76SDS4228
7 MAY 1976

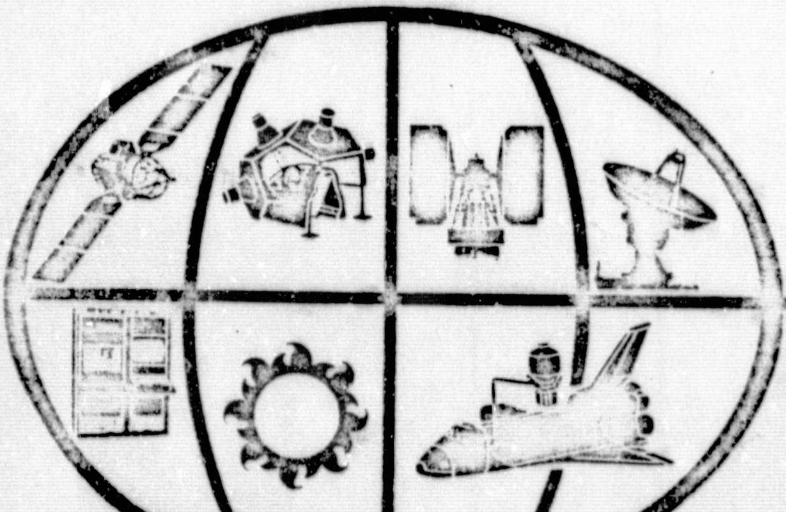
SPACE SHUTTLE EARTH OBSERVATION SENSORS POINTING & STABILIZATION REQUIREMENTS STUDY

(NASA-CR-152434) SPACE SHUTTLE EARTH OBSERVATION SENSORS POINTING AND STABILIZATION REQUIREMENTS STUDY (General Electric Co.) 107 p HC A06/MF A01 CSCL 14B

N77-18204

Unclas
G3/19 16673

THIS REPORT WAS PREPARED UNDER THE AUSPICES OF THE EARTH VIEWING APPLICATIONS LABORATORY STUDY EFFORT



space division

GENERAL ELECTRIC

76SDS4228
7 MAY 1976

SPACE SHUTTLE EARTH OBSERVATION SENSORS POINTING & STABILIZATION REQUIREMENTS STUDY

THIS REPORT WAS PREPARED UNDER THE AUSPICES OF THE EARTH VIEWING APPLICATIONS LABORATORY STUDY EFFORT

GENERAL ELECTRIC
SPACE SYSTEMS ORGANIZATION
Valley Forge Space Center
P. O. Box 8555 • Philadelphia, Penna. 19101

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SECTION 1

INTRODUCTION

SECTION 1

INTRODUCTION

The Shuttle Orbiter has the capability of achieving and maintaining any desired space or earth referenced attitude with respect to either the Orbiter navigation base or a payload provided and mounted sensor. The pointing accuracy, however, is a function of the error sources associated with the characteristics of the particular attitude sensor, the type of control system, and the orbiter flexure.

The Orbiter Inertial Measurement Unit (IMU), located in the Orbiter cabin, is used to supply inertial attitude reference signals; and, in conjunction with the onboard navigation system, can provide a pointing capability of the navigation base accurate to within $\pm 0.5^{\circ}$ for earth viewing missions. This pointing accuracy can degrade to approximately $\pm 2.0^{\circ}$ for payloads located in the aft bay due to structural flexure of the Shuttle vehicle, payload structural and mounting misalignments, and calibration errors with respect to the navigation base. In order to provide greater accuracy in payload pointing, the Orbiter is capable of accepting error signals from a more accurate payload supplied and mounted sensor. In this case, the Orbiter is capable of maintaining a specified attitude to within 0.01 deg/sec by using the full capability of the RCS jets, or 0.1 deg/sec with partial RCS capability.

The drawbacks to obtaining pointing accuracy by using the Orbiter RCS jets are an increased amount of coordination and crew involvement; the fact that changing the orbiter attitude for one experiment necessarily affects all the other experiments which may be operating at the same time; and, an increase in the local contamination level.

Supplementary electromechanical pointing systems which can provide independent pointing for individual sensors, or sensor groupings, are therefore required for earth viewing payloads. The requirements for such a system(s) are developed within this report.

This activity was necessitated by the urgency of an earth viewing input to NASA's Experiment Pointing Mount Committee. Ideally, selected missions would have been obtained from the Earth Viewing Application Laboratory (EVAL) discipline working groups and used as input data. These working groups, however, are presently in an embryonic stage and have not yet completed an evaluation of all missions within their respective disciplines. Candidate missions were therefore selected by GE, in conjunction with the working group chairmen, based on suggested objectives identified in the Total Earth Resources System for the Shuttle Era (TERSSE) study, the Global Atmospheric Research Program Stockholm Report, and NASA's Outlook For Space.

THUS, WHILE THE MISSIONS CANNOT BE CONSIDERED AS OFFICIAL EVAL RECOMMENDED MISSIONS; THEY ARE LEGITIMATE CANDIDATES.

The approach used and the results obtained in this report are summarized in Section 2. The missions considered and sensors required for these missions are discussed in Section 3; while the parameters for each sensor are described in Section 4. In Section 5 assumptions made to derive pointing and stabilization requirements in Section 6 are delineated.

SECTION 2

SUMMARY AND CONCLUSIONS

SECTION 2

SUMMARY AND CONCLUSION

The approach followed in developing pointing/stabilization requirements for earth viewing payloads is depicted in Figure 2-1 and expanded in Figure 2-2. This approach results in requirements which are both justifiable and traceable to specific instruments/missions.

The missions selected are used to dictate operational requirements, which in turn are used to define realistic sensors and groupings. A deliberate attempt was made in the mission and sensor selection to include a representative variety of sensor types and combinations. This results in the inclusion of cameras, scanners, and interferometers/spectrometers operating in both the infrared and microwave regions of the spectrum. Figure 2-3 indicates the missions and sensors that were used in this exercise. By tabulating the pointing/stability requirements for each sensor necessary to accomplish its associated mission, practical limiting values for supplementary pointing/stabilization systems can be obtained. These values are summarized in Figure 2-4.

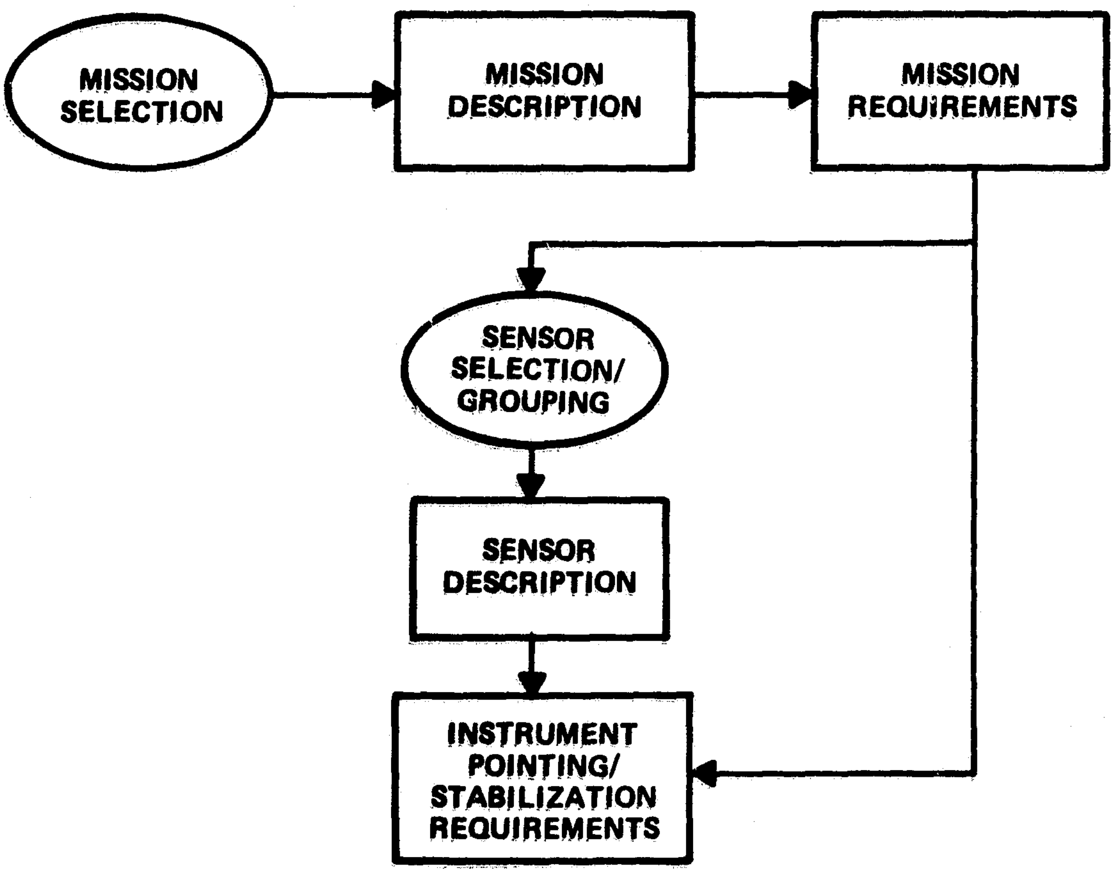


Figure 2-1. Earth Observations Instrument Pointing/Stabilization Requirements

MISSION SELECTION

- OPERATIONAL
- TECHNIQUE DEVELOPMENT
- TECHNOLOGY DEVELOPMENT

MISSION DESCRIPTION

- JUSTIFICATION
- READINESS
- SHUTTLE APPLICABILITY
- OBSERVATION REQUIREMENTS
- SENSOR CONFIGURATION REQUIREMENTS

MISSION REQUIREMENTS

- TYPE COVERAGE (E. G., MAPPING, TARGETTING, TRACKING, LIMB, ETC.)
- ALTITUDE
- CALIBRATION
- MEASUREMENT ACCURACY
- SPATIAL RESOLUTION
- INSTRUMENT GROUPING

SENSOR SELECTION

- FILM CAMERAS
- SCANNERS
- SPECTROMETERS/INTERFEROMETERS (INFRARED AND MICROWAVE)

SENSOR DESCRIPTION

- TYPE OF SENSOR/GENERIC NAME
- SIZE/WEIGHT
- PARAMETERS AFFECTING POINTING/STABILIZATION REQUIREMENTS (E. G., IFOV, SCAN RATE, EXPOSURE TIME, ETC.)
- SPECIAL SUPPORT REQUIREMENTS

INSTRUMENT POINTING/STABILIZATION REQUIREMENTS

- POINTING ACCURACY
- POINTING STABILITY ERROR AMPLITUDE/RATE
- DURATION OF STABILIZATION
- MAXIMUM SLEW RATE
- SETTLING TIME
- STABILITY TO DISTURBANCES
- INTERNALLY GENERATED DISTURBANCES

ALL TYPES OF EO SENSORS WITH CREDIBLE MISSIONS AND MULTIPLE MODES OF OPERATION HAVE BEEN INVESTIGATED, PROVIDING TYPICAL POINTING/STABILITY REQUIREMENTS

Figure 2-2. Task Description

MISSION	SENSORS
EARTH RESOURCES Mineral Exploration Survey	• Thematic Mapper • Large Format Camera • Synthetic Aperture Radar (SAR)
Timber Volume Inventory	• Thematic Mapper • Earth Terrain Camera (S-190B)
U. S. Census	• Multispectral Camera (S-190A) • Earth Terrain Camera (S-190B) • Optical Bar Panoramic Camera (S-163) • Thematic Mapper
ENVIRONMENTAL QUALITY/WEATHER & CLIMATE Urban Air Pollution	• Measurement of Air Pollution Species (MAPS) • Correlation Interferometer Meas. of Trace Species (CIMATS) • Temperature/Humidity IR Radiometer (THIR)
Tropospheric/Stratospheric Pollution	• Lower Atmospheric Composition and Temperature Experiment (LACATE) • Solar Backscatter UV and Total Ozone Mapping Spectrometer (SBUV/TOMS)
EARTH AND OCEAN PHYSICS Tropical Storm Research	• Altimeter • Synthetic Aperture Radar (SAR) • Scanning Multichannel Microwave Radiometer (SMMR) • Scatterometer • Visual and IR Radiometer (VIRR)
COMM/NAV EEE AMBA (Adaptive Multibeam Antenna)	• Electromagnetic Environment Experiment (EEE) • Adaptive Multibeam Phased Array (AMPA)
TECHNIQUE DEVELOPMENT Soil Moisture	• Thematic Mapper • Imaging Radar • Shuttle Imaging Microwave System (SIMS) • Polarimeter
TECHNOLOGY SENSOR DEVELOPMENT LIDAR	• LIDAR

Figure 2-3. EO Sensor Groupings Per Mission

• POINTING ACCURACY	10 $\widehat{\text{SEC}}$ TO 1800 $\widehat{\text{SEC}}$
• POINTING STABILITY ERROR AMPLITUDE	0.2 $\widehat{\text{SEC}}$ TO 360 $\widehat{\text{SEC}}$
• POINTING STABILITY ERROR RATE	2 $\widehat{\text{SEC}}$/SEC TO 360 $\widehat{\text{SEC}}$/SEC
• DURATION OF STABILIZATION	10 MILLISEC TO 30 MINUTES
• SLEW ANGLE	± 25 DEGREES
• SETTLING TIME	2 SECONDS (MAX)
• MAXIMUM ACCELERATION	0.1 RADIANS/SEC^2
• MAXIMUM SLEW RATE	0.1 RADIANS/SEC
• MASS	9 KG TO 1500 KG (PER INSTRUMENT) 97 KG TO 2407 KG (PER MISSION)

Figure 2-4. Preliminary EO Instrument Pointing/ Stabilization Requirements Summary

The pointing and stability requirements for each sensor are established by considering the selected sensor characteristics and the observation/coverage requirements of the designated mission.

The pointing accuracy relates the relative location of area viewed by the sensor with respect to the desired coverage area. The pointing stability error amplitude is the amount of temporal variation of the sensor line of sight (LOS) from the desired LOS less the pointing error during the viewing period. The pointing stability error rate is the average time derivative (slope) of the variation over a period as shown in Figure 2-5.

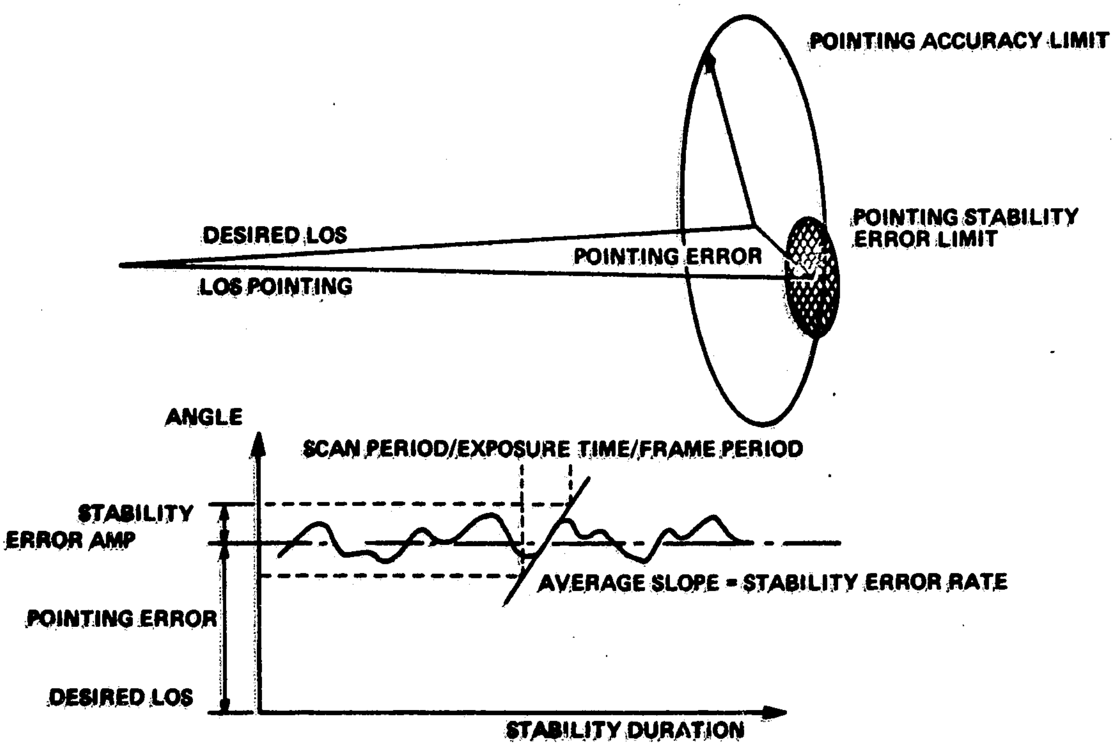


Figure 2-5. Pointing Stability Error Rate

Although it was recognized that different limit values would be required for pitch, roll and yaw axes, for simplicity only one limit value for each sensor has been established in this study.

The pointing accuracy is established primarily from the field of view of the sensor and the size of coverage area. As shown in Figure 2-6 the limit values range from 10 arc seconds for Lidar to 1800 arc seconds (0.5 degree) for the earth resources mission sensors. It indicates that a pointing capability of 0.05 degree can satisfy most of the sensor pointing requirements while 0.5 degree accuracy provided by the on board navigation system meets the requirements of the earth resources mission sensors only.

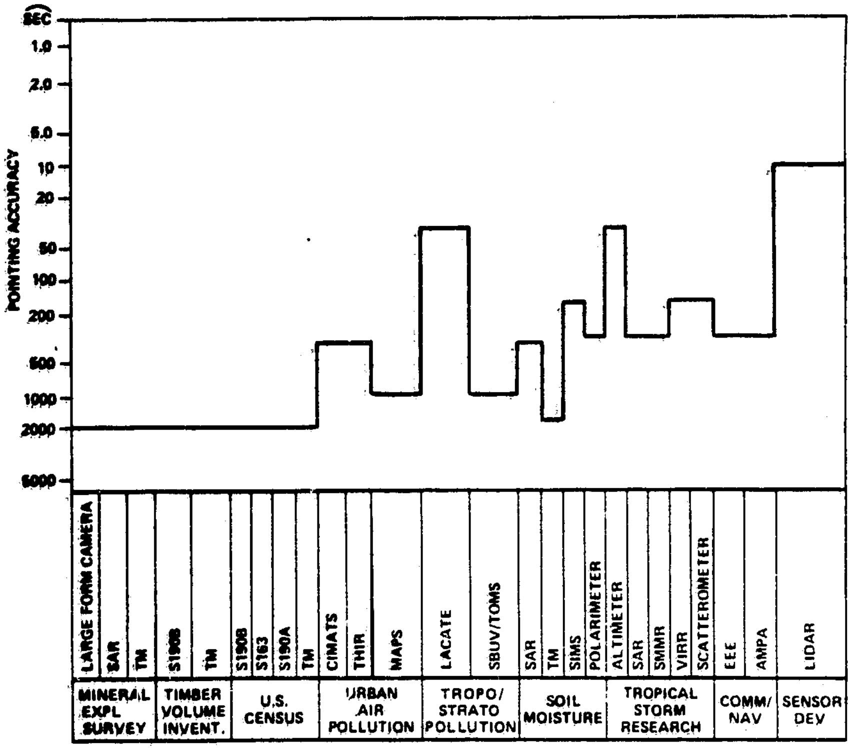


Figure 2-6. EO Missions/Sensors
EO Sensors Pointing Accuracy

The limit value of pointing stability error amplitude is obtained from the sensor spatial resolution since it relates to the overlapping of resolution cells. The limit values tabulated in Figure 2-7 show that they range from 0.2 arc second for Lidar to 360 arc seconds (0.1 deg) for MAPS. It indicates that a stability error of less than 6 arc seconds satisfies most of the requirements. Since the major portion of stability error would be caused by the disturbances generated by the payloads and the crew motion, the pointing mount design must include a detailed study of these disturbances (amplitudes and frequencies).

The limit value of pointing stability error rate is established from the sensor resolution, desired ground resolution and scan rate/exposure time. It ranges from 2 arc seconds per second for Lidar to 360 arc seconds per second (0.1 deg per sec) for MAPS as shown in Figure 2-8. For a scanning type sensor a higher error rate could be tolerated if the scanning rate were higher. However, the higher scanning rate causes higher disturbing momentum and larger error rate, therefore, the scanning rate should be maintained at the lowest value providing contiguous coverage.

The duration of stabilization is established based on the time required to map the desired mission coverage area. It ranges from 10 milliseconds for S190A or S190B cameras used in the US Census Mission to 30 minutes for the Tropical Storm Research Mission as shown in Figure 2-9. The pointing mount should provide required stabilization in all three axis for the duration.

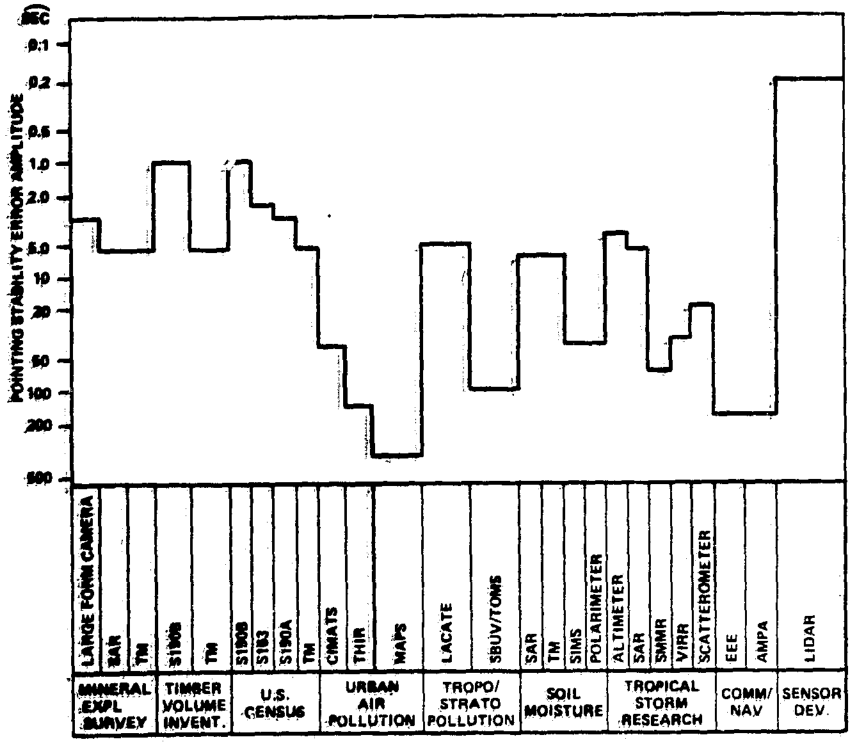


Figure 2-7. EO Missions/Sensors
EO Sensors Pointing Stability Error Amplitude

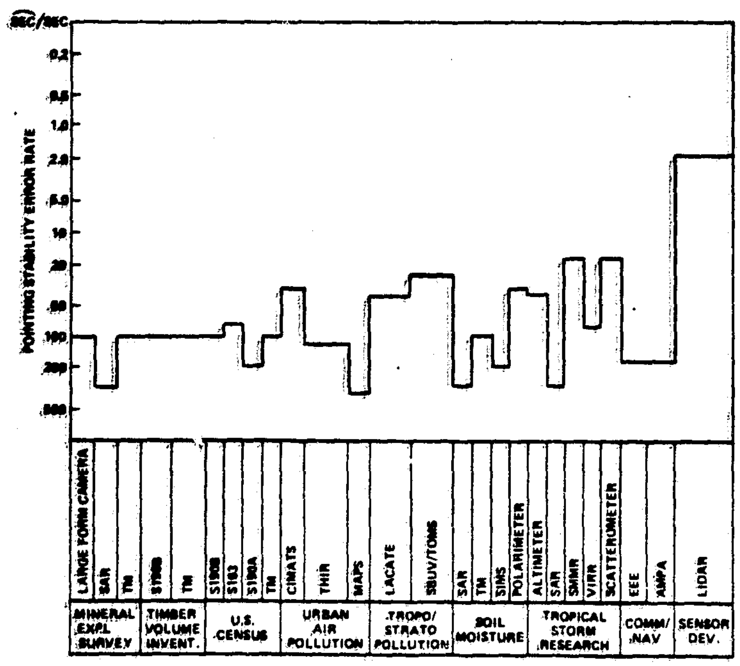


Figure 2-8. EO Missions/Sensors
EO Sensors Pointing Stability Error Rate

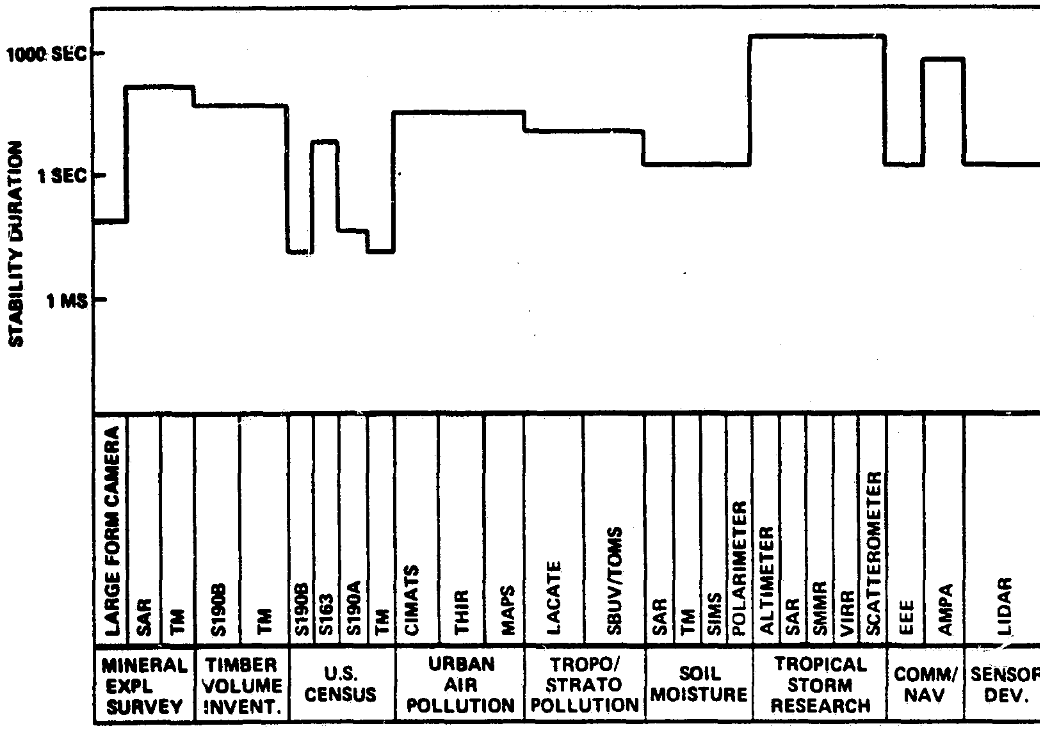


Figure 2-9. EO Missions/Sensors
EO Sensors Stability Duration

Some of the experiments do not require slewing by the pointing mount since the sensor either has a large FOV or provides offset pointing internally. Even for those sensors requiring slew, the pointing movement is required in roll axis only since the shuttle ground velocity vector is in the pitch plane and no pointing in this axis is required for line scanning sensors.

For a stereoscopic view some cameras require pointing in the pitch axis which is provided internally.

The worst case pointing slew requirement is presented by the US Census Mission where slewing 22.5 degrees in 5 seconds is required. Assuming 1 ft/lb acceleration torque for each instrument with the slew profile described in Section 5 (Assumptions), the S190A and S190B cameras require a slew time of 5.6 seconds (settling time is not included). The thematic mapper and S163 camera do not require slewing. The combined weight of these two cameras (S-190A & S-190B) is 146 Kg (estimated moment of inertia in roll axis is 9 Kg-m^2), and the same slewing performance could be obtained with 1 ft/lb acceleration torque limit.

The largest slew angle required is 50 degrees in roll axis for the alignment of the large format camera LOS to that of the SAR in the Mineral Exploration Survey Mission. With the assumed acceleration torque limit of 1 ft/lb the slew motion can be accomplished in

13.5 seconds including a 2-second settling time. The thematic mapper for the same mission requires slewing of 10 degrees, which can be accomplished within 9.4 seconds, including a 2-second settling time. The combination of these two sensors has a weight of 209 Kg and an estimated moment of inertia of 80 Kg-m^2 in roll axis. This combined package can be slewed 50 degrees within 20.5 seconds, including a 2-second settling time with 1 ft/lb acceleration torque limit. Since this mission does not require a slew during flight over the target area no problem exists.

For the Urban Air Pollution Mission two sensors, CIMATS and SBUV/TOMS, should be slewed 30 degrees across track ($\pm$15 degrees). Each sensor package can be slewed 30 degrees in 8 seconds including 1 second settling time. When these two sensors are combined the weight is 103 Kg and the moment of inertia in roll axis is 3 Kg-m^2. The combined package can also be slewed 30 degrees in 8 seconds with 1 ft/lb acceleration torque limit. A summary of slew profiles for these sensors is tabulated in Figure 2-10. The combined weight and the estimated moments of inertia of all sensors for each mission involving several sensors are tabulated in Figure 2-11.

MISSION/SENSOR	SLEW ANGLE	MAX ACCELERATION	ACCELERATION TIME	COASTING TIME @ 0.1 RAD/SEC	DECELERATION TIME	SETTLING TIME (DESIRABLE)
U.S. CENSUS/S190A	22.5°	0.1 RAD/SEC^2	1.6 SEC	2.4 SEC	1.6 SEC	1 SEC
U.S. CENSUS/S190B	22.5°	0.1 RAD/SEC^2	1.6 SEC	2.4 SEC	1.6 SEC	1 SEC
MINERAL EXPL SURVEY/LARGE FORMAT CAMERA	50°	0.05 RAD/SEC^2	3.1 SEC	5.6 SEC	3.1 SEC	2 SEC
MINERAL EXPL SURVEY/THEMATIC MAPPER	10°	0.02 RAD/SEC^2	3.7 SEC	N/A	3.7 SEC	2 SEC
URBAN AIR POLL/ CIMATS	30°	0.1 RAD/SEC^2	1.6 SEC	3.2 SEC	1.6 SEC	1 SEC
URBAN AIR POLL/ MAPS	30°	0.1 RAD/SEC^2	1.6 SEC	3.2 SEC	1.6 SEC	1 SEC
AMPA	40°	0.001 RAD/SEC^2	33 SEC	N/A	33 SEC	2 SEC

Figure 2-10. EO Sensors Slew Profile Summary

A comparison of the stability requirements summarized in Figure 2-7 with those for the astronomy or the solar physics experiments shows that the earth observation experiments demand relatively low stability requirements. Since the duration of viewing and the time available between the successive target area pointings for the earth observation experiments are very short compared to the other experiments, however, the earth observation

MISSION	COMBINED WEIGHT (Kg)	COMBINED MOMENT OF INERTIA (Kg-m²)		
		PITCH	ROLL	YAW
MINERAL EXPLORATION SURVEY	1559	90	480	430
TIMBER VOLUME INVENTORY	217	27	22	31
U. S. CENSUS	478	39	31	42
URBAN AIR POLLUTION	145	4	4	4
TROPO/STRATO POLLUTION	97	6	2	5
SOIL MOISTURE	2407	436	441	831
TROPICAL STORM RES.	1425	22	412	419
EEE	672	1000	1000	1000
AMPA	1500	1000	1000	2000
LIDAR	100	3	3	0.5

Figure 2-11. EO Sensors Combined Weight/Moment of Inertia Summary

experiments require fast slewings with quick settling when they are needed. This can be achieved by an open loop control of slew resulting in zero accelerations and zero rate at the end of the slew by utilizing the maximum available acceleration/deceleration capability. Although a near zero settling time can be realized in this approach, a large pointing error could result due to the nature of open loop control. Since FOV's of the earth viewing sensors are relatively large, the pointing accuracy can be traded-off for the fast slew and settling. Hence the main problem areas for the earth observation experiments are the isolation of distrubance motion from the sensor LOS.

Basically there are two sources of disturbance input to the sensors: the externally generated disturbances and the internally generated disturbances. The external disturbances include all sources influencing the vehicle attitude stability (deterministic as well as random), crew motions, structural flexibilities of the vehicle and the mount, and the disturbance generated by the other sensors aboard. These disturbances can be effectively decoupled from the sensor by use of a mount with passive isolators, active (servo controlled) isolators, or a combination of both.

Many of the scanning sensors included in the earth observation experiments utilize mechanical motion of mirrors (Thermatic Mapper, S163, THIR, LACATE, SBUV/TOMS, VIRR, etc.), antennae (SMMR, EEE, etc.) or others (feed assembly of SIMS for example). The mechanical motions of these sensor components generate disturbances which are presently not well defined, and are not included in this report. It is recommended that these disturbances be assessed to facilitate the grouping of sensors and the design of isolators and momentum compensation devices.

SECTION 3

EARTH OBSERVATION MISSIONS SENSOR REQUIREMENTS

SECTION 3

EARTH OBSERVATION MISSIONS SENSOR REQUIREMENTS

The Space Shuttle Program provides low-cost transportation to and from Earth orbit, and will open many avenues for conducting investigations in space. The Earth Observation Experiments evolve from the emerging developments in using remotely sensed data to enable man to manage earth resources, to monitor and predict weather conditions and to provide data to enhance his ability to monitor and control the environmental conditions. Although no official missions are recommended, candidate missions for this study have been selected by GE, in conjunction with the various discipline Working Group Chairmen. A deliberate attempt was made to include a representative variety of sensor types and combinations. The following missions are considered in this study:

A. Earth Resources
   1. Mineral Exploration Survey
   2. Timber Volume Inventory
   3. U.S. Census
B. Environmental Quality/Weather & Climate
   1. Urban Air Pollution
   2. Tropospheric/Stratospheric Pollution
   3. Tropical Storm Research
C. Communication/Navigation
   1. Electromagnetic Environment Experiment
   2. Adaptive Multibeam Antenna
D. Technique/Sensor Technology Development
   1. Soil Moisture Remote Sensing
   2. LIDAR

These missions are further delineated below. The sensor descriptions and characteristics associated with these missions are compiled in Section 4 to avoid repetition, since the same sensor is frequently required for several different missions.

EARTH RESOURCES - MINERAL EXPLORATION SURVEY

A. JUSTIFICATION

1. With an increasing demand for mineral resources brought about by a steadily industrializing world, rapid and cost-effective exploration techniques are required to ensure that raw materials will be available when they are needed.
2. A major factor in the exploration of new mineral reserves is that most of the deposits in accessible regions of the world which are close to, or at, the surface have already been exploited. Thus, new deposits required to satisfy present and projected needs must be sought in areas which are largely inaccessible, because of geographic remoteness or substantial surface cover.
3. Geographically remote areas can be effectively surveyed by remote sensors, at least at the reconnaissance level.

B. READINESS

1. Aerial photography has long been used as a tool in mineral exploration surveys.
2. Imagery taken from orbital altitudes has already been effectively utilized by geologists.

C. MISSION REQUIREMENTS

1. The mineral exploration mission will involve a detailed and comprehensive multi-sensor effort designed to detect geologic evidence of commercial copper-bearing ores. Although the mission is really much broader than just the search for copper, it is desirable from the standpoint of this discussion to constrain the mission scope in order to provide more specific requirements and descriptions. When the mission is actually implemented, the scope can be expanded, with little impact, to include: other metallic minerals, petrochemicals, geothermal resources, and the reconnaissance of geologically active areas.
2. The rationale for selection of copper exploration as the narrow mission for the focusing of this discussion can be summarized as follows:
   a. Considered to be a scarce metal resource
   b. Strategic/industrial importance
   c. U.S. consumption exceeds U.S. production
   d. Can be profitably mined from concentrations as low as 0.5%
   e. Demonstrated feasibility for remote sensor exploration (both aircraft and spacecraft)

3. The primary goal of this mission is to locate ore bodies of copper (primarily porphyry deposits due to their large size), but not excluding stratiform (sedimentary sulfied) and vein deposits. This will be accomplished by detecting and analyzing surface indicators of ore emplacement, including: stressed vegetation, characteristic lithologic associations, zones of geochemical alteration (e.g. gossans) and tonal anomalies, lineament concentrations and intersections, and structural setting.

D. OBSERVATION AND COVERAGE REQUIREMENTS

1. Areas to be covered:

   Known copper-producing regions and adjacent areas - in particular, the "copper belt" of the Southwestern U.S., which includes large portions of Arizona, New Mexico, Utah, and Colorado, and smaller regions of Idaho and Wyoming.

   The total area to be surveyed approaches 78,000 Km^2 (30,000 mi^2).

2. The optimum information grid size desired by the majority of potential users for mineral resources information is 30 meters.

3. The timeliness requirement is between two to six months. For geologic phenomena, timeliness is not a critical concern.

4. The update cycles requested most frequently are seasonal (quarterly) to take advantage of changes in vegetation and sun angle. In some investigations, the required update cycle is yearly or one time only, due to the slow rate at which most geological processes take place.

5. Progressive changes in vegetation or seasonal snow cover, resulting from long-term climatic fluctuations may enhance the underlying terrain to different degrees, necessitating quarterly coverage over a series of years.

6. Swath width: 180 Km (based on 100 m resolution), but may be traded off for higher resolution.

7. Sun angle: 30^{o} and 60^{o} (useful range); $20-40^{o}$ and $60-90^{o}$ (desired).

8. Observation Schedule: At least twice, once at each sun angle (possibly more if thermal inertia measurements are wanted).

E. SENSOR REQUIREMENTS

Requirements for the remote sensing mineral exploration mission include the following:

1. Primary sensing technique - visual color imaging, metric quality desirable

2. Supplementary sensing techniques - radar imaging

Ground resolution of 30 m is desired with a thermal resolution of $0.5^{o}C$.

Candidate sensors for this application include:

1. Multispectral Scanner (Thematic Mapper)

   - For detecting water penetration, sediment concentration surface tones, vegetation types and geochemical information, for distinguishing geologic structure, for differentiating rocks from soils and soil types.

2. Large Format Camera

   - For high resolution stereo color and color IR, for detecting surface tones, vegetation type, and geochemical information

3. Imaging Radar (SAR)

   - For cloud penetration, structural discrimination, drainage, lineaments, and structural grain or surface roughness

The assumption is the Thematic Mapper and Large Format Camera line of sight is aligned with the SAR and fixed for a given orbit.

F. ORBIT PARAMETERS

Orbital altitude and inclination for the mineral exploration mission are a function of the resolution and geographical areas specified. In this case a ground resolution of at least thirty meters is desired by many users for locating small rock out-croppings. This relatively fine resolution is obtained more easily from a low altitude orbit; thus an orbit altitude on the order of 200 Km is desirable. Similarly, the geographical areas of interest are concentrated in the Southwestern U.S. On-orbit inclination of 55^o-57^o is therefore required.

EARTH RESOURCES - TIMBER VOLUME INVENTORY

A. JUSTIFICATION

1. Forest inventories are necessary to forecast supply problems in the wood-using industries, and to indicate the need for changes in forest management policies and programs.
2. Periodic forest inventories are mandated by Federal Law.

B. READINESS

1. Aerial photography has been utilized in forest inventories for the past three decades.
2. Imagery from Landsat-1 and Skylab has demonstrated that spacecraft-derived imagery can increase the efficiency of forest inventory.

C. MISSION REQUIREMENTS

1. The objective of the mission is to estimate the amount (volume) and quality of commercial timber in the U. S.
2. Specific requirements are shown in Table 3-1.

D. OBSERVATION AND COVERAGE REQUIREMENTS

1. Area to be inventoried: 300 million hectares (750 million acres). Two-thirds of this is considered to be of commercial value. The majority of the forested areas containing commercial timber is located in the eastern half of the U. S.
2. Frequency of inventory: once every five years.
3. Timliness: two to four months
4. Flight timing: deciduous - April to October; coniferous - not critical.

E. SENSOR REQUIREMENTS

1. S190B high resolution camera: used to measure crown diameter which is related to the stem diameter, and crown closure, related to the timber volume per acre. Tree height can be estimated by differential parallax measurements on stereoscopic pairs of aerial photographs.
2. Thematic Mapper: used to identify species, age groupings and tree health.

F. ORBIT PARAMETERS

The orbit inclination required is 55° and 400 Km altitude. Targets of forest areas over North Eastern U.S. with at least four (4) targets of 200 Km length and 100 Km width are required in three (3) minutes.

Table 3-1. Timber Inventory Information Elements for Inventory of National Forests

Information Element	Use	Accuracy Requirements
Locate and map timber stand boundaries	Determine acreage of National forests by standard timber land use classification	± 50 feet of actual location; min. size - 10 acres
Locate and map stand boundaries by forest type	Determine stand area by forest type	Boundary - ± 50 ft. of actual; min. size - 10 acres; ± 1% for total area
Stand condition as to stem basal area per acre of trees by age and species groupings	Determine current stand conditions in order to develop the management treatments required on all commercial forest land	Identification of species and age grouping - 95%; sq. ft. stem basal area per acre ± 5%
Cubic foot volume by species in each timber stand	Determine each National forest's potential yield of wood products	Stand volume ± 10%; by individual species ± 20%

EARTH RESOURCES - US CENSUS

A. JUSTIFICATION

1. Constitutional directive to carry out dicenial national census for reapportionment of House of Representatives.
2. Federal Revenue Sharing Act requires demographic data for various administrative units (cities, counties and states).
3. National land use planning assistance.

B. READINESS

1. Nominal aerial imagery was acquired for the 1960 & 1970 Census.
2. USGS Geographic-Application's Program (GAP) Census Cities Project was the principal experimental effort toward a methodology development for the Bureau's assessment. NASA acquired the coverage over some 24 cities in support of the USGS project.
3. Landsat & SKYLAB data analysis by USGS - (GAP) & Bureau of Census have been underway to develop the necessary techniques for implementing a 1980 program using multispectral analysis and photo interpretation of imagery.

C. MISSION REQUIREMENTS

1. 1980 Census urbanized area delineation
2. Post 1980 census analysis
3. Map revision for the mid-decade census of population and housing for 1985.

D. OBSERVATION & COVERAGE REQUIREMENTS

1. Urbanized area is used to delineate the urban population concentrations.
2. Daylight coverage of the major US cities in a single sortie flight. There are 56 cities over 250,000 population.
3. Desired orbit is the one that covers a finite set of ground locations a maximum number of times (at least once for each target) during the flight.
4. A maximum crosstrack (roll) angle of $\pm 15^{o}$, to minimize the geometric distortion of the images produced but to allow for some latitude in ground trace/target centerline offset.
5. US coverage obtained during daylight.

E. SENSOR REQUIREMENTS

1. REGIONAL CONTEXTURAL OVERVIEW

Accomplished by a PANORAMIC CAMERA (S-163) using black and white, true color or color IR film at a ground resolution of 10 m or better. Quick look, first-cut urban area delineation and outlying area analysis are the primary uses.

2. GEOGRAPHIC CONTROL DATA UPDATE

Cartographically useful film output is desired for planning and field use. Resolution sufficient to delineate streets is necessary. The candidate camera is the S-190 B with a 5 to 10 meters ground resolution.

3. URBAN LAND USE CLASSIFICATION

Spectral characteristics are required. Ground resolutions between 15 to 20 meters with spectral gray lines of between 64 to 128 levels over the spectral range are required. Five or six bands covering the spectral range of 0.42 to 1.1μm plus 2.0 to 2.6μm and 10.4 to 12.5μm are the required spectral range for machine based urban land use classification. Both multi-band camera and multispectral scanner are desired types for this use.

The S-190A camera and the Thematic Mapper are candidates.

F. ORBIT PARAMETERS

An orbit inclination of 48 degrees and altitude of 443 Km is required to observe most of the largest US cities.

The worst case targetting requirement occurs between Indianapolis and Cincinatti with the roll angle between the two cities of 22.5° and less than 10 seconds time available. The assumption is that the TM operates for 4 seconds over each city whereas the cameras take pictures instantaneously. The S-163 camera has a wide field of view (108°) therefore no offset pointing is required. The S-190A, S-190B cameras and the TM have to be pointed because of their narrow field of view (14° to 20°).

ENVIRONMENTAL QUALITY/WEATHER AND CLIMATE URBAN AIR POLLUTION MISSION

A. JUSTIFICATION

Federal agencies have responsibility for basic problem areas related to:

1. Pollution-caused damage to human health and welfare, and the ecology.
2. Pollution-caused changes in the earth's climate, and inadvertant weather modification.

B. READINESS

1. Sensors for the urban air pollution mission are currently being developed and have not become operational from satellites as yet. Many of the candidate sensors have been flight tested on aircraft and balloons and have demonstrated their measurement capabilities.
2. By 1978 a number of sensors capable of satisfying some of the requirements of the urban air pollution mission will be developed to the point where they can be integrated into a shuttle payload to provide required information on the minor atmospheric species and aerosols.

C. MISSION REQUIREMENTS

The basic information requirements needed to satisfy the urban air pollution mission are the following.

1. Determine baseline concentrations of the pollutant gases and aerosols.
2. Determine variations in the ambient concentrations.
3. Identify the sources and sinks of the pollutants.
4. Determine the horizontal and vertical transport of the pollutants.
5. Determine vertical profiles of temperature and water vapor.
6. 24/72 Km resolution is desired.

D. OBSERVATION AND COVERAGE REQUIREMENTS

1. Desired orbit should provide coverage over the major urban areas once every 24 hours.
2. The time over the target may be day or night, however the CIMATS 2 to 2.4μm channel will not be useable during the night.
3. Offset pointup is necessary (± 15 degrees) for the target area coverage.

E. SENSOR REQUIREMENT

Accomplished with a sensor having a ground resolution of the order of 30 Km. A sensor with measurement capabilities in the spectral region above 4 microns will permit day/night operation and improve the data gathering efficiency. A sensor with measurement capabilities in the reflected solar spectral region will permit sensing to the earth's surface which may not be possible at all times at the longer wavelengths. Candidate sensors are the MAPS, CIMATS and THIR.

F. ORBIT PARAMETERS

The orbit parameters required are the same as the US Census Mission requirements. If it is desired to achieve 24 Km resolution, however, the altitude should be reduced to 220 Km.

ENVIRONMENTAL QUALITY/WEATHER AND CLIMATE-TROPOSHPERIC/STRATOSPHERIC POLLUTION MISSION

A. JUSTIFICATION

1. Stratospheric pollutants may be depleting the earth's ozone layer with resulting changes in the ultraviolet radiation reaching the earth's surface.

2. Stratospheric pollutants (gases and aerosols) may be producing changes in the radiative transfer characteristics of the atmosphere with resulting changes in weather and climate.

B. READINESS

1. Some sensors for the stratospheric pollution mission have been developed and flown in satellites. However the advanced sensors required to provide the necessary comprehensive data are still in the advanced development stage.

2. By 1978 a number of the advanced sensors required for the stratospheric pollution mission will be developed to a stage where they will be available for inclusion in shuttle payloads with minimal modifications.

C. MISSION REQUIREMENTS

1. Monitor ozone and the minor atmospheric constituents in the stratosphere associated with the ozone depletion problem on both a short term and long term basis.

2. Monitor the stratospheric aerosols on the basis of physical properties and spatial distribution to determine short term and long term variations.

3. Continuous scan measurement of atmosphere during orbit.

4. Altitude: 200/600 Km

5. Resolution: Rectangular element ranging in size from 1 x 200 Km to 4 x 100 Km

D. OBSERVATION AND COVERAGE REQUIREMENTS

1. Since the stratospheric pollution problem is more global in nature than the local urban pollution problem, the orbital coverage in terms of ground track is of less importance. The desired orbit should provide global coverage over as wide a latitude range as possible for nadir viewing sensors. The orbit should provide an opportunity for solar looking limb occultation experiments over the largest possible latitude range.

E. SENSOR REQUIREMENTS

The required sensors for the stratospheric pollution mission are of two types:

1. The limb emission sensor which operates in the thermal infrared and scans the atmospheric limb both vertically and horizontally providing vertical profiles of the atmospheric constituents. LACATE is one of these types of sensors.
2. The nadir viewing sensor which measures upward radiative flux from the atmosphere. A candidate sensor for this type of measurement is SBUV/TOMS.

ENVIRONMENTAL QUALITY/WEATHER AND CLIMATE-TROPICAL STORM RESEARCH MISSION

A. JUSTIFICATION

1. Although hurricanes and typhoons are extremely destructive, the forces that operate to cause a tropical depression to intensify to hurricane force are poorly understood. Only about one tropical storm emerges from forty tropical depressions. Similarly, the forces that cause developed storms to move in particular paths are poorly understood, making even rather short term predictions uncertain.

2. Recent developments in microwave remote sensing provides powerful new tools that can provide all weather measurement of many of the parameters that are known to be important and related to tropical storm development and movement. These include: sea surface temperatures, sea state, wind speed and direction, wave length and direction, and atmospheric properties. These sensors, combined with a visable and IR imaging sensor can provide very valuable data for research into tropical storm research.

3. This combination of sensors will be flown together on Seasat A. However, the orbit of Seasat A will permit the observation of a single place only once about every thirty-six hours, a rate much too slow to permit the elucidation of hurricane etiology. Moreover, it does not have the capability to store data from the Synthetic Aperature Radar (SAR) which is an important sensor in this application.

4. The Seasat sensors, with suitable modifications because of the change in orbit altitude, could be flown on Shuttle. Their swath widths can be made such that at latitudes near the orbit inclination (e.g. $28^{\circ} \pm 6^{\circ}$ latitude) coverage of tropical storm areas can be made several times a day. During the peaks of the tropical storm season there should be a number of tropical depressions/storms in various stages of evolution to be studied.

B. READINESS

1. All of the sensors needed for this mission either exist or are under active development for Seasat A. Most have a space flight demonstration completed with equipment of an earlier stage of development than Seasat. The Skylab mission demonstration of S-193, a combined altimeter/radiometer/scatterometer showed the capability for remote sensing of sea state and ocean temperature, and inferred wind speed. A more advanced altimeter is flying on GEOS-C measuring sea state. A scanning microwave multichannel radiometer (SMMR) is being developed to fly on Nimbus-G. Numerous visible and IR radiometers have flown on Nimbus and TIROS programs.

2. With a Seasat flight in 1978, not only will the instrument technology be available, but the techniques for using the data and correlating it with ground truth will be worked out well before needed for Shuttle flights.

3. By 1979 the instruments will be demonstrated in flight and the data analysis techniques worked out and verified by ground truth. Given some prior study as to the type of sensor modifications needed for Shuttle flights, a sound research program could be defined by then, and hardware procurement started leading to flight early in the 1980's.

4. On-board magnetic tape recording of the outputs will be very desirable for all regions of interest. It will be essential if research on typhoons in the Indian Ocean is to be carried out, since that is in the blind zone for TDRSS coverage.

C. MISSION REQUIREMENTS

Figure 3-1 shows typical hurricane and typhoon tracks. Note that there are three regions of interest in the Northern hemisphere, with peak activity generally in the September to November period; and three other areas in the Southern hemisphere, with peak activity from December to March. Flights in those periods will be required to obtain the research data. Flights of seven days are necessary, and longer - up to 21 days - would be highly desirable.

WORLD WEATHER
NAVAER 00-80U-24

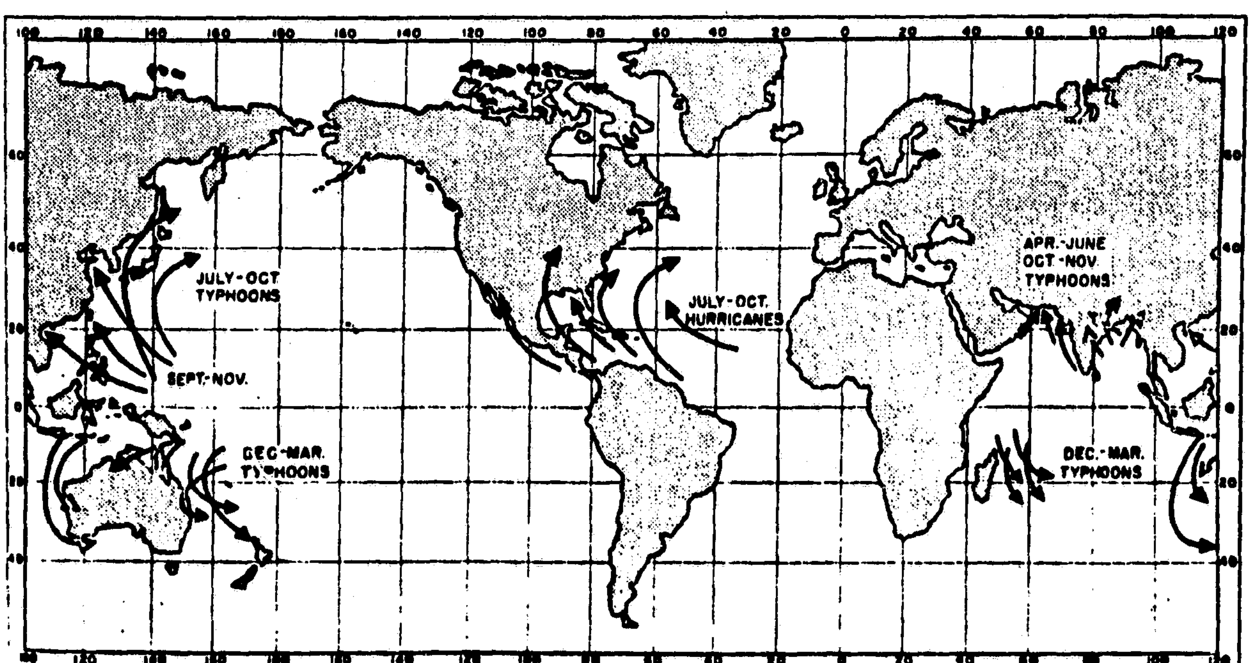


Figure 3-1. Typical Hurricane and Typhoon Tracks

D. OBSERVATION AND COVERAGE REQUIREMENTS

1. The orbit should be ~ 250 NM (472 Km) to achieve adequate frequency of coverage (i.e., Swath Width) of evolving storms. A lower orbit (160 NM or 296 Km) may be usable but will be marginal. Inclination must be low (e.g., 28° or less) to assure fill-in between adjacent swaths at the latitude of interest.

2. There are three regions of interest for coverage, as seen on Figure 3-1. Data should be taken as the orbit track goes from about 20° North (or South) latitude through 28° and back to 20°; about a quarter of an orbit. Typically, this will occur about once per orbit; i.e., in general when data is available in the Atlantic, the Pacific and India Oceans are not accessible, etc. Data can be taken day or night, on either ascending or decending modes. Since the sensors were designed for an automated satellite, there should be no problems in having automatic operations to allow for crew rest.

3. Various instruments will view the earth from nadir to 69° off nadir (i.e., 26° down from local horizon). The scatterometer will look out both sides over a wide swath, and should be able to pivot its nominal line of sight by ± 5 deg. The SAR should be capable of looking to either side of the flight path at a nominal off nadir angle of 23°, adjustable ± 13° SMMR will scan on one or both sides of the flight path in a cone that goes from in front of the Orbiter position to 69° off nadir either side.

E. SENSOR REQUIREMENTS

1. Sea Surface Temperature. This parameter is obtained from an instrument like SMMR, to fly on Nimbus-G and Seasat-A. It could be modified to use a larger aperture - lower frequency to make the surface temperature less sensitive to surface wind speed. An 30 cm scanning aperture is needed.

2. Wind Speed and Direction. This will be measured over the areas of interest with a Seasat type scatterometer. Four beams, two on each side of the ground track must be formed to measure this parameter. It is desirable to be able to bias this pattern either to the right or to the left to favor the desired coverage area, but only a small amount can be allowed before the signal becomes unusable. In addition, the sensor should be rotated about yaw to keep the footprint constant in view of the earth rotation.

3. Sea State. This condition is sensed by a GEOS-C/Seasat-A type radar altimeter. This instrument must be kept nadir looking to < 0.75 deg. It can provide altitude information (to bias yaw rotation) eliminating altitude variation affects for the scatterometer and the SAR. It can also provide, if useful, a measure of the total off nadir error, but without any indication of how this error is distributed between roll and pitch.

4. Wave Spectra. This measurement is made by a synthetic aperature radar (SAR). This instrument is characterized by a very large aperture, ~30 m^2 area. It should be pointed to either side of the ground track at an angle of from 10^o to 36^o from nadir. The FOV is about 10^o across the track so most of this represents a steering requirement.

5. Storm Imagery. This measurement is needed to allow correlation between what is seen in the optical and IR bands with data from the microwaves. This can be done with a scanning radiometer (SR). This is a line scanner with a horizon to horizon capability. It is nadir looking and fixed.

COMMUNICATION/NAVIGATION-ELECTROMAGNETIC ENVIRONMENT EXPERIMENT

A. JUSTIFICATION

1. Radio frequency spectrum occupancy is experiencing an exponential growth, and there is an increasing possibility of interference at frequencies allocated for space use. The Shuttle/Spacelab provides an opportunity to develop space-monitoring EE capability that will prove valuable both to NASA as a spectrum user and to government regulatory agencies.

2. The primary objective of the EEE is to measure and characterize electromagnetic environment interference by establishing a capability for continuous RF spectrum monitoring and electromagnetic environment mapping from space in the frequency range of 0.4 to 40 GHz. An objective of the Shuttle/Spacelab experiment is to determine the feasibility of monitoring earth-based interference from space and to establish techniques for measurement, storage, and processing of data.

B. READINESS

The MMAP/Electromagnetic Environment Experiment (EEE) utilizes an antenna/receiver assembly defined and sized for stowing in the pallet bay area of the Shuttle. Mission profiles have been determined for a 400 Km altitude, 57^{o} inclination angle, circular orbit. Viewing time over seven geographical areas have been studied.

C. MISSION REQUIREMENT

The EEE requires only that the Shuttle fly inverted with the EEE antenna boom pointed at nadir at all times, with a nominal angular accuracy of $\pm 2^{o}$ for each coordinate for normal operating modes. All selectable angle coverages are adequately provided by hinged or flexible joints on the EEE antenna assembly and do not reflect any additional requirements on the Shuttle or pallet; resolutions and geometrical distortion correction are also handled within the EEE system without imposing requirements on the Shuttle or pallet (beyond those normally supplied such as ephemeris data). Calibration of the EEE system will be achieved via ground based beacons, with Shuttle ephemeris and pointing data. Data processing in the EEE provides system calibration information with the desired accuracy.

1. Swath and Orbit Parameters. The EEE system imposes no special requirements on the pallet. As long as the antenna boom is directed at Nadir, the additional directing requirements are accomplished entirely by the EEE antenna mount hinged and/or flexible joints. The swath at any one time is a function only of the EEE antenna direction and scanning, and does not reflect into the EEE mounting/pallet interface. Data are used within the EEE system to determine locations of "targets", requiring a cable from the EEE Upper Antenna Assembly (UAA) to the Spacelab EEE processing equipment for signal transfers.

2. Calibrations. The EEE system will provide its own ground-based beacons for calibrating the antenna pointing subsystem. The accuracy required is quite nominal for the normal EEE operation - generally up to $\pm 2^{o}$ is tolerable. A knowledge of the Shuttle ephemeris and pointing will then permit corrections to be included in the EEE data by referencing directly to the antenna platform. Shuttle pointing changes during operation after the calibration process should be provided to the EEE but this is not a function unique to the pallet configuration. Geometric corrections for earth curvature effects, propagation distortions, and any other distortions will be corrected within the EEE data processing subsystem and does not reflect on the Shuttle or pallet.

3. Ancillary Measurements. Absolute location of a "target" source detected by the EEE system requires antenna position information as determined from the servos, with correction applied from the calibration procedures, and updated by changes in the Shuttle/pallet pointing and ephemeris information. The supporting measurements required from the Shuttle are the changes in pointing, once the initial conditions of pointing are accounted for in the EEE system, and ephemeris update which would also be tied in with the determination of a calibration correction factor.

D. SENSOR REQUIREMENT

The sensor for this mission is the EEE system mounted on a pallet. The pallet is required to provide only a firm base for the Upper Antenna Assembly and basic pointing and ephemeris data which can be improved as required with the EEE calibration subsystem.

COMMUNICATION/NAVIGATION-ADAPTIVE MULTIBEAM PHASED ARRAY (AMPA) EXPERIMENT

A. JUSTIFICATION

1. The Adaptive Multibeam Phased Array (AMPA) experiment offers great operational versatility for a number of diverse applications. With the ability of Space Shuttle to accommodate payloads of several thousand kilograms and several hundred cubic meters, many sophisticated antenna systems formerly used only for ground, sea, and airborne applications can now be realistically considered for use in space. The most versatile of these antenna systems is the adaptive multibeam phased array.

2. Three AMPA experiments were selected for conducting meaningful experiments on Spacelab from a large number of applications missions considered in the fields of communications, radar, and radiometry. The three selected experiments are the L-band Communications Experiment, the L-band Radiometer Experiment, and the Ku-band Communications Experiment. The purpose of these experiments is the flight demonstration of an Adaptive Multibeam Phased Array (AMPA) antenna system having high operational potential.

B. READINESS

1. The Adaptive Multibeam Phased Array (AMPA) was chosen as the preferred antenna system for conducting the selected experiments over multibeam reflector and lens antenna systems because of its greater versatility and its ability to better meet the antenna performance requirements. The AMPA antenna system on Spacelab is integrated for the greatest commonality of equipment consistent with the experiment objectives. A single L-band phased array is used for both the L-band Communications Experiment at 1.5/1.6 GHz and the L-band Radiometer Experiment at 1.4 GHz, with much of the RF circuitry shared by both experiments. Separate phased arrays are used on transmit and receive for the Ku-band Communications Experiment at 12/14 GHz because of the greater frequency separation and bandwidth. The adaptive processing and beam control equipment is shared by all three experiment, as is the on-board data processing equipment. A data link between the Shuttle/Spacelab and ground via the Tracking and Data Relay Satellite (TDRS) system is assumed for experiment coordination.

2. The users for the L-band Communications Experiment would be small shipboard terminals, or possibly buoys specially instrumented for an adaptive multibeam data collection experiment at L-band. The users for the Ku-band Communications Experiment would be medium size ground terminals. For the soil moisture measurements in the L-band Radiometer Experiment, gross water sheds would be observed in mountainous regions as well as the water content of valleys and plains.

C. MISSION REQUIREMENTS

1. The basic AMPA mission requirements are that the Space Shuttle fly inverted with the AMPA antenna system pointed toward nadir, with a nominal pointing accuracy of 0.5° for normal communications and radiometer experiment operations. This pointing accuracy can be relaxed to 2° for merely establishing communications, since adaptive beamforming is employed, but the 0.5° accuracy is desired for experimental evaluation of the adaptive beamforming performance. The 0.5° accuracy is desired for the radiometer experiment to obtain more accurate mapping.

2. For other operational modes, such as aiming the AMPA antenna system for coverage to one side of the ground track and then the other on two or more segemented passes over a given user area, provision for tilting the AMPA antenna system would be made in its mounts. No additional requirements are thus placed on the Spacelab pallet for such operations.

3. The L-band Communications Experiment is intended to demonstrate the feasibility of low power, point-to-point communications via low orbiting spacecraft using narrow beams. Low power cooperating shipboard terminals having near hemispheric overhead coverage and operating at the maritime L-band communications frequencies are assumed for the experiment. The key measurement parameters are acquisition time, track accuracy, S/N at Spacelab, doppler compensation, receiver signal quality, and interference cancellation ratio.

4. The L-band Radiometer Experiment is intended to demonstrate the feasibility of radiometric soil moisture measurement from low orbiting spacecraft using multiple narrow beams. The key measurement parameters are beam control versus sequence, optimum beam stepping dwell time, temperature reading and calibration, temperature resolution, and determination of the optimum combination of beams and receivers.

5. The Ku-band communications experiment is intended to demonstrate the feasibility of low power, wideband, point-to-point communications via low orbiting spacecraft using narrow beams and to demonstrate the feasibility of frequency re-use by means of adaptive dual polarization. Moderate power cooperating ground terminals of moderate gain (40 to 50 dB) that will track Spacelab are assumed for the experiment. The key measurement parameters are acquisition time, track accuracy, S/N at Spacelab, doppler compensation, received signal quality, interference cancellation ratio, and dual polarization isolation.

6. From these requirements, the following mission requirements are obtained:

	Communications	Radiometry
• Swath width	± 350 Km	± 350 Km
• Along track coverage	35 Km	35 Km
• No. of targets per orbit	2 to 12	N/A

	Communications	Radiometry
• Offset Pointing	0° (Normal Mode) ± 30° (Alternate Mode)	0°
• Altitude	400 Km	400 Km
• Spatial Resolution	35 Km	35 Km
• Geometric Accuracy (% of Resolution)	4 Km	4 Km
• Calibrations Provided by:	Cooperating Users	Earth
• Ancillary Measurements	(1) Ephemeris Data (2) Data link via TDRS	Ditto Ditto
• Special Instruments	Data Recording	Ditto

D. SENSOR REQUIREMENTS

The sensor required for this experiment is the AMPA antenna system. The antenna performance requirements for the three selected AMPA experiments are given in the following table:

Table 3-1. Summary of Antenna Performance Requirements

Parameter	L-band Communications	L-band Radiometer	Ku-band Communications
Transit Frequency, GHz	1.54	N/A	12
Freceive Frequency, GHz	1.64	1.4	14
Bandwidth, MHz (each band)	20	50	500
Minimum Antenna Gain, dB	27	27	27
-3 dB Beamwidth, degrees	5	5	5
Number of Independent Receive Beams	2	4	2
Number of Corresponding Transmit Beams	2	N/A	2
Beam efficiency (in main beam), %	N/A	85	N/A
Coverage Angle Rel. to Nadir, degrees	±40	±40	±40
Beam Steering Method	Adaptive Control	Program Controlled	Adaptive Control
Beam Pointing Accuracy, degrees	0.5	0.5	0.5
Beam repositioning time, millisec.	N/A	0.1	N/A
Maximum Sidelobe Level, dB	-20	-20	20
Transmit Polarization	RH circular	N/A	R&L circ. or Dual 4 in.
Receive Polarization	LH circular	Dual Linear	Orthog. to Tx
Transmitter Power, Watts	10	N/A	10
Signal Acquisition Time, sec.	<5	N/A	<5
Signal Tracking Rate, degrees/sec.	>1	N/A.	>1

TECHNIQUE/SENSOR TECHNOLOGY DEVELOPMENT-REMOTE SENSING SOIL MOISTURE

A. JUSTIFICATION

1. There is a definite need for soil moisture data in a number of different areas: e.g. agriculture, water resources management, meteorology, and land management.

2. There is considerable support within the scientific community for the development of techniques for remotely sensing of soil moisture.

B. READINESS

1. Research suggests that there are three basic wasy in which remote sensing might be applied to obtain soil moisture data:

   a. Polarimeter measurement

   b. Spectral analysis

   c. Microwave measurement

2. At present, none of these approaches can be considered operational; however, they are mature enough in terms of being based on sound analytical models and fairly-well-developed instruments so that they can be realistically considered for a soil moisture technique development mission.

3. Comments about the three methods:

   a. Polarimeter measurement:

      (1) A photo polarimeter may be designed with a small FOV yielding the fine spatial resolution required by some soil moisture applications.

      (2) Current instruments are "single spot" types; however, mechanical scanning can provide wide-area coverage, and the emergence of photodiode arrays allows solid state imaging sensors to be developed.

      (3) Several unknown areas must be investigated before this approach may be considered:e.g. operation over vegetative cover, operation with multiple spectral band coverage, and determination of sensitivity to viewing angle in the principal plane.

      (4) One very encouraging result noticed to date in measurements over bare fields was a lack of sensitivity to soil type. Due to its reliance on sunlight as a source of illumination, however, this approach suffers from all of the classical drawbacks of other optical or spectral systems, and must have clear atmospheric conditions and operate in daylight.

b. **Spectral analysis:**

(1) Two methods are possible: spectral reflectance in the region from .4μm to 2.0μm; and measurement of diurnal temperature differences using the far IR (10μm).

(2) Both methods can be implemented through the use of a multispectral scanner such as the Thematic Mapper. The diurnal ΔT approach can also use imaging IR radiometers to make the measurement.

c. Microwave measurement:

Three types of sensors are possible: scatterometer (active); imaging radar (active); and microwave radiometer (passive).

C. MISSION REQUIREMENTS

1. Development of individual techniques for remotely sensing of soil moisture.
2. Evaluation of the improvements to be derived as a result of using the different individual techniques in a complementary manner.

D. OBSERVATION AND COVERAGE REQUIREMENTS

1. In order to accomplish the objectives of the mission and to gather data for as wide a range of soil moisture conditions as possible, several flights of the proposed types of sensors should be made at different times of the year.
2. Each flight must be closely correlated with extensive ground truth and aircraft underflights.
3. At least one flight must be made during each season in order to gather data under different weather and vegetative cover conditions.

E. SENSOR REQUIREMENTS

1. The sensors required for the mission consist of those sensors which in existing experiments have shown realistic promise of providing measurements relatable to soil moisture. Four major sensing methods have shown promise of being able to indicate soil moisture content, either alone or in combination with others. These are as follows: optical polarization; multispectral signature; passive microwave radiometry; and active microwave scatterometry. High resolution, large aperture, microwave scatterometry requires a sensor such as the Synthetic Aperture Radar (SAR).
2. Sensors selected for the soil moisture mission are shown in Table 3-2.

Table 3-2. Soil Moisture Mission Sensor Requirements

	Polarimeter	Thematic Mapper	SIMS	SAR
Instantaneous Field of View	1^{o}	30 Rad (15 meters)	1.1 to 17^{o}, depending on frequency	40-100 Km
Total Field of View	Spot Scan within $\pm 60^{o}$ of nadir	60 Km	$\pm 60^{o}$ of nadir	TBD

A spot photo-polarimeter of the type currently being flown on the NASA CV-990 aircraft, the Thematic Mapper proposed for Landsat D, the Shuttle Imaging Microwave Sensor (SIMS) and a Synthetic Aperture Radar will be required operating simultaneously in order to develop a technique for sensing soil moisture from space.

F. ORBIT PARAMETERS

1. The orbit should be such that a short revisit cycle, on the order of a couple of days, is obtainable to assess temporal effects.

2. The flight must have a nominal orbit inclination ($\sim 35^{o}$) sufficient to include calibration of well-instrumented test sites such as swamps, deserts, and controlled fields, bare, vegetated, irrigated, etc.) at an altitude compatible to the Space Shuttle capability ($\sim$120 to 240 NM).

3. The test sites (swamp, desert, bare soil, etc.) will be located throughout the continental US and therefore will require localized data taking over small designated areas.

4. a. The SIMS with a 60^{o} field of view in the crosstrack direction will require no platform pointing.

   b. The SAR is limited to a pointing angle of 15^{o} to 25^{o} off nadir and the assumption here is that all the targets will be selected on the one side of the SAR. Therefore no pointing of the Shuttle or platform will be required (the antenna provides its own pointing capability).

   c. The polarimeter scans from horizon to horizon ($\pm 60^{o}$) off nadir, therefore, no platform pointing is required.

   d. The Thematic Mapper will require pointing out to $\pm 25^{o}$ off nadir with no stringent slewing requirements.

TECHNIQUE/SENSOR TECHNOLOGY DEVELOPMENT-LIDAR SENSOR DEVELOPMENT MISSION

A. JUSTIFICATION

1. A LIDAR sensor would benefit in its development from a Shuttle flight. The first flight test of the sensor would demonstrate the performance of critical components, such as the laser and the image motion compensator, demonstrate and help in the development of the data interpretation and inversion techniques, and demonstrate a solar occultation measurement which cannot be simulated.

2. Based on the sensitivity obtained from the measurement of one or two species, calculations could be made of the LIDAR sensitivity for a large number of other atmospheric species.

3. A LIDAR sensor with range gating could provide directly an altitude profile of the species being measured. In both MAPS and CIMATS, operating in the thermal infrared, the altitude profile is obtained; but it is strongly dependent on the chosen weighting function. Measurements made with CIMATS in the solar infrared provide a total column density and not an altitude profile. LIDAR provides this information directly, thus increasing the value of the Pollution missions.

B. READINESS

The LIDAR sensor is in the conceptual consideration stage, and most of the parameters are not defined yet. It is included in this study, however, since it represents an experiment requiring high stability.

C. MISSION REQUIREMENTS

1. Swath Width: 0.2/0.6 Km
2. Along Track Coverage: 0.2/0.6 Km
3. No. of Targets per Orbit: Continuous measurement.
4. Offset Pointing Angle: Not necessary but useful if available.
5. Altitude: 200/600 Km
6. Resolution: 0.2/0.6 Km
7. Geometric Accuracy (% of Resolution): Not available.
8. Calibration Requirements (Special View Directions): To be determined.
9. Ancillary Measurement Requirements: To be determined.

D. SENSOR REQUIREMENTS

The LIDAR is a laser system operating in the pulsed mode. The laser operates in the infrared region of the electromagnetic spectrum. Proper selection of the laser system and the specific laser lines might permit the measurement of more than one gaseous species simultaneously. Operation of the instrument for both day and night coverage is possible.

SECTION 4

SENSOR DESCRIPTIONS

SECTION 4

SENSOR DESCRIPTIONS

The sensors identified in the previous section are described in the following pages. Some of the sensors are existing operational sensors while others are either under active development or in the conceptual consideration stage. The best available information is compiled for this study.

4.1 THEMATIC MAPPER

The Thematic Mapper provides high resolution imagery from the visual through the thermal infrared spectral bands with high radiomatric accuracy. It is a line scan device that mechanically scans in a direction normal to the flight velocity vector. It contains seven spectral bands from 0.4 to 12.6 microns. The swath width is limited due to signal-to-noise ratio and data rate considerations. An off-nadir pointing capability of approximately ± 20 degrees is provided. Each spectral band has an array of 20 detectors (with the exception of the thermal IR band which has only 5) which scan over a cross-scan angle of 14 degrees. The scan rate is controlled based upon the vehicle orbital velocity (or altitude) such that the scan time per line is compatible with the distance travelled during that time for contiguous ground coverage.

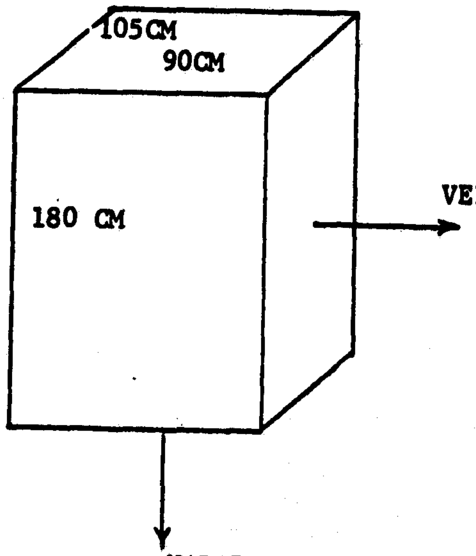
The Thematic Mapper is currently in the breadboard design phase of development. Three contractors have proposed three inherently different scanning concepts for the EOS mission application. Two of the concepts, the Image Plane Conical Scanner (Honeywell) and the Object Plane Linear Scanner (Hughes) are used as a basis for the performance parameters shown.

THEMATIC MAPPER PARAMETERS

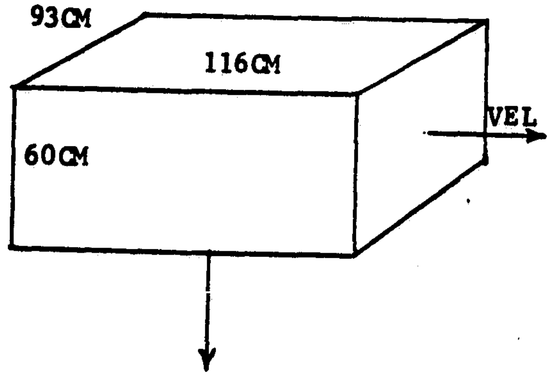
Size, cm	
Conical Scanner	180 x 105 x 90
Linear Scanner	116 x 93 x 60
Weight, Kg	
Conical Scanner	173
Linear Scanner	180
Angular IFOV, Microradians	60 (185-330 KM ALT) 43 (330-740 KM ALT)
Scan Angle, Degrees	14
Off-Nadir Pointing, Degrees	± 20
Total View Angle, Degrees	
Conical Scanner	55 Cross Track 19 Forward of Nadir Along Track
Linear Scanner	55 Cross Track 2 Along Track
Time per Scan Line, Milliseconds	44.3
Dwell Time per IFOV, μ sec	7.14
Number of Detectors per Band	20 (Bands 1-6) 5 (Band 7)
Cooling Requirement	$100^{o}K$
Operating Time/Orbit	15 minutes
Angular Momentum Compensation	0.2 Ft. Lb. Sec. (Residual Disturbance)

THEMATIC MAPPER

CONICAL



LINEAR



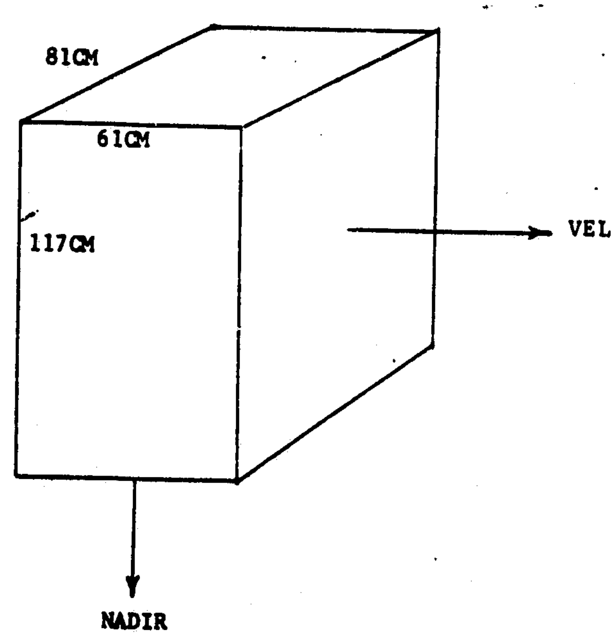
4.2 LARGE FORMAT CAMERA

The large format camera provides high resolution, large area coverage in the visual and near infrared spectral bands (0.4 - 0.9 μm). It provides hard copy return and can be used for stereo photography. The performance parameters as indicated are based upon a modification of an Itek design for a precise metric camera. The capability for changing lenses with 12", 18", and 24" focal lengths on a mission basis is included. The parameters shown are for the 12" focal length optic.

LARGE FORMAT CAMERA PARAMETERS

Size, cm	
Camera	81 x 61 x 117
Power Conditioner	15 x 43 x 51
Control Electronics	30 x 43 x 69
Weight, Kg	
Camera	136
Power Conditioner	11
Control Electronics	34
Format Size, Inches	9 x 18
Photographic Performance, lp/mm	
3414 Film, On-Axis	
High Contrast (6.3:1)	100
Low Contrast (2:1)	85
View Angle, Degrees	40 Cross Track 80 Along Track
Exposure Time, Seconds	1/50 to 1/500
V/h Range, mrad/sec	10 to 35
Framing Rate, sec/frame	10 to 45
Operating Time/Orbit, Minutes	10

LARGE FORMAT CAMERA



4.3 SYNTHETIC APERTURE RADAR (SAR)

The SAR is a two-frequency (X and L Band) instrument operating with dual polarization in both frequencies. Transmitted power (peak) is 6.8 KW (L-Band 1.04 GHz) and 17 KW (X-Band 9.0 GHz). Clutter tracking is used to ease Shuttle pointing requirements. A nominal ground resolution of 25 meters is obtained with a maximum swath width on the ground of 100 Km within a possible 290 Km illumination range at angles of $20^{\circ} \pm 5^{\circ}$ off nadir (either side of the track). Processing and recording of the data is performed digitally; the data rate is variable with an upper limit of 480 Mb/sec at maximum resolution (~ 6 meters).

SAR PARAMETERS

Size: 10 x 3.1 meters

Weight: 1248 Kg

Total Ground Swath Width: 290 Km

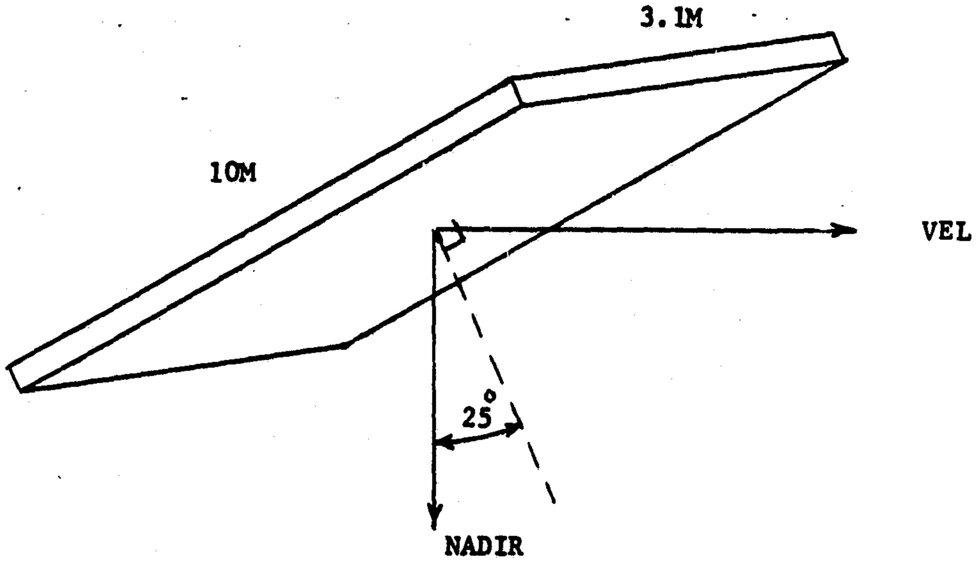
Instantaneous Swath Width Imaged: X-Band - 70 Km
L-Band - 100 Km

Ground Resolution: X-Band - 12.5 meters
L-Band - 25 meters

Angular Coverage: 20° off nadir $\pm 5^{\circ}$

Orientation Requirement: 20° off Nadir viewing

SAR



4.4 S-190B - EARTH TERRAIN CAMERA

The S-190B Camera is a cartographic framing type camera for the production of metric imagery. This camera has an 18 inch focal length lens and provides approximately 5 meter ground resolution from an altitude of 440 Km with EK 3414 black and white film. The area of coverage on the ground from 440 Km altitude is about 110 Km square. The film capacity of the camera is 5 inches by 200 feet.

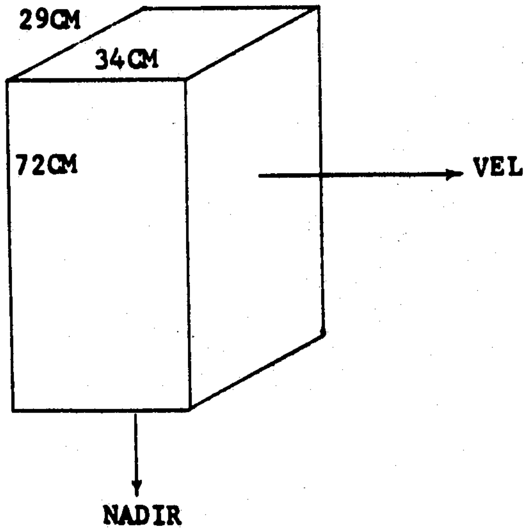
When used for the U.S. Census mission, the resolution and scale provided by this camera are adequate for planning purposes and for map revision with scales of 100,000 to 10,000,000.

When used for the timber volume inventory mission, the resolution and scale provided by this camera are adequate for the initial estimate of timber volume by use of photo-interpretive techniques.

S-190B PARAMETERS

Size, cm	29 x 34 x 72
Weight, Kg	36.4
Format Size, inches	4.5 x 4.5
Photographic Performance 3414 Film, on-axis High contrast	115 lp/mm
View Angle, Degrees	14 x 14
Exposure Time, seconds	1/100, 1/140, and 1/200
V/h Range, mr/sec	0 to 25
Framing Rate, Frames/min	0 to 25

S-190 B



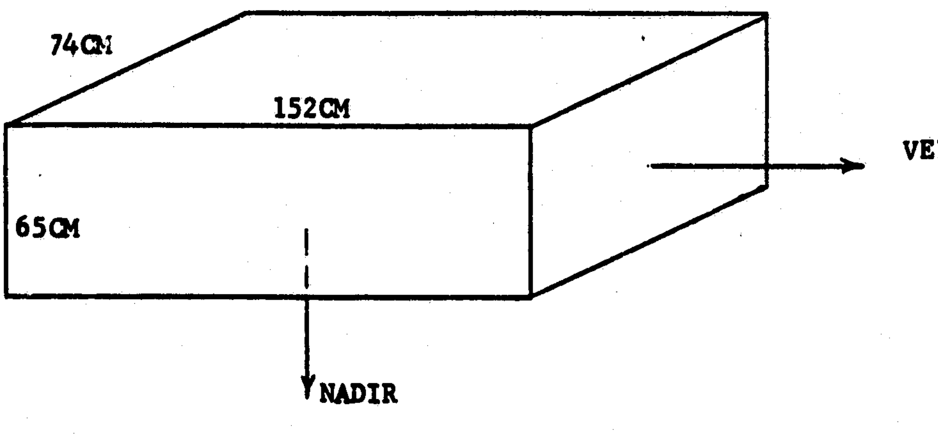
4.5 S-163 - OPTICAL BAR PANORAMIC CAMERA

The S-163 optical bar camera provides high quality stereo photography over a large area. The camera provides relatively high resolution but is most desirable because of its ability to provide a very wide swath which allows correlation of the images of sensors with smaller fields of view to the adjacent terrain. With a 24 inch focal length lens this camera can provide about 6 meter resolution from a 440 km altitude and when used in the U.S. Census mission can allow delineation of urban areas and location of new roads and development.

In the optical bar system, the lens continuously rotates 360 degrees, with imagery recorded a specified number of degrees ($\pm 60^{o}$) on either side of vertical. Although film motion across the image plane is intermittent, the film supply and take-up spools revolve continuously. Continuous rotation of the lens and film spools reduces operating power and eliminates stop-start perturbations that would degrade photography.

S-163 CAMERA PARAMETERS

Size, cm	152 x 65 x 74
Weight, Kg	185
Format Size, inches	45.2 x 4.5
Photographic Performance, lp/mm	65
View Angle, Degrees	108 Cross-Track 11 Along-Track
Exposure Time, Milliseconds	0.35 to 29.0
V/h Range, mrad/sec	10 to 19
Framing Rate, sec/frame	4.7 to 8.9



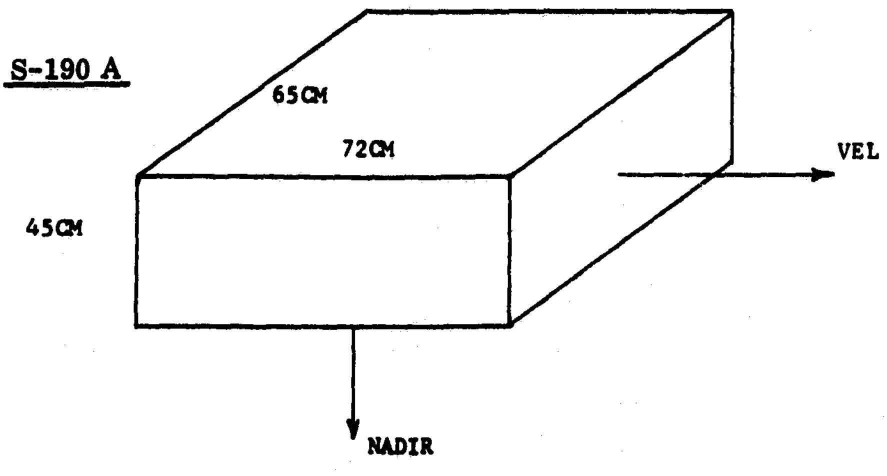
4.6 S-190A - MULTISPECTRAL CAMERA

The S-190A Camera is a high resolution, boresighted, metric quality camera array that simultaneously takes six registered photographs in the 0.4 to 0.9 micrometer spectral band. Stereo imagery can be obtained for height estimation and direct hard copy output minimizes data storage requirements and ground data processing. The performance parameters as indicated are based upon the Skylab camera designed and fabricated by Itek. Provision for a camera pointing mechanism in roll axis is required to allow photographing of off-Nadir targets outside the ± 10° camera field of view.

S-190A CAMERA PARAMETERS

Size, CM	
Camera	45 x 65 x 72
Control & command electronics	31 x 46 x 46
Weight, Kg	
Camera	109
Control & command electronics	34
Format Size, inches	2¼ x 2¼
Photographic Performance, lp/mm	
3414 Film, on-axis	
High contrast (6.3:1)	103
Low contrast (1.6:1)	62
Photographic Field, degrees	20 x 20
View Angle, degrees	40 cross track 25 along track
Exposure Time, MSEC	2.5,5, and 10
V/h Range, mrad/sec	10 to 35
Framing Rate, sec/Frame	2 to 32
Operating Time/Orbit, minutes	10

S-190 A



4.7 MONITORING AIR POLLUTION FROM SATELLITES (MAPS)

MAPS is a gas filter correlation analyzer operating in the thermal infrared. It is planned to measure in this spectral region carbon monoxide, methane, and formaldehyde. These measurements are made continuously to provide day and night coverage.

MAPS PARAMETERS

Size: Electronics ; Sensor with telescope
32 x 32 x 20 cm; 50 x 37 cm diam.

Weight: 43 kg (no separate component data available)

Cooling Requirements: Thermoelectric cooling

Total Angular Coverage: 7 deg.

Instantaneous Angular Field of View: 7 deg.

Look Angle Limitations: Should not view sun directly

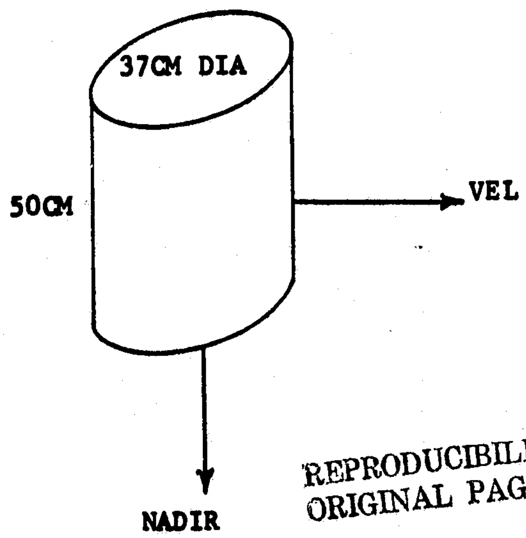
Operational Altitude Limitations: None

Orientation Requirements: Nadir viewing

Scan Rate: Continuous measurement

Calibration Requirements: Internal to sensor

MAPS



4.8 CORRELATION INTERFEROMETER FOR MEASUREMENT OF ATMOSPHERIC TRACE SPECIES (CIMATS)

CIMATS is a two-channel interferometer, one operating in the non-thermal infrared (2 to 2.4 μm) and the other in the thermal infrared (4 to 9 μm). Each channel is capable of containing 5 narrow band filters, thus providing the capability of making ten different spectral measurements. The non-thermal infrared channel uses reflected sunlight and thus provides only day-time coverage. The thermal infrared channel operates continuously to provide day and night coverage.

CIMATS PARAMETERS

	Sensor Box	7° Telescope	Electronics
Size:	60 x 35 x 38 cm;	36 x 18 cm diam.;	50 x 50 x 20
Weight:	27 kg	5Kg	9Kg

Cooling Requirements: Thermoelectric cooling for detectors

Total Angular Coverage: 7 deg.

Instantaneous Angular Field of View: 7 deg.

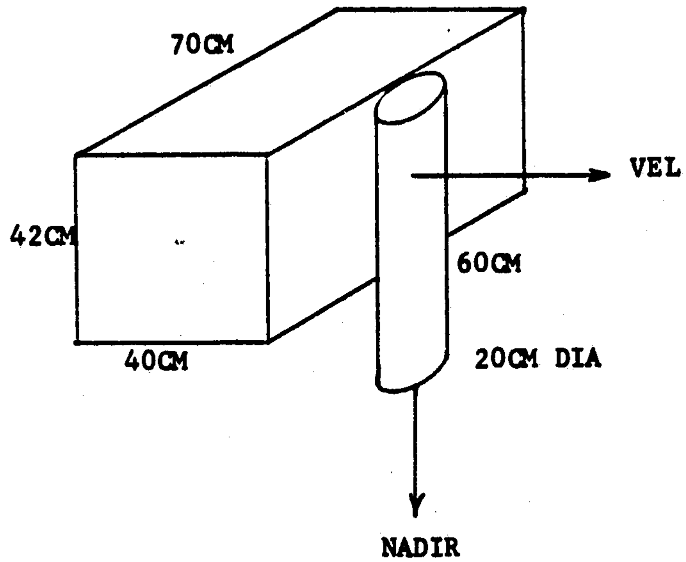
Look Angle Limitations: Should not view the sun directly

Operational Altitude Limitations: None

Orientation Requirements: Nadir viewing

Scan Rate: 1 frame/second

Calibration Requirements: Internal to sensor



4.8 TEMPERATURE HUMIDITY INFRARED RADIOMETER (THIR)

THIR is a two-channel scanning radiometer designed to measure earth radiation. A 10.3 μm to 12.5 μm (11.5 μm) window channel provides an image of the cloud cover, and temperatures of the cloud tops, land, and ocean surfaces. A 6.5 μm to 7.1 μm (6.7 μm) channel provides information on the moisture content of the upper troposphere and stratosphere, and the location of jet streams and frontal systems. Both channels operate continuously to provide day and night coverage.

The THIR consists of an optical scanner and an electronics module. The scanner uses an elliptically shaped plane scan mirror and primary optics, which are common to both channels. The scan mirror, set at an angle of 45 degrees to the scan axis, rotates at 48 rpm and scans in a plane perpendicular to the direction of the satellite velocity vector.

THIR PARAMETERS

	Sensor Optics	Electronics
Size:	17 x 17 x 40 cm;	15 x 15 x 15 cm

Weight: 9 kg (no separate component data available)

Cooling Requirements: None

Total Angular Coverage: $\pm 60^\circ \times 1.17^\circ$ for 6.7 μm channel
$\pm 60^\circ \times 0.43^\circ$ for 11.5 μm channel

Instantaneous Angular Field of View: $1.17^\circ \times 1.17^\circ$ for 6.7 μm channel
$0.43^\circ \times 0.43^\circ$ for 11.5 μm channel

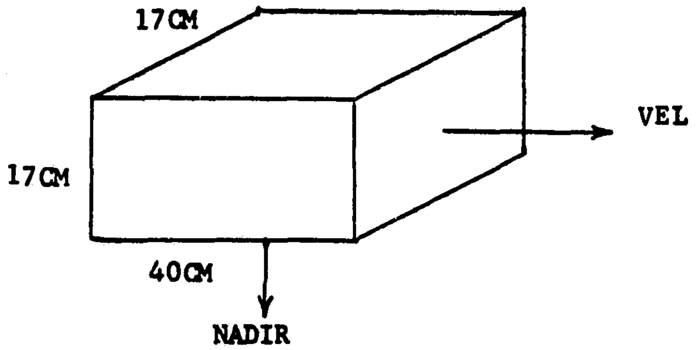
Look Angle Limitations: Should not view the sun directly

Operational Altitude Limitations: None

Orientation Requirements: Nadir viewing

Scan Rate: 48 scans per sec., horizon to horizon across the track

Calibration Requirements: Sensor must see clear space once per scan



4.9 LOWER ATMOSPHERIC COMPOSITION AND TEMPERATURE EXPERIMENT (LACATE)

LACATE is designed to determine the vertical distribution of certain atmospheric constituents and temperature on a global scale from the upper troposphere through the stratosphere and into the lower mesosphere. This instrument is scheduled for flight on Nimbus-G. The experiment calls for measurements to be made in each of nine bands in the 6.2 - 17.5 μm spectral interval. A programmed scanning mirror causes the fields of view of the detectors to make a vertical scan across the Earth's horizon. Azimuth coverage is obtained by commanding the scanning mirror to desired azimuthal pointing directions.

LACATE PARAMETERS

	Sensor Optics	Cooler
Size:	15.7 x 37 cm diam.;	67 x 35 cm diam.
Weight:	28 kg	49 Kg

Cooling Requirements: 65°K

Total Angular Coverage: +6°, -5° vertical horizon scan
±45° horizontal scan

Instantaneous Angular Field of View: 0.014° x 0.286°;
0.028° x 0.143°;
0.057° x 0.143°.

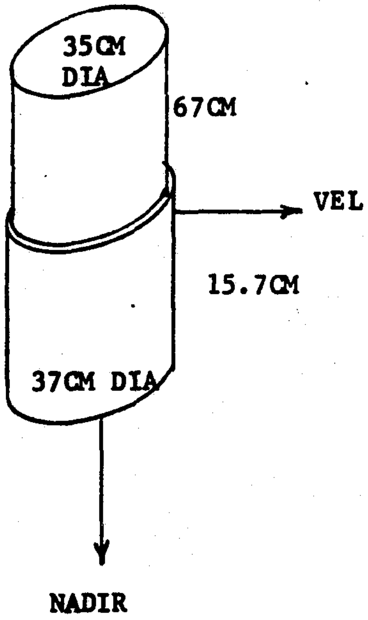
Look Angle Limitations: Should not view the sun directly.

Operational Altitude Limitations: None

Orientation Requirements: Horizon viewing.

Scan Rate: 0.125 sec/scan

Calibration Requirements: None



4.10 SOLAR BACK SCATTER ULTRAVIOLET - TOTAL OZONE MAPPING SPECTROMETER (SBUV-TOMS)

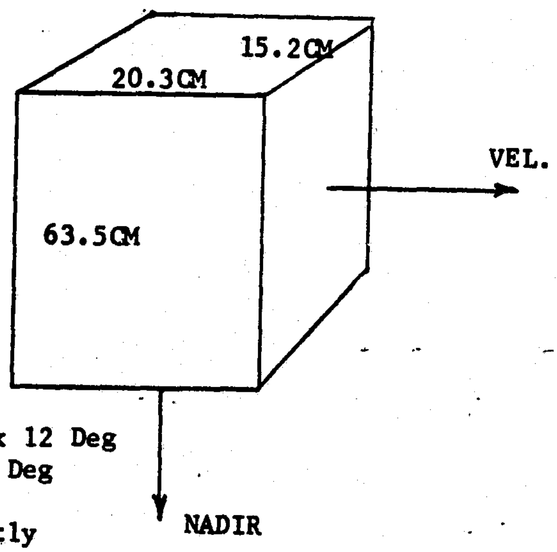
The SBUV-TOMS is a combination of two instruments which measure the vertical and spatial ozone distribution. This instrument is scheduled for flight on the Nimbus-G vehicle.

The UV spectrometer measures solar ultraviolet that is back scattered by the Earth's atmosphere at 12 wavelengths between 2500 Å and 3400 Å with a spectral bandpass of 10 Å. The instrument FOV of 0.21 radians is directed at nadir. A parallel photometer channel at 3800 Å measures the reflectivity of the lower boundary of the atmosphere in the same 0.21 rad FOV. The UV spectrometer has a second mode of operation that allows a continuous spectral scan from 1600 to 4000 Å for detailed examination of the extra-terrestial solar spectrum and the earth radiance spectrum and their temporal variations.

The ozone mapper, operated in parallel with the UV spectrometer, has a step scan across the orbital track. At each scan position the earth radiance is monitored at four wavelengths between 3100 and 3400 Å, and at 3800 Å to infer the total ozone amount.

SBUV-TOMS PARAMETERS

SBUV-TOMS



Size: Sensor - 63.5 x 15.2 x 20.3 cm
Electronics - 16.5 x 15.2 x 20.3 cm

Weight: Sensor - 15.5 Kg
Electronics - 4.5 Kg

Cooling Requirements: None

Total Angular Coverage: SBUV - 11.3 x 12 Deg
TOMS - 3 x 90 deg

Instantaneous Angular Field of View: SBUV - 11.3 x 12 Deg
TOMS - 3 x 3 Deg

Look Angle Limitations: Should not view sun directly

Operational Altitude Limitation: None

Orientation Requirement: Nadir Viewing

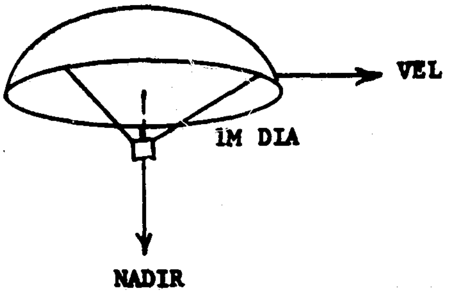
Scan Rate: SBUV - 96 sec. spectral scan (continuous)
TOMS - 3.25 sec/line

Calibration Requirements: Solar view with diffuser plate

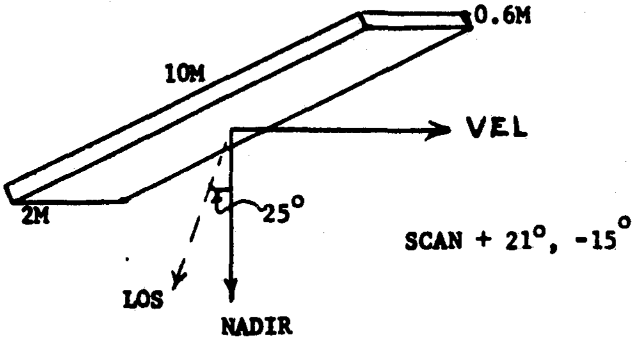
TROPICAL STORM RESEARCH MISSION

SENSOR PARAMETERS	ALT	SAR	SCAT	VIRR	SMMR
Size					
Antenna	1 m Dish	3 x 10 m	(4 ea) 3 m x 0.17 m x 0.15 m	N/A	0.8 m dish
Electronics	32 x 25 x 64 cm	100 x 80 x 20 cm	100 x 41 x 35 cm	21 x 16 x 24 cm	3 ea. 15 x 20 x 30 cm
Weight					
Antenna (Kg)	3		55	N/A	15.1
Electronics (Kg)	67	75	80	10	22.6
Cooling Requirements	None	None	None	None	None
Total Angular Coverage	1.5^{o}	$10^{o} \times 1.2^{o}$	$25^{o} \times 0.5^{o}$	5.3 mr x 140^{o}	4.0^{o}
IFOV/Resolution	IFOV 2 mr	25 m res.	25 Km res.	IFOV 5.3 mr	50 Km res.
Look Angle from Nadir	$\pm 1.5^{o}$	$\pm 46^{o}$	$\pm 64^{o}$	$\pm 70^{o}$	$\pm 64^{o}$
Operational Altitude Limitations	> 160 Km	> 160 Km	> 160 Km	> 160 Km	> 160 Km
Orientation Requirements	Nadir	10 - 36^{o} off nadir	20 - 64^{o} off nadir	0 - 70^{o} off nadir	Conical Scan - 45^{o} fwd. to 64^{o} side view of cold space
Scan Rate	N/A	N/A	N/A	2/Sec	1/6.5 Sec
Uncompensated Momentum	None	None	None	Negligible	Negligible
Pointing Accuracy Attitude	$\pm 0.5^{o}$ P/R any yaw	$\pm 0.5^{o}$	$\pm 1.0^{o}$	$\pm 1^{o}$	$\pm 1^{o}$ all axes
Rate - Goal	0.1^{o}/Sec	0.001^{o}/sec	0.1^{o}/Sec	0.01^{o}/Sec	0.1^{o}/Sec
- Requirement	NR	0.01^{o}/Sec	-	NR	NR

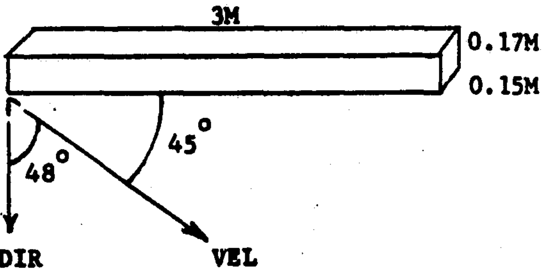
ALTIMETER



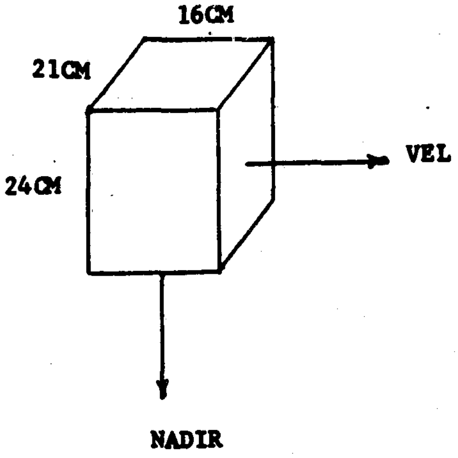
SAR



SCAT

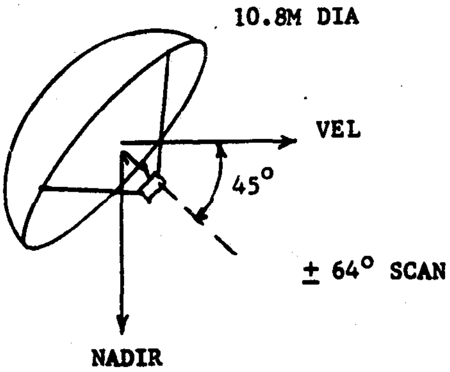


VIRR



LINE SCAN NORMAL TO VELOCITY
VECTOR-HORIZON TO HORIZON

SMMR



4.11 ELECTROMAGNETIC ENVIRONMENT EXPERIMENT (EEE)

The EEE sensors consist of a pallet mounted antenna assembly and pressurized equipment in the Spacelab (Figure 4-1).

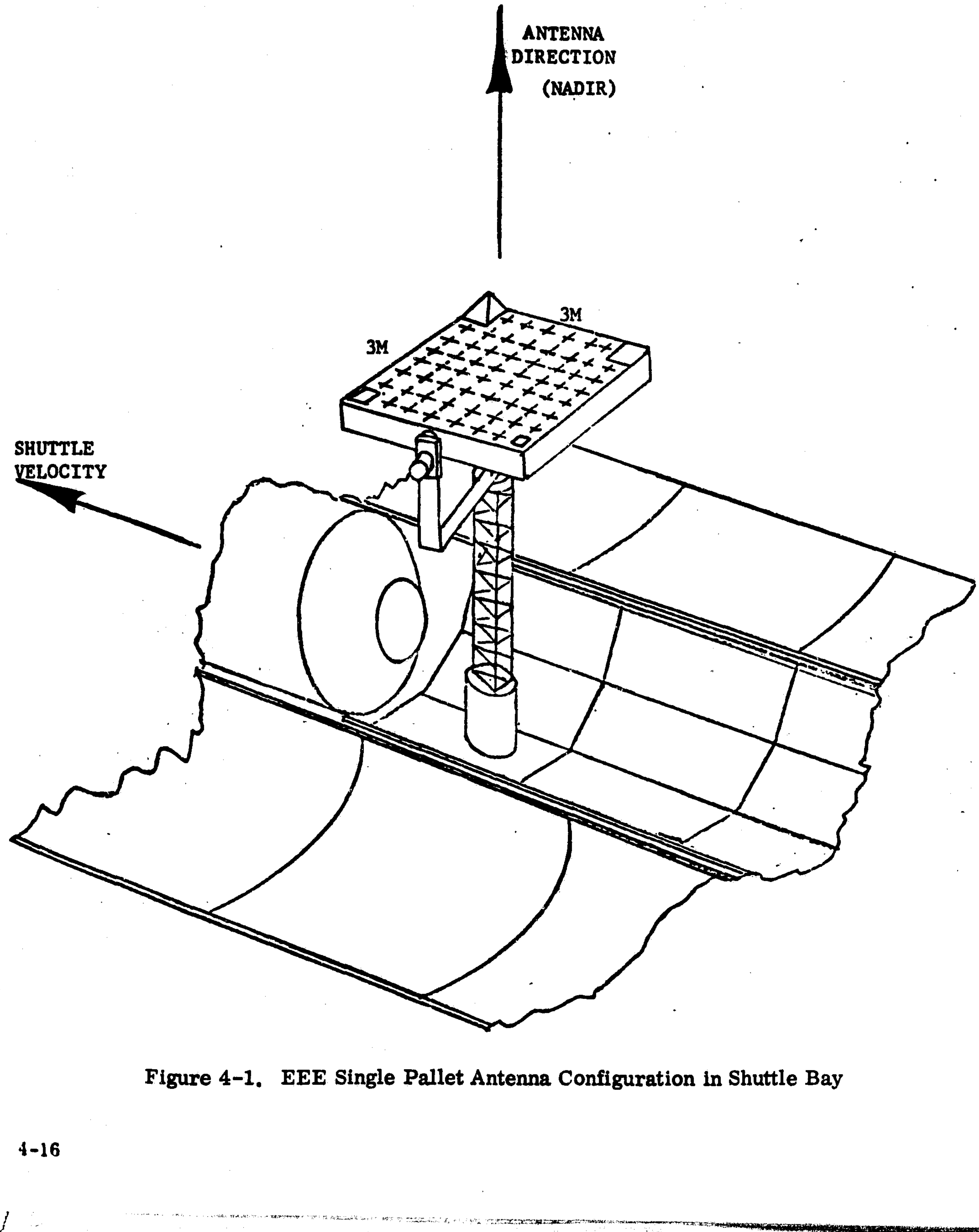


Figure 4-1. EEE Single Pallet Antenna Configuration in Shuttle Bay

The sensor parameters which impact on the pallet and Shuttle configurations and performance are listed below:

EEE PARAMETERS

Size: Restricted to operation with a single 2.876 m long pallet: may overlap another pallet during stowage where space is available.

Weight: Complete EEE system - 672 kg on pallet, including boom; 514 kg in Spacelab

Reduced "Single Pallet" EEE system: 258 kg on pallet, 384 kg in Spacelab.

Cooling Requirements:

- UAA equipment self contained, no external thermal requirements
- Cabling temperature controlled to insure no damage by thermal extremes.
- Spacelab pressurized equipment requires air cooling of the three racks (1100 watts in full system 674 watts in abbreviated "single pallet" system)

Total Angular Coverage: Shuttle and Pallet orient the antenna boom at Nadir and provide a firm base for the UAA. The EEE antennas are self-scanable anywhere within a cone of up to 70^{o} away from Nadir. Antenna controls implemented by the EEE Control Unit provides for scanning as required for a specific experiment.

Instantaneous Field of View: Defined by the antenna beamwidth for the antenna in use for an experiment; varies from less than 1^{o} to several degrees for the various antennas, and to 70^{o} with widebeam antennas that will be included in the complete EEE system. These numbers have no bearing on the Shuttle or pallet configurations.

Look Angle Limitations: With the Shuttle oriented as required above, the only requirement is that the extendable boom or platform from the pallet floor be sufficient to lift the antenna assembly free of the Shuttle such that mechanical scanning to 70^{o} away from Nadir can be accomplished in any direction. (Possible interference from the tail of the Shuttle is not considered to be critical at this time.)

Operational Altitude Limitations: None as long as within Shuttle tolerances.

Orientation Required: EEE requires only Nadir pointing of antenna boom with an accuracy of at least $\pm 2^{o}$. (Other MMAP experiments may have other requirements but these are not adequately defined for including as Shuttle requirement at this time.)

Scan Rate and Exposure Time: No applicable to pallet and Shuttle parameters. Data processing provides for map resolution where required; total exposure operating time up to 12 minutes for the EEE; scan rate limited within EEE by drive motors; oscillatory scan in azimuth likely to be used.

Calibration Requirements: EEE requires accuracy of about 2^o which is accomplished with a ground-based beacon combined with Shuttle ephemeris and pointing data. The known locations of beacons combined with antenna pointing angles permits the EEE system to generate an angle correction which is utilized during the balance of the specific run. Additional corrections require an integration of Shuttle pointing rates during each run to determine the pointing error correction after the calibration function is completed. Parameters of beacons are not required for defining Shuttle/pallet. (Certain other MMAP experiments, including METRAD and MWISE, may be found to have much higher accuracy requirements than the $\pm 2^o$ of the EEE, and this possibility should be noted; the requirements for these two MMAP experiments are yet to be established.)

Special Support Requirements: Requires operating specialist in the Spacelab to conduct experiments and provide preliminary evaluation of data and experiment progress. Non-operating requirements include launch and land tiedowns and appropriate safety devices to cover contingency EVA's. (System does not require EVA's.)

Geometric Linearity: All problems in this area will be handled within EEE and requires no special consideration by the Shuttle/pallet configurations. The system requirement is for Nadir pointing of the antenna boom or platform, from which corrections for distortions are accomplished in the data processing using antenna pointing data with corrections, using Shuttle pointing and ephemeris data as required.

Disturbance Torque: The EEE antennas may be relatively massive, particularly as other MMAP experiments are added to the Upper Antenna Structure, and these represent a relatively significant load to start/stop rotating. A typical EEE configuration with a complete set of antennas and associated electronic equipment would have a torque of 13.8 kg-m, a value selected by an antenna subcontractor related to the EEE program. (They calculated an angular acceleration of 0.13 rad/sec^2, which is about the maximum with the marked error of the antenna configuration; this does not reflect into Shuttle/pallet requirements however, since only the basic torque is of significance.)

4.12 ADAPTIVE MULTIBEAM PHASED ARRAY (AMPA) (Figure 4-2)

AMPA Experiment Integration Requirements

Parameters	Requirement
(Physical)	
Antenna Dimensions	3m x 3m x 0.5m (L-band) 0.4m x 0.4m x 0.5m (Ku-band Xmit) 0.4m x 0.4m x 0.5m (Ku-band Receive)
Antenna Weight*	1500 kg (L-band) 100 kg (Ku-band Xmit) 100 kg (Ku-band Receive)
Electronics Volume*	0.5 m^3 (Internal)
Electronics Weight*	150 kg (Internal)
Antenna Alignment	~ 0.5°
Antenna Viewing	± 40° Scan Angle
Total FOV	Full Earth
Thermal Control	TBD
Consumables	None
Special Protection	None anticipated
(Functional)	
Electric Power	500 W (L-band Communication) 300 W (L-band Radiometer) 600 W (Ku-band Communication) 800 W (Standby)* dc
Data Rate	50 KBps (L-band Communication) 1 KBps (L-band Radiometer) 2 MBps (Ku-band Communication) TBD (Housekeeping) TBD (Commands)
Heat Rejection	600 W **
Caution and Warning	None
Fluids	None

*Estimates
** Does not include allowance for space heating or cooling.

The overall experiment configuration based on the preceding experiment integration and operational requirements is as follows:

Experiment Configuration

Parameters	Description	Remarks
(Physical)		
Dimensions-External	3m x 3.5m x 1m (Stowed) 3m x 3m x 0.5m (Deployed) with 15m mast	Antennas, electronics, mounts, mechanisms
Dimensions-Internal	0.5 m^3	Electronics
Weight-External*	2000 kg	Antenna System plus Cables and Support
Weight-Internal *	150 kg	
Location-External	Mounted on 3 m pallet segment. Deployed to position above pressurized module	
Location-Internal	Electronics mounted in standard 19-inch Spacelab rack	
Orientation	Normal to Orbiter + Z0 axis when deployed	
Alignment	Misalignment $\leq 0.7^\circ$ to pallet reference	Total pointing error $\leq 1^\circ$
Power Hookups	28 VDC Reg, 115 VAC (Pallet) 28 VDC Reg, 115 VAC (Racks)	
Data Hookups	Data Bus, High Rate Digital (Pallets) Data Bus, High Rate Digital (Racks)	
C & W Hookups	N/A (Pallet) N/A (Racks)	
Fluid Hookups	N/A (Pallet) N/A (Racks)	
Special Protection	N/A	
(Functional)		
Electric Power	800 W Standby 1200 W Operating	
Electric Energy	140 kWh	
Science Data	2 MBPS (Ku-band Communication) 50 KBPS (L-band Communication)	
Housekeeping Data	TBD	
Commands	TBD	
Heat Rejection	TBD	
C & W Signals	None	

AMPA experiment operational requirements are given in the following table:

Experiment Operations

Parameter	L-band Communications	L-band Radiometer	Ku-band Communications
(Normal)			
Experiment Ops.	50 sec/pass	15 min/pass	50 sec/pass
Setup	TBD	TBD	TBD
Shutdown	TBD	TBD	TBD
Cycles/Day	2	8	2
Cycles/Mission	14	56	14
Deployment	15 min	Same	Same
Retraction	15 min	Same	Same
Targets	Two ships, 100 to 400 km apart	Selected land areas (CONUS)	Two earth stations, 100 to 400 km apart
Pointing	$\pm 0.5^{\circ}$	$\pm 0.5^{\circ}$	$\pm 0.5^{\circ}$
Stability	0.5°	0.5°	0.5°
Stability Rate	0.1°/sec	0.1°/sec	0.1°/sec
Crew	See Table 7-1	Same	Same
(Contingency)			
On Orbit Repair	Use EVA to repair simple malfunctions (mechanical problems, component replacement)	Same	Same
Retraction Malfunction	Jettison antenna, electronics, and deployment mechanism	Same	Same

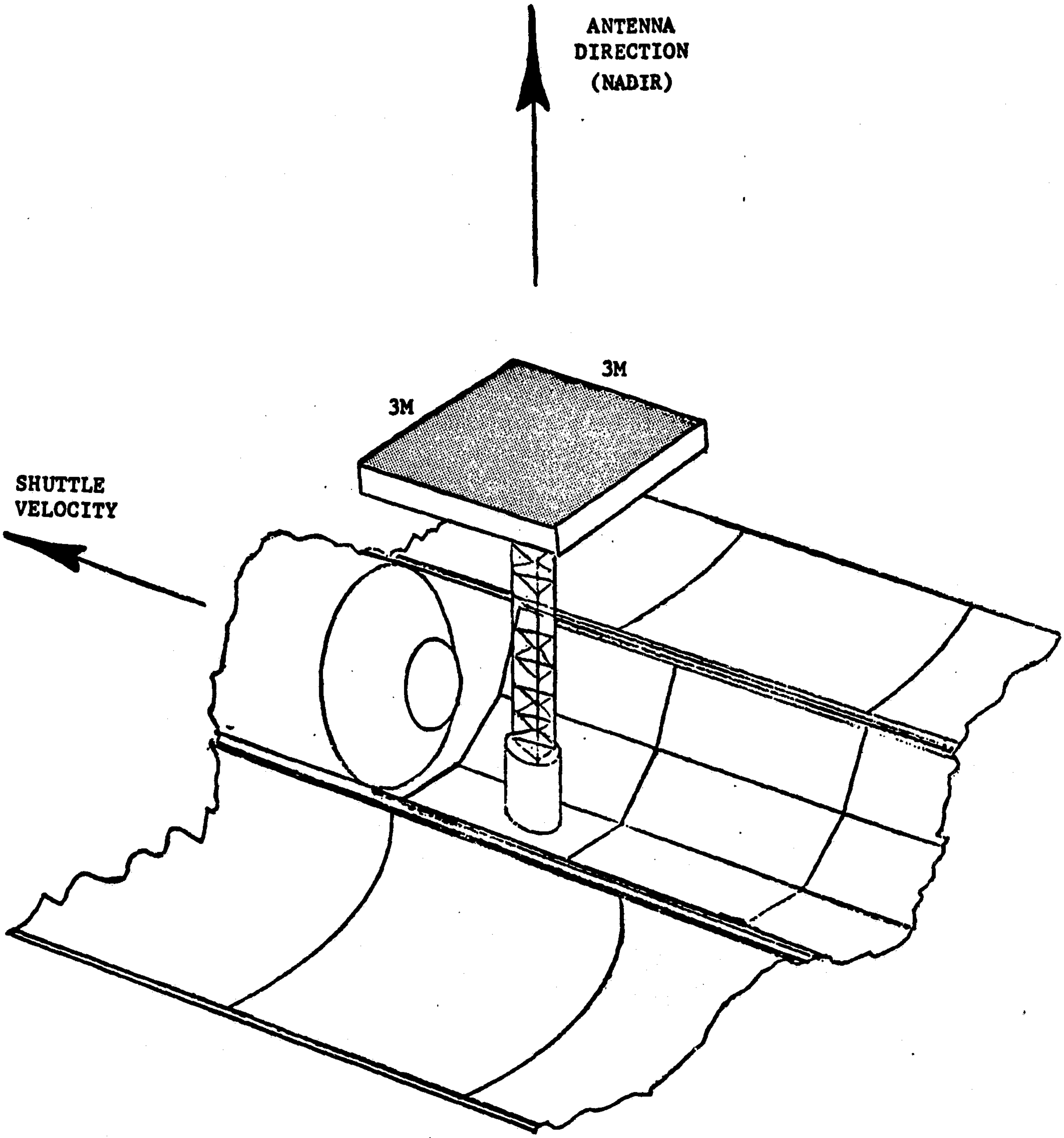


Figure 4-2. AMPA Antenna Configuration in Shuttle Bay

4.13 SHUTTLE IMAGING MICROWAVE SYSTEM (SIMS)

The SIMS is a high resolution, passive microwave system used for measurements of thermal emissions from the earth's surface and atmosphere in the 0.6 to 118.79 GHz spectrum. The instrument is comprised of a four-meter wide reflector antenna, a rotating feed assembly, and a series of receiver/processor for each of its eleven frequencies. Each radiometer feed sweeps a cross-track swath of $\pm 30^{\circ}$ as it rotates past the reflector. The amount of the reflector which is illuminated is varied with frequency to provide an instantaneous field of view ranging from 0.1 deg. (at 118.79 GHz) to 17 deg. (at 0.6 GHz). The instrument is currently configured to mount directly to the cargo bay and replaces a pallet section in a Spacelab configuration.

SIMS PARAMETERS

Size: 400 x 590 x 250 cm

Weight: 952 Kg

Total Angular Coverage: 60° cross-track
17° along-track

Instantaneous Field of View:

0.61 GHz	- 17.0°
1.413	- 7.3°
2.695	- 3.8°
6.6	- 1.6°
10.69	- 1.0°
20	- 0.5°
22.2	- 0.47°
37	- 0.3°
53	- 0.2°
94	- 0.11°
118.7	- 0.09°

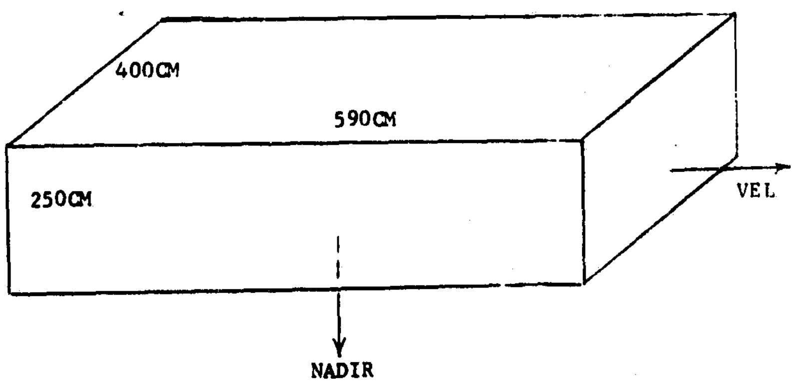
Operational Altitude Limitation: None

Orientation Requirements: Nadir Viewing

Scan Rate: Not Available

Uncompensated Momentum: Not Available

SIMS



4.14 PHOTO POLARIMETER

The spot-scanning photo polarimeter is a three channel device which measures the polarized components of usable light with a spectral bandwidth as narrow as 100-150 Å. It is comprised of a small telescope, with three optical barrels (one for each polarization channel), a polarizing prism and a photodetector/amplifier assembly. The instantaneous field of view is 1° and the entire instrument is scanned cross-track by a single axis gimbal over a range of ± 60 degrees.

PHOTOPOLARIMETER PARAMETERS

Size: 35 x 35 x 50 cm

Weight (including Gimbal): 27.2 Kg

Cooling Requirements: None

Total Angular Coverage: 120° Cross-Track
1° Along-Track

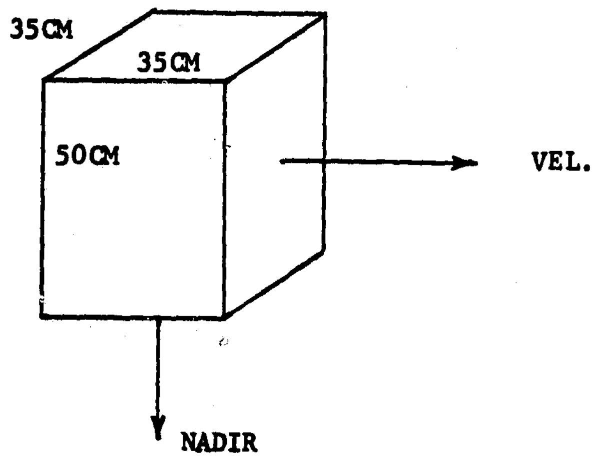
Instantaneous Angular Field of View: 1°

Operational Altitude Limitations: None

Orientation Requirements: Nadir Viewing

Scan Rate: Not Available

PHOTO POLARIMETER



4.15 LIDAR

As mentioned in the previous section even the key parameters for LIDAR including wavelength, type of laser, power level, pulse rate, modes of detection, etc., are not defined yet. The following list of parameters is included for completeness only.

LIDAR PARAMETERS (CONCEPTUAL)

Size: 1 m^3

Weight: 100 kg

Cooling Requirements: To be determined

Total Angular Coverage: To be determined

Instantaneous Angular Field of View: 0.057° or less

Look Angle Limitations: None

Orientation Requirements: Nadir viewing

Scan Rate/Exposure Time: Less than 1 per sec.

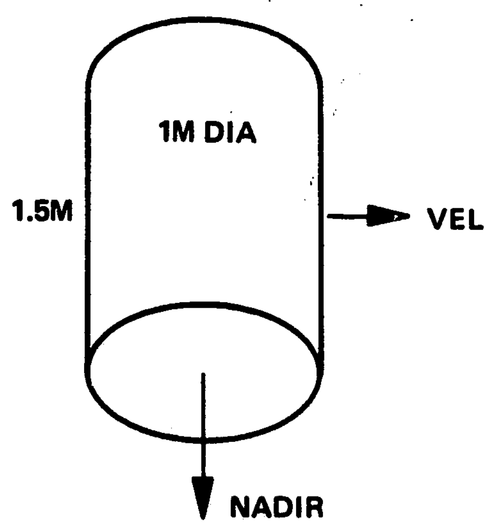
Calibration Requirements: To be determined

Special Support Requirements: None

Geometric Linearity: Not applicable

Distrubance Torques/Uncompensated Momentum: Not available

LIDAR (CONCEPTUAL



SECTION 5

ASSUMPTIONS

SECTION 5

ASSUMPTIONS

In order to establish pointing and stabilization requirements for Earth Observation Experiments certain assumptions are made. Some assumptions apply to all the missions considered and others are applicable to specific missions.

A. GENERAL ASSUMPTIONS

1. It is assumed for this study that the pointing and stabilization of each sensor line of sight (LOS) is accomplished independently since groupings of sensors on a pointing mount are not established. The requirements derived in this report, however, can be used to facilitate the groupings and to establish requirements for a pointing mount accommodating the group of sensors.

2. The slewing of a point mount if required is assumed to be accomplished by an open loop servo with an optimum command signal generated by a computer. The stabilization control system is assumed to be a closed loop servo. Since the computer would generate an optimum command signal based on the slew requirement and all the attitude state information of the Shuttle and the mount at the time of slew initiation, the command includes estimated dynamic motion of the mount; and the performance of the servo can be considered as a "pseudo-closed loop".

3. The slew profile is assumed to be as shown in Figure 5-1. The acceleration and the deceleration profiles are skew-symmetric half-sine waves and have the same amplitude and the same period. Hence, the net momentum contributed by the slew motion is zero. The acceleration/decleration amplitude is limited either by the available torque from the pointing mount drive if the slew angle is large or by the required slew angle if the angle is small. 1 ft-lb torque limit is assumed for each sensor.

4. 0.1 radian per second per second acceleration limit and 0.1 radian per second rate limit are assumed from the consideration of G-loading and momentum disturbance amplitudes. The optimum acceleration/deceleration amplitude and the duration for the minimum slew time are to be calculated by the computer with the given constraints on the torque, the accelerations and the rate. The computer generates the required command signal which produces the profile. The assumed slew profile can be mathematically expressed as follows.

Slew (maneuver) time $t_m = t_{max} + t_s$

Max. open loop slew time $t_{max} = 2T + \dfrac{\theta_{max} - \theta_o}{\theta_o}$

Acc/Dec time $T = \sqrt{\dfrac{\pi}{2} \quad \dfrac{\theta_{max}}{\theta_{max}}}$

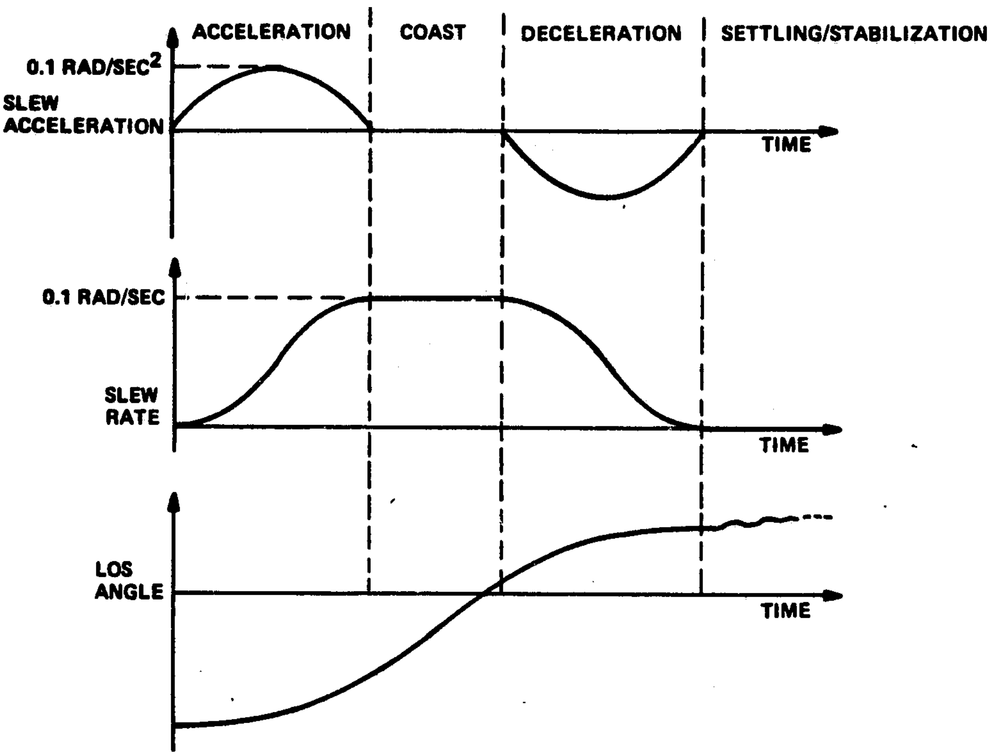


Figure 5-1. EO Sensors Slew Profile

$$\text{Max acceleration} \quad \ddot{\theta}_{max} = \frac{F}{I}, \text{ for } \frac{F}{I} \leq \ddot{\theta}_o$$

$$= \ddot{\theta}_o \text{ otherwise}$$

where

θ_{max} = desired slew angle (angle between the old LOS and the new LOS)

$\dot{\theta}_o$ = slew rate limit = 0.1 rad/sec

$\ddot{\theta}_o$ = slew acceleration limit = 0.1 rad/sec^2

F = torque limit = 1 ft-lb

I = moment of inertia

The acceleration equation is

$$\ddot{\theta} = \ddot{\theta}_{max} \sin\left(\pi \frac{t}{T}\right) \qquad \text{for } O \le t < T$$

$$= O \qquad \text{for } T \le t \le t_{max} - T$$

$$= -\ddot{\theta}_{max} \sin\left(\pi \frac{t_{max}-t}{T}\right) \qquad \text{for } t_{max} - T < t \le t_{max}$$

5. It is assumed that the pointing error resulting from an open loop slewing may be corrected by the closed loop stabilization servo. In order to bring the sensor LOS to the desired LOS line with the closed loop servo, however, a settling time has to be considered.

6. It is assumed that no sensor is slewed even though the desired coverage area is not on the center of FOV, provided the sensor has either a large FOV or an internal offset pointing capability such that the target area is adequately covered (target centroid within 40% of the sensor FOV).

7. If more than one sensor within the same group were to be slewed, it is assumed that these sensors would be slewed together. The pointing and stabilization requirements are independently established, however, since the stabilization of all sensors for the same mission can be grouped various ways.

8. Although the following errors are not considered separately in this study, it is assumed that the pointing command accuracy includes the effect of these errors:

   a. Target area location uncertainty

   b. Vehicle ephemeris errors

   c. Vehicle attitude errors

   d. Alignment errors

9. The moments of inertia are estimated on the basis of the best information available on the mass and the dimension sizes. It is assumed that the mass is uniformly distributed and the sensors are rotated about the center of mass.

B. SPECIFIC ASSUMPTIONS

1. Mineral exploration survey:

   a. LOS of the large format camera and the Thematic Mapper are aligned with that of SAR and fixed for a given pass over a target area

   b. In order to achieve a contiguous coverage by the Thematic Mapper 440 Km altitude is assumed. Continuous mapping of 100 second maximum is assumed.

c. The pointing accuracy of the SAR is 1% of cross track coverage. The stability requirement is based on the along track resolution and the 20 milliseconds exposure time of the camera is used for the stability rate.

d. The pointing accuracy of the large format camera is made compatible with the SAR which is also consistent with the 10% of 1/2 FOV. The stability requirement is based on the film resolution capability and 20 millisecond exposure time is used for the stability rate.

e. A conically scanning Thematic Mapper is assumed even though a linear scan mapper can be used also. Since the across track FOV is larger than SAR FOV, the pointing accuracy is made compatible with the SAR. The stability requirement is based on the IFOV of the mapper and the scan period of 20 milliseconds is used for the stability rate.

2. Timber volume inventory:

a. It is assumed that coverage of forest areas over Northeastern U.S. with mapping of at least four areas of 200 Km length and 100 Km width are required in 3 minutes.

b. In order to achieve a contiguous coverage by the Thematic Mapper 440 Km altitude is assumed. Maximum 30 second coverage for each area is assumed.

c. The S190B camera is to provide stereoscopic view of the area covered. 60% overlap of the successive photograph is assumed. The pointing accuracy is based on 10% of 1/2 FOV of the camera. The stability requirement is based on the film resolution and 10 millisecond exposure time is used for the stability rate. It is assumed the camera needs slewing of ±10 degrees.

d. A linearly scanning Thematic Mapper is assumed even though a conically scanning mapper can be used as well. The pointing accuracy is based on 10% of 1/2 FOV crosstrack. The stability requirement is based on the IFOV and the scan period of 44 milliseconds is used for the stability rate. Because of the internal capability to offset point it is assumed that the slew by the mount is not necessary.

3. U.S. Census:

a. It is assumed that 56 U.S. cities having over 250,000 population are to be observed during the ascending and descending passes during daylight.

b. In order to achieve a contiguous coverage by the Thematic Mapper 440 Km altitude is assumed. At least 4 second coverage period for each city is assumed from the mapping time required by the Thematic Mapper.

c. The pointing accuracy of the S190B camera is based on 10% of 1/2 FOV. The stability requirement is based on the film resolution capability and 10 millisecond camera exposure time is used for the stability rate. In order to cover all large cities it is assumed that the camera needs offset pointing of up to ±15 degrees, across the track.

d. The pointing accuracy of the S163 camera is 10% of 1/2 FOV in the direction of flight. The stability requirement is based on the film resolution capability and the 30 millisecond camera exposure time is used for the stability rate.

e. Pointing accuracy of the S190A camera is made compatible with the S190B camera. The stability requirement is based on the film resolution capability and 10 millisecond exposure time is used for the stability rate. It is assumed that this camera also needs offset pointing of up to ±15 degrees across track.

f. A linear scan 'Thematic Mapper is assumed. The pointing accuracy of the Mapper is made compatible with the S190B camera. The stability requirement is based on the IFOV and the scan period of 44 milliseconds is used for the stability rate.

4. Urban Air Pollution Mission:

a. It is assumed that the Urban Air Pollution Mission requires the coverage same as the US Census mission except that a longer observation (up to 20 seconds) for a urban area may be made.

If resolution of CIMATS and MAPS were to meet 24 Km requirement, the altitude should be reduced to 220 Km.

b. The pointing accuracy of the THIR is based on 10% of IFOV in infrared band. The stability requirement is based on 10% of IFOV in visible band and the 1.25 sec frame rate is used for the stability rate.

c. The pointing accuracy of the CIMATS is made compatible with the above two sensors which have smaller IFOV. The stability requirement is based on 10% of the limiting resolution of correlations and the 1 second frame rate is used for the stability rate. For the coverage of off track target areas this sensor needs up to ±15 degrees offset pointing.

d. The pointing accuracy of the MAPS is based on 10% of the 1/2 FOV. The stability amplitude and rate requirements are based on 10% of the overlapping coverage over 1 second period. This sensor requires offset pointing to cover target areas off the track.

5. Stratospheric Pollution Mission

a. It is assumed that the stratospheric pollutants are continuously measured from 440 Km altitude.

b. It is assumed that the LACATE scans the atmospheric limb vertically without changing azimuthal angle over 8 second period. The pointing accuracy of LACATE is based on the highest ground resolution. The stability is based on 10% of IFOV and the 0.125 second vertical scan rate is used for the stability rate.

c. It is assumed that the mapper portion of SBUV/TOMS has 5 second per line scan period to provide contiguous coverage. The pointing accuracy is based on 10% of the IFOV. The stability requirement is based on 1% of the IFOV and the scan period is used for the stability rate.

6. Tropical Storm Research Mission

a. It is assumed that the low inclination 470 KM altitude orbit is required for this mission and data would be taken over a quarter of an orbit. 30 minute observation period is assumed.

b. The altimeter measures always within ± 1.5 degree from the nadir. The pointing accuracy is based on 10% of the IFOV. The stability requirement is based on 1% of the IFOV and for the stability rate 100 millisecond frame rate is assumed. The altimeter information is necessary to calibrate the data from the SAR and the Scatterometer.

c. The pointing accuracy of the SAR is 1% of crosstrack coverage. The stability requirement is based on the along track resolution and 20 millisecond frame period is used for the stability rate.

d. It is assumed that the SMMR include the disturbance momentum compensation device as an integral part of the sensor. Although the SMMR may scan either one side of the track or both sides of track with different scan amplitude, it is assumed that it sinusoidally scans ± 28 degrees across the track. The pointing accuracy of the SMMR is based on 10% of the 1/2 IFOV and a 4 second scan period is used for the stability rate.

e. A fan beam type Scatterometer is assumed to allow multiple measurements. The pointing accuracy is based on 10% IFOV. The stability amplitude and rate requirements are based on resolution cell size obtainable from 1 second doppler gating. It is assumed the Scatterometer maps the general area mapped by the SMMR while it is boresighted to the altimeter.

f. The pointing accuracy of VIRR is based on 10% IFOV of the sensor in IR band. The stability requirement is based on the 1 KM resolution desired and 2 scan per second rate is used for the stability rate.

7. Electromagnetic Environment Experiment

a. 400 KM altitude is assumed for the EEE. It is also assumed that all the scanning and pointing in two axes are provided by the experiment itself (self-contained gimbal system).

b. The pointing mount is assumed to provide stabilized platform pointing to nadir. (Decouplings of the externally generated disturbances). The disturbance momentum generated by the scanning antenna is assumed to be internally compensated by the experiment package.

c. The pointing accuracy is based on 10% of the IFOV. The stability requirement is based on 10% of 1/2IFOV and a 1 second frametime is assumed for the stability rate.

8. Adaptive Multibeam Antenna Experiment

a. It is assumed that the AMPA experiment includes radiometric as well as communication experiment operations from 400 KM altitude. It is assumed that the radiometer experiment requires 15 min. per pass operations while the communication requires less than 1 minute operation.

b. It is assumed that the pointing mount provides an optional capability of aiming the AMPA antenna system ±20 degrees either side of the track although beam steering is electronically accomplished.

c. The pointing accuracy is based on 10% of 1/2 beamwidth. The stability requirement is based on 1% of beamwidth and 1 second signal acquisition time is used for the stability rate.

9. Remote Sensing of Soil Moisture

a. It is assumed that the Soil Moisture Mission will be well coordinated with other moisture measurement activities (such as ground truth and aircraft underflights). 330 KM altitude with 1 second measurement per site is assumed to provide a contiguous coverage for the Polarimeter. It is also assumed that no slewing of the pointing mount is necessary for this mission.

b. The pointing accuracy of the SAR is 1% of the cross-track coverage. The stability requirement is based on the along track resolution and a 20 millisecond frame time is used for the stability rate.

c. It is assumed that the disturbing momentum generated by the rotating feed assembly of the SIMS is compensated by a mechanism integrated into the sensor. The pointing accuracy of the SIMS is 1/2 IFOV at 119 GHz. The stability requirement is based on 10% of IFOV and 6 scan line per second rate is used for the stability rate.

d. It is assumed that the disturbance momentum generated by the scanning gimbal of the Polarimeter is compensated internally. The pointing accuracy is 10% of the IFOV. The stabilization requirement is based on 1% of IFOV and 1 second per scan is used for the stability rate.

e. A linearly scanning Thematic Mapper is assumed. The pointing accuracy is based on 10% of 1/2 cross track coverage. The stability requirement is based on the IFOV and the scan period of 44 milliseconds is used for the stability rate.

10. LIDAR Sensor Development Mission

a. It is assumed that one object of this mission is to demonstrate the performance of the laser and the image motion compensator, requiring a stable platform. A 400 KM altitude is assumed. Disturbance from the laser device is not defined at present time.

b. The pointing accuracy is 10% of 1/2 FOV. The stability requirement is assumed to be 0.1% of the FOV and a frame rate of 100 millisecond is used for the stability rate (with image motion compensator).

c. It is assumed that tracking in pitch axis is provided by the image motion compensation device for the laser. Maximum tracking of 1 second is required for vertical profile measurement.

SECTION 6

SENSOR CHARACTERISTICS - POINTING AND STABILIZATION REQUIREMENTS

SECTION 6

POINTING AND STABILIZATION REQUIREMENTS

Pointing and stability requirements are derived from the mission and sensor requirements under the assumptions made in Section 5. Figure 6-1 depicts the methodology used for the derivation. The pointing/stabilization requirements for each sensor/mission are tabulated in this section.

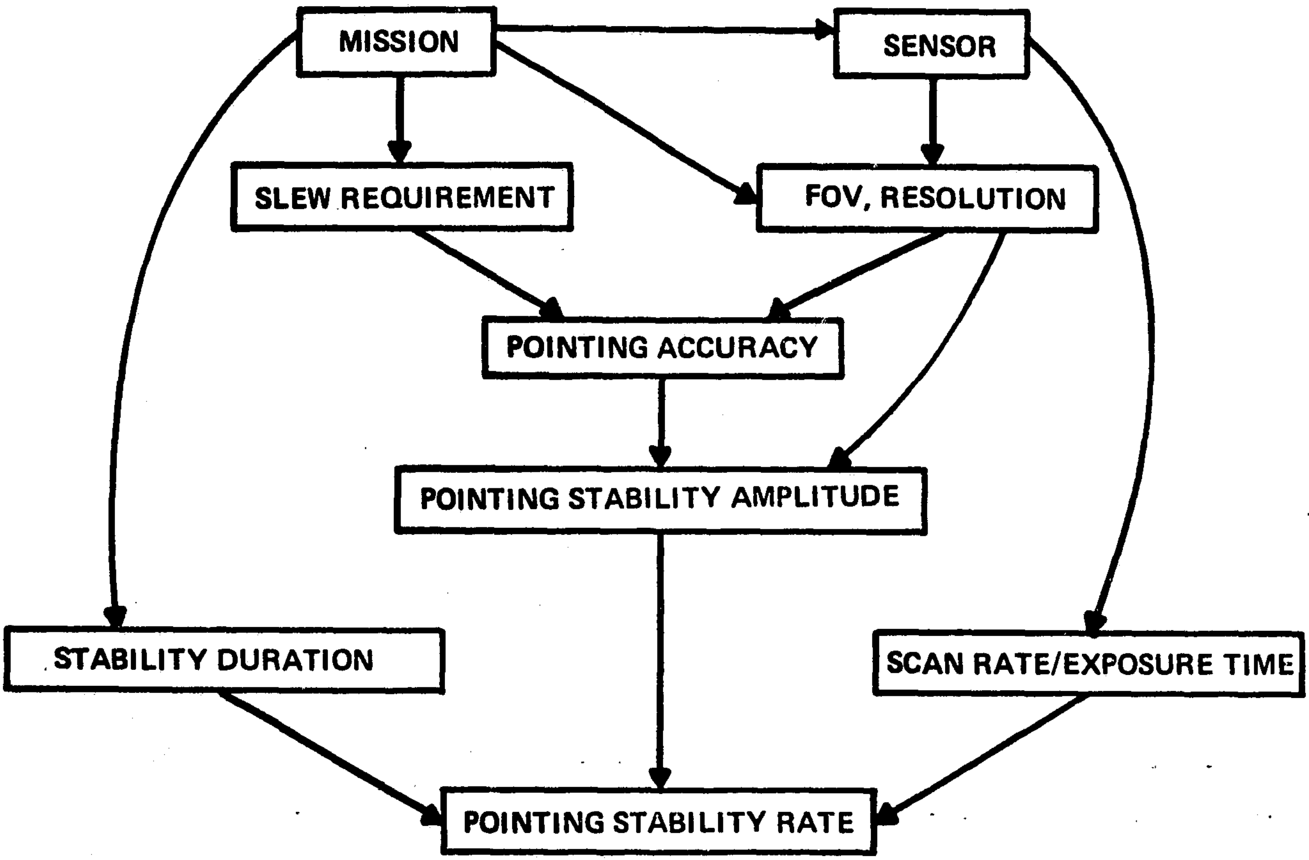


Figure 6-1. Pointing/Stabilization Requirements

MISSION: MINERAL EXPLORATION SURVEY
ALTITUDE: 200 ~ 500 KM, NOMINAL 440 KM

SENSOR: THEMATIC MAPPER (CONICAL SCAN)

SENSOR CHARACTERISTICS

SIZE		180 x 105 x 90 cm
WEIGHT		173 Kg
TOTAL ANGULAR COVERAGE		14 Deg Across Track
INSTANTANEOUS FOV		0.0035 Deg
SWATH WIDTH		110 Km
ALONG TRACK COVERAGE		520 M
NO. OF TARGET PER ORBIT		Continuous Mapping
RESOLUTION		26 M
ORIENTATION		Cone Angle 19 Deg. FWD
OFFSET POINTING ANGLE AVAILABLE		±20 Deg Across Track
SCAN RATE/EXPOSURE TIME		44m sec per scan line
MOMENT OF INERTIA	P	55 Kg - m^2
	R	60 Kg - m^2
	Y	20 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.5 Deg
POINTING STABILITY ERROR AMP	6 SEC (3 σ)
POINTING STABILITY ERROR RATE	100 SEC/SEC (3 σ)
STABILITY DURATION	100 SEC
SLEW PROFILE	ACC - COAST-DEC (in roll) Max ACC/DEC time 3.7 sec
MAX SLEW ACCELERATION	0.02 RAD/SEC^2
MAX SLEW RATE	0.1 RAD/SEC
SETTLING TIME	2 SEC
MAX SLEW ANGLE/TIME	10 DEG/9.4 SEC (incl. settling)
POINTING CMD ACCURACY	0.3 DEG
PAYLOAD GENERATED DISTURBANCE	Scanning Mirror (0.2 ft.-lb-sec max)
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: MINERAL EXPLORATION SURVEY
ALTITUDE 200~500 KM, NOMINAL 440 KM

SENSOR: COHERENT IMAGING RADAR
(SYNTHETIC APERTURE RADAR-SAR)

SENSOR CHARACTERISTICS

SIZE		10 x 3 M Antenna
WEIGHT		1250 Kg
TOTAL ANGULAR COVERAGE		10 DEG Across Track
INSTANTANEOUS FOV		0.003 DEG
SWATH WIDTH		100 Km (L-Band)
ALONG TRACK COVERAGE		25 M (L-Band)
NO. OF TARGET PER ORBIT		Continuous Mapping
RESOLUTION		25M
ORIENTATION		25 DEG Either side of track
OFFSET POINTING ANGLE AVAILABLE		$\pm$25 DEG from NADIR
SCAN RATE/EXPOSURE TIME		20 MHz BW
MOMENT OF INERTIA	P	10 Kg - m^2
	R	400 Kg - m^2
	Y	400 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.1 DEG
POINTING STABILITY ERROR AMP	6 SEC (3σ)
POINTING STABILITY ERROR RATE	SEC/SEC (3σ)
STABILITY DURATION	100 SEC.
SLEW PROFILE	Not Required
	-
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	-
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: MINERAL EXPLORATION SURVEY
ALTITUDE: 200 ~ 500 KM, NOMINAL 440 KM

SENSOR: LARGE FORMAT CAMERA (WITH 300 MM FL LENS)

SENSOR CHARACTERISTICS

SIZE		81 x 61 x 117 cm
WEIGHT		136 Kg
TOTAL ANGULAR COVERAGE		38 DEG x 74 DEG
INSTANTANEOUS FOV		38 DEG x 74 DEG
SWATH WIDTH		300 Km
ALONG TRACK COVERAGE		670 Km
NO. OF TARGET PER ORBIT		Frame Rate 10 ~ 45 SEC
RESOLUTION		1500 M
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		-
SCAN RATE/EXPOSURE TIME		2 ~ 20 m SEC (Exp)
MOMENT OF INERTIA	P	25 Kg - m^2
	R	20 Kg - m^2
	Y	10 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.5 DEG
POINTING STABILITY ERROR AMP	3 SEC (3 σ)
POINTING STABILITY ERROR RATE	100 SEC (3 σ)
STABILITY DURATION	20 MSEC
SLEW PROFILE	ACC-COAST-DEC (in roll) Max ACC/DEC Time 3.1 SEC
MAX SLEW ACCELERATION	0.05 RAD/SEC^2
MAX SLEW RATE	0.1 RAD/SEC
SETTLING TIME	2 SEC
MAX SLEW ANGLE/TIME	50 DEG/1 . SEC (Incl Settling)
POINTING CMD ACCURACY	0.2 DEG
PAYLOAD GENERATED DISTURBANCE	-
TRACKING REQUIREMENT (INCL V/H)	V/H Comp Available from Sensor

MISSION: TIMBER VOLUME INVENTORY
ALTITUDE: 200 ~ 500 KM, NOMINAL 440 KM

SENSOR: THEMATIC MAPPER (LINEAR SCAN)

SENSOR CHARACTERISTICS

SIZE		.16 x 93 x 60 cm
WEIGHT		180 Kg
TOTAL ANGULAR COVERAGE		±7 DEG Across Track
INSTANTANEOUS FOV		0.0035 DEG
SWATH WIDTH		110 KM
ALONG TRACK COVERAGE		520 M
NO. OF TARGET PER ORBIT		Continuous Mapping
RESOLUTION		26 M
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		±20 DEG Across Track
SCAN RATE/EXPOSURE TIME		44.3 MSEC Per Scan
MOMENT OF INERTIA	P	25 Kg - m^2
	R	20 Kg - m^2
	Y	30 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.5 DEG
POINTING STABILITY ERROR AMP	6 $\widehat{SEC}$ (3σ)
POINTING STABILITY ERROR RATE	100 $\widehat{SEC}$/SEC (3σ)
STABILITY DURATION	30 SEC
SLEW PROFILE	Not Required
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	Scanning Mirror (0.2 ft-lb-sec-max)
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: TIMBER VOLUME INVENTORY
ALTITUDE: 200~500 KM, Nominal 440 KM

SENSOR: EARTH TERRAIN CAMERA (S190B WITH 8 INCH FL LENS)

SENSOR CHARACTERISTICS

SIZE		29 x 34 x 72 cm
WEIGHT		37 Kg
TOTAL ANGULAR COVERAGE		14 DEG x 14 DEG
INSTANTANEOUS FOV		14 DEG x 14 DEG
SWATH WIDTH		110 KM
ALONG TRACK COVERAGE		110 KM
NO. OF TARGET PER ORBIT		Frame Time 2.4 SEC
RESOLUTION		5M
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		-
SCAN RATE/EXPOSURE TIME		5, 7 & 10 m SEC Exp.
MOMENT OF INERTIA	P	2 Kg - m^2
	R	2 Kg - m^2
	Y	1 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.5 DEG
POINTING STABILITY ERROR AMP	1 SEC (3 σ)
POINTING STABILITY ERROR RATE	100 SEC/SEC (3 σ)
STABILITY DURATION	30 SEC
SLEW PROFILE	ACC-COAST-DEC (in roll) Max ACC/DEC Time 1.6 SEC
MAX SLEW ACCELERATION	0.1 RAD/SEC^2
MAX SLEW RATE	0.1 RAD/SEC
SETTLING TIME	1 SEC
MAX SLEW ANGLE/TIME	20 DEG/6.5 SEC (Incl Settling)
POINTING CMD ACCURACY	0.3 DEG
PAYLOAD GENERATED DISTURBANCE	-
TRACKING REQUIREMENT (INCL V/H)	V/H Comp Available from Sensor

MISSION: US CENSUS
ALTITUDE: 200~500 KM, NOMINAL 440 KM

SENSOR: MULTISPECTRAL CAMERA
(S190A WITH 6 INCH FL LENS)

SENSOR CHARACTERISTICS

SIZE		45 x 65 x 72 cm
WEIGHT		109 Kg
TOTAL ANGULAR COVERAGE		20 DEG x 20 DEG
INSTANTANEOUS FOV		160 KM
SWATH WIDTH		160 KM
ALONG TRACK COVERAGE		Frame Time 2~32 SEC
NO. OF TARGET PER ORBIT		25M (Visual Band)
RESOLUTION		NADIR
ORIENTATION		± 10 DEG Across Track
OFFSET POINTING ANGLE AVAILABLE		5 DEG Along Track
SCAN RATE/EXPOSURE TIME		2.5, 5 + 10 m SEC Exp.
MOMENT OF INERTIA	P	6 $Kg - m^2$
	R	7 $Kg - m^2$
	Y	9 $Kg - m^2$

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.5 DEG
POINTING STABILITY ERROR AMP	3 SEC (3σ)
POINTING STABILITY ERROR RATE	200 SEC/SEC (3σ))
STABILITY DURATION	10 MSEC
SLEW PROFILE	ACC-COAST-DEC (in roll)
	Max ACC/DEC Time 1.6 SEC
MAX SLEW ACCELERATION	0.1 RAD/SEC^2
MAX SLEW RATE	0.1 RAD/SEC
SETTLING TIME	1 SEC
MAX SLEW ANGLE/TIME	30 DEG/8 SEC (Incl Settling)
POINTING CMD ACCURACY	0.3 DEG
PAYLOAD GENERATED DISTURBANCE	-
TRACKING REQUIREMENT (INCL V/H)	V/H Comp Available from Sensor

MISSION: US CENSUS
ALTITUDE: 200~500 KM, NOMINAL 440 KM

SENSOR: EARTH TERRAIN CAMERA
(S190B WITH 8 INCH FL LENS)

SENSOR CHARACTERISTICS

SIZE		29 x 34 x 72 cm
WEIGHT		37 Kg
TOTAL ANGULAR COVERAGE		14 DEG x 14 DEG
INSTANTANEOUS FOV		14 DEG x 14 DEG
SWATH WIDTH		110 KM
ALONG TRACK COVERAGE		110 KM
NO. OF TARGET PER ORBIT		Frame Time 2.4 SEC
RESOLUTION		5 M
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		-
SCAN RATE/EXPOSURE TIME		5,7 & 10 MSEC Exp
MOMENT OF INERTIA	P	2 Kg - m^2
	R	2 Kg - m^2
	Y	1 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.5 DEG
POINTING STABILITY ERROR AMP	1 SEC (3 σ)
POINTING STABILITY ERROR RATE	100 SEC/SEC (3σ)
STABILITY DURATION	10 m SEC
SLEW PROFILE	ACC-COAST-DEC (in roll) Max ACC/DEC Time 1.6 SEC
MAX SLEW ACCELERATION	0.1 RAD/SEC^2
MAX SLEW RATE	o.1 RAD/SEC
SETTLING TIME	1 SEC
MAX SLEW ANGLE/TIME	30 DEG/8 SEC (incl Settling)
POINTING CMD ACCURACY	0.3 DEG
PAYLOAD GENERATED DISTURBANCE	-
TRACKING REQUIREMENT (INCL V/H)	V/H Comp Available from Sensor

MISSION: US CENSUS

ALTITUDE: 200 ~ 500 KM, NOMINAL 440 KM

SENSOR: OPTICAL BAR PANORAMIC CAMERA (S163)

SENSOR CHARACTERISTICS

SIZE		153 x 74 x 65 cm^2
WEIGHT		152 Kg
TOTAL ANGULAR COVERAGE		108 DEG Across Track
INSTANTANEOUS FOV		10.7 DEG
SWATH WIDTH		Horison/Horison
ALONG TRACK COVERAGE		80 KM
NO. OF TARGET PER ORBIT		Frame Time 3.5~17.5 SEC
RESOLUTION		11 M
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		-
SCAN RATE/EXPOSURE TIME		0.4 30 MSEC Exp
MOMENT OF INERTIA	P	6 Kg - m^2
	R	2 Kg - m^2
	Y	2 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.5 DEG
POINTING STABILITY ERROR AMP	2.5 SEC (3σ)
POINTING STABILITY ERROR RATE	80 SEC/SEC (3σ)
STABILITY DURATION	30 M SEC
SLEW PROFILE	Not Required
	-
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	Rotating Optical Bar
TRACKING REQUIREMENT (INCL V/H)	V/H Comp Available from Sensor

MISSION: US CENSUS
ALTITUDE: 200~500 KM, NOMINAL 440 KM

SENSOR: THEMATIC MAPPER (LINEAR SCAN)

SENSOR CHARACTERISTICS

SIZE		116 x 93 x 60 cm
WEIGHT		180 Kg
TOTAL ANGULAR COVERAGE		±7 DEG Across Track
INSTANTANEOUS FOV		0.0035 DEG
SWATH WIDTH		110 KM
ALONG TRACK COVERAGE		26 M
NO. OF TARGET PER ORBIT		Continuous Mapping
RESOLUTION		26 M
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		±20 DEG Across Track
SCAN RATE/EXPOSURE TIME		44.3 m SEC Per Scan Line
MOMENT OF INERTIA	P	25 Kg - m^2
	R	20 Kg - m^2
	Y	30 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.5 DEG
POINTING STABILITY ERROR AMP	6 SEC (3 σ)
POINTING STABILITY ERROR RATE	100 SEC/SEC (3 σ)
STABILITY DURATION	4 SEC
SLEW PROFILE	Not Required
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	Scanning Mirror (0.2 ft. lb-sec max)
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: URBAN AIR POLLUTION
ALTITUDE: 200 ~ 500 KM, NOMINAL 440 KM

SENSOR: MEASUREMENT OF AIR POLLUTION SPECIES (MAPS)

SENSOR CHARACTERISTICS

SIZE		32 x 32 x 20 cm + 37 ϕ x 50 cm (cooler)
WEIGHT		43 Kg
TOTAL ANGULAR COVERAGE		7 DEG
INSTANTANEOUS FOV		7 DEG
SWATH WIDTH		53 KM
ALONG TRACK COVERAGE		53 KM
NO. OF TARGET PER ORBIT		Continuous Mapping
RESOLUTION		53 KM
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		-
SCAN RATE/EXPOSURE TIME		
MOMENT OF INERTIA	P	1 Kg - m^2
	R	1 Kg - m^2
	Y	1 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.3 DEG
POINTING STABILITY ERROR AMP	360 SEC (3σ)
POINTING STABILITY ERROR RATE	360 SEC/SEC (3σ)
STABILITY DURATION	20 SEC
SLEW PROFILE	ACC-COAST-DEC (in roll) 1.6 SEC MAX ACC/DEC TIME
MAX SLEW ACCELERATION	0.1 RAD/SEC
MAX SLEW RATE	0.1 RAD/SEC
SETTLING TIME	1 SEC
MAX SLEW ANGLE/TIME	30 DEG/8 SEC (Incl. Settling)
POINTING CMD ACCURACY	0.3 DEG
PAYLOAD GENERATED DISTURBANCE	-
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: URBAN AIR POLLUTION
ALTITUDE: 200~500 KM, NOMINAL 440 KM

SENSOR: CORRELATION INTERFEROMETER MEASUREMENT OF TRACE SPECIES (CIMATS)

SENSOR CHARACTERISTICS

SIZE		60 x 35 x 38 cm, 18 ϕ x 36 cm, 50 x 50 x 20 cm
WEIGHT		60 Kg
TOTAL ANGULAR COVERAGE		7 DEG
INSTANTANEOUS FOV		7 DEG
SWATH WIDTH		53 KM
ALONG TRACK COVERAGE		53 KM
NO. OF TARGET PER ORBIT		Continuous Mapping
RESOLUTION		0.7 KM
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		-
SCAN RATE/EXPOSURE TIME		1 SEC/Frame
MOMENT OF INERTIA	P	2 Kg - m^2
	R	2 Kg - m^2
	Y	2 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.1 DEG
POINTING STABILITY ERROR AMP	36 SEC (3 σ)
POINTING STABILITY ERROR RATE	36 SEC/SEC (3 σ)
STABILITY DURATION	20 SEC
SLEW PROFILE	ACC-COAST-DEC (in roll) Max ACC/DEC Time 1.6 SEC
MAX SLEW ACCELERATION	0.1 RAD/SEC^2
MAX SLEW RATE	0.1 RAD/SEC
SETTLING TIME	1 SEC
MAX SLEW ANGLE/TIME	30 DEG/8 SEC (Incl. Settling)
POINTING CMD ACCURACY	0.05 DEG
PAYLOAD GENERATED DISTURBANCE	-
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: URBAN AIR POLLUTION
ALTITUDE: 200~500 KM, NOMINAL 440 KM

SENSOR: TEMPERATURE/HUMIDITY IR RADIOMETER (THIR)

SENSOR CHARACTERISTICS

SIZE		17 x 17 x 40 cm
WEIGHT		9 Kg
TOTAL ANGULAR COVERAGE		±60 DEG, 0.43 DEG
INSTANTANEOUS FOV		1.17 DEG, 0.43 DEG
SWATH WIDTH		Horizon/Horizon
ALONG TRACK COVERAGE		9 Km, 3 Km
NO. OF TARGET PER ORBIT		Continuous Mapping
RESOLUTION		9 Km
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		-
SCAN RATE/EXPOSURE TIME		1.25 SEC Frame Rate
MOMENT OF INERTIA	P	0.15 Kg - m^2
	R	0.15 Kg - m^2
	Y	0.05 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.1 DEG
POINTING STABILITY ERROR AMP	150 SEC (3 σ)
POINTING STABILITY ERROR RATE	120 SEC/SEC (3 σ)
STABILITY DURATION	20 SEC
SLEW PROFILE	Not Required
	-
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	Scanning Mirror
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: TROPOSPHERIC/STRATOSPHERIC POLLUTION
ALTITUDE: 200∼500 KM, NOMINAL 440 KM

SENSOR: SCANNING SPECTRAL RADIOMETER (LACATE)

SENSOR CHARACTERISTICS

SIZE		37 ϕ x 15.7 cm + 35 ϕ x 67 cm
WEIGHT		77 Kg
TOTAL ANGULAR COVERAGE		+6 DEG - 5 DEG Across Horizon
INSTANTANEOUS FOV		0.014x0.286 DEG – 0.028x0.143 DEG – 0.057x0.143 DEG
SWATH WIDTH		Vertical Limb Scan
ALONG TRACK COVERAGE		Not Applicable
NO. OF TARGET PER ORBIT		Continuous Mapping
RESOLUTION		1∼4 Km at Horizon
ORIENTATION		Horizon
OFFSET POINTING ANGLE AVAILABLE		± 45 DEG in yaw
SCAN RATE/EXPOSURE TIME		0.125 SEC per Scan
MOMENT OF INERTIA	P	5 Kg - m^2
	R	1 Kg - m^2
	Y	5 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.01 DEG
POINTING STABILITY ERROR AMP	5 SEC (3 σ)
POINTING STABILITY ERROR RATE	40 SEC/SEC (3 σ)
STABILITY DURATION	8 SEC
SLEW PROFILE	Not Required
	-
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	Scanning Mirror
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: TROPOSPHERIC/STRATOSPHERIC POLLUTION
ALTITUDE: 200 ~ 500 KM, NOMINAL 440 KM

SENSOR: SOLAR BACKSCATTER UV & TOTAL OZONE MAPPING SPECTROMETER (SBUV/TOMS)

SENSOR CHARACTERISTICS

SIZE		15 x 20 x 64 cm
WEIGHT		20 Kg
TOTAL ANGULAR COVERAGE		±45 DEG Across Track
INSTANTANEOUS FOV		3 DEG
SWATH WIDTH		1000 KM
ALONG TRACK COVERAGE		23 KM
NO. OF TARGET PER ORBIT		Continuous Mapping
RESOLUTION		23 KM
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		-
SCAN RATE/EXPOSURE TIME		4 SEC Per Scan (Incl Retrace)
MOMENT OF INERTIA	P	1 Kg - m^2
	R	1 Kg - m^2
	Y	0.1 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.3 DEG
POINTING STABILITY ERROR AMP	100 SEC (3 σ)
POINTING STABILITY ERROR RATE	25 SEC/SEC (3 σ)
STABILITY DURATION	8 SEC
SLEW PROFILE	Not Required
	-
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	Scanning Mirror
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: TROPICAL STORM RESEARCH/OCEAN PHYSICS
ALTITUDE: 200～500 KM, NOMINAL 470 KM

SENSOR: MICROWAVE ALTIMETER
(OCEAN TOPOGRAPHY ALTIMETER)

SENSOR CHARACTERISTICS

SIZE	1 M Parabolic Antenna
WEIGHT	Antenna 3 Kg/Electronics 67 Kg
TOTAL ANGULAR COVERAGE	0.115 DEG
INSTANTANEOUS FOV	0.115 DEG
SWATH WIDTH	1 KM
ALONG TRACK COVERAGE	1 KM
NO. OF TARGET PER ORBIT	Continuous Measurement
RESOLUTION	Not Applicable
ORIENTATION	NADIR
OFFSET POINTING ANGLE AVAILABLE	$\pm$1.5 DEG from NADIR
SCAN RATE/EXPOSURE TIME	Not Applicable
MOMENT OF INERTIA P	4 Kg - m^2
R	4 Kg - m^2
Y	7 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.01 DEG
POINTING STABILITY ERROR AMP	4 SEC (3 σ)
POINTING STABILITY ERROR RATE	.40 SEC/SEC (3 σ)
STABILITY DURATION	30 Minutes
SLEW PROFILE	Not Required
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	-
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: TROPICAL STORM RESEARCH/OCEAN PHYSICS
ALTITUDE: 200~500 KM, NOMINAL 470 KM

SENSOR: SYNTHETIC APERTURE RADAR (SAR)

SENSOR CHARACTERISTICS

SIZE		10 x 3 m Antenna
WEIGHT		1250 Kg
TOTAL ANGULAR COVERAGE		10 DEG Across Track
INSTANTANEOUS FOV		0.003 DEG
SWATH WIDTH		100 KM (L-Band)
ALONG TRACK COVERAGE		25 M (L-Band)
NO. OF TARGET PER ORBIT		Continuous Mapping
RESOLUTION		25 M
ORIENTATION		25 DEG Either Side of Track
OFFSET POINTING ANGLE AVAILABLE		$\pm$ 25 DEG from NADIR
SCAN RATE/EXPOSURE TIME		20 MHz BW
MOMENT OF INERTIA	P	10 Kg - m^2
	R	400 Kg - m^2
	Y	400 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.1 DEG
POINTING STABILITY ERROR AMP	6 $\widehat{SEC}$ (3σ)
POINTING STABILITY ERROR RATE	300 $\widehat{SEC}$/SEC (3σ)
STABILITY DURATION	30 Minutes
SLEW PROFILE	Not Required
	-
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	-
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: TROPICAL STORM RESEARCH/OCEAN PHYSICS
ALTITUDE: 200~500 KM, NOMINAL 470 KM

SENSOR: SCANNING MULTICHANNEL MICROWAVE RADIOMETER (SMMR)

SENSOR CHARACTERISTICS

SIZE		0.8 Parabolic Antenna
WEIGHT		40 Kg
TOTAL ANGULAR COVERAGE		±25 DEG Across Track (Conical Scan)
INSTANTANEOUS FOV		0.7 DEG (37 GHz), 4 DEG (6.6GHz)
SWATH WIDTH		400 KM
ALONG TRACK COVERAGE		50 KM (6.6GHz)
NO. OF TARGET PER ORBIT		Continuous Mapping
RESOLUTION		10 KM (37GHz)
ORIENTATION		Cone Angle 45 ~ 64 DEG
OFFSET POINTING ANGLE AVAILABLE		±64 DEG Across Track
SCAN RATE/EXPOSURE TIME		4 Second Per Scan
MOMENT OF INERTIA	P	2 Kg - m^2
	R	2 Kg - m^2
	Y	1 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.1 DEG
POINTING STABILITY ERROR AMP	72 SEC (3 σ)
POINTING STABILITY ERROR RATE	18 SEC/SEC (3 σ)
STABILITY DURATION	30 Minutes
SLEW PROFILE	Not Required
	-
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	Scanning Antenna
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: TROPICAL STORM RESEARCH/OCEAN PHYSICS
ALTITUDE: 200~500 KM, NOMINAL 470 KM

SENSOR: SCATTEROMETER (FAN BEAM)

SENSOR CHARACTERISTICS

SIZE		(4 EA) 300 x 17 x 15 cm Antenna
WEIGHT		55 Kg Antenna
TOTAL ANGULAR COVERAGE		± 65 DEG Across Track
INSTANTANEOUS FOV		0.5 DEG
SWATH WIDTH		2000 KM (Multibeam)
ALONG TRACK COVERAGE		25 KM
NO. OF TARGET PER ORBIT		Continuous Measurement
RESOLUTION		5 KM
ORIENTATION		4 Fan Beams at 45 & 135 DEG
OFFSET POINTING ANGLE AVAILABLE		-
SCAN RATE/EXPOSURE TIME		Not Applicable
MOMENT OF INERTIA	P	4 Kg - m^2
	R	4 Kg - m^2
	Y	10 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.05 DEG
POINTING STABILITY ERROR AMP	18 SEC (3 σ)
POINTING STABILITY ERROR RATE	18 SEC/SEC
STABILITY DURATION	30 Minutes
SLEW PROFILE	Not Required
	-
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	-
TRACKING REQUIREMENT (INCL V/H)	-

32

MISSION: TROPICAL STORM RESEARCH/OCEAN PHYSICS
ALTITUDE: 200 ~ 500 KM, NOMINAL 470 KM

SENSOR: VISUAL & IR RADIOMETER

SENSOR CHARACTERISTICS

SIZE		41 x 16 x 24 cm
WEIGHT		10 Kg
TOTAL ANGULAR COVERAGE		± 70 DEG Across Track
INSTANTANEOUS FOV		0.3 DEG
SWATH WIDTH		Horizon/Horizon
ALONG TRACK COVERAGE		3.5 KM (Visual)
NO. OF TARGET PER ORBIT		Continuous Mapping
RESOLUTION		3.5 KM (Visual) - 7 KM (IR)
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		-
SCAN RATE/EXPOSURE TIME		2 Scan Per SEC
MOMENT OF INERTIA	P	2 Kg - m^2
	R	2 Kg - m^2
	Y	1 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.05 DEG
POINTING STABILITY ERROR AMP	40 $\widehat{SEC}$ (3 σ)
POINTING STABILITY ERROR RATE	80 $\widehat{SEC}$/SEC (3 σ)
STABILITY DURATION	30 Minutes
SLEW PROFILE	Not Required
	-
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	Scanning Mirror
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: ELECTROMAGNETIC ENVIRONMENT EXPERIMENT
ALTITUDE: 200 ~ 500 KM, NOMINAL 400 KM

SENSOR: ELECTROMAGNETIC ENVIRONMENTAL EXPERIMENT (EEE)

SENSOR CHARACTERISTICS

SIZE		2.875 M Pallet
WEIGHT		672 Kg on Pallet
TOTAL ANGULAR COVERAGE		±70 DEG from NADIR
INSTANTANEOUS FOV		1 DEG to 70 DEG Wide Beam
SWATH WIDTH		Horizon/Horizon
ALONG TRACK COVERAGE		1 DEG to Several DEG
NO. OF TARGET PER ORBIT		Continuous Scan
RESOLUTION		7 KM
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		2-Axis Gimbal
SCAN RATE/EXPOSURE TIME		20 DEG Per SEC Max Scan Rate
MOMENT OF INERTIA	P	1000 Kg - m^2
	R	1000 Kg - m^2
	Y	1000 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.1 DEG
POINTING STABILITY ERROR AMP	180 $\widehat{SEC}$ (3 σ)
POINTING STABILITY ERROR RATE	180 $\widehat{SEC}$/SEC (3 σ)
STABILITY DURATION	1 SEC
SLEW PROFILE	Not Required
	-
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	Gimbal Motor Max Acceleration: 0.13 RAD/SEC^2
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: ADAPTABLE MULTIBEAM ANTENNA EXPERIMENT
ALTITUDE: 200 ~ 500 KM, NOMINAL 400 KM

SENSOR: ADAPTIVE MULTIBEAM PHASE ARRAY (AMPA)

SENSOR CHARACTERISTICS

SIZE		300 x 300 x 50 cm Antenna
WEIGHT		1500 Kg Antenna
TOTAL ANGULAR COVERAGE		±40 DEG From NADIR
INSTANTANEOUS FOV		5 DEG
SWATH WIDTH		700 KM
ALONG TRACK COVERAGE		35 KM
NO. OF TARGET PER ORBIT		2 to 12
RESOLUTION		35 KM
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		Not Applicable
SCAN RATE/EXPOSURE TIME		Electronic Scan
MOMENT OF INERTIA	P	1000 Kg - m^2
	R	1000 Kg - m^2
	Y	2000 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.3 DEG
POINTING STABILITY ERROR AMP	180 SEC (3 σ)
POINTING STABILITY ERROR RATE	180 SEC/SEC (3 σ)
STABILITY DURATION	15 MIN
SLEW PROFILE	ACC-COAST-DEC MAX ACC/DEC TIME 33 SEC
MAX SLEW ACCELERATION	0.001 RAD/SEC^2
MAX SLEW RATE	0.021 RAD/SEC
SETTLING TIME	2 SEC
MAX SLEW ANGLE/TIME	40 DEG/68 SEC (INCL SETTLING)
POINTING CMD ACCURACY	0.1 DEG
PAYLOAD GENERATED DISTURBANCE	
TRACKING REQUIREMENT (INCL V/H)	

MISSION: REMOTE SENSING OF SOIL MOISTURE
ALTITUDE: 200~500 KM, NOMINAL 330 KM

SENSOR: THEMATIC MAPPER (LINEAR SCAN)

SENSOR CHARACTERISTICS

SIZE		116 x 93 x 60 cm
WEIGHT		180 Kg
TOTAL ANGULAR COVERAGE		± 7 DEG Across Track
INSTANTANEOUS FOV		0.0035 DEG
SWATH WIDTH		87 KM
ALONG TRACK COVERAGE		400 M
NO. OF TARGET PER ORBIT		Continuous Mapping
RESOLUTION		20 M
ORIENTATION		Nadir
OFFSET POINTING ANGLE AVAILABLE		±20 DEG Across Track
SCAN RATE/EXPOSURE TIME		44.3 M SEC Per Scan Line
MOMENT OF INERTIA	P	25 Kg - m^2
	R	20 Kg - m^2
	Y	30 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.5 DEG
POINTING STABILITY ERROR AMP	6 SEC (3 σ)
POINTING STABILITY ERROR RATE	100 SEC/SEC (3 σ)
STABILITY DURATION	1 SEC
SLEW PROFILE	Not Required
	-
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	Scanning Mirror
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: REMOTE SENSING OF SOIL MOISTURE
ALTITUDE: 200~500 KM, NOMINAL 330 KM

SENSOR: COHERENT IMAGING RADAR (SAR)

SENSOR CHARACTERISTICS

SIZE		10 x 3M Antenna
WEIGHT		1250 Kg
TOTAL ANGULAR COVERAGE		10 DEG Across Track
INSTANTANEOUS FOV		0.003 DEG
SWATH WIDTH		100 KM (L-Band)
ALONG TRACK COVERAGE		25 M (L-Band)
NO. OF TARGET PER ORBIT		Continuous Mapping
RESOLUTION		6 M
ORIENTATION		25 DEG Either side of Track
OFFSET POINTING ANGLE AVAILABLE		±25 DEG From NADIR
SCAN RATE/EXPOSURE TIME		25 MHz BW
MOMENT OF INERTIA	P	10 Kg - m^2
	R	400 Kg - m^2
	Y	400 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.1 DEG
POINTING STABILITY ERROR AMP	6 $\widehat{SEC}$ (3 σ)
POINTING STABILITY ERROR RATE	300 $\widehat{SEC}$/SEC (3 σ)
STABILITY DURATION	1 SEC
SLEW PROFILE	Not Required
	-
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	-
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: REMOTE SENSING OF SOIL MOISTURE
ALTITUDE: 200~500 KM, NOMINAL 330 KM

SENSOR: SHUTTLE IMAGING MICROWAVE SYSTEM (SIMS)

SENSOR CHARACTERISTICS

SIZE		4 M Wide Antenna
WEIGHT		950 Kg
TOTAL ANGULAR COVERAGE		± 30° Across Track
INSTANTANEOUS FOV		0.1 DEG (119 GHz), 17 DEG (0.6 GHz)
SWATH WIDTH		400 KM
ALONG TRACK COVERAGE		100 KM (0.6 GHz)
NO. OF TARGET PER ORBIT		Continuous Scan
RESOLUTION		600 M (119 GHz)
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		-
SCAN RATE/EXPOSURE TIME		6 Scan Lines Per SEC
MOMENT OF INERTIA	P	400 Kg - m^2
	R	20 Kg - m^2
	Y	400 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.05 DEG
POINTING STABILITY ERROR AMP	36 SEC (3 σ)
POINTING STABILITY ERROR RATE	200 SEC/SEC (3 σ)
STABILITY DURATION	1 SEC
SLEW PROFILE	Not Required
	-
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	Rotating RF Feed Assembly
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: REMOTE SENSING OF SOIL MOISTURE
ALTITUDE: 200~500 KM, NOMINAL 330 KM

SENSOR: PHOTOPOLARIMETER (SPOT-SCANNING)

SENSOR CHARACTERISTICS

SIZE		35 x 35 x 50 cm
WEIGHT		27 Kg
TOTAL ANGULAR COVERAGE		±60 DEG Across Track
INSTANTANEOUS FOV		1 DEG
SWATH WIDTH		1200 KM
ALONG TRACK COVERAGE		6 KM
NO. OF TARGET PER ORBIT		Continuous Scan
RESOLUTION		6 KM
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		-
SCAN RATE/EXPOSURE TIME		1 Scan Per SEC
MOMENT OF INERTIA	P	1 Kg - m^2
	R	1 Kg - m^2
	Y	1 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.1 DEG
POINTING STABILITY ERROR AMP	36 SEC (3 σ)
POINTING STABILITY ERROR RATE	36 SEC/SEC (3 σ)
STABILITY DURATION	1 SEC
SLEW PROFILE	Not Required
	-
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	Scanning Gimbal
TRACKING REQUIREMENT (INCL V/H)	-

MISSION: SENSOR DEVELOPMENT
ALTITUDE: 200 ~ 500 KM, NOMINAL 400 KM

SENSOR: LIDAR

SENSOR CHARACTERISTICS

SIZE		50 φ x 200 cm
WEIGHT		100 Kg
TOTAL ANGULAR COVERAGE		Not Applicable
INSTANTANEOUS FOV		0.057°
SWATH WIDTH		0.4 KM
ALONG TRACK COVERAGE		0.4 KM
NO. OF TARGET PER ORBIT		Continuous Measurement
RESOLUTION		0.4 KM
ORIENTATION		NADIR
OFFSET POINTING ANGLE AVAILABLE		TBD
SCAN RATE/EXPOSURE TIME		Less Than 1 Per SEC
MOMENT OF INERTIA	P	3 Kg - m^2
	R	3 Kg - m^2
	Y	0.5 Kg - m^2

POINTING/STABILIZATION REQUIREMENTS

POINTING ACCURACY	0.003 DEG
POINTING STABILITY ERROR AMP	0.2 SEC (3 σ)
POINTING STABILITY ERROR RATE	2 SEC/SEC (3 σ)
STABILITY DURATION	1 SEC
SLEW PROFILE	Not Required
	-
MAX SLEW ACCELERATION	-
MAX SLEW RATE	-
SETTLING TIME	-
MAX SLEW ANGLE/TIME	-
POINTING CMD ACCURACY	-
PAYLOAD GENERATED DISTURBANCE	-
TRACKING REQUIREMENT (INCL V/H)	TBD