EXPERIMENTER'S DATA PACKAGE

FOR THE

DESCENDING LAYERS ROCKET

PROJECT INITIATION CONFERENCE

NASA/WALLOPS FLIGHT FACILITY

9 SEPTEMBER 1992

PIC Document for the Descending Layer Rocket Experiment

TABLE OF CONTENTS

1. INTRODUCTION

In response to a proposal from Science Applications International Corporation (SAIC), NASA headquarters has approved a sounding rocket mission designed to study the physics of intermediate layers in the Earth's ionosphere at middle latitudes. The experiment will be carried out by a team of scientists and engineers from the NASA Wallops Flight Facility, SAIC, the NASA Goddard Space Flight Center, and the Millstone Hill radar observatory.

1.1 List of experimenters

To promote a continuing dialog between NASA engineers and the experiment teams, the list below provides contact information for all of the experimenters taking part in the mission.

TITLE	NAME	PHONE & FAX
Principal Investigator:	Dr. Greg Earle SAIC	(703) 749-8642 (703) 821-1134 FAX
Co-Investigators:	Dr. Fred Herrero Goddard SFC	(301) 286-5660 (301) 286-9240 FAX
	Dr. John Foster Millstone Hill	(617) 981-5621 (617) 981-5766 FAX
	Dr. Mike Buonsanto Millstone Hill	(617) 981-5628 (617) 981-5766 FAX
Co-PI for Smart RPA:	Dr. Satya-Narayana SAIC	(703) 556-7082 (703) 821-1134 FAX
Research Engineers:	Ty Bateman SAIC	(703) 556-7305 (703) 821-1134 FAX
	Jeff Miller Goddard SFC	(301) 286-3509 (301) 286-9240 FAX

1.2 Experiment overview

The mission will involve the launch of an instrumented sounding rocket from the Wallops Island rocket range in the summer of 1994, with the objective of penetrating a descending ionized layer in the E-region between altitudes of 115 and 140 km. Instrumentation aboard the rocket will measure the ion and neutral composition of the layer, its plasma density, driving wind and electric field forces, the thermal ion distribution function, and electron temperature. Depending on payload weight constraints and subject to availability, a particle detector to measure energetic ion and/or electron fluxes near the layer may also be included.

This document has been prepared as a reference for the NASA payload development and experiment teams, for distribution at the Project Initiation Conference (PIC). The design specifications discussed herein are therefore of a preliminary nature; the intent is to promote open discussions between experimenters and NASA engineers that will lead to a final design capable of achieving the experiment objectives.

2. SCIENTIFIC OBJECTIVES

2.1 Description of the Phenomenon

The nighttime appearance of descending layers in the low and mid-latitude ionosphere has been documented in scientific literature for over twenty years [Smith, 1970; Shen et al., 1976], but many aspects of the phenomenon are still not understood. Figure 1 shows an example of one such early observation made by the Arecibo incoherent scatter radar. Figure 2 shows a similar event occurring over NASA's Wallops Flight Facility, as evidenced by plasma density profiles measured by five sequentially launched rockets. In both figures the layers can be seen initially forming near 140 km, and slowly descending over a period of about 6 hours to altitudes of about 110 km. As they descend the layers generally become thinner, while their peak density simultaneously increases. It is important to note that these layers are distinct from the sporadic-E or E_s layers that often form near 105 km (also visible in Figure 1). These lower lying structures have been intensively studied, and are known to consist of metallic ions.

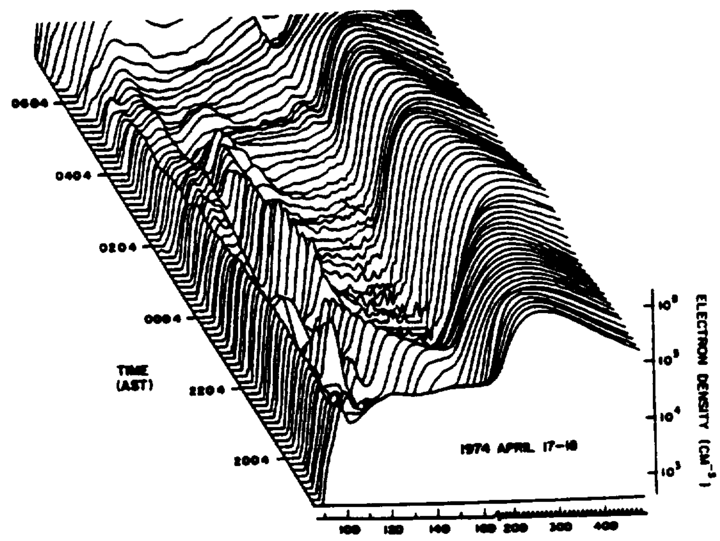


Figure 1: A dynamic descending layer over Arecibo (from Shen et al., 1976).

Motion of the descending layers is thought to be driven by a combination of tidal winds and electric fields, with winds being the dominant force. The tidal theory seems to explain the quasiregular occurrence of the layers, since tidal winds are caused primarily by solar heating of the upper atmosphere. Solar forcing has a regular period that varies as a function of season, latitude, and altitude, which should make the appearance of descending layers a routine, ultimately predictable event. The peak density of the layers seldom exceeds 10^5 cm^{-3}, however, so radars and ionosondes often have difficulty detecting their presence.

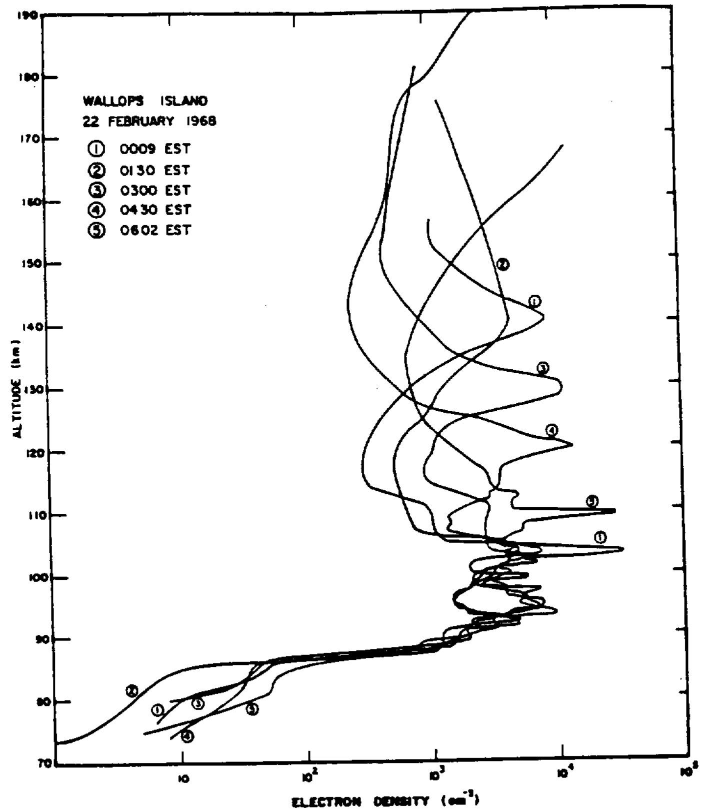


Figure 2: Ionospheric plasma density profiles measured on five consecutive sounding rocket flights from Wallops Island (from Smith, 1970).

The composition of the layers is even less certain. Some theories predict that metallic ions from meteors entering the atmosphere provide the source for the ionized layers. Other theories cite the correlation between layer appearance and magnetic activity as evidence that particle precipitation plays a role. No reliable measurement has ever been made of the composition of a descending layer.

The descending layer phenomenon is a unique geophysical process that may have applications as a tracer of high altitude tidal mode oscillations, or as a refractive structure for use by AM and meteor scatter radio links. They may also exert an influence on the Earth's dynamo electric field pattern by enhancing the conductivity in the E-region of the ionosphere, especially at night. Since the dynamo drives middle and low latitude plasma convection at high altitudes, the layers may in turn have wide ranging influence on ionospheric heat flux and dissipation, low latitude convection patterns, ozone hole motion, etcetera. In order to realize any potential application, we must first strive to fully understand the physics of the process.

2.2 Experiment Goals

The rocket experiment that we will perform will penetrate a layer as it descends in the early morning hours over Wallops Island. Instruments on the rocket will measure the neutral winds, electric fields, plasma density, ion composition, electron and neutral temperatures, and low energy ion distribution function. If a viable source can be found, and if weight and power limits permit, we will also include a particle detector to measure energetic proton precipitation in the 10-100 keV range. These observations will establish the true nature of the descending plasma layers by making high resolution measurements of all the parameters currently thought to be important to the layer formation and descent process.

Our primary mission objective is to unambiguously answer two main questions about the layers:

1. Is their downward motion caused by neutral winds, electric fields, or some combination of the two?
2. Do they consist of metallic ions (from meteor ablation), or are they composed of more common molecular ions such as NO^+ and O_2^+?

In addition to answering these main questions, we will gather data that should clarify other issues, such as whether particle precipitation is important to the layer formation process, whether the structures support local plasma instabilities, and how ion and neutral temperatures vary within the layers.

Early rocket shots through descending layered structures carried fairly crude instrumentation that was incapable of making high resolution measurements. For example, the experiment by Smith in 1968 estimated neutral winds with ground based observations of TMA trails, while simultaneously measuring the plasma density by sensing the current to a portion of the rocket's skin. A great deal was learned from this experiment, but the enhanced instrumentation and telemetry capabilities now available should allow us to greatly improve upon the accuracy and resolution of these early measurements.

3. INSTRUMENTATION

3.1 Descriptions of instruments

Since the goal of this mission is to measure all of the plasma and neutral parameters relevant to complete understanding of the descending layer process, a large complement of instruments is necessary. In this section we briefly describe the instruments necessary for proper performance of the mission, the measurement approach, and the flight heritage. Engineering estimates of power, weight, telemetry, and other hardware details are presented in Section 3.2.

3.1.1 Sweeping Langmuir probes (SLP)

Two boom mounted, swept voltage Langmuir probes (SLP) will be used on this mission to measure the ambient plasma density, electron temperature, and low frequency density fluctuation power spectra. The booms and sensor elements will be identical to those flown on the recent SCEX-3 and AA-3B rocket missions (see section 3.2 for details of the boom design). The instrument design will be simpler electronically than the experiments flown on either SCEX-3 or AA-3B, since the probe bias voltages will be swept smoothly rather than pulsed. The sweep voltage applied to the probe will be an intermittent triangle wave with a period of about 300 milliseconds, repeated at 10-15 second intervals. In the period between sweeps the bias voltages on the two probes will be held constant at plus and minus a few volts, in order to measure the density fluctuations. Section 3.2 discusses our engineering design estimates of weight, power, size, and telemetry for this instrument in more detail.

3.1.2 Vector electric field detectors (VEFD)

The payload will carry six electric field booms, four with a single spherical sensing element and two carrying two sensors each. These will measure both the low frequency three dimensional vector electric field, and the spectrum of the electric field from 1-10 MHz. All of the booms will be of the one piece, rigid fiberglass "fishing rod" variety, with lengths ranging from 5.5-6 feet. A drawing of the planned boom configuration is presented in Section 3.2.

Electronically, the VEFD instrument will be similar to the designs commonly flown by Cornell University. Estimates of the instrument power, weight, and TM are summarized in Section 3.2. The sensing elements will be aluminum spheres firmly mounted to the booms, with probe wires running through the hollow boom element and connecting to the electronics module. A hinge system will be used to deploy the booms and lock them in place. Design drawings of the hinge system are not yet available, but will be sent to the NASA mechanical engineer assigned to this payload as soon as they are completed.

3.1.3 Smart retarding potential analyzer (SRPA)

The "smart" RPA is a new instrument concept that has been funded by NASA under the innovative research program for a test flight on the descending layers rocket. Drs. Earle and Satya-

Narayana are the co-PIs in the instrument development effort, and Mr. Bateman is the research engineer. The instrument will use a standard RPA sensor assembly consisting of a "pillbox" detector containing 3 biased grids for attracting ions, energy gating, and secondary electron suppression. A planar collector will be used to measure the ion current as a function of discriminator voltage. The electrometer for the ion current measurement is based on the same design as the SLP electrometers (see Section 3.1.1).

The new part of the instrument is the electronic data processing system. The instrument will use a neural network algorithm to process the data in real time during the flight. The algorithm is currently being developed and trained to discriminate between ions based on the shapes of measured current versus voltage curves. Real-time processing of the data will be done using a dedicated CPU within the SRPA instrument package.

Due to the innovative nature of this instrument, it will be necessary to telemeter both the unprocessed raw data and the neural network's processed output to the ground for post-flight comparison and analysis. Further details on the instrument sizes, weight estimates, telemetry allocation, power usage and other engineering estimates can be found in Section 3.2.

Since the SRPA achieves the highest signal to noise ratio when plasma flow to the aperture is unobstructed, the instrument should be mounted in a ram configuration.

3.1.4 Temperature and winds rocket sensor (TAWRS)

The TAWRS instrument will be provided by Dr. Fred Herrero of the Goddard Space Flight Center. It measures the neutral wind velocity and the neutral temperature using an electrostatic deflection technique. Neutral gas enters the instrument through a small aperture, and then passes through an ionizing electron beam. The beam converts the neutral particles to ions, and the ions are electrostatically deflected and imaged onto a position sensitive micro-channel plate detector. Comparison of the image with a theoretical Maxwellian distribution gives the temperature of the neutral gas and the direction of the wind. The neutral wind speed is determined by comparing the count rates from different detectors and folding in the rocket velocity vector.

A low resolution prototype of the TAWRS device was flown successfully on NASA flights 31.066 and 31.067. A cut-away sketch of this early instrument design is presented in Figure 3, to illustrate the measurement technique. The version to be flown on this mission will have much better resolution, since more detector elements with tighter angular spacing will be used. A higher resolution version of the instrument was flown on the recent CRRES campaign out of Puerto Rico. Analysis of the data from that flight is currently underway.

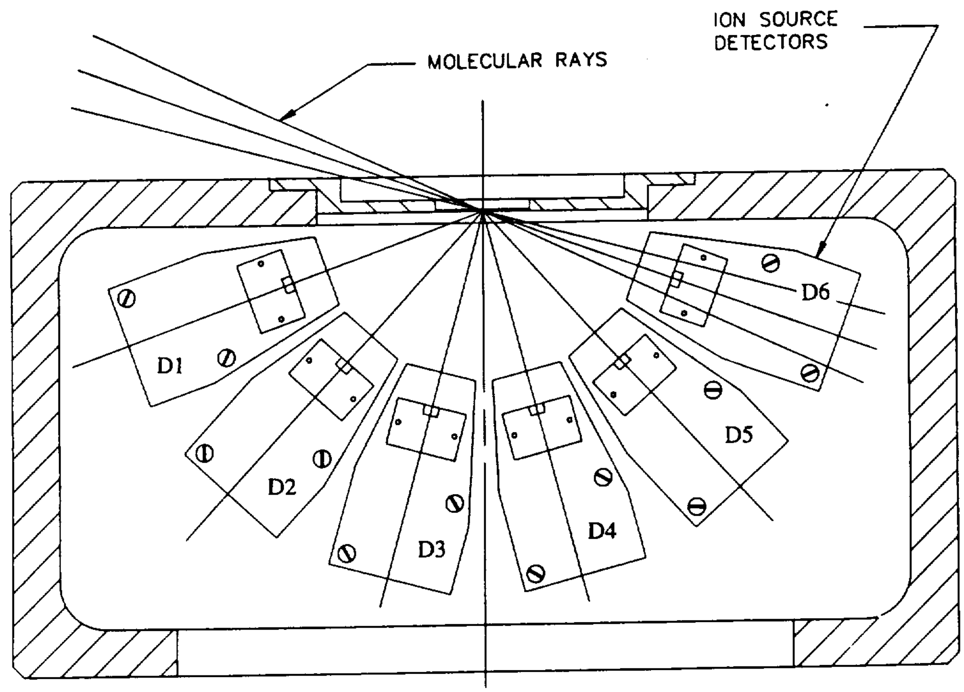


Figure 3: A cut away sketch of an early version of the TAWRS instrument.

In order to function properly and make the highest quality measurement, the TAWRS instrument should be mounted on the ram surface of the rocket. The size, weight, and power estimates for this device are discussed in Section 3.2.

3.1.5 Rocket mass spectrograph (RMS)

Dr. Herrero will also provide the RMS instrument, which was successfully flown on rocket 36.064 of the recent CRRES campaign. This instrument simultaneously measures the relative abundances of various ions in the plasma, using a permanent magnet to focus ions onto a position sensitive detector. The detector uses a microchannel plate electron multiplier with multiple anodes. An illustration of the instrument is shown in Figure 4. The spacing of the detector elements is determined according to the mass distribution of ions to be measured. For this mission, the ion mass ranges of interest include several metallic ion species, since these may comprise a significant part of the total layer density.

Like the TAWRS instrument, the RMS uses a small aperture to admit the ion gas. Consequently, the sensor element should be mounted in a ram configuration on the rocket, along with the SRPA and TAWRS detectors. Estimates of the instrument size, weight, and power are presented in Section 3.2.

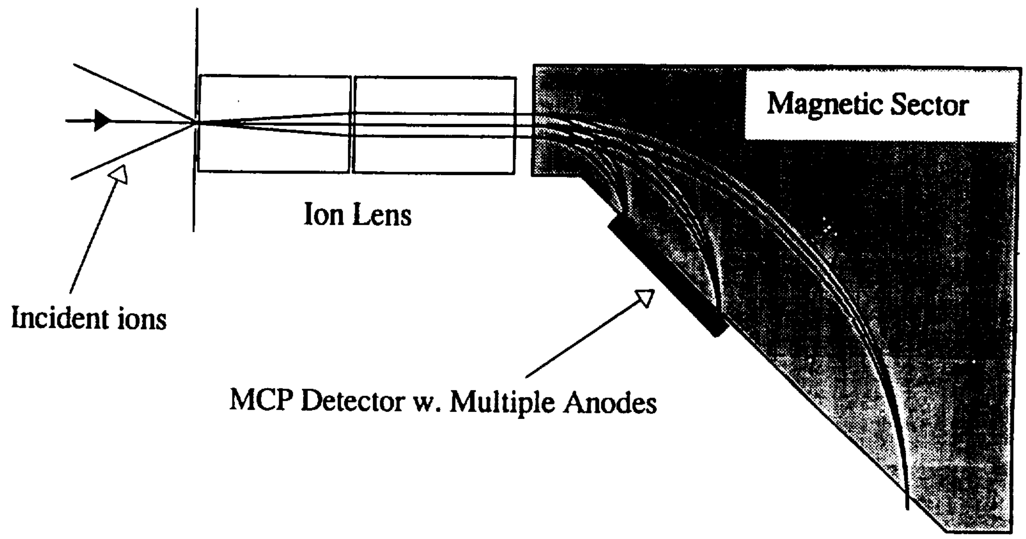


Figure 4: A cut-away illustration of the RMS instrument.

3.1.6 Energetic particle detector (EPD)

In order to check whether precipitating protons or electrons are responsible for some or all of the ionization in the layers, it is desirable to include an energetic particle detector on the rocket. The specific instrument to be used has not yet been identified, but several options are being pursued. Details will be provided to NASA as soon as they are available.

3.2 Engineering design estimates

The purpose of this section is to provide initial working values of the size, weight, and power requirements for each of the instruments included on the payload. For planning purposes and initial layout considerations, the specifications listed here should be sufficient. Our intention is to work closely with NASA engineers to finalize these specifications, with the overall goal of meeting all measurement requirements while satisfying payload design constraints.

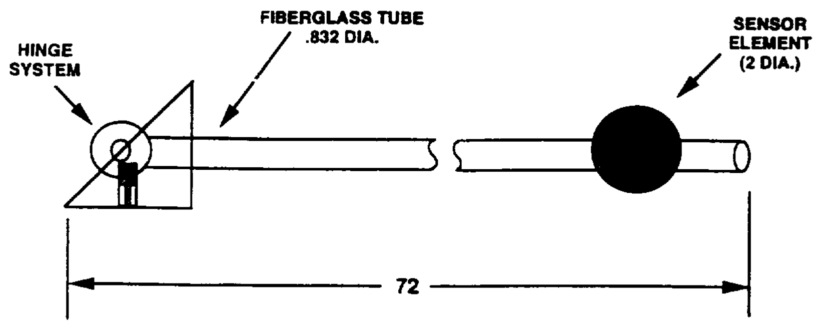
3.2.1 Instrument weights & sizes

Table 1 summarizes the sizes and weights for all of the scientific instruments making up this payload. Since the final design process for many of these instruments is currently underway, these characteristics are subject to small modifications. In creating the table, however, we have attempted to give conservative numbers where actual parameters are not yet available, thereby building in a margin of safety in terms of both weight and size.

INSTRUMENT		WEIGHT	SIZE
SLP	Electronics	3.6 kg (8 lbs.)	12.7 x 15.3 x 18.4 cm (5 x 6 x 7.25 in.)
	Booms (2 req'd)	.22 kg apiece (0.5 lb. apiece)	64 x 1.2 cm OD (25 x .5 in.)
VEFD	Electronics #1	4 kg (8.8 lbs.)	12.7 x 15.3 x 18.4 cm (5 x 6 x 7.25 in.)
	Electronics #2	1 kg (2.2 lbs.)	12.7 x 15.3 x 5.1 cm (5 x 6 x 2 in.)
	Booms (6 req'd)	0.7 kg apiece (1.5 lbs. apiece)	183 x 2.1 cm OD (72 x .83 in.)
SRPA	Electronics	4 kg (8.8 lbs.)	12.7 x 15.3 x 18.4 cm (5 x 6 x 7.25 in.)
	Sensor	.5 kg (1.1 lbs.)	7.6 OD x 2.5 cm (3 OD x 1 in.)
TAWRS & RMS	Electronics	12 kg (26.4 lbs)	TBD
EPD	Electronics	TBD	TBD

Table 1: Estimates of weights and dimensions for the scientific instruments.

As is evident from Table 1, this payload will carry many boom systems. Since the specifications of boom dimensions are typically required early in the payload layout process, we are providing the drawings in Figure 5 to supplement the information in Table 1. The Langmuir probe boom system is identical to those flown on the SCEX-3 and AA-3B missions, but the VEFD booms will be a new design. The basic mechanism envisioned is shown in Figure 5, with the understanding that an engineering design drawing will be furnished to NASA as soon as it becomes available.



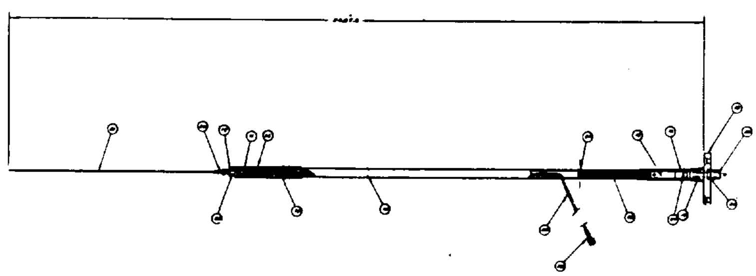


Figure 5: Diagrams of the two types of boom systems to be used in this experiment. Top figure shows an E-field boom, and bottom figure shows a Langmuir probe boom. Dimensions shown are in inches.

3.2.2 Instrument power estimates

The total power budget for the science instruments is shown in Table 2. As in the previous section, these estimates have been made deliberately conservative to allow a margin of safety. The sensitive nature of the analog measurements made by the vector E-field detector precludes the use of switching DC/DC converters within the VEFD, so a separate ±18 volt supply is required for this instrument. The TAWRS and RMS instruments will also use the ±18 V power lines, and will need an additional ±9 V supply as well.

INSTRUMENT	SUPPLY VOLTAGE	SUPPLY CURRENT	POWER
SLP	+28 V	430 mA	12 W
VEFD	±18 V	±400 mA	14.4 W
SRPA	+28 V	400 mA	11.2 W
TAWRS/RMS	±18 V and ±9 V		TBD
EPD			TBD

Table 2: Power estimates for the scientific instruments.

3.2.3 TM allocation

Two PCM telemetry links will be required for this mission in order to support all of the instruments on the payload. An 800 kbps system can support the Langmuir probe, electric field detector, SRPA, and aspect magnetometer with ample room left over for housekeeping signals. Estimates of the telemetry required for each of these instruments are presented in Table 3. A second PCM link will be necessary to handle the TAWRS, RMS, and EPD instruments, plus additional housekeeping. Table 4 gives an overview of the data channels and rates needed by these instruments.

Instrument	Channel Description	Data Type	kbps
SLP	I_e	Analog	80
	I_i	Analog	80
	Range & Sweep Start	Digital	80
	V_e	Analog	10
	V_i	Analog	10
VEFD	DC - High Gain	Analog	6x1
	DC - Low Gain	Analog	6x1
	AC	Analog	4x80
	V sweep (SFA)	Analog	18
	V spectrum (SFA)	Analog	18
SRPA	V_d & Range	Digital	20
	I_c	Analog	20
	NN	Analog	8x1
	V status	Digital	1
Magnetometer	B_x	Analog	10
	B_y	Analog	10
	B_z	Analog	10
Housekeeping			93
		Total:	800 kbps

Table 3: Telemetry estimates for PCM link #1

Instrument	Channel Description	Data Type	kbps
TAWRS	Counts - data	Digital	100x1
	V status	Digital	10
RMS	Counts - data	Digital	1024x0.1
	V status	Digital	10
EPD	TBD	TBD	TBD
Housekeeping			
			Total: 400 kbps

Table 4: Telemetry estimates for PCM link #2

3.2.4 Instrument configuration on payload

The configuration of the boom systems and instrument apertures for this experiment are shown in Figure 6. The E-field boom systems have been designed to provide a complete vector measurement, with the inclusion of two sensor elements on booms 1 and 2 intended to provide for redundant measurement of a single field component over two distinct length scales. This feature provides a valuable check on measurement integrity. The small SLP booms do not make a differential measurement, so their orientation is less critical than the E-field booms. However, since the SLP booms are quite short, they should be mounted at the forward end of the payload to minimize wake effects from the longer boom systems.

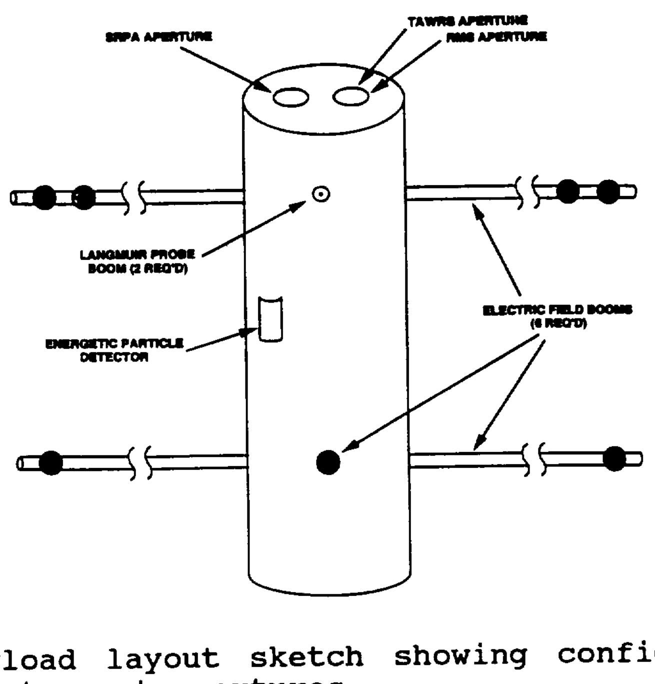


Figure 6: Payload layout sketch showing configuration of boom systems and instrument apertures.

As previously mentioned, the apertures of the TAWRS, RMS, and SRPA detectors should be mounted on the forward end of the payload, so that they detect ram currents. This will require using either a clamshell or deployable nosecone that is separated from the payload at an altitude just above the sensible atmosphere (100 km).

4. VEHICLE PERFORMANCE

4.1 Apogee requirement

The objective of the mission is to penetrate a descending layer between altitudes of 115 and 140 km. We prefer to have the layer centered at about 125 km at the time of launch, so that it is both well defined and clearly in its descent phase. Our desire is to pass completely through the layer on the upleg, so that the data show clear signatures of the density gradients on both the bottom and top edges. Depending on the horizontal extent of the layer, we should then penetrate it a second time on the downleg. Should the vehicle performance be less than nominal, we prefer to build in a sufficient safety margin so that the payload still passes through the layer completely. Consequently, the apogee should be chosen so that two sigma below the nominal is at an altitude of 140 km.

4.2 Flight attitude and vehicle maneuvers

This experiment has been designed for best results with the payload spinning at a rate between 0.25 and 1 revolution per second. This spin rate will facilitate safe and reliable deployment of the boom systems, and will provide for reliable electric field measurements.

In addition to the spin requirement, the flight attitude of the payload should ideally keep the payload's axis parallel to the velocity vector throughout the flight. In this configuration the instruments mounted on the forward end of the payload (TAWRS, RMS, SRPA) will continuously face in the ram direction. The measurements made by these instruments are most reliable in this flight configuration. Furthermore, this payload attitude will allow science data about the layered structures to be reliably gathered on both the upleg and downleg passes through the layer.

4.3 Azimuth and QE

The Millstone Hill incoherent scatter radar will support this rocket launch by detecting the presence of a layer along the predicted flight path. Since the radar is located over 700 km northeast of Wallops, and since the layers form relatively low in the ionosphere, very low look elevations must be used. This presents several technological challenges to the radar experimenters. At low elevation angles the effects of ground clutter on the radar return are more pronounced, and this coupled with the low plasma density of the target means long integration times may be necessary. A more serious concern is the restricted field of view from Millstone, since several buildings block the radar line of sight at certain azimuths.

Figure 7 shows a simple map of the Millstone Hill field of view at 120 km altitude near Wallops. Close inspection of this figure shows that there are two clear options to investigate. One option is to launch the rocket so that it remains in the region of the "finger" that extends over Wallops. The other choice is to launch so that the rocket apogee (ideally) occurs within the middle "finger" shown in the figure. Both of these options pose potential obstacles. In the first case, the nominal impact range would presumably be very close to land, possibly violating safety regulations. The latter option requires that apogee occur some 300 km downrange at an azimuth of about 124 degrees (for the shortest path). This may be unrealistic from a vehicle performance point of view.

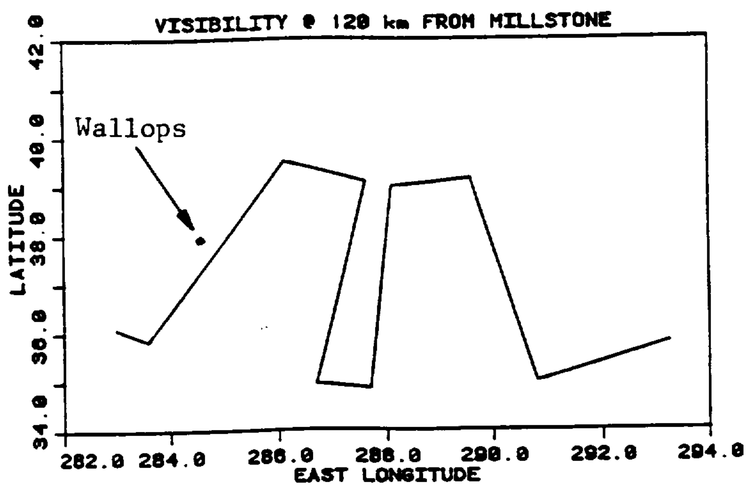


Figure 7: Map of the Millstone Hill observatory's field of view at 120 km near Wallops. The cut-outs are caused by interference from buildings on the horizon.

This document is being prepared with little knowledge of either the launch azimuths allowable from the Wallops range, or of specific vehicle performance characteristics. Resolution of these issues will require a concerted effort by the experimenters and the NASA flight safety and vehicle performance experts.

5. MISSION PLANNING

5.1 Geophysical requirements

The obvious condition for carrying out this experiment is the existence of a descending layer along the predicted path of the rocket. Past observations have tentatively shown that on any given night at mid-latitudes the probability of sporadic-E layer formation is about 15-20%, depending on the specific latitude and longitude of the site. No similar statistics have been compiled for the descending layer phenomenon in which we are interested, so we cannot predict the occurrence probabilities with confidence. However, assuming that descending layer formation is driven by tidal winds (as theories suggest), the phenomenon should be very regular. We will use both the Millstone Hill incoherent scatter radar and the Wallops ionosonde to determine that a layer is in place before launch. These supporting measurements are discussed in Section 6 of this document. In addition, we will attempt to establish a database of observations from the Wallops ionosonde in the near term, so that empirical models of layer formation probabilities can be created and used to help plan the experiment.

There are indications from past measurements that formation of descending layers (and sporadic-E layers) is correlated with the occurrence of magnetic storms. For this reason we will monitor magnetic activity during the countdown phase of the mission. Further observational evidence for sporadic-E indicates that it is more common at mid-latitudes near solstice than equinox. Since this condition is likely to hold for descending layers as well, we prefer a summer launch window.

Since there are no optical observations in support of this mission we have no requirements for clear skies, lunar phase, or lunar depression angle. It is necessary to perform the launch at night, however, since the background plasma density in the E-region of the ionosphere is lowest at night, and the descending layers therefore stand out more clearly. If a tidal mode is responsible for the descent of the layer, it should occur in the post midnight period over Wallops.

5.2 Other mission requirements

5.2.1 Payload preparation and readiness

Assuming that the launch window is scheduled for the summer of 1994, we should anticipate hot and humid daytime conditions at Wallops, with much cooler evenings. These conditions can cause potentially serious problems due to condensation of water vapor on the payload. We recently experienced such conditions during the CRRES rocket campaign in Puerto Rico. While the technique used during the CRRES campaign involved "bagging" the payload and maintaining a nitrogen purge, inspection of the payload on the launcher showed that condensation could still be quite severe. Furthermore, the tight fit of the bag effectively formed puddles in close proximity to the payload, especially when the launcher was in a horizontal position.

To avoid similar problems during a summer mission at Wallops it is desirable to build a styrofoam enclosure for the rocket while it is on the launcher, and to launch through the enclosure as is done in high latitude missions. A strong nitrogen purge will still be required to maintain positive pressure inside the payload while it is on the launcher. In this way the temperature and humidity inside the styrofoam box can be monitored and controlled, eliminating the problem of condensation. There may be unforeseen problems with this suggested technique, so it and other ideas should be investigated further by knowledgeable NASA engineers.

5.2.2 Payload recovery

The physics of descending layer formation may be different in different altitude regimes, in which case a single rocket experiment will likely not be sufficient to fully understand the process. For this reason we would like to investigate the impact of a payload recovery operation on mission logistics. If further investigations of the layer process are to be carried out in future years, it may be cost effective to salvage the instrument complement from this payload for use in a reflight opportunity.

The feasibility of payload recovery depends on payload weight constraints, the logistics of deploying a recovery vehicle, and cost. This payload is anticipated to be of the Taurus-Orion or Nike-Orion class, in which case either air or water recovery may be viable. At least one aspect of this mission helps to make the recovery option feasible; namely, the slow descent of the layer should allow ample time prior to launch for deploying and positioning a recovery vehicle. During the countdown phase of the mission we should have a fairly clear idea of the developing probability of launch, based on the supporting observations. This should eliminate the wasteful practice of sending out a recovery vehicle on each night of the launch window. Following the PIC for this rocket we hope to investigate the recovery option further, with the assistance of NASA engineers and managers.

6. MEASUREMENTS IN SUPPORT OF LAUNCH OPERATIONS

As mentioned in previous sections, this experiment will utilize a broad array of supporting measurements to determine when and where layers are present. This section briefly describes these supporting measurements.

6.1 Millstone Hill radar

Drs. John Foster and Michael Buonsanto of the Millstone Hill Observatory will provide incoherent scatter radar coverage of the region over Wallops and along the nominal rocket trajectory. The radar data will be a primary indicator of conditions suitable for launching the rocket. During the countdown phase of the mission, Drs. Earle and Herrero will maintain close telephone and FAX contact with the Millstone scientists, so that local conditions can be accurately determined.

Radar observations are particularly important for this experiment, since little is known about the longitudinal or latitudinal extent of the layers. By range gating their receiver and closely controlling their look azimuth and elevation, the scientists at Millstone Hill will attempt to pinpoint these parameters and correlate them with the rocket's predicted flight path. As discussed in Section 4.3, the low look angle requirement placed on the radar by the layer altitude presents some potential challenges that must be addressed in choosing the rocket's flight azimuth and elevation.

6.2 Wallops ionosonde

Another remote sensing instrument of crucial importance to the success of this experiment is the Wallops ionosonde. This vertically-pointing, swept-frequency radar is capable of performing vertical soundings of the ionosphere over Wallops. It can therefore provide a good indication of when descending layers are present locally. In this role it will corroborate the data from the Millstone Hill radar, while also providing valuable data on the horizontal extent of the layers. In addition, the ionograms will provide continuous monitoring of the layer height throughout its descent. Since the layers are often quite thin, these altitudes cannot be measured as accurately from Millstone Hill, owing to the separation distance and radar beam width. Ionosonde estimates of layer height will therefore be critical to the timing of the launch.

While it is known that Wallops maintains a functional ionosonde station, the procedures for obtaining routine data from the station are presently unknown. This is therefore another area in which the scientific team requests cooperation and assistance from Wallops personnel. If possible, we would like to begin archiving and analyzing ionosonde data as soon as possible, so that we may begin to study the occurrence probabilities and typical layer dynamics over Wallops in preparation for planning the launch.

6.3 Magnetic storm monitoring

There is some evidence that layer formation is correlated with magnetic storm activity. Presumably the storms induce particle precipitation that enhances the layer densities, or even initiates their formation. To study these effects further, and to provide estimates during the countdowns of the launch probability on any given night, we will monitor the status of global magnetic activity through a telephone link to the space science data center in Boulder, Colorado.

6.4 Arecibo tidal measurements

The occurrence of descending layers in the ionosphere is thought to be driven by global tidal oscillations in the atmosphere. To study this possibility and provide additional data for comparison with rocket and ionosonde results, arrangements will be made with the Arecibo incoherent scatter radar to monitor E-region and F-region tidal oscillations nightly during our launch window. While these data will not have a direct effect on the decision to launch the rocket, they will undoubtedly be useful in post-flight data analysis.

7. CONCLUDING COMMENTS

The rocket experiment described here has been designed to answer a number of intriguing questions about layer formation in the ionosphere. We will resolve existing controversies over the plasma composition of the layers, the processes that control their formation, and the forces responsible for their descent to lower levels of the ionosphere. To definitively answer all of these questions, a large complement of plasma and neutral instrumentation is required. This document has attempted to provide an overview of the experiment plan, along with estimates of the instrument characteristics for use in preliminary payload design efforts.

The altitude range at which descending layers form makes it impossible to study them with stably orbiting satellites, and their thinness and comparatively low plasma density makes them quite difficult to study with incoherent scatter radars. For this particular phenomenon, sounding rockets provide the best platform presently available for serious study. We look forward to developing this payload in the coming years, and to working closely with NASA engineers in designing not only a technically sound payload, but also a meaningful and successful mission.