-array tracking radar and two telemetry ground stations

In this alternative, the molecular fluorescence densitometer becomes operational at about 60 km altitude on the ascent and makes density measurements to above 100 km. The parachute/thermistor device is ejected at this same 60 km altitude and makes temperature measurements and telemeters the results on its descent to earth (wind measurements are not made on the parachute/thermistor package). These two sensors then cover the range (30-100 km) for density/pressure and temperature data. Winds are obtained over the 30 to 90 km range by releasing chaff at five altitudes (nominally 30, 45, 60,

75, and 90 km) on the ascent leg and tracking the chaff cluster with the phased-array radar. The radar also skin tracks the thermistor's parachute for altitude information and skin tracks the payload on the up-leg for altitude for the molecular fluorescence densitometer measurements.

- (6) A pitot system, a thermistor/parachute and chaff, a rocket-launch vehicle, a phased-array tracking radar and two telemetry ground stations

In this alternative, the pitot system makes density (pressure) measurements on the ascent-leg from approximately 70 to greater than 100 km. The thermistor/parachute is ejected at about 70 km and telemeters temperature data on its retarded descent to earth. Chaff is used over the entire range for wind measurement as in alternative (4). As in alternative (4), the altitude location of the thermistor/parachute and pitot system (during its up-leg sensing) are determined by the phased-array radar.

V. COST ANALYSIS

V. COST ANALYSIS

Figure 3 is a cost comparison of the total program costs of each option over a 13-year program period—three years of R&D and 10 years of operation. The gun-launched/passive sphere system (Option 1) has the lowest estimated program costs of \$279 million. The transponder sphere/boosted dart system (Option 2) and the passive sphere/chaff/rocket (Option 3) have program costs of approximately \$359 million and \$303 million, respectively. Option 4 which uses chaff, spinning wire densitometer, a thermistor/parachute and a rocket has a program cost of approximately \$438 million. Option 5 which replaces the spinning wire densitometer with the molecular fluorescence device has a program cost of approximately \$541 million. Option 6 is the same as Option 4 except the spinning wire densitometer is replaced with a pitot sensor. Option 6 has a program cost of approximately \$618 million.

Using these costs as a basis, the cost of a single sounding using Option 1 (with R&D and acquisition amortized over 100,000 launchings) over the 13-year program is \$2,788 as compared to the per shot cost of Option 6 of \$6,177. Table 5 is a summary of

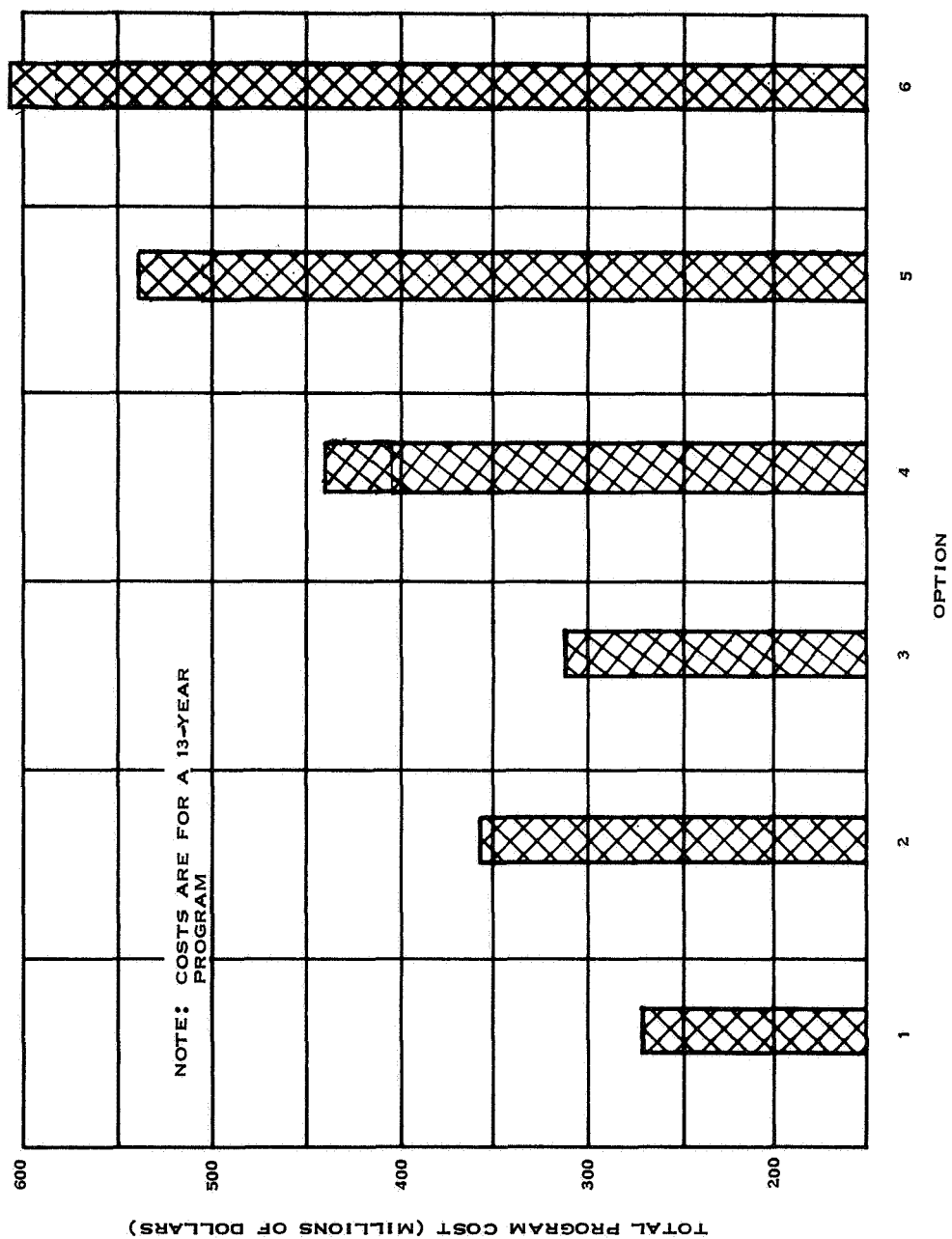


FIGURE 3. Cost Comparison Total Program Costs by Option

Table 5
Cost Per Sounding

OPTION*	Launch Costs Based on Annual Operations (\$)	Launch Costs Based on Total Program Costs (\$) **
1	1,483	2,788
2	2,545	3,586
3	1,835	3,031
4	3,084	4,384
5	4,114	5,407
6	4,887	6,177

*See Chapter IV for definition of options

**Includes total R&D, Acquisition and Operating costs
for a 13-year program

amortized costs which shows the cost-per-sounding over the full 13-year program, and the cost-per-sounding based on steady-state operations. The latter cost is applicable to a fully amortized system, and it represents full system steady-state operating costs divided by 10,000 launchings per year. These costs are shown graphically in Figure 4.

Table 6 is a summary of the estimated unit costs for launch vehicles and payloads by option.

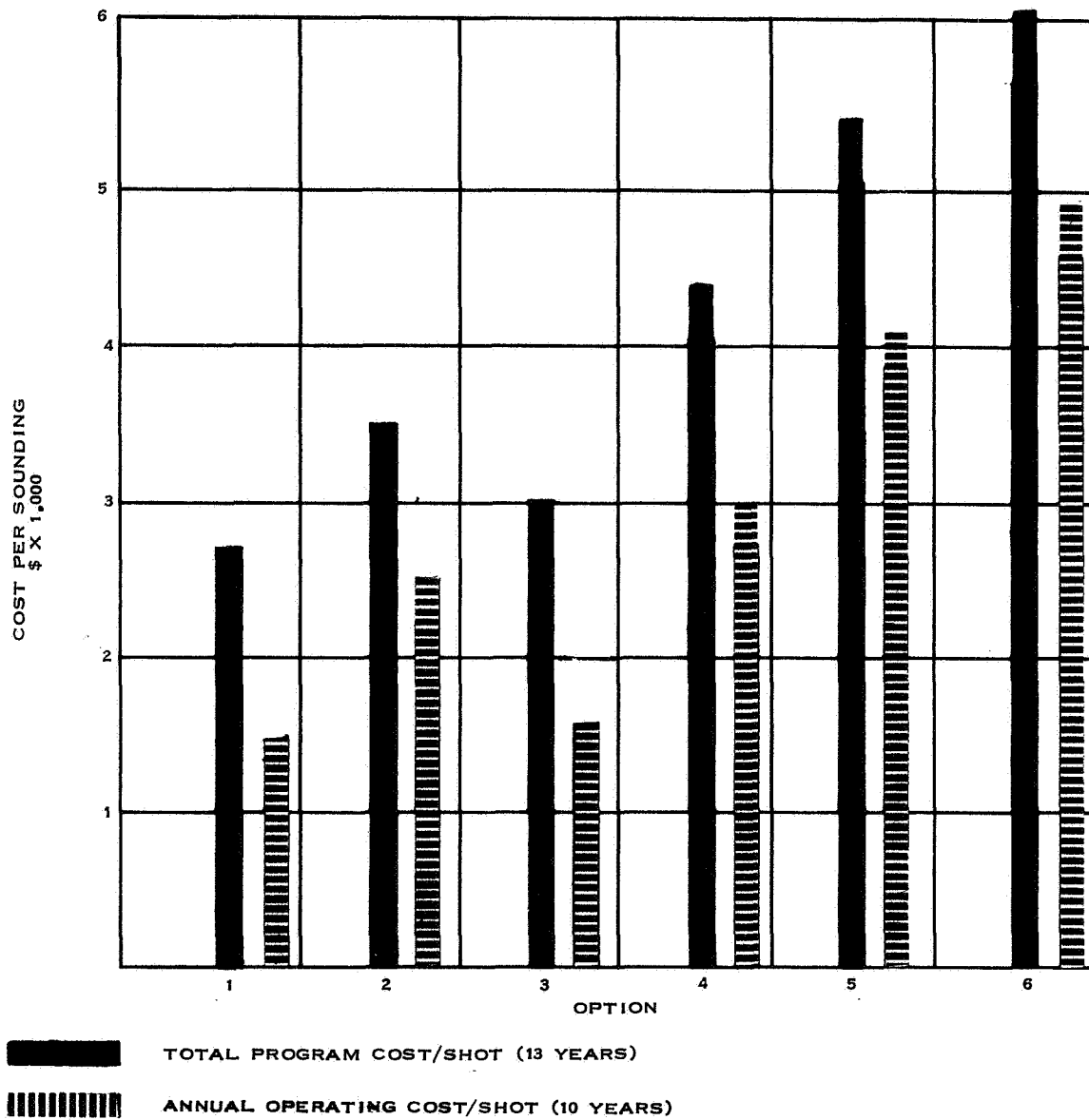
Table 6
Unit Costs for Launch Vehicle and the Payload by Option (\$)

ITEM	OPTION*					
	1	2	3	4	5	6
Launch Vehicles	347	995	612	1, 224	1, 020	1, 785
Payload	87	530	170	755	1, 979	1, 979
Total Expendable Cost/Launch	434	1,525	782	1, 979	2, 999	3, 764

A review of Table 6 shows that there are large differences in launch vehicles and payload costs. The payloads for Options 5 and 6 cost approximately 20 times more than the payload for Option 1. In terms of annual costs, at the rate of 10,000 soundings per year,

*See Chapter IV for definition of options

FIGURE 4
Cost Comparisons for
Amortizing 100,000 Soundings



Options 5 and 6 have a payload incremental cost difference of \$18.9 million above Option 1. In terms of launch vehicles, the annual incremental cost difference above Option 1 is approximately \$8.8 million for Option 5, and \$6.8 million for Option 6. With each launch vehicle/payload differential of \$100, the annual cost difference is \$1,000,000. The total expendable row of Table 6 shows the absolute minimum cost which can be associated with a sounding for each option. It will be observed that Option 6 is approximately five times more expensive than Option 3 and nine times more expensive than Option 1 from the standpoint of consumables per shot. A review of the table shows that these costs come closer together as ground equipment, R&D and site operations are amortized over each shot. Passive sensors (Table 7) require pulsed radars, which have relatively high R&D costs when compared to the active devices (such as the transponder sphere, Option 2).

Table 7
Tracking System R&D and Units Cost Per Option

ITEM	OPTION (x \$1,000)*					
	1	2	3	4	5	6
Tracking System R&D	22,300	8,000	22,300	22,300	22,300	22,300
Tracking System Unit Costs	700	700	700	800	800	800

*See Chapter IV for definition of options.

Figure 5 is a graphic presentation of estimated annual operating costs by option.

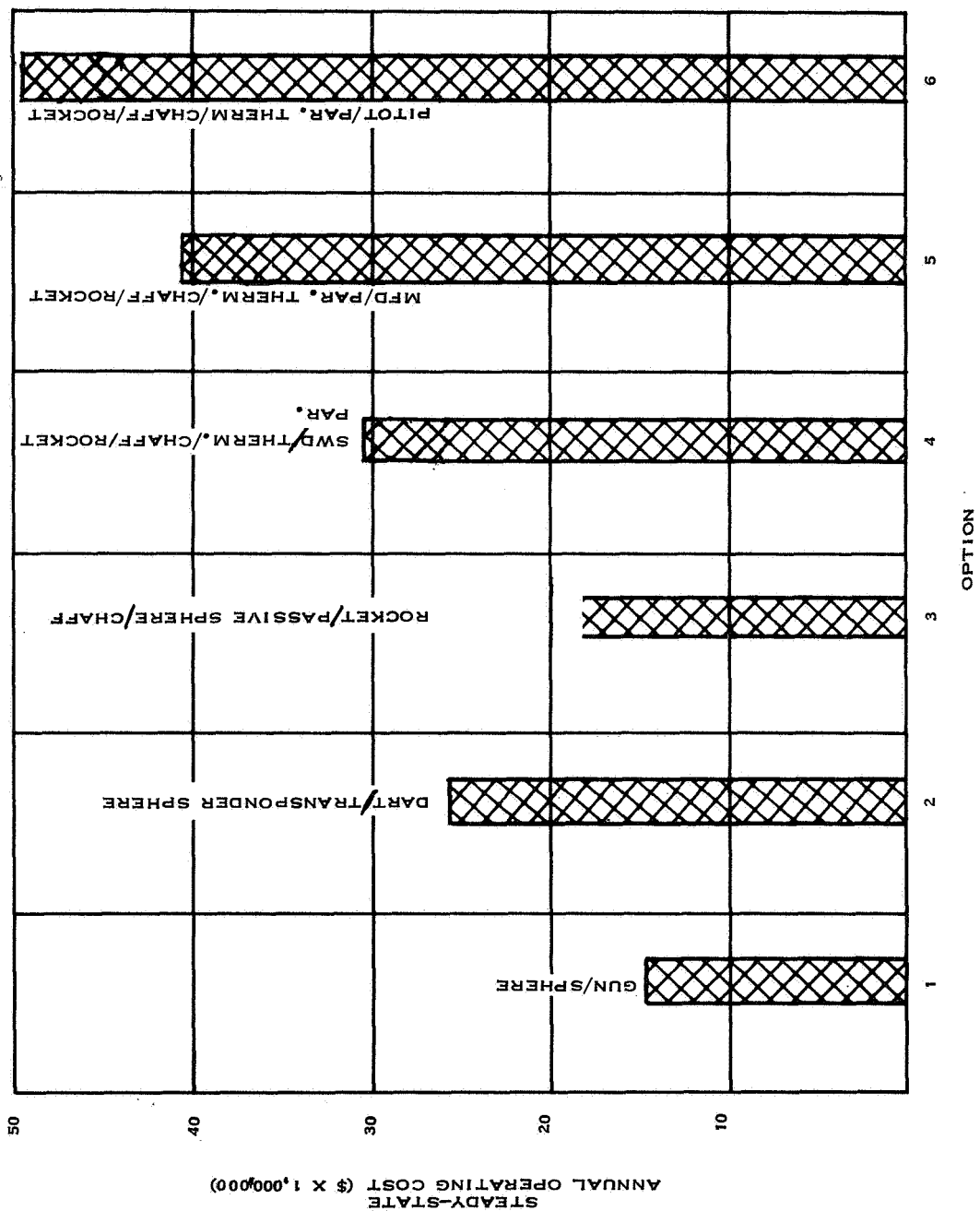


FIGURE 5. Cost Comparison Annual Operating Costs

VI. CONCLUSION

VI. CONCLUSION

Six candidate systems have been described and discussed in previous chapters. Their respective capability to obtain synoptic measurements of wind speed and direction, temperature, and pressure (or density) over the range of 30-100 kilometers has been described. This is the prime criteria which enables them to be considered as candidates. The next criteria is the establishment of their compatibility with respect to reasonable development risk and operational constraints (i. e. , worldwide use, civilian operation, falling mass hazard insurance, potential operation over ocean areas). The final criterion for candidacy is a system characterized by simplicity and reliability which can be categorized by considerations of cost for research, development, test and evaluation, investment or capital equipment acquisition and by operational—expendable items—spare and replacement equipments, utilities, personnel wages and associated support requirements.

The candidate systems have been described previously. It is convenient to briefly re-identify them here:

- (1) Passive sphere, 7-inch gun-launch vehicle, phased-array tracking radar
- (2) Passive sphere with transponder, rocket-boosted 3-inch diameter dart, interferometer tracking system
- (3) Passive sphere, 1 canister of chaff, rocket or rocket-boosted dart vehicle, phased-array tracking radar
- (4) Spinning Wire Densitometer (SWD), thermistor/parachute 5 canisters of chaff, rocket-launch vehicle, 2 telemetry ground stations, phased-array tracking radar
- (5) Molecular Fluorescence Densitometer (MFD), thermistor/parachute, 5 canisters of chaff, rocket-launch vehicle, 2 telemetry ground stations, a phased-array tracking radar
- (6) Pitot system, thermistor/parachute, 5 canisters of chaff, rocket-launch vehicle, 2 telemetry ground stations, a phased-array tracking radar.

1. RECOMMENDED SYSTEM

The passive sphere, one canister of chaff, the phased-array tracking radar and the rocket or rocket-boosted dart vehicle constitutes the recommended system.

The following paragraphs summarize the development risks and the operational considerations of the various candidate systems; Chapter V contains detailed cost analysis of the candidate systems.

The recommended system is not the lowest cost system, however, its capability to measure a greater altitude range of horizontal winds, its lower development risk and greater operational compatibility outweigh the slightly greater costs.

A complete description of this system is contained in previous chapters. Volume III, the Conceptual Design, contains a full system description under a single cover. Volume IV, the Technology Plan, presents the technological problems to be overcome and an orderly plan for their solution prior to the implementation of the system. Volume V, the Program Development Plan, is an orderly plan for the system implementation.

2. DEVELOPMENT RISK

Payload

1. Tracking System

All sounding systems considered have a requirement for a tracking system—either a phased-array radar or an interferometer-type system—which does not exist. Five of the candidate systems (all except the system with the transponder/sphere payload) require essentially the same tracking system, therefore, there is no relative difference in risk/cost between them. The transponder/sphere system requires the development of an interferometer-type tracking system (somewhat like the "single station DOVAP") and its development risk/

cost is somewhat less than the other five, a situation which is offset by the necessity to develop a suitable transponder/sphere system.

2. Payload Systems

The passive sphere constitutes two of the candidate payloads and is the minimum risk payload with the exception of the "hardening" requirement for the gun projectile launch concept which is not considered excessive.

The transponder/sphere constitutes the next payload on the risk scale; however, a technological breakthrough is not required. It largely is a matter of a packaging challenge.

The payloads which contain the spinning wire densitometer (SWD), the molecular fluorescence densitometer (MFD) and the pitot system are all high-risk concepts. Both the SWD and the MFD are very early in the development cycle, each having "flowed" several times with very limited success. The pitot systems, which have been in use for a long time, represent a risk to bring the weight and cost down to acceptable levels without a sacrifice in performance.

3. Launch Systems

None of the launch systems represent a development risk. All three types — 7-inch gun, 3-inch darts boosted by a rocket and the rockets themselves — have a long history of satisfactory performance. The risks on the launch vehicles lie in the projected cost of production.

3. OPERATIONAL CONSIDERATIONS

The attached chart, Figure 6, indicates the various degrees of conformance of the candidates against the Falling Mass Hazard

SYSTEM	FALLING MASS HAZARD	SURFACE WIND CONSIDERATION	SEA-BASED LAUNCH COMPATIBILITY	ON-SITE CALIBRATION	HANDLING AND SHIPPING WEIGHT	VERSATILITY & ADAPTABILITY OF LAUNCH SUBSYSTEM
PASSIVE SPHERE; 7" GUN.	• LEAST IMPACT AREA • PROJECTILE POSES A POTENTIAL PROBLEM	NO PROBLEM	HIGH INVESTMENT COST PER INSTALLATION	NONE	PROJECTILE & POWDER SEPARATE; • 45 LB PROJECTILE • 120 LBS POWDER	VERY RESTRICTED
TRANSPONDERED SPHERE; DART (ROCKET)	• SMALL IMPACT AREA • TRANSPONDER DISPOSAL IS A PROBLEM	ACCOMMODATED WITH A SHORT RAIL LAUNCHER	LAUNCHER IS SMALL & EASILY INSTALLED	TRANSPONDER CHECK	ABOUT 140 LBS TOTAL	VERY VERSATILE
PASSIVE SPHERE. CHAFF; ROCKET OR ROCKET-BOOSTED DART	• POSSIBLE SMALL IMPACT AREA • LOWEST WEIGHT PER IMPACTING ITEM	ACCOMMODATED WITH A SHORT RAIL LAUNCHER	LAUNCHER IS SMALL & EASILY INSTALLED	NONE	ABOUT 160 LBS TOTAL	VERY VERSATILE
MOLECULAR FLUORESCENCE DENSITOMETER. THERMISTOR PARACHUTE, CHAFF; ROCKET-LAUNCHED	• LARGE IMPACT AREA • MEDIUM WEIGHT PER IMPACTING ITEM	ACCOMMODATED WITH DUAL-THRUST ROCKET	MEDIUM SIZED LAUNCHER	EXTENSIVE	ABOUT 300 LBS TOTAL	HIGH
SPINNING WIRE DENSITOMETER. THERMISTOR PARACHUTE, CHAFF; ROCKET-LAUNCHED	• LARGE IMPACT AREA • MEDIUM WEIGHT PER IMPACTING ITEM	ACCOMMODATED WITH DUAL-THRUST ROCKET	MEDIUM SIZED LAUNCHER	• SPIN MOTOR • SENSOR • TELEMETRY	ABOUT 260 LBS TOTAL	VERY VERSATILE
PITOT DENSITOMETER, THERMISTOR/PARACHUTE CHAFF; ROCKET-LAUNCHED	• LARGE IMPACT AREA • HIGH WEIGHT PER IMPACTING ITEM	ACCOMMODATED WITH DUAL-THRUST ROCKET	LARGE LAUNCHER REQUIRED	EXTENSIVE	450 TO 500 LBS TOTAL	HIGH

FIGURE 6. Operational Compatibility

situation, surface wind conditions, on-site calibration requirements, handling and shipping considerations, potential for sea-based launch, and versatility-adaptability of the system.