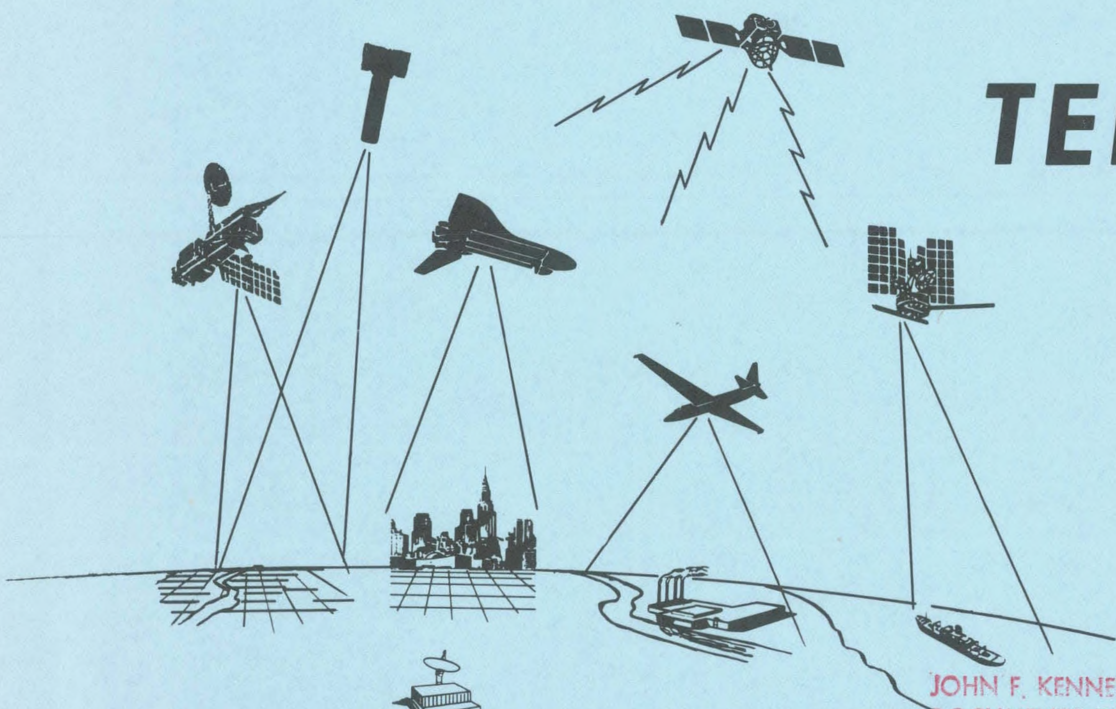
definition of the

TOTAL EARTH RESOURCES SYSTEM FOR THE SHUTTLE ERA

NAS9-13401

VOLUME 6
AN EARLY SHUTTLE PALLET CONCEPT FOR THE EARTH RESOURCES PROGRAM



TERSSE

GENERAL ELECTRIC
SPACE DIVISION

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DEFINITION OF THE TOTAL EARTH RESOURCES SYSTEM FOR THE SHUTTLE ERA

VOLUME 6

AN EARLY SHUTTLE PALLET CONCEPT FOR THE EARTH RESOURCES PROGRAM

PREPARED FOR

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PREFACE

The pressing need to survey and manage the earth's resources and environment, to better understand remotely sensible phenomena, to continue technological development, and to improve management systems are all elements of a future Earth Resources System. The Space Shuttle brings a new capability to Earth Resources Survey including direct observation by experienced earth scientists, quick reaction capability, spaceborne facilities for experimentation and sensor evaluation, and more effective means for launching and servicing long mission life space systems.

The Space Shuttle is, however, only one element in a complex system of data gathering, translation, distribution and utilization functions. While the Shuttle most decidedly has a role in the total Earth Resources Program, the central question is the form of the future Earth Resources system itself. It is only by analyzing this form and accounting for all elements of the system that the proper role of the Shuttle in it can be made visible.

This study, entitled TERSSE, Total Earth Resources System for the Shuttle Era, was established to investigate the form of this future Earth Resources System. Most of the constituent system elements of the future ER system and the key issues which concern the future ER program are both complex and interrelated in nature. The purpose of this study has been to investigate these items in the context of the total system utilizing a rigorous, comprehensive, systems oriented methodology.

The results of this study are reported in eight separate volumes plus an Executive Summary; their titles are:

Volume 1 Earth Resources Program Scope and Information Needs

Volume 2 An Assessment of the Current State-of-the-Art

Volume 3 Mission and System Requirements for the Total Earth Resources System

Volume 4 The Role of the Shuttle in the Earth Resources Program

Volume 5 Detailed System Requirements: Two Case Studies

Volume 6 An Early Shuttle Pallet Concept for the Earth Resources Program

Volume 7 User Models: A System Assessment

Volume 8 User's Mission and System Requirement Data

Executive Summary.

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We would also like to acknowledge the support of Mr. Tom Vogt of the Itek Corporation who generously supplied consultation and much of the information contained herein on the photographic sensor systems.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

SECTION 1

INTRODUCTION AND SUMMARY

SECTION 1

INTRODUCTION AND SUMMARY

This report deals with one of the more detailed and specific tasks of the TERSSE study: the design of a Space Shuttle pallet-only mission which can be flown very early in the Shuttle Program. It was well understood at the beginning of the study that there would likely be profitable missions evolved by the TERSSE study team for which the Shuttle Sortie was suited even though the form of these missions would not be known until well into the study. Thus, a pallet-only mission design task of brief scope was planned for the late months of the study.

The guidelines adopted at the beginning of the TERSSE study for the design of this typical Shuttle pallet mission were as follows:

1. The mission should be a useful one which is consistent with the overall context of the TERSSE concept for the Shuttle era.
2. It should be (uniquely) suited for execution via the Shuttle sortie flight mode, as opposed to a polar or synchronous satellite.
3. It should be a relatively low-cost concept and, wherever possible, use available sensors and concentrate on the applications development aspects of the mission.

Later in the study, at the initiation of effort on the Shuttle Pallet Design task, additional guidelines were adpoted:

1. The pallet hardware baseline to be used in the effort was to be a single 3 meter section of the ERNO pallet design (adopted by ESRO and NASA subsequent to the start of the TERSSE study).
2. The TERSSE Shuttle Pallet mission was to be defined with a specific early Shuttle flight as context in order that the physical and operational integration of such an Earth Resources payload with another "primary" mission and payload could be examined. Shuttle Mission #4 was selected as the contextual Shuttle flight for such use.

The study team examined those TERSSE missions or portions of missions which had been identified as candidates for the sortie platform and selected the Urban Land Use/1980 Census Mission previously identified and treated in the Land Resources Management Case Study (TERSSE Final Report, Volume 5). This mission embodies all of the characteristics desired for the task: it is useful, it has enthusiastic user interest at USGS and the Census Bureau, its timing is compatible with the early Shuttle era, it is uniquely performed by Shuttle sortie, and it can be performed (primarily) by the use of off-the-shelf sensors.

Much preparation for the mission will be required, as a major technological advance for the Census Bureau is involved. The shuttle flight described herein provides comprehensive photographic (film) and scanner imagery of the major U. S. urban centers to aid in Census Bureau planning for the 1980 Census to occur on 1 April 1980. Additional imagery is also to be obtained one year after the first flight to permit the issuance of a series of urban land use maps concurrently with the 1980 Census data.

The orbital configuration created for the Urban Land Use/1980 Census Mission is illustrated in Figure 1-1. It includes four sensors and support equipment. A high-resolution film camera (S163) provides first-look urban area delineation and the location of streets and roads via photointerpretation. A high-resolution framing camera (S190B) provides imagery for map updating and detailed census procedure planning. A low-resolution framing camera (S190A) provides imagery for gross land use classification via photointerpretation and a multispectral scanner permits precise digital land use classification of the urban area. An alternate configuration which does not require the Orbiter roll maneuvering is illustrated in Figure 1-2.

The information flow for the mission is illustrated in Figure 1-3. The field enumerable imagery produced will be used by the Census Bureau field teams. Thematic maps and computer data tapes will also be produced and, as a byproduct, be provided to other agencies dealing with urban land use problems.

Thus, the study team has identified and performed conceptual definition of a Shuttle sortie mission which can be performed inexpensively in the early Shuttle era and which, if the necessary intermediate steps are accomplished, will provide a major technological advance for the user organization - the U. S. Bureau of Census. The Census Bureau, Geography Division, and its remote-sensing interface, the USGS Geography Applications Program, has provided the concept their enthusiastic interest during the conduct of the study. It is our opinion that the Earth Resources Program should continue to investigate this project as one of the very first demonstrations of the real value of Shuttle sortie missions.

EPILOGUE

As the mission design progressed, continued discussions with the U. S. Census Bureau sharpened our realization, and theirs, of a broader utility of such a mission for Census Bureau operations. Responsibilities of the Bureau such as provision of statistics for fuel allocation guidelines, Federal revenue sharing, and legislature redistricting are but a few of the emerging potential applications of the information which could be produced by the concept described herein. These additional applications, when considered collectively, form an even stronger mandate for continued investigation of the use of Shuttle in support of the U. S. Census Bureau.

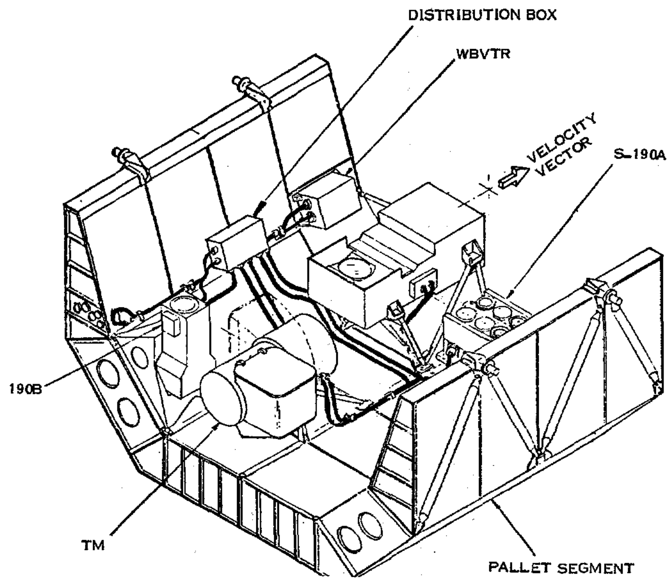


Figure 1-1. TERSSE Pallet Concept

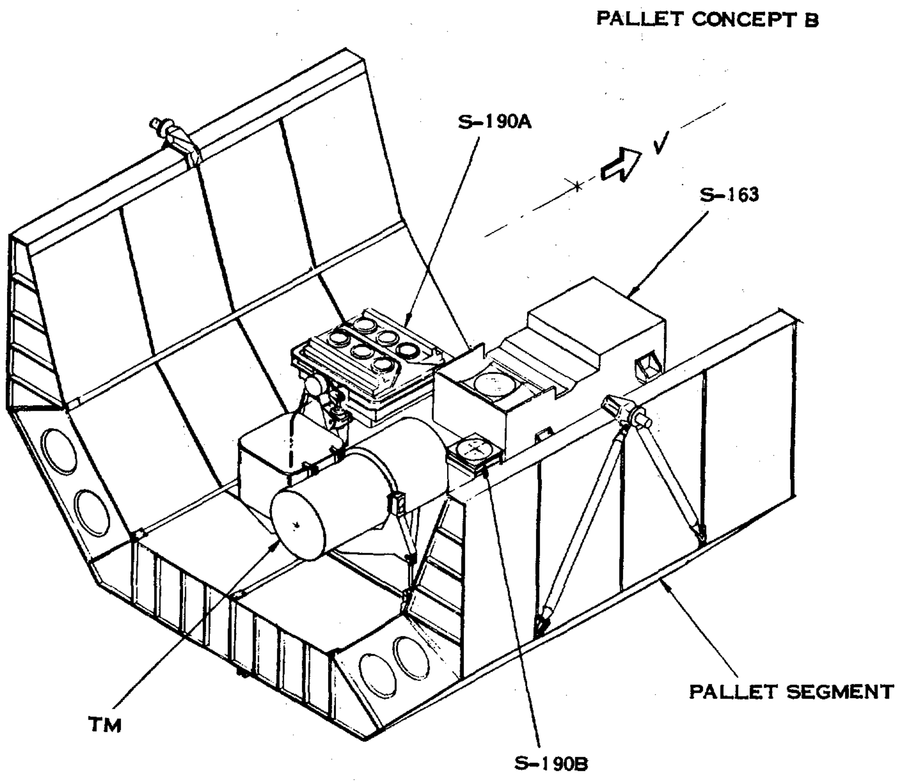


Figure 1-2. Pallet Configuration

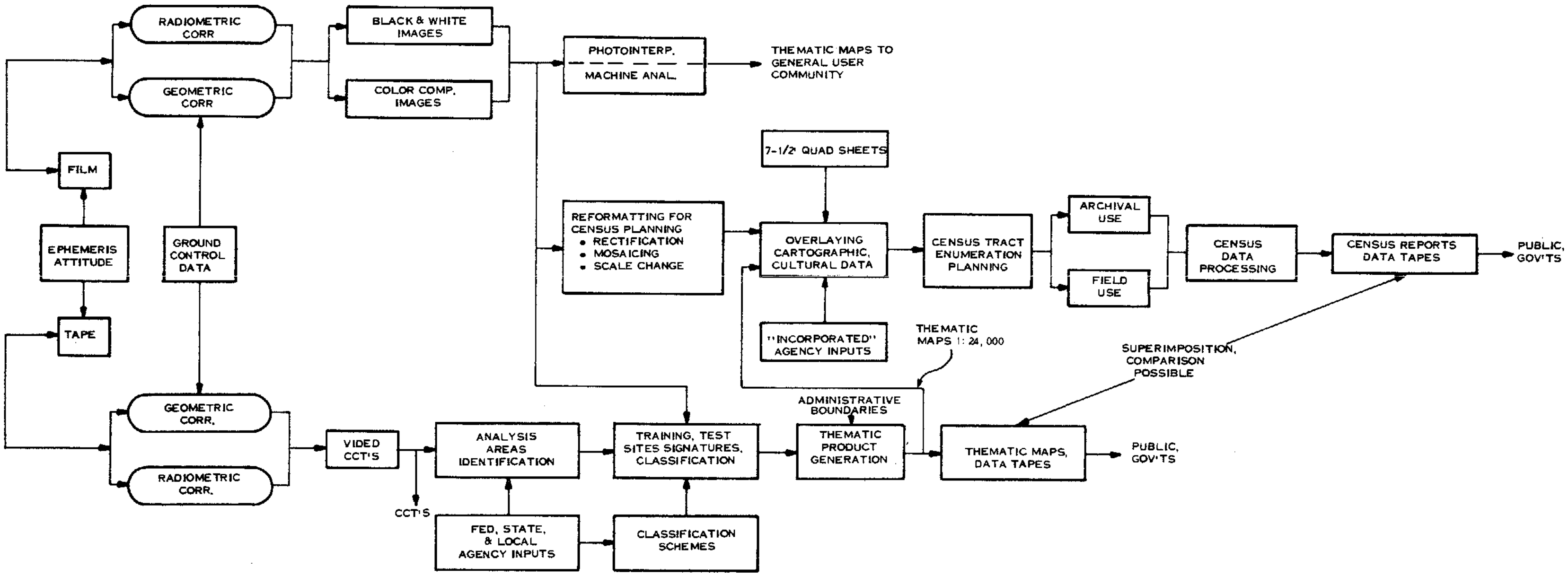


Figure 1-3. Information Flow

SECTION 2

MISSION REQUIREMENTS

SECTION 2

MISSION REQUIREMENTS

This section of the report describes the background for the selection of the Urban Land Use/1980 Census* mission for this task, the specific Census Bureau functions to be supported by the mission, and the detailed mission requirements for accomplishing it.

2.1 TERSSE STUDY BACKGROUND, GUIDELINES, AND ASSUMPTIONS

The Shuttle Pallet design task drew heavily on the methodology and results of earlier phases of the TERSSE study. A contextual synopsis of the approach and results of the earlier phases is presented in the paragraphs which follow.

The discipline requirements considered early in the TERSSE study represent a comprehensive list of scientific information classes and the parameters needed to fulfill these information classes, catalogued according to scientific discipline. We have gone beyond this classification of parameters to an analysis of their capability of being sensed remotely in the Shuttle era, considering the likely progress to be made by that time. The results of this analysis produced a forecast of the feasibility of each parameter's potential "signatures" in each of several wavelengths of interest as shown in Figure 2-1. This forecast was used in the current task as a guideline for the definition of sensor requirements.

Much care was taken in the entire TERSSE effort to separate that which is desired to be measured from that which must be done with the information in fulfilling a user organization responsibility. Figure 2-2 illustrates how the two concepts were brought together to create total system requirements. In this situation, we were not interested in science for science's sake at all, but consider information classes as a means to an end: the monitoring or management of a resource by an organization which is chartered (by law, executive order, or other legitimate authority) to do so. So, in addition to the discipline analysis, the TERSSE team accomplished two other things in the earlier study phases: (1) we conducted a comprehensive study of the "mission", tasks, and information requirements of the likely user organizations in order to understand their jobs and the legal and economic motivating forces behind them, and (2) we combined this work with a scientific discipline breakdown to produce an assessment of who needs what information (and why). Figures 2-3 and 2-4 illustrate some of the results of the integration of these two TERSSE study thrusts and illustrate our position that science for science's sake is not the ultimate motivation of the Earth Resources Program, but that furnishing information useful for the management of resources is.

With regard to the concept definition and rationale of an early Shuttle pallet mission, the importance of the foregoing results is this: a set of resource management problems, or "missions", was defined which form the basis for performance requirements for the total Earth Resources system (of which the pallet must be an integrated

*Current research in this area is directed by two government agencies: U. S. Geological Survey and U. S. Census Bureau

Information Required	Parameters	Spectral Signature				Temporal/ Spectral Signature				Thermal Radiance Signature		Multispect Spectral Signature				Scattering Cross Section Signature			Polarization Signature			
Land Use Mapping		Visible	Near IR	Thermal IR	Microwave	Visible	Near IR	Thermal IR	Microwave	Thermal IR	Microwave	Visible	Near IR	Thermal IR	Microwave	Microwave - 1 Band	Microwave - Multi	Optical	Visible	Near IR	Thermal IR	Microwave
8. Agricultural Land	8. Extent, location and intensity of:																					
	- Cropland and pasture	1	1	4	3	1	1	2	3	2	3	3	3	4	4	2	3	3	3	3	4	3
	- Orchards, groves, bush fruits, vineyards, and horticultural areas	1	1	4	3	1	1	2	3	2	3	3	3	4	4	2	3	3	3	3	4	3
	- Feeding operations	1	1	4	3	1	1	2	3	2	3	3	3	4	4	3	3	3	3	3	4	3
	- Other agricultural land	1	1	4	3	1	1	2	3	2	3	3	3	4	4	3	3	3	3	3	4	3
9. Rangeland	9. Extent, location and intensity of:																					
	- Grass	1	1	4	3	1	1	2	3	2	3	3	3	4	4	2	3	3	3	3	4	3
	- Savannas (palmetto prairies)	1	1	4	3	1	1	2	3	2	3	3	3	4	4	3	3	3	3	3	4	3
	- Chaparral	1	1	4	3	1	1	2	3	2	3	3	3	4	4	3	3	3	3	3	4	3
	- Desert shrub	1	1	4	3	1	1	2	3	2	3	3	3	4	4	3	3	3	3	3	4	3
10. Forest Land	10. Extent, location and intensity of:																					
	- Deciduous	1	1	4	3	1	1	2	3	2	3	3	3	4	4	2	3	3	3	3	4	3
	- Evergreen (coniferous and other)	1	1	4	3	1	1	2	3	2	3	3	3	4	4	2	3	3	3	3	4	3
	- Mixed	1	1	4	3	1	1	2	3	2	3	3	3	4	4	2	3	3	3	3	4	3
11. Transportation Nets	11. Highways/Roads	1	1	2	3	1	1	2	3	2	3	3	3	4	3	2	3	3	3	3	3	3
	Railroads	1	1	3	3	2	2	2	3	2	3	3	3	4	3	2	3	3	3	3	4	3
	Canals	1	1	3	3	2	2	2	3	2	3	3	3	4	3	2	3	3	3	3	4	3
12. Urbanization	12. Location	1	1	4	3	1	1	2	3	2	3	3	3	4	3	2	3	3	3	3	3	3
	Gross morphology	4	4	4	4	4	4	4	4	4	4	3	3	4	4	2	3	3	3	3	3	3
	Vegetation/bare ground ratio	1	1	3	3	2	2	2	3	2	3	3	3	4	4	3	3	3	3	3	4	3
	Asphalt/grass ratios	1	1	3	3	2	2	2	3	2	3	3	3	4	4	3	3	3	3	3	4	3
	Distribution and density of structures	1	1	4	3	2	2	2	3	2	3	3	3	4	4	2	3	3	3	3	4	3
	Size spectrum of structures	1	1	4	3	2	2	2	3	2	3	3	3	4	4	2	3	3	3	3	4	3
	Lineaments	1	1	4	3	2	2	2	3	2	3	3	3	4	4	2	3	3	3	3	4	3
	Highway/street patterns	1	1	4	3	2	2	2	3	2	3	3	3	4	4	2	3	3	3	3	4	3
	Open space/recreational areas	1	1	4	3	2	2	2	3	2	3	4	4	4	4	3	3	3	3	3	4	3
	Temperature patterns	4	4	3	3	4	4	1	3	1	3	4	4	4	4	4	4	4	4	4	4	4

Key:

1. Signature contributes directly to the assessment of the parameter. Documented evidence of feasibility.
2. Signature is useful only in a supporting way to the assessment of the parameter. Other measurements required to obtain a complete assessment of the parameter.
3. No documented evidence of the study or use of this signature to assess the parameter. Use of this signature cannot be rejected on theoretical grounds, however.
4. Signature not useful in assessing parameter.

Figure 2-1. Remote Sensing Feasibility

part). These resource management "missions" were, in turn, analyzed individually to determine their requirements, with results which are depicted in Figure 2-5. It will be noted that many types of users are included in each mission, and that their resource management jobs dictate a varied set of requirements for performance of their future.

The next step in the TERSSE analysis was a treatment of the collective requirements of these missions to answer (1) which missions should be performed by which platform (Shuttle sortie, polar spacecraft, geosynchronous spacecraft, aircraft) and sensors, and (2) what are the top-level performance requirements for the total system

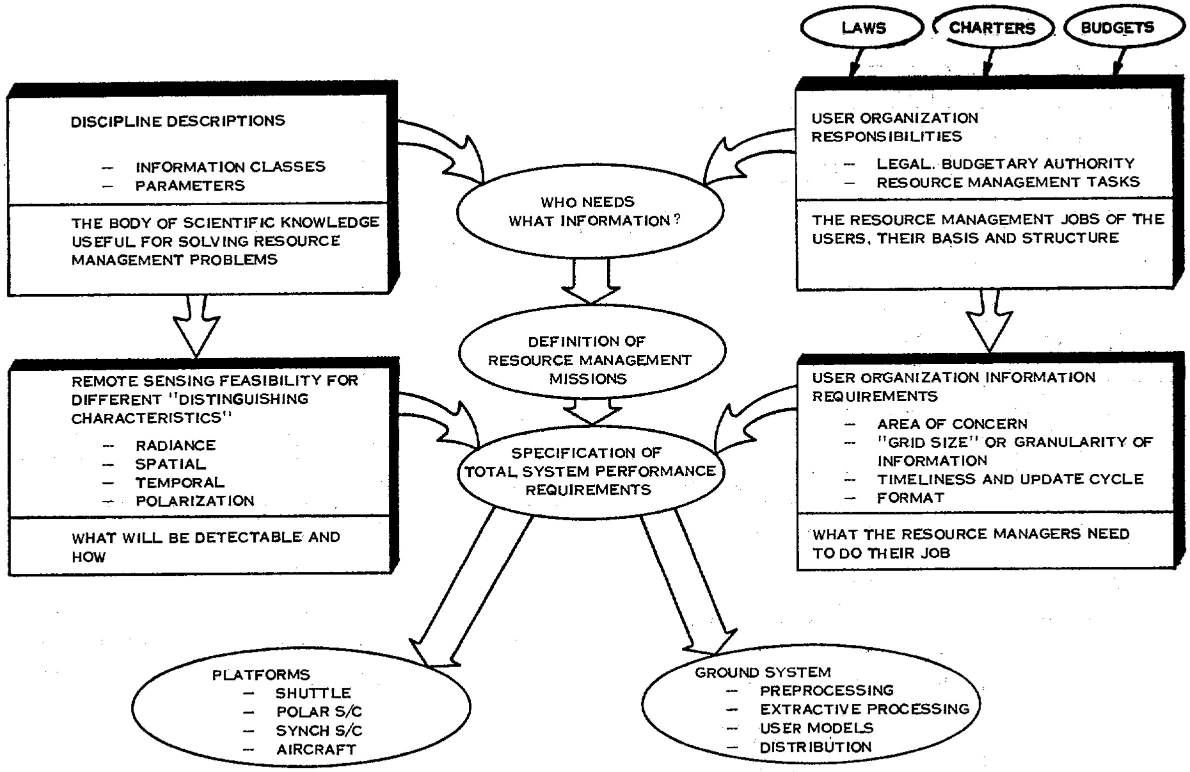


Figure 2-2. Total Earth Resources System Requirements

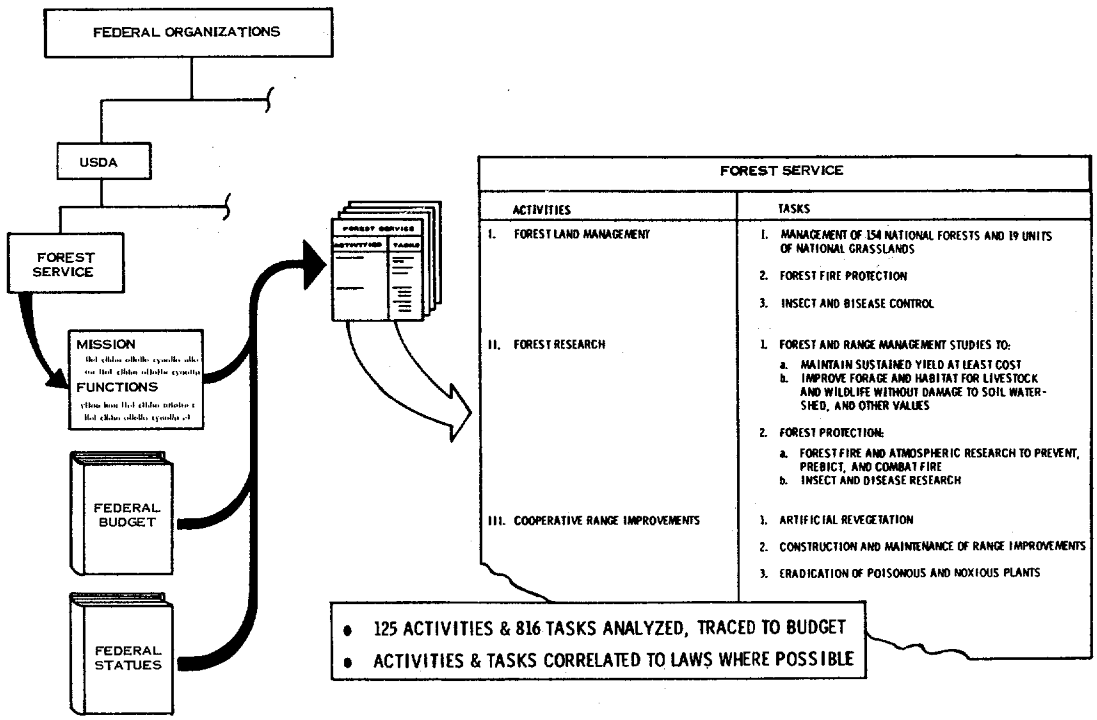


Figure 2-3. Example of Organization Analysis of Activities and Tasks

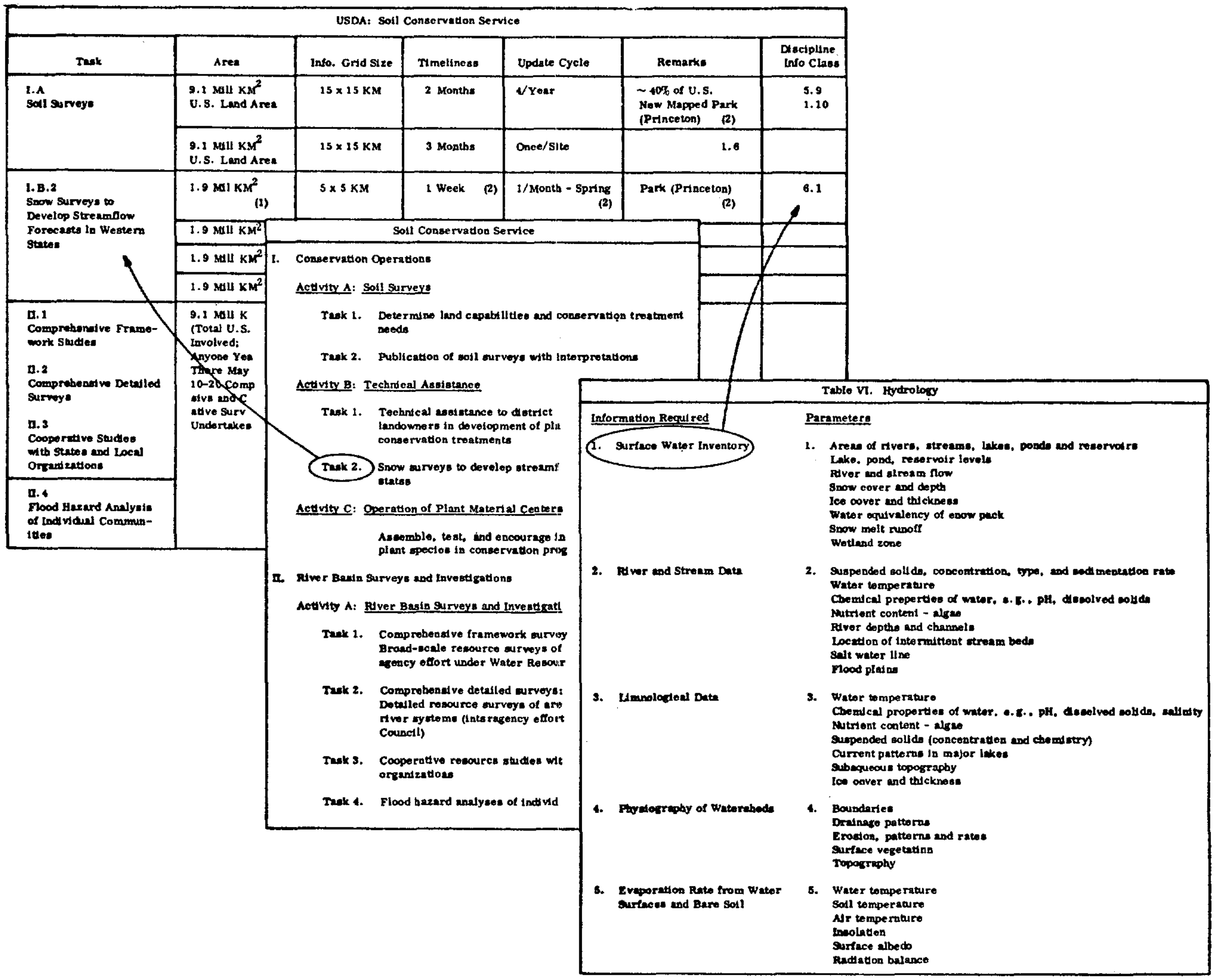


Figure 2-4. Example Correlation Among Discipline Information Requirements, Organization Activities and Resource Management Information

AG. 3		
EXTRACTIVE PROCESSING REQ'TS.	ANCILLARY DATA	OPTICAL DEPTH OF THE ATMOSPHERE ALBEDO OF TERRAIN SPECULAR & DIFFUSE INCIDENT RADIATION
	TECHNIQUE	INTENSITY AND EXTENT OF CULTIVATION, CROP ROTATION, TIME OF PLANTING AND TIME OF HARVEST, SOIL SALINITY, SOIL BOUNDARIES → SPECTRAL/SPATIAL/TEMPORAL FEATURES
		IRRIGATION, ELEMENT COMPOSITION, ORGANIC CONTENT, TEMPERATURE, MOISTURE CONTENT, SOIL MOISTURE PROFILE → SPECTRAL FEATURES
		WATERSHED BOUNDARIES, TOPOGRAPHY → COLOR LEVEL SLICE
	OUTPUT	SOIL TYPE, SOIL MOISTURE, AND TOPOGRAPHIC INFORMATION ON TAPE
USER MODEL REQ'TS.	TYPE	RELATE SOIL COMPOSITION, TOPOGRAPHY, MOISTURE PROFILE AND CURRENT & HISTORICAL CROP PRACTICE TO COMPUTE "PRODUCTIVITY INDEX" BY CROP TYPE
	ANCILLARY INPUTS	FERTILIZATION PRACTICE, HISTORICAL YIELD DATA, CROP TYPE HISTORY AND DEPTH OF TOP SOIL
	OUTPUT	SOIL PRODUCTIVITY ESTIMATE BY CROP TYPE (POTENTIAL YIELD)

MISSION: (AG 3) SURVEY U.S. CROPLAND TO IDENTIFY CURRENT FARMING PRACTICES AND CLASSIFY AREAS ON THE BASIS OF PRODUCTIVITY.						
INFORMATION CLASSES: 1.2 (CROP YIELD), 1.5 (FARMING PRACTICES), 1.6 (SOIL CAPABILITY), 1.7 (SOIL MOISTURE), 6.4 (PHYSIOGRAPHY OF WATER SHED).						
USERS		USDA-SCS	USDA-SRS	USDI-BIA	STATE AG DEPTS	STATE LAND USE DEPTS
OBSERVATION REQ'S	LOCATION/AREA	US CROPLAND	US CROPLAND	US INDIAN RESERVATIONS	CROPLANDS WITHIN EACH STATE	CROPLANDS WITHIN EACH STATE
	COVERAGE CYCLE	FOR 1.6, 1.7, 6.4: JUNE IN MIDWEST OR WHEN BARE GROUND IS SHOWING FOR 1.2, 1.5: (EVERY 2 WEEKS				
	DURATION	EARLY SPRING TO EARLY WINTER				
	SUN ANGLE	>30° ELEVATION ANGLE				
	OBLIQUITY	OBSERVATIONS AT : 10°, 20°, 30° OFF NADIR FOR 1.7 FOR 6.4, 30° OFF NADIR.				

Figure 2-5. Resource Management Mission Results

necessary to collect, process, and distribute the information needed to accomplish the missions. In performing step (1) the TERSSE team analyzed the capabilities of different platforms and assigned each portion of each mission to the platform optimally suited for its conduct (by optimally we mean the best combination of performance, system cost, and fulfillment of user requirements).

Figure 2-6 contains a list of TERSSE missions suitable for Shuttle sortie flights. Many of these are integrated missions, that is, they are to be performed by a Shuttle sortie working in conjunction with another platform such as a polar orbiter. Their requirements, collectively, are characterized by a requirement for relatively high resolution imagery obtained over large areas but at relatively infrequent intervals.

SENSOR	SHUTTLE SORTIE MISSIONS																		
	AG 1 US CROP SURVAY	AG 3 FARMING PRACTICES	AG 5 GLOBAL CROP SURVAY	E/M1 MINERAL SURVAY	E/M3 SUBMARINE OIL SURVAY	E/M4 EXTRACTION POLLUTION MONITOR	E/M7 THERMAL POLLUTION MONITOR	FOR* 1 TIMBER INVENTORY	FOR* 2 INSECT DISEASE STRESS	FOR 3 FIRE MONITOR & ASSESSMENT	LAND* 1 US LAND USE INVENTORY	LAND* 2 LANDFORM & COVER MAPPING	LAND 4 GEOLOGICAL MAPPING	MAR 1 OCEAN DYNAMICS MONITOR	WAT 1 URBAN/AG SUPPLY INVENTORY	WAT 2 HYDROELECTRIC SUPPLY INVENTORY	WAT 3 GREAT LAKES ICE	WAT 4 WATER QUALITY MONITOR	WAT 6 COASTAL WETLANDS MONITOR
50 METER SCANNER	X		X	X	X	X					X	X		X	X		X	X	X
10 METER SCANNER	X	X	X			X	X	X	X	X	X	X	X	X	X	X		X	
5 METER (FILM CAMERA)			X	X				X	X		X	X	X		X		X		
MICROWAVE	X	X	X	X	X	X		X	X				X	X	X	X	X		X

*MISSION/USERS THAT WILL BE SERVED BY SHUTTLE SORTIE OPERATIONALLY

Figure 2-6. Potential Shuttle Missions

Selection of a representative mission for detailed study in the design of a Shuttle pallet was performed by using the following criteria:

1. The mission must be an early operational one - that is it should serve a real (operational) user who can confidently be ready to utilize the information in the early Shuttle period.

2. The mission must be traceable - that is the mission be able to be defined in terms of the underlying laws, charters, and functions of the performing organization.

3. The mission must meet the test of sensor feasibility - that is, the original ground rule that off-the-shelf or available sensors be capable of being used must be met.

Of the missions suitable for shuttle sortie discussed in TERSSE Volumes 3 and 4, the land use group was found to be ready for early implementation, was traceable with respect to requirements, and appeared feasible from a sensor standpoint. As was described in detail in the Land Use Resources Management Case Study, the land use missions are characteristically fragmented by region and resource management function and are best treated on an ad hoc basis. It was thus decided that a particular ad hoc land use mission selected from those analyzed in the Land Resources Management Case Study would be used as the representative mission for detailed study in the Shuttle pallet design.

The several ad hoc missions studied in depth in the Land Resources Management Case Study included a regional planning mission (DVRPC), a state coastal zone land management mission (Delaware), and the Bureau of Census urbanized area definition/Census planning mission. The latter was selected because of its national emphasis, its timing requirements coinciding with early Shuttle mission, and its traceable requirements. It should be mentioned that an additional factor was the interest and support received from the USGS Geography Applications Program and the Census Bureau, Geography Division. Their support of the concept and willingness to provide guidance to the TERSSE team were and continue to be valuable in the definition of this potential early Shuttle pallet mission.

2.2 DESCRIPTION OF THE CANDIDATE MISSION

The following paragraphs described the background and objectives of the candidate mission to provide field enumeration census planning imagery and land use maps for the 1980 census and the mid-decade census of population and housing being considered for 1985.

Statutory Requirements for Census Bureau Operations

The statutory requirements for the work being done at the Bureau of the Census stem from (1) the historic constitutional directive to carry out the decennial national census for continual reapportionment of the House of Representatives based on population distribution; (2) The current Federal Revenue Sharing Act and other legislation, again requiring demographic data for the various administrative units of cities, counties and states; and (3) The (still) pending National Land Use Planning Assistance bills,* with the need for the above administrative units for correlative and application data.

*USGS currently has research responsibility for remote sensing

Current Census Procedures and Potential Impact of a Shuttle Census Mission

Since its formation as a permanent organization early in the 20th century, the Bureau of Census' methodology for planning and conducting the census has been based on conventional topographic procedures and field techniques for data acquisition. Data processing has been modernized through the use of digital computers in an integral fashion since the 1950 Census. The geographic data base digitization activities initiated for the 1970 Census and since enlarged have expanded the scope of automated geoprocessing application to the Census Bureau operations.

The organizational structure of the Bureau of the Census has developed in response to the procedures and practices currently in use to implement their functions. In carrying out the 1970 Decennial Census, the functional flow of data followed through the respective administrative units along the lines shown in Figure 2-7.

The computerized geographic reference and demographic data processing system has expedited the post-enumeration processing. However, the Bureau will be required to release a greater amount of data than ever before in the 1980 Census Report on an even shorter time schedule than achieved in 1970.

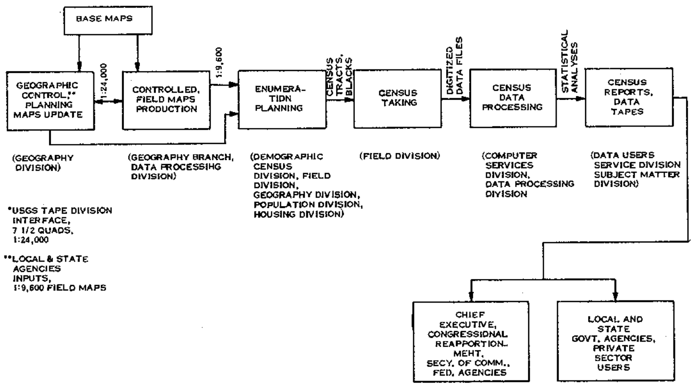


Figure 2-7. Current Census Functional Flow

To achieve this goal the Census Bureau has determined that a major technological advance will be necessary in the planning phase of its operation that will expedite the entire procedure. In addressing this problem, the Geography Division of the Bureau of Census has been evaluating the potential use of aircraft data on an operational basis for 1980. A major factor in this consideration is the methodology and the costs for converting acquired data into the data base format for the Bureas's use. The development of "ancillary technology" for data conversion is thus as important an item as the acquisition of reference data itself.

Table 2-1 lists the key events and their timing which will be necessary to carry out this mission.

In terms of preparedness of the Census Bureau to embark on such a project, a nominal amount of aerial imagery was acquired for the 1960 and 1970 Census. Independent of the 1970 census the USGS - Geography Applications Program's (GAP) Census Cities Project was the principal experimental effort towards a methodology development for the Bureau's assessment. Nasa acquired the coverage over some 24 cities in support of the USGS Project. Photointerpretation of imagery over a number of major urban areas was carried out to arrive at delimitation of the urban area boundaries and intensive urban land use classification to levels below level 2 defined in USGS Circular 671. The orthophoto maps and theme overlays formed a base data for broad-application studies during the 1970's; the specific needs of the Census Bureau only being a partial consideration.

Table 2-1. Urban Areas Land Use/ Census Planning Mission

Mid 1975 - Late 1978	Planning/Evaluation Phase
1 Apr 1979	Earliest Flight No. 1 Date
1 Oct 1979	Latest Flight No. 1 Date
31 Dec 1979	Latest fill-in flight date
1 Oct 1979 - 1 Apr 1980	Enumeration planning phase
1 Apr 1980	Census Day
1 Sep 1980	Preliminary Census data release (estimated)
1 Oct 1980	Latest Flight No. 2 Date

ERTS and Skylab data analyses by the USGS - GAP and Bureau of the Census - Geography Division have been underway to develop the necessary techniques for assessing and possibly implementing the 1980 program using multispectral analysis end photointerpretation of imagery. These studies are just beginning and are continuing in cooperation with NASA and industry.

Future Preparations

From discussions with researchers at each of these agencies, both human photointerpretation and machine analyses methods are begining to be investigated using ERTS and EREP imagery and MSS scanner data. The experimental investigation and evaluation of electronic analyses techniques undertaken at the USGS with ERTS computer - compatible tapes and Skylab scanner data, including underflights, would provide the thrust for the necessary technology transfer to the Bureau of the Census - Geography Division for operational application to the 1980 Census Planning. Digitization of the reference data, namely Census Block and Track geometry, for interactive use with ERTS computer - compatible tape analyses is an integral function in this technology assessment.

While beginning efforts are underway, it is clear that a major effort is required to develop multispectral analysis techniques and procedures which are specifically keyed to Census Bureau requirements and which make the best use both photointerpretation and machine analysis.

Thus, by 1979, the Census Bureau should be in a position to process both imagery as well as scanner data in transparency and in computer compatible tape formats. Having established the feasibility of use in these data formats, both film and scanner sensor configurations can be considered as candidates. The utility of film and tape formats is focussed primarily on the census planning and analysis functions respectively. The film format will also be useful in the field operations activity if the resolution is adequate. Both data formats are also of considerable usefulness to the U. S. G. S. in their Land Use Data Analysis program as well as to a large number at other federal, state and local governments and private users.

2.3 SPECIFIC MISSION REQUIREMENTS

Discussions with researchers from the Geography Division, Bureau of Census and Geography Applications Program U. S. G. S. led to a formulation of the observation, coverage and output products formats described below. The sensor configuration and processing system formulation outlined here in this report meet these requirements.

This data will permit the following: (1) 1980 Census urbanized area (UA) delineation (provided a block system has been established for the entire area of the potential UA's and preliminary steps have been completed making it possible to integrate the UA classification into the overall census system within the time limitations imposed by the other census operations and the final legally established reporting date for census results.), (2) post 1980 census analysis, and (3) map revision for the mid-decade censuses of population and housing being proposed for 1985.

Observation and Coverage Requirements

Determining the coverage requirements for the observation system can begin by using one of the nationally-oriented products of the Decennial Census, Figure 2-8 showing the 1970 Census Urban and Rural Population. The Urbanized Area Concept is used to delineate these urban population concentrations. Daylight coverage of the major U. S. cities, listed on Table 2-2, in a single sortie flight is required (cloud cover conditions permitting) a fill-in flight is also possibly as was indicated in Table 2-1.

Orbit selection for this mission presented a different problem from that normally associated with remote sensing. Instead of full-coverage in a given amount of time, what is desired in this instance is an orbit that passes through a finite set of ground locations a maximum number of times (and at least once for each) during the flight. The first computer program used (courtesy of MSFC) identified a family of orbits that satisfied the set of constraints which follow:

1. At least one overflight of each target city during a six-day flight.
2. A maximum cross-track (roll) angle of $\pm 15^{\circ}$, to minimize the geometric distortion of the images produced but to allow for some latitude in ground trace/target centerline offset.
3. A minimum solar elevation angle of 30° to provide adequate lighting for the imaging.
4. An orbit injection data and time of June 18, 1979, 0930 GMT (It should be noted that orbit injection time is different from launch time because of the deployment of the LDEF and transfer orbit maneuvers required before commencing the Census portion of the flight)

The parameters of the selected orbit are 443.1 km (239.5 nm) altitude and 48.1 degrees inclination. Ground traces for this orbit were then produced as shown in Figure 2-9. Table 2-3 presents an observation history of the 56 largest (over 250,000 population) U. S. cities. U. S. coverage is obtained each day during three ascending and three descending passes during daylight. In general, the cities at the northern latitudes are overflown a larger number of time than those in the southern U. S. because of the 48.1 degree inclination. With regard to cloud cover, the cities which receive only one overflight are: Tucson, Arizona; Miami, Florida; Honolulu, Hawaii; New Orleans, Louisiana; and El Paso, Texas.

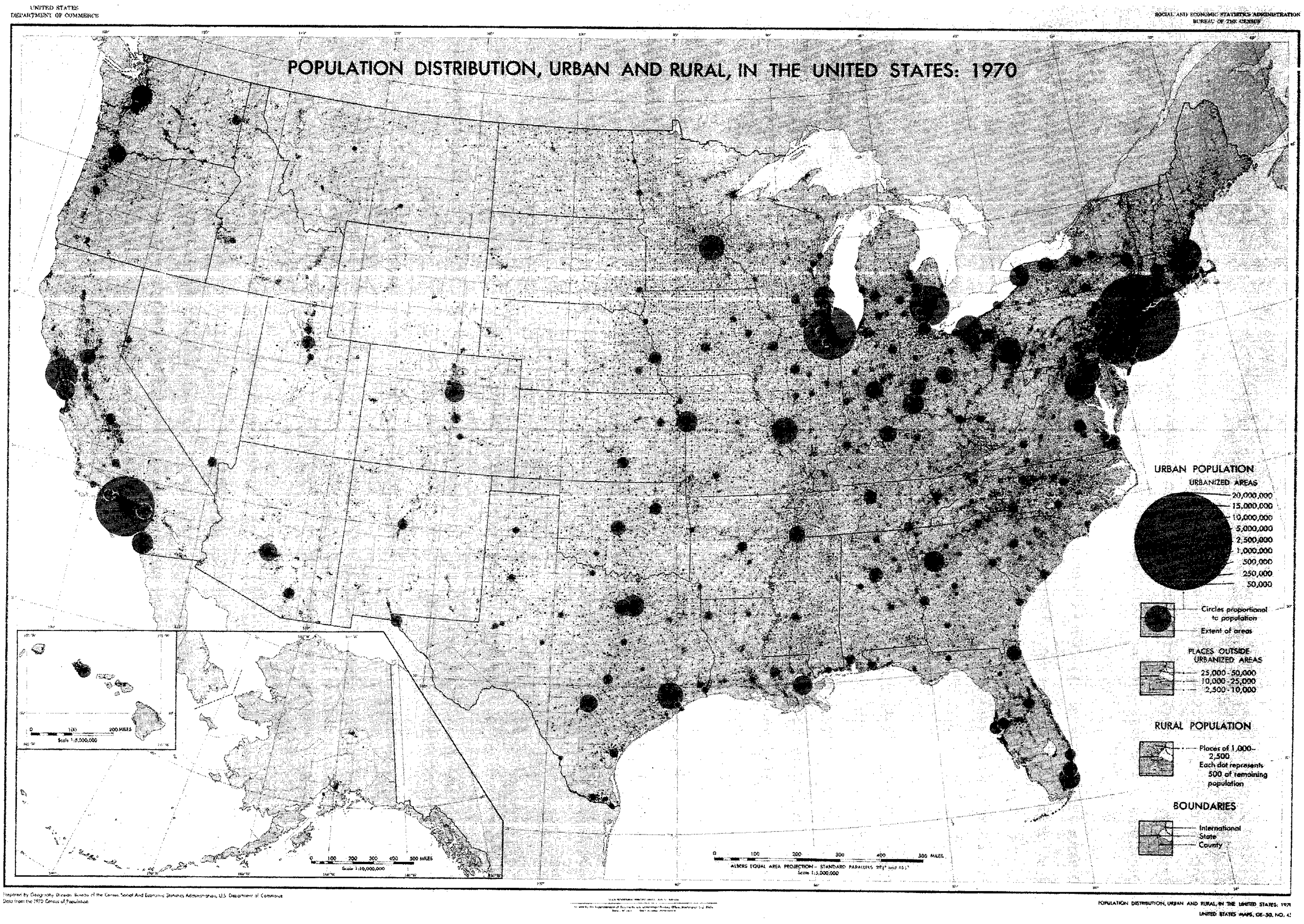


Figure 2-8. U.S. Urban and Rural Population, 1970

Table 2-2. Urban Incorporated Areas in the U.S., Population >100,000

STATE / PLACE	POPULATION	LAT. N	LONG. W
ALABAMA			
BIRMINGHAM	301,000	33° 30.7'	86° 48.4'
HUNTSVILLE	138,000		
MOBILE	190,000		
MONTGOMERY	133,000		
ARIZONA			
PHOENIX	582,000	33° 27'	112° 04'
TUCSON	263,000	32° 13'	110° 58'
ARKANSAS			
LITTLE ROCK	132,000		
CALIFORNIA			
ANAHEIM	166,000		
BERKELEY	117,000		
EAST LOS ANGELES	105,000		
FREMONT	101,000		
FRESNO	166,000		
GARDEN GROVE	121,000		
GLENDALE	133,000		
HUNTINGTON BEACH	116,000		
LONG BEACH	359,000	33° 46'	118° 11'
LOS ANGELES	2,810,000	34° 03'	118° 15'
OAKLAND	362,000	37° 48'	122° 16'
PASADENA	113,000		
RIVERSIDE	140,000		
SACRAMENTO	257,000	38° 35'	121° 29'
SAN DIEGO	697,000	32° 43'	117° 09'
SAN BERNANDINE	105,000		
SAN FRANCISCO	716,000	37° 46'	122° 25'
SAN JOSE	446,000	37° 20'	121° 53'
SANTA ANA	157,000		
STOCKTON	104,000		
TORRANCE	135,000		
COLORADO			
COLORADO SPRINGS	135,000		
DENVER	515,000	39° 44'	105°
CONNECTICUT			
BRIDGEPORT	157,000		
HARTFORD	158,000		
NEW HAVEN	134,000		
STAMFORD	109,000		
WATERBURY	108,000		

Table 2-2. Urban Incorporated Areas in the U. S., Population >100,000

STATE PLACE	POPULATION	LAT. N	LONG. W
DISTRICT OF COLUMBIA			
WASHINGTON	757,000	38° 53'	77° 02'
NORTHEAST	184,000		
NORTHWEST	347,000		
SOUTHEAST	194,000		
FLORIDA			
FORT LAUDERDALE	140,000		
HIALEAH	102,000		
HOLLYWOOD	107,000		
JACKSONVILLE	529,000	30° 20'	81° 39'
MIAMI	335,000	25° 46'	80° 11'
ST. PETERSBURG	216,000		
TAMPA	278,000	27° 57'	82° 27'
GEORGIA			
ATLANTA	497,000	33° 45'	84° 23'
COLUMBUS	155,000		
MACON	122,000		
SAVANNAH	118,000		
HAWAII			
HONOLULU	325,000	21° 19'	157° 52'
ILLINOIS			
CHICAGO	3,369,000	41° 53'	87° 37'
PEORIA	127,000		
ROCKFORD	147,000		
INDIANA			
EVANSVILLE	139,000		
FORT WAYNE	178,000		
GARY	175,000		
HAMMOND	108,000		
INDIANAPOLIS	745,000	39° 46'	86° 09'
SOUTH BEND	126,000		
IOWA			
CEDAR RAPIDS	111,000		
DES MOINES	201,000		
KANSAS			
KANSAS CITY	163,000		
TOPEKA	125,000		
WICHITA	277,000	37° 41'	97° 20'
KENTUCKY			
LEXINGTON	108,000		
LOUISVILLE	362,000	38° 15'	85° 46'

Table 2-2. Urban Incorporated Areas in the U.S., Population >100,000

STATE PLACE	POPULATION	LAT. N	LONG. W
LOUISIANA			
BATON ROUGE	166,000		
METAIRE	136,000		
NEW ORLEANS	593,000	29° 58'	90° 04'
SHREVEPORT	182,000		
MARYLAND			
BALTIMORE	906,000	39° 17'	76° 37'
MASSACHUSETTS			
BOSTON	641,000	42° 22'	71° 03'
CAMBRIDGE	100,000		
SPRINGFIELD	164,000		
WORCESTER	177,000		
MICHIGAN			
DETROIT	1,514,000	42° 20'	83° 03'
DEARBORN	104,000		
FLINT	193,000		
GRAND RAPIDS	198,000		
LANSING	132,000		
LIVONIA	110,000		
WARREN	179,000		
MINNESOTA			
DULUTH	101,000		
MINNEAPOLIS	434,000	44° 59'	93° 16'
ST. PAUL	310,000	44° 57'	93° 06'
MISSISSIPPI			
JACKSON	154,000		
MISSOURI			
INDEPENDENCE	112,000		
KANSAS CITY	507,000	39° 06'	94° 35'
ST. LOUIS	622,000	38° 37'	90° 12'
SPRINGFIELD	120,000		
NEBRASKA			
LINCOLN	150,000		
OMAHA	347,000	41° 17'	96° 00'
NEVADA			
LAS VEGAS	126,000		
NEW JERSEY			
CAMDEN	103,000		
ELIZABETH	113,000		
JERSEY CITY	261,000	40° 41'	74° 04'
NEWARK	382,000	40° 44'	74° 10'
PATERSON	145,000		
TRENTON	105,000		

Table 2-2. Urban Incorporated Areas in the U. S., Population >100,000

STATE PLACE	POPULATION	LAT. N	LONG. W
NEW MEXICO			
ALBURQUERQUE	244,000		
NEW YORK			
ALBANY	116,000		
BUFFALO	463,000	42° 53'	78° 52'
NEW YORK	7,896,000	40° 42'	74° 00'
BRONX	1,472,000		
BROOKLYN	2,602,000		
MANHATTAN	1,539,000		
QUEENS	1,987,000		
RICHMOND	295,000		
ROCHESTER	296,000	43° 09'	77° 36'
SYRACUSE	197,000		
YONKERS	204,000		
NORTH CAROLINA			
CHARLOTTE	241,000		
GREENSBORO	144,000		
RAYLEIGH	124,000		
WINSTON-SALEM	135,000		
OHIO			
AKRON	275,000	41° 05'	81° 31'
CANTON	110,000		
CINCINNATI	453,000	39° 06'	84° 31'
CLEVELAND	751,000	41° 30'	81° 42'
COLUMBUS	540,000	39° 58'	83° 00'
DAYTON	244,000		
PARMA	100,000		
TOLEDO	384,000	41° 39'	83° 25'
YOUNGSTOWN	141,000		
OKLAHOMA			
OKLAHOMA CITY	389,000	35° 30'	97° 30'
TULSA	330,000	36° 09'	95° 54'
OREGON			
PORTLAND	331,000	45° 32'	122° 37'
PENNSYLVANIA			
ALLENTOWN	110,000		
ERIE	129,000		
PHILADELPHIA	1,950,000	39° 57'	75° 10'
PITTSBURGH	520,000	40° 26'	80° 00'
SCRANTON	104,000		
RHODE ISLAND			
PROVIDENCE	179,000		
SOUTH CAROLINA			
COLUMBIA	114,000		

Table 2-2. Urban Incorporated Areas in the U.S., Population >100,000

STATE / PLACE	POPULATION	LAT. N	LONG. W
TENNESSEE			
CHATTANOOGA	119,000		
KNOXVILLE	175,000		
MEMPHIS	624,000	35° 07'	90° 03'
NASHVILLE-DAVIDSON	448,000	36° 10'	86° 47'
TEXAS			
AMARILLO	127,000		
AUSTIN	252,000	30° 17'	97° 45'
BEAUMONT	118,000		
CORPUS CHRISTI	205,000		
DALLAS	844,000	32° 47'	96° 49'
EL PASO	322,000	31° 45'	106° 29'
FORT WORTH	393,000	32° 45'	97° 18'
HOUSTON	1,233,000	29° 46'	95° 22'
LUBBOCK	149,000		
SAN ANTONIO	654,000	29° 25'	98° 30'
UTAH			
SALT LAKE CITY	176,000		
VIRGINIA			
ALEXANDRIA	111,000		
ARLINGTON	174,000		
HAMPTON	121,000		
NEWPORT NEWS	138,000		
NORFOLK	308,000	36° 51'	76° 17'
PORTSMOUTH	111,000		
RICHMOND	249,000		
VIRGINIA BEACH	172,000		
WASHINGTON			
SEATTLE	531,000	47° 36'	122° 20'
SPOKANE	171,000		
TACOMA	155,000		
WISCONSIN			
MADISON	172,000		
MILWAUKEE	717,000	43° 02'	87° 55'
NONE			
ALASKA			
DELAWARE			
IDAHO			
MAINE			
MONTANA			
NEW HAMPSHIRE			
NORTH DAKOTA			
SOUTH DAKOTA			
VERMONT			
WEST VIRGINIA			
WYOMING			

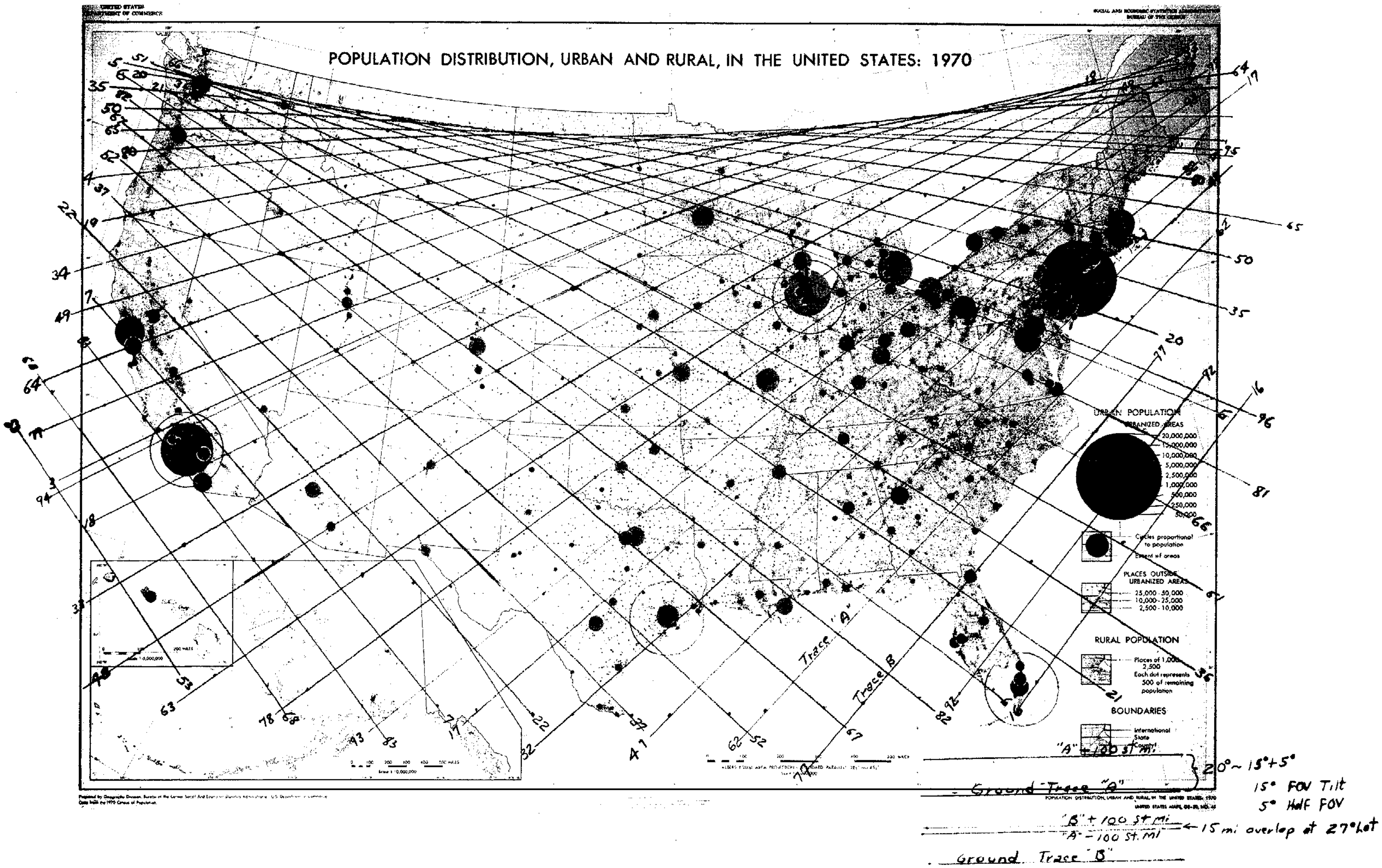


Figure 2-9. Continental U.S. Orbit Trace

Table 2-3. City Observation Frequency

I. D. No.	City	OBSERVATIONS			
		Ascending	Descending	Total	Additional (Sun Angle $< 30^{\circ}$)
1	BIRMINGHAM	2	1	3	2
2	PHOENIX	1	2	3	1
3	TUCSON	0	1	1	1
4	LONG BEACH	1	1	2	1
5	LOS ANGELES	1	1	2	1
6	OAKLAND	1	2	3	
7	SACRAMENTO	2	1	3	
8	SAN DIEGO	1	1	2	2
9	SAN FRANCISCO	1	2	3	
10	SAN JOSE	1	2	3	
11	DENVER	1	1	2	
12	WASHINGTON, D.C.	2	2	4	1
13	JACKSONVILLE	1	1	2	3
14	MIAMI	1	0	1	5
15	TAMPA	1	1	2	5
16	ATLANTA	1	1	2	2
17	HONOLULU	0	1	1	7
18	CHICAGO	1	1	2	
19	INDIANAPOLIS	2	1	3	
20	WICHITA	1	1	2	
21	LOUISVILLE	2	2	4	1
22	NEW ORLEANS	0	1	1	3
23	BALTIMORE	2	1	3	
24	BOSTON	1	2	3	
25	DETROIT	2	2	4	
26	MINNEAPOLIS	3	3	6	
27	ST. PAUL	3	3	6	
28	KANSAS CITY	1	2	3	
29	ST. LOUIS	1	2	3	1
30	OMAHA	2	2	4	
31	JERSEY CITY	2	2	4	
32	NEWARK	2	2	4	
33	BUFFALO	2	2	4	
34	NEW YORK	2	2	4	
35	ROCHESTER	2	2	4	
36	AKRON	1	2	3	
37	CINCINNATI	2	1	3	
38	CLEVELAND	2	1	3	
39	COLUMBUS	2	1	3	
40	TOLEDO	3	2	5	
41	OKLAHOMA CITY	1	1	2	2
42	TULSA	1	2	3	
43	PORTLAND	2	2	4	
44	PHILADELPHIA	2	1	3	
45	PITTSBURGH	1	2	3	2
46	MEMPHIS	1	1	2	2
47	NASHVILLE	2	1	3	2
48	AUSTIN, TEXAS	1	1	2	3
49	DALLAS	1	1	2	3
50	EL PASO	0	1	1	2
51	FORT WORTH	1	1	2	3
52	HOUSTON	1	1	2	3
53	SAN ANTONIO	1	1	2	3
54	NORFOLK, VA.	1	1	2	1
55	SEATTLE	5	4	9	
56	MILWAUKEE	2	2	4	

Fortunately these cities fall substantially below the national average for summer cloud cover probability. On the other extreme, the relatively cloudy city of Seattle, Washington receives nine over flights and Minneapolis - St. Paul six. While there exists a finite probability (approximately 60-80%) that the mission could be fulfilled in a single flight because of the relatively good correlation between number of overflights and cloud cover probability, Mission planning alternatives for cloud-covered cities include either extending the first flight in duration or scheduling the mission for a fill-in flight (e.g., Shuttle Flight No. 6) within 90 days.

The question of how complete is the access of such an orbit to the total U.S. land mass was also addressed; ancillary mission use of the sensors in non-urbanized areas (or urban areas of less than 250,000 population) is the motivation for the question. Figure 2-9 illustrates that, at the southernmost latitudes. The maximum off track distance is approximately 148 kM (80nm). This figure translates to less than 20^{o} degrees off nadir angle (15^{o} roll $+5^{o}$ half FOV), a feasible value both from the point of view of hardware complexity and data processing. The mission thus may be considered to have full access to all points on the continental U.S., subject to mission scheduling and cloud cover constraints.

Sensor Configuration Requirements

The spatial and spectral resolution requirements of the data needs of the Census Bureau for planning, field use and post-cencus use cover a broad range. The data format as well as analysis methods vary for each of these functional uses. The data needs of the U.S.G.S. and the other users are commensurate with the Census Bureau requirements in the urban areas. These considerations can be translated into generic sensor type and characteristics and then matched against the availability, suitability and packageability to arrive at the sensor configuration for this mission.

1. Regional Contextual Overview. This can be accomplished with a panoramic camera, using black and white, true color or color infrared film giving ground resolution of 10 meters or better. Quick look, first - cut urban area delineation and outlying area analysis are the primary uses. A candidate sensor is the S163 camera.

2. Geographic Control Data Update. Here a cartographically-useful film output is desired for planning and field use. Resolution sufficient to delineate streets is necessary. A candidate sensor is the S190B camera flown on Skylab. Films used should produce a resolution of 5 to 10 meters.

3. Urban Land Use Classification. For fulfilling (or approaching the fulfillment) this functional requirement the spectral characteristics of the data and machine processing are more critical than spatial resolution and are in contrast with the previous two categories of data requirements. Ground resolution between 15m to 20m effective field of view, with spectral gray levels of between 64 to 128 levels over the spectral range are required. Five or six bands covering the spectral range of 0.42 to 1.1 μm plus 2.0 to 2.6 μm and 10.4 to 12.5 μm are the required spectral ranges for a scanner for machine-based urban land use classification.

   Both a multi-band camera and a multispectral scanner are desired sensor types for this use. In the former category, the S190A camera used on Skylab is a candidate. Selection of a suitable multispectral scanner as well as any design modifications to the camera types mentioned above will be discussed in more detail in Section 3.

As mentioned earlier, the Geography Division of the Census Bureau and the Geography Applications Program at USGS have ongoing efforts to evaluate utility of the S190A and S190B as well as the ERTS MSS for their operational use.

Data Processing Requirements

The degree to which any Earth Observations Mission can meet the operational needs of an on-going, mandatory program of a governmental agency, is determined not only by the availability of raw or base observational data but also by how far the data has been processed to be user-ready. For the Census Urbanized Areas Land Use Analysis Mission, this question of data processing to user-readiness is especially important in view of the overriding requirement of a short turn-around for use of the data in developing selected 1980 Census Reports. Hence, even though the Census Bureau is preparing technologically to adopt whatever innovative procedures are necessary to enable them to meet their goal of an expeditious Census Report, a very careful consideration of the data processing flow depicted in Figure 2-10 will be required to provide the overall mission utility to the primary user. Therefore, the following discussion of data processing has been prepared to accompany the initial outline of the ground data processing associated with the mission.

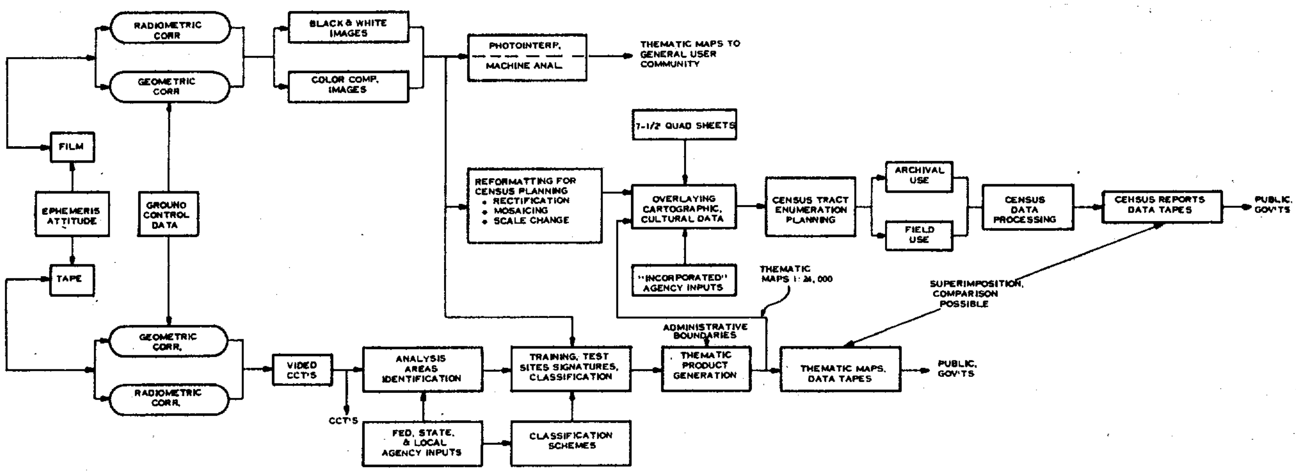


Figure 2-10. Acquisition, Processing and Distribution Flow for Bureau of Census Usage

The interaction with the user throughout the data processing flow is a feature of this mission that impacts significantly on its success. Figure 2-10 illustrates the flow of data through the ground processing system. Radiometric and geometric corrections are applied to both film and tape data. Both film and tape products are used jointly to construct thematic maps to which administrative and demographic data is added. These products then enter the enumeration planning flow and, as well, become a final output of the project. Enumeration planning involves the superposition of cultural data on the thermatic maps and photographs, from which the census tract scenarios and enumeration plans are derived. The completion of the flow includes the actual census field work and the issuance of standard census data products. Ground control data would be supplied jointly by the USGS Topographic

Division and the Census Bureau's Geographic Division. The geometric corrections applied to each of the acquired data products must meet the final data use criteria, both for field enumeration as well as the national geographic data base of the Census Information System. The radiometric corrections, made in parallel, must account for the diurnal ground illumination conditions to yield the user-supplied classification accuracies regionally and nationally. The ability to routineley accomplish these corrections represent a significant technological problem which must be addressed.

The transformation of the data from the "Acquisitor's Frame of Reference" to the "User's Frames of Reference" is a very crucial one from the potential user's viewpoint. It involves the conversion of the remote sensor field of view to the ground reference frame. While there are necessarily a multiplicity of user reference frames, a consensus is emerging on the part of users in the use of the Universal Transverse Mercator Grid for geographic information systems.

The flow shown in Figure 2-10 was based on the requirements of the Bureau of Census, coordinated with those of the U. S. Geological Survey; processing downstream from this point more specifically user orientated, and the data produced, can serve a multitude of users outside the Census Bureau.

Output Products Requirements

The mission outputs needed by the various users were generically shown in Figure 2-10. The raw or base data will be used primarily by the USGS while the Bureau of Census requires further processed outputs.

The film data must be available in the shortest time for quick-look and planning use as well as for field use with further processing. Both the film transparencies and the computer-compatible tapes are required in parallel for machine processing for land use classification to correlate with census planning as well as post-census analysis.

Current data use procedures, especially for the field enumeration purposes, require products such as maps at 1:24,000 scale and larger. Shuttle derived data can be processed to yeild map overlays at 1:24,000 scale but procedures for the ultimate field extraction of desired information must yet be determined. Development of techniques to field-extract and record the reference data must be identified and addressed based on combining available output formats for non-image data and the new technology involved in the Shuttle mission products.

The in-house development of a computerized geographic data base system at the Bureau of Census make the translation of data from this mission to compatible digital formats a desired goal. The post-census (second) flight change-detection and trend evaluation in particular would require machine-processibility of the outputs from the initial (precensus) flight in this mission.

SECTION 3

DESIGN REQUIREMENTS

SECTION 3

DESIGN REQUIREMENTS

The previous section of the report has described the mission requirements and their basis. This section will describe the hardware and flight operations necessary for the implementation of the mission. Selection of candidate sensors will first be described, followed by design descriptions of the European Spacelab pallet and the sensor and support hardware to be used. The section will be completed by a description of the integration of the TERSSE Pallet into Shuttle Mission No. 4, currently scheduled for launch in the summer of 1979 to deploy the Long Duration Exposure Facility.

3.1 SELECTION OF CANDIDATE SENSORS

The objective of this portion of the study was to utilize the requirements of the mission to select sensor and subsystem components to fulfill those requirements.

The criteria for sensor selection are threefold: suitability, availability, and system cost. The prime factors determining suitability are the performance parameters of the sensors, e.g., does it meet the performance requirements? Does it have the required resolution? Can it handle the required volume? Is the data of adequate quality?

Availability is a combination of physical being and state of flight worthiness. The ideal is a sensor which has been repeatedly used on space missions and which is readily available. A second category of sensors given strong consideration are those which will be developed by 1979 under the auspices of other ongoing programs and which can reasonably be expected to be available for this mission.

System cost must not only include the procurement cost (and R&D costs or modification costs), the integration cost, and supporting flight subsystem costs, but also the cost of the equipment necessary to process the data and prepare user materials. Excessive costs in this area can mitigate against certain equipment and force trade-offs to determine proper cost/benefit ratios.

These trade-offs have been made primarily by reference to the known list of sensors which are ready now, Table 3-1; Flight ready in 1978, Table 3-2; and those being developed for post 1978 use, Table 3-3.

When the performance and specifications of these sensors are considered against the mission requirements, it becomes apparent that some are very well suited for the chosen mission, others definitely need modification to work, while still others can be used but are marginal.

The sensors which meet the requirements as now designed and flown are the S-163 24" panoramic optical bar camera, and the S-190A six lens multi-spectral camera.

Table 3-1. Current Earth Observation Sensors

Sensor Classification	Name	Objective	Type	Spectral Coverage	Number of Spectral Bands	IFOV	Angular Scan Coverage	Data Rate	Average Power	Size	Weight	Cooling Requirement	Special Considerations
Mechanical Imager	Multispectral Scanner (linear scan)	Provide multispectral imager for land resource management	Scanning Spectral Radiometer	0.5 - 1.1 μm	4	85.7 μrad	11.6 deg	15 Mbps	52 W	14" x 15" x 34"	112 lb	None	
	Multispectral Scanner (conical scan)	Provide multispectral imagery for land resource management	Scanning Spectral Radiometer	0.41 - 1.2 μm 1.20 - 1.30 μm 1.55 - 1.75 μm 2.10 - 2.35 μm 10.2 - 12.5 μm	9 1 1 1 1	100 μrad 100 μrad 100 μrad 100 μrad 200 μrad	10 deg	1 Mbps	180 W	19.3 ft^3	300 lb	100°K closed cycle	
	Scanning Microwave Spectrometer	Vertical temperature using O_2 line. Water vapor distribution	Scanning Microwave Radiometer	22.2 - 55.4 GHz	5	7.5 deg	86 deg	4 Kbps	36.8 W	20" x 6" x 8"	69 lb	NA	No metallic objects below antenna horns
Electrical Imager	Return Beam Vidicon System	Provide multispectral imagery for land resource management	Spectral Radiometer	0.48 - 0.83 μm	3	90 μrad	11.6 x 11.6 deg	5 MHz	29.5 W	26" x 27" x 13"	186.7 lb	None	
	Electrically Scanning Microwave Radiometer	Map liquid water content of clouds, sea ice cover, gross land characteristics	Microwave Scanning/Imaging Radiometer	37 GHz	2	1.1 x 0.73 deg	74 deg	4 Kbps	51.6 W	35" x 36" x 5.4"	90 lb	NA	Horizontal and vertical polarization
Film Cameras	**Multispectral Photographic Facility**	High resolution multispectral mapping for land resource measurement	Mapping Camera	0.5 - 0.7 μm	6 Simultaneous	50 μrad	21 x 21 deg	NA	119 W	25" x 22" x 16"	197 lb	NA	Shutter speeds: 2.5, 5, and 10 msec
	Earth Terrain Camera	High resolution mapping for land resource measurement	Mapping Camera	0.4 - 0.88 μm	3 Interchangeable	25 - 100 μrad Depends on spectral band	15 x 15 deg	NA		11" x 14" x 28"	80 lb	NA	0 - 25 frames/minute. Shutter speeds: 10, 7, and 5 msec
Non-Imager	Infrared Spectrometer	Atmospheric calibration data	Spectral Radiometer	0.42 - 2.5 μm 6.6 - 16.0 μm	90	1 mrad	NA	6.84 Kbps	200 W	11 ft^3	300 lb	100°K	
	L-Band Radiometer		Microwave Radiometer	1.4 - 1.427 GHz	1	15 deg	NA	180 bps	10 W	10 ft^3	38 lb	NA	
	Limb Radiance Inversion Radiometer	Stratospheric measurements of temperatures, water vapor, and ozone profiles	Scanning Spectral Radiometer	8.8 - 17.2 μm 20 - 25 μm	3 1	5 x 0.5 mr 13 x 0.6 mr	±1 deg/ ±5 deg about horizon	4 Kbps	28 W	3.77 ft^3	126 lb	65°K solid cryogen	
	High Resolution Infrared Radiometer	Vertical temperature profile and H_2O distribution	Scanning Spectral Radiometer	0.7 - 15 μm	17	1.5 deg	72 deg	3.4 Kbps	19.3 W	20" x 10" x 17"	45 lb	120°K radiative cooling	
Active	**S-193**	Temperature distribution for oceanology	Microwave Radiometer/ Scatterometer and Altimeter	13.9 GHz	1	27 mrad	48 deg max	Alt - 10 Kbps Rad/Scat - 5.3 Kbps	153 W	24 ft^3	210 lb	NA	

Table 3-2. 1978 Flight Ready Sensors

Sensor Classification	Name	Objective	Type	Spectral Coverage	Number of Spectral Bands	IFOV	Angular Scan Coverage	Data Rate	Average Power	Size	Weight	Cooling Requirement	Special Considerations
Mechanical Imager	Thematic Mapper	Provide multi-spectral imagery for land resource management	Scanning Spectral Radiometer	0.5 - 1.1 μm 1.55- 1.75μm 2.1 - 2.35μm 10.1 -12.6 μm	4 1 1 1	30 μrad 30 μrad 30 μrad 120 μrad	11.0 deg	120 Mbps	200 W	36" dia x 84" long	450 lb	100°K Radiative	
	Coastal Zone Color Scanner	Measure ocean & coastal zone water color	Scanning Spectral Radiometer	0.44- 0.80μm 10.5 -12.5 μm	5 1	730 μrad	40.6 deg	4 Mbps	25 W	27"x17"x10"	80 lb	100°K Radiative	Variable pointing angle (±20 deg)
	5-Band Multi-spectral Scanner	Provide multi-spectral imagery for land resource management	Scanning Spectral Radiometer	0.5 - 1.1 μm 10.4 -12.6 μm	4 1	85.7μrad 257.1μrad	11.6 deg	15 Mbps	65 W	18"x24"x47"	141 lb	110°K Radiative	
	Scanning Multi-channel Microwave Radiometer	Provide ocean momentum & energy transfer parameters on an all-weather basis	Scanning Microwave Radiometer	37.0 GHz 22.05 GHz 18.0 GHz 10.69 GHz	1 1 1 1	0.71 deg 1.19 deg 1.46 deg 2.46 deg	Conical ±25.0 deg	2 Kbps	50 W	Antenna 30"dia 16" high Electronics 32"x8"x8"		None	Requires momentum compensation
	Temperature Humidity IR Radiometer	High resolution terrestial, cloud, and atmospheric radiation imaging	Scanning Radiometer	10.5 -12.5 μm 6.5 - 7.0 μm	1 1	5 μrad 16 μrad	Horizon-N-Horizon	240 Hz	7.6 W	7.5"x7"x15.6"	20 lb	None	
Electrical Imager	High Resolution Pointable Imager	High resolution, multispectral imagery for land resource Management	"Pushbroom" Solid State Array Spectral Radiometer	0.5 - 1.1 μm	4	10 μrad	3.0 deg	120 Mbps	100 W	27" dia x 72" long	500 lb	0°C ±0.5 deg Stability	Variable pointing angle (±45 deg)
Non-Imager	Earth Radiation Budget	Determine the earth radiation budget by measuring incoming sun radiation and outgoing earth radiation	Fixed & Scanning Spectral Radiometer	0.2 -50 μm	22	0.25x5.14 deg 1.5 x1.5 deg	Scan fixed	4 Kbps	25 W	14"x13"x19"	56 lb	None	Separate assemblies Viewing Sun & Earth
	Lower Atmospheric Composition & Temperature Experiment	Measure atmospheric concentrations of O_3, NO_2, H_2O, HNO_3, N_2O, CH_4, & temperature soundings at 1 km altitude resolution	Scanning Spectral Radiometer	6.2 -17.0 μm	10		Horizon +6, -6 deg Yaw 60 deg	4 Kbps	50 W	15" dia x 63" long	167 lb	65°K Solid	Contains own attitude reference sensor
	Measurement of Air Pollution from Satellites	Measure global distribution of CO, SO_2, CH_4, NH_3 and aerosols	Spectral Radiometer	0.5 -10 μm	6	8 deg	NA	100 bps	67 W	Sensor 13"x9"x8" Electronics 13"x8"x8"		200°K Thermo-electric	Requires radiative cooler to dump power from thermoelectric
	Stratospheric and Mesospheral Sounder	Provide data on temperature sounding and distribution of atmospheric pollutants	Spectral Radiometer	3.1 - 1.7 μm	8	2.0x1.5 deg	±3 deg across Horizon ±20 deg yaw		24 W	Sensor 15"x10"x17" Electronics 13"x8"x8"	75 bl	200°K Radiative	
	Straospheric Aerosol Meas.	Monitor global concentrations of aerosols	Spectral Radiometer	0.37- 1.0 μm	3	5.0x30 deg	NA	640 bps	6 W	18"x8"x8"	16 lb	None	2-axis gimbal, tracks the sun at the horizon
Film Camera	Optical Bar Panoramic Camera	High resolution & mapping for land use measurement	Scanning Mapping Camera	Depends on filter/film characteristics	1	15 μrad	10x108 deg	NA		55"x25"x19"	230 lb	NA	

Table 3-3. Post 1978 Sensors

Sensor Classification	Name	Objective	Type	Spectral Coverage	Number of Spectral Bands	IFOV	Angular Scan Coverage	Data Rate	Average Power	Size	Weight	Cooling Requirement	Special Considerations
Mechanical Imager	Sea Surface Temperature Imaging Radiometer	Ocean Surface Temperature with Atmospheral Correction	Scanning Spectral Radiometer	.2-4.0 μm 3.6-4.1 6.5-7.0 8.85-9.35 10.5-11.5	1 1 1 1 1	2 mrad	102 deg.	.33 Mbps	30 W	8" x 8" x 24"	45 lb.	$100^{o}K$	
	Ocean Scanning Spectrophotometer	Spatial Distribution of Ocean Color	Scanning Spectral Radiometer	.4-.7 μm	20	2 mrad	38 deg.	.5 Mbps	60 W	10" x 20" x 20"	45 lb.	None	
	Passive Multichannel Microwave Radiometer	Provide Measurement of Ocean Energy Transfer Parameters	Scanning Microwave Spectral Radiometer	4.99 GHz 10.69 18.0 21.5 37.0	2 2 2 2 2	3.79 deg. 1.77 1.05 .88 .51	Conical $\pm 35^{o}$	2.4 Kbps	141 W	7.8 M^3	263 lb.	NA	Dual Polarization Per Frequency
Non-imager	Microwave Sounder	Vertical Sounding of Atmospheric Temperature Structure	Spectral Radiometer	60 GHz	4	12 deg.	NA	50 bps	25 W	.56 Ft^3	25 lb.	NA	Nadir Viewing
	Remote Gas Filter Correlation Analyzer	Monitor Global Air Pollution	Spectral Radiometer	2-20 μm	3-5	5 x 5 deg.	NA	400 bps	7 W	.5 Ft^3	30 lb.	$65^{o}K$	Nadir Viewing; Gas Filter Correlation
	Carbon Monoxide Pollution Experiment	Monitor Potential CO Build-Up in Environment	Spectral Radiometer	2.01-2.00 μm 2.32-2.37 μm	1 1	Nadir 2 x 2 deg. Limb 0.1 x 0.1 deg.	NA	400 bps	12 W	.4 Ft^3	30 lb.	$150^{o}K$	Correlation Interferometer
Active	Synthetic Aperture Radar	All-weather, Day & Night Analystial Sensor	Imaging Radar	9.3-9.5 GHz 1.7 GHz	1 1	0.6 x 3.3 deg. 1.5 x 16.2 deg.	NA	124.9 Mbps	1075 Watt For 10 Min. 10 W for 90 Min.	Electronics 5.1 Ft^3 Antenna 27" x 2.5" x 1"	387 lb.	NA	Spatial High Data After Data Processing (≈ 30 μrad IFOV)
	Active Optical Scatterometer	Determine Temporal & Spatial Distribution of Aerosols and Clom Height	Selective Spectral Scatterometer	.35-1.5 μm	1 Wavelength Selected by Experiment	1.8 mrad	NA	80 Mbps	270 W	14 Ft^3	487 lb.	NA	Tunable Laser Transmitter

The radiometric accuracy requirements combined with the spectral band requirements dictate the use of an electronic multi-spectral imager. Several such advanced designs are now in the preliminary phases of implementation. The Hughes Thematic Mapper has been chosen for this pallet as an engineering example. The final choice will depend upon the evaluation of all Thematic Mappers by GE and NASA after the mapper development is further along.

The requirement for a cartographic (metric) camera can be marginally met by existing equipment, S-190B. To fully meet the user desires the available, flight proven, available cameras of this type are marginal with respect to resolution.

The sensors which were chosen therefore for this mission and their application within the total mission are shown in Table 3-4. Their most optimistic resolutions are shown in Table 3-5.

Table 3-4. Sensor Choice

Sensor	Application
S163	First look - Delineation of urban areas - location of streets/roads nearby features - wide angle coverage
S190B	Map correction - detailed planning
S190A	Gross land use classification by photo-interpretation methods.
Thematic Mapper	Precise, digital land use classification

Table 3-5. Resolution of Sensors

Instrument	Spectral Coverage/Film	Resolution (Meters)
Thematic Mapper	Visible Spectrum Thermal	20 or 16 m 70 or 56 m
S190A	(SO-242) Visible Color (2424) Near IR	21 m 58 m
S190B	(EK 3414) B&W Visible Color	5 m 8.5 m
S163	(EK 3414) B&W	5 m

3.2 HARDWARE CONCEPT DESCRIPTION

The TERSSE Pallet concept includes a set of mission equipment (sensors and support hardware); a three-meter ERNO pallet section, igloo, and support equipment; and orbiter control and support functions. Figure 3-1 is a block diagram

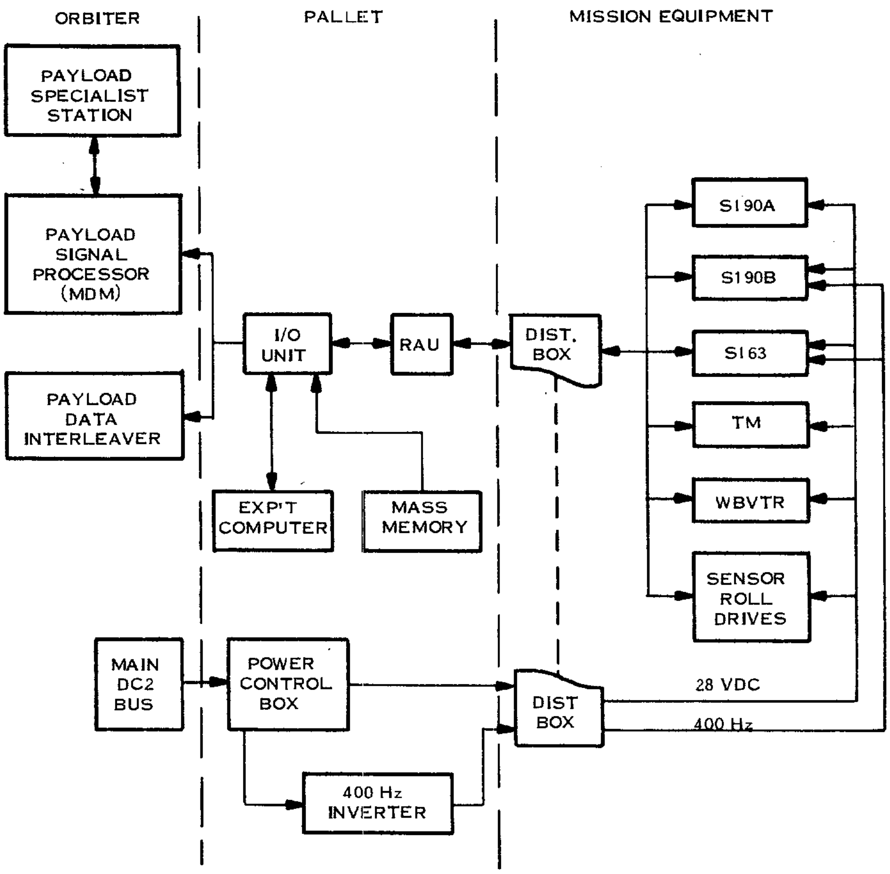


Figure 3-1. System Block Diagram

of the system illustrating the components in each segment. Power, control, and housekeeping data recording are provided by the Shuttle orbiter.

Maximum use is made of standard hardware and services of the ERNO pallet. In addition to providing structural support, it serves as the power and data interface between the orbiter and the mission equipment, thus reducing the cost of the latter. An experiment computer is provided by the pallet to perform sequencing and pointing computations, reducing both the crew involvement and the complexity of the associated ground operations.

The mission equipment consists of four sensors, a wideband tape recorder for the scanner, a power and segment distribution box, and sensor roll-axis drives for offset pointing.

The physical configuration of the pallet system is illustrated in Figures 3-2 and 3-3. Figure 3-2 depicts the original concept developed which is characterized by fixed sensors. The requirements on orbiter RCS propellant and maneuvering scheduling were sufficiently high that an alternate concept, illustrated in Figure 3-3, was developed with sensors pointable $\pm$ 0.26 rad ($\pm$ 15°) in roll. It is the alternate concept that is currently preferred by the study team, in spite of its slightly higher equipment cost, and which has been used in the weight estimates.

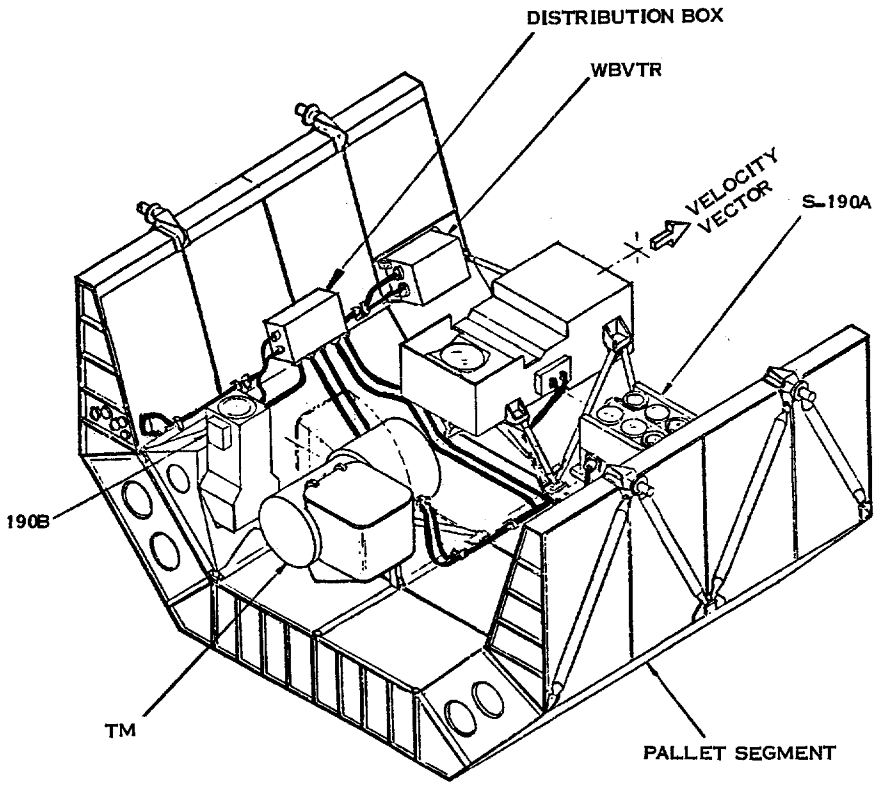


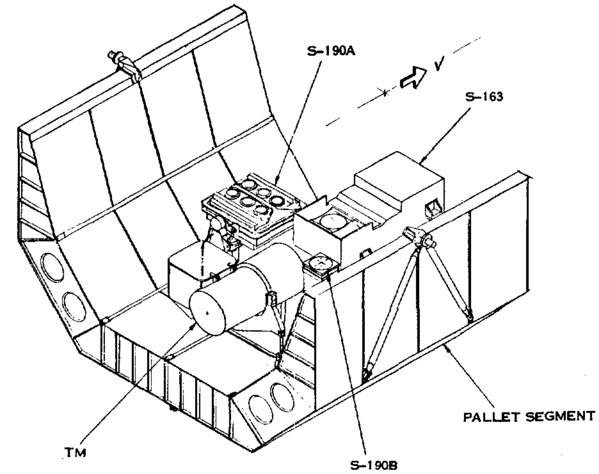
Figure 3-2. Fixed Sensor Concept

The three cameras, the S163, the S190A, and the S190B, and the Thematic Mapper are all mounted by structural brackets to the floor and sides of the ERNO pallet. The mounting brackets are adjustable for the shims to aid in boresighting the sensors. Adequate floor and wall space exists to mount the sensors without crowing. Note that the bracket for the S163 must hold it sufficiently off the floor so that the line of sight from the lens at the $\pm$ 0.94 rad ($\pm$ 54^{o}) point does not intersect the pallet sill. All of the major instruments are attached to the standard ERNO pallet hardpoints but small junction boxes and other minor items are bolted to attachments made by potting the honeycomb skin at the proper point.

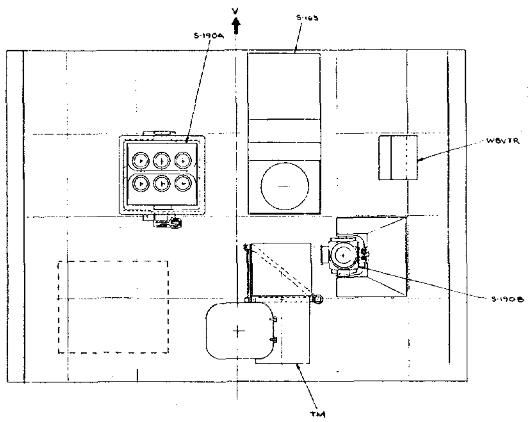
The inter-instrument harness is laid on the surface of the pallet and fastened down with harness clamps. The main power cabling, command and data circuits, caution and warning harnesses are the standard pallet provided circuits which run inside the pallet. The pallet-to-pallet and pallet-to-orbiter interfaces need not be changed. They are adequate as installed by ERNO and that the pallet orbiter interface is standard. A more detailed description of the ERNO pallet and mission equipment follows, subsequent to which no description of the integration of the TERSSE Pallet into Shuttle Mission No. 4 is given.

3.2.1 ERNO PALLET DESCRIPTION

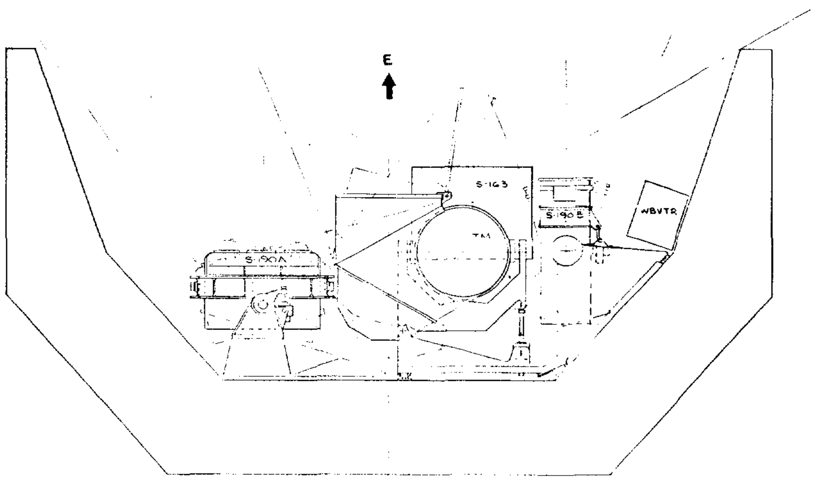
A description of the ERNO pallet and support equipment pertinent to the TERSSE Pallet mission follows. We have excerpted material from a recent ERNO Spacelab description report draft in order to use and present the latest



a. Overall View



b. Plan View



c. End View

Figure 3-3. Alternate Concept With Pointable Sensors

Spacelab design information available. Of concern to the TERSSE Pallet design are (1) a single 3-meter pallet, and (2) the igloo, which contains the pallet-furnished electrical support equipment.

Basic Structural Configuration

The pallet's cross-section is U-shaped and is made of aeronautical shell-type construction. It provides hard points for mounting heavy experiments and a large panel surface area to accommodate various payload configurations. The pallets are modular (3-m nominal length) and can be flown independently or interconnected. As many as three pallets can be interconnected and supported by one set of retention fittings to avoid the mass penalty chargeable to Spacelab for supporting bridges below the payload bay sill and additional sets of fittings.

One or more pallet segments, carrying self-contained experiments, can be mounted at any suitable location within the Orbiter payload bay and require no other Orbiter support. This is the "pallet element mode" and is a configuration flown to take advantage of available volume and weight of any Shuttle mission.

Figure 3-4 shows the basic pallet structural configuration. The basic pallet structure is used for all flight configurations. The only variation required is the location of Orbiter attachment fittings. Generally, the "corner configuration" shown in the figure is used unless the pallet is to be located at the extreme aft position in the payload bay as part of a pallet "train." In this case, central fittings are located at the mid-points along the pallet sides.

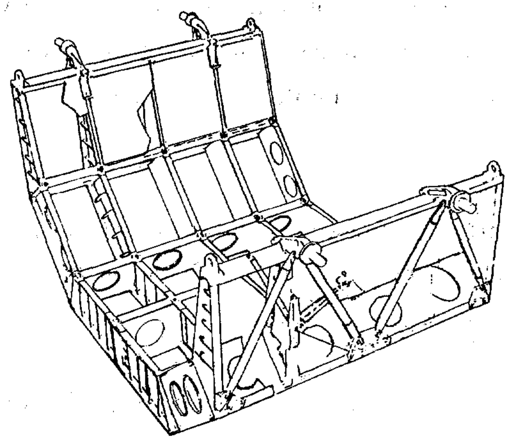


Figure 3-4. Pallet Structure

Standard Pallet

Interchangeable "standard pallets" are provided. These pallets consist of the basic structure described earlier plus additional subsystem equipment including:

1. Electrical power distribution cables
2. Signal distribution cables
3. Remote acquisition unit
4. Thermal insulation

The electrical items are located between the inner and outer skins of the pallet and thus do not reduce available experiment installation volume. Access covers are provided for installation and maintenance. Space is allocated in this same area for the addition of other subsystem equipment such as more RAU's, cold plates (on the inside surface), dc-dc converters, etc.

The utilities routed from the Orbiter to the first pallet are supported by the forward utility bridge connected at the forward end by its Orbiter interface plate to the Orbiter midfuselage strcutre, as shown in Figure 3-5. At the aft end, the utility bridge is connected to the TCS-package support bracket, carrying:

1. Interloop heat exchanger
2. Water pump package
3. Freon pump package.

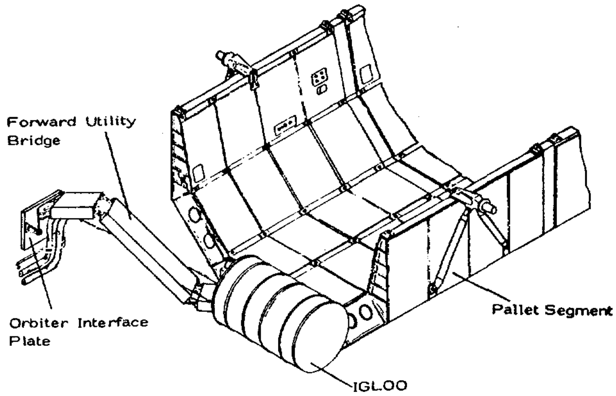


Figure 3-5. Utility Bridge and IGLOO Arrangement, Pallet-Only Mode

All other Spacelab subsystem support equipment in other flight modes that is integrated within the module and requires no access in orbit is installed within the igloo; the remaining items are located in the Orbiter PSS.

Igloo

The igloo is a cylinder pressurized by GN_2 up to 1.013 bars having an internal diameter of 0.95 meters and a length of approximately 1.5 meters. It has on one side a removable bulkhead (Marman clamp) providing full-diameter access to the interior.

The temperature range (15-30°C) compatible with CAM equipment requirements, is achieved by active and passive thermal control devices.

The igloo shell, including its bulkheads, are covered by HPI panels. These panels consist of HPI layers and an external protective cover made out of fiberglass.

Active thermal control is achieved by a dry nitrogen cooling loop. The flow is provided by redundant CAM fans and controlled by the avionics heat exchanger interfacing with the pallet freon loop. The central tube, primarily a structural member, assumes the function of distribution by adjustable outlets along its length.

The igloo has an internal secondary structure consisting of various circular floors connected to the central tube and three longerons. The entire secondary structure can be removed together with the front bulkhead.

The following CDMS and EPDS equipment is mounted within the igloo for the pallet-only mode:

- 3 computers
- 2 I/O units
- 1 mass memory

- 3 subsystem RAU's
- 3 experiment inverters (50, 60, and 400 Hz)
- 1 subsystem inverter
- 1 emergency battery and box
- 1 power control box
- 1 secondary power distribution box
- 1 caution and warning logic

The ECS equipment consists of

- 1 avionics heat exchanger (freon)
- 1 avionics fan assembly
- 2 ground cooling air and N_2 shutoff valves
- 1 cabin differential pressure control valve is premanently installed in the forward bulkhead to simplify interfaces

The subsystem igloo is cantilevered to the front side of the forward pallet. Although each pallet is capable of carrying the igloo, no volume or area of the pallet is taken by the igloo.

All utilities are fed into the igloo and out again through the forward bulkhead. The utility bridge is attached to the front side of the pallet adjacent to the igloo.

Command and Data Management Subsystem

The command and data management subsystem (CDMS) provides a variety of services including data acquisition, monitoring, formatting, processing, displaying, recording, and transmission in addition to providing command and control capability for the payloads.

Figure 3-6 illustrates the assemblies comprising the CDMS with respect to experiments. Experiment outputs including status and scientific data are sampled by remote acquisition units (RAUs), converted from analog to digital form, if necessary, and transferred to the experiment-dedicated computer by the input/output (I/O) controller.

Electrical Power and Distribution Subsystem

The Electrical Power conditioning and Distribution Subsystem (EPDS) receives its primary power from the Shuttle Orbiter (see Figure 3-7).

The unregulated power delivered from one fuel cell of the Orbiter is limited to 7.0 kW average, 12 kW peak nominally, and 5/8 kW degraded.

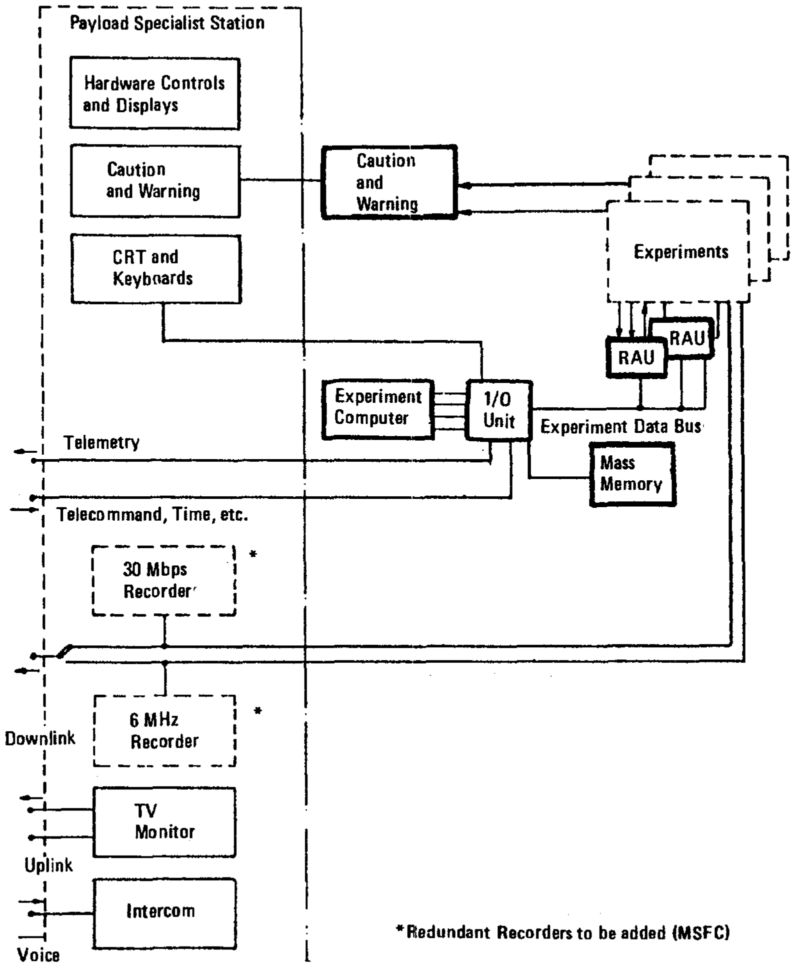


Figure 3-6. Command and Data Management for Experiments, Pallet-Only

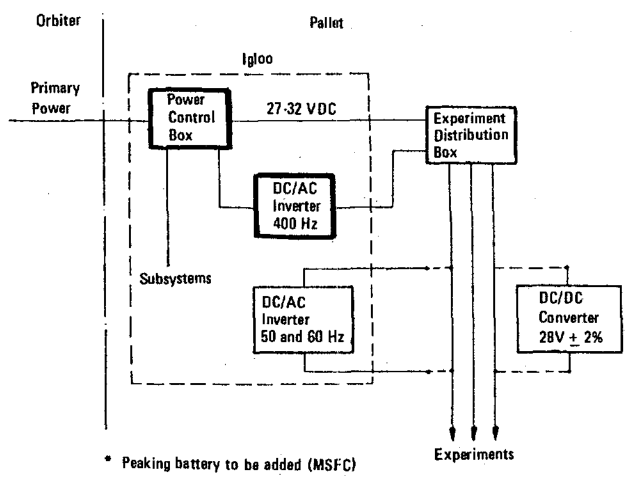


Figure 3-7. Power Distribution Scheme, Pallet-Only Mode

The energy available is limited by the Orbiter fuel tank capability. The amount of power and energy, respectively, which can be used by experiments depends on the flight configuration and the use of mission-dependent subsystem equipment.

The conditioning and distribution of the electrical power is strictly divided between subsystem and experiment loads. The following resources are provided to the payloads:

1. Supply of unregulated DC, regulated DC, AC at 400, 60 and 50 Hz
2. Power switching and fusing
3. Wiring
4. Illumination

The capability provided for the experiments is the same in principle for the module and pallet-only configurations. Only the power switching panels located in the racks within the module(s) are not available for pallet-only modes.

There are two power bus systems running through all modules and pallets:

1. The DC bus supplying 26 to 32 VDC
2. The AC bus supplying three-phase 115/200 VAC at 400 Hz.

Caution and Warning

The Spacelab hardwired caution and warning system accepts signals generated by the experiments indicating critical situations. The system warns by visual and audible means the crew throughout the Spacelab or at the payload specialist station.

A Level 1 alarm is given if immediate evacuation of the Spacelab is necessary. It is indicated by a flashing light at each caution and warning panel and a rising/falling tone via intercom.

The Level 2 caution is initiated if corrective action within 5 minutes is required. The situation is indicated by lights labeled with the problem area and a continuous tone via intercom.

The Level 3 situation is initiated if a signal acquired by the bus system is out of tolerance. It is indicated by all CRTs overriding any display just asked by the operator. All signals interfacing with any RAU input can be checked for that purpose, if necessary.

Analog inputs are checked against upper and lower limits: discrete inputs are checked against bit patterns. The limits and the bit patterns, respectively, are entered into the system via the computer software or by the keyboards.

3.2.2 SENSOR DESCRIPTIONS

The S190A

The S190A Multispectral Camera is a six lens camera which normally takes four black and white images and two broad spectrum color images. The four black and white images are of four 1000 Å wide bands centered at 5500 Å, 6500 Å, 7500 Å and 8500 Å. One wide spectrum image is strictly visible while the other extends into the infrared (8800 Å).

This camera will take images approximately 166 Km by 166 Km (90 miles by 90 miles) from the altitude of 443 Km (239 nm) chosen for this mission.

The resolution of this camera under the best of conditions using film as specified by Itek can be no better than 21 meters on the visible color image and 58 meters on the longer wave images. Table 3-6 and Figure 3-8 contains S190A design particulars.

S190A resolution is satisfactory for first cut photo interpretation but the radiometric accuracy is not good enough for the detailed work required by the Census Bureau. That detailed analysis is best done digitally using Thematic Mapper data.

The S190B

The S190B is a cartographic type camera for the production of metric imagery. This camera has a lens of 45.7 cm (18 inch) focal length and a resolution of approximately 200 1/mm using EK 3414. At that resolution the ground resolution can be no more than 5 meters. At an altitude of 443 Km (239 nm) the contact scale on the film is 1:980,000.

The area of coverage on the ground from 442.6 Km (239 nm) is about 111 Km (60 nm) square.

The resolution and scale provided by this camera are adequate for planning purposes and for the revision of maps with scales of 100,000 to 10,000,000 but are marginal for the revision of large scale maps such as 1:24,000. Particulars of this camera are given in Table 3-7 and Figures 3-9 and 3-10.

The S163

The third camera included in this array is the S163, the 24" optical bar panoramic camera. This camera takes panoramic cross track strips by rotating the lens around an axis parallel to the flight path. The images produced cover a field of view 1.88 rad (108^{o}) cross track and 0.188 rad (10^{o} 46') along track.

This camera provides relatively high resolution but is most desirable because of its ability to provide a very wide swath that extends far beyond the limits of any of the other sensors proposed to be carried by the TERSSE pallet. This wide swath allows correlation of the images of the sensors with smaller fields of view to the adjacent terrain.

Table 3-6. S190A Technical Data

TECHNICAL DATA

LENSES

Six 6-inch-focal length f/2.8 lenses boresighted to 60 arc-seconds

SHUTTERS

Type	Between the lens
Speed	2.5, 5, and 10 milliseconds

APERTURE CONTROL

Waterhouse stop adjustable from f/2.8 to f/16 in ½-stop increments

PHOTOGRAPHIC PERFORMANCE

Spectral Region, Å	Film Type	Resolution High Contrast On Axis: Static Specification	Lens Static	Camera Dynamic
5000 to 6000	3400	116	116	114
6000 to 7000	3400	130	141	137
7000 to 8000	2424	55	60	53
8000 to 9000	2424	50	56	50
5000 to 8800	3443	45	50	50
4000 to 7000	SO-242	130	145	145

FORMAT

70mm by 70mm (2¼ by 2¼ inches)

FILM

2.54m (100 feet) standard base

IMAGE REGISTRATION CAPABILITY

Radially	1000 Å band	5 micrometers
	Combined bands	10 micrometers
Tangentially	1000 Å band	20 x tan β* micrometers
	Combined bands	20 x tan β micrometers (5.3 micrometers at edge of field)

*β = Field Angle

IMAGE DISTORTION

Less than 10 micrometers

DIMENSIONS

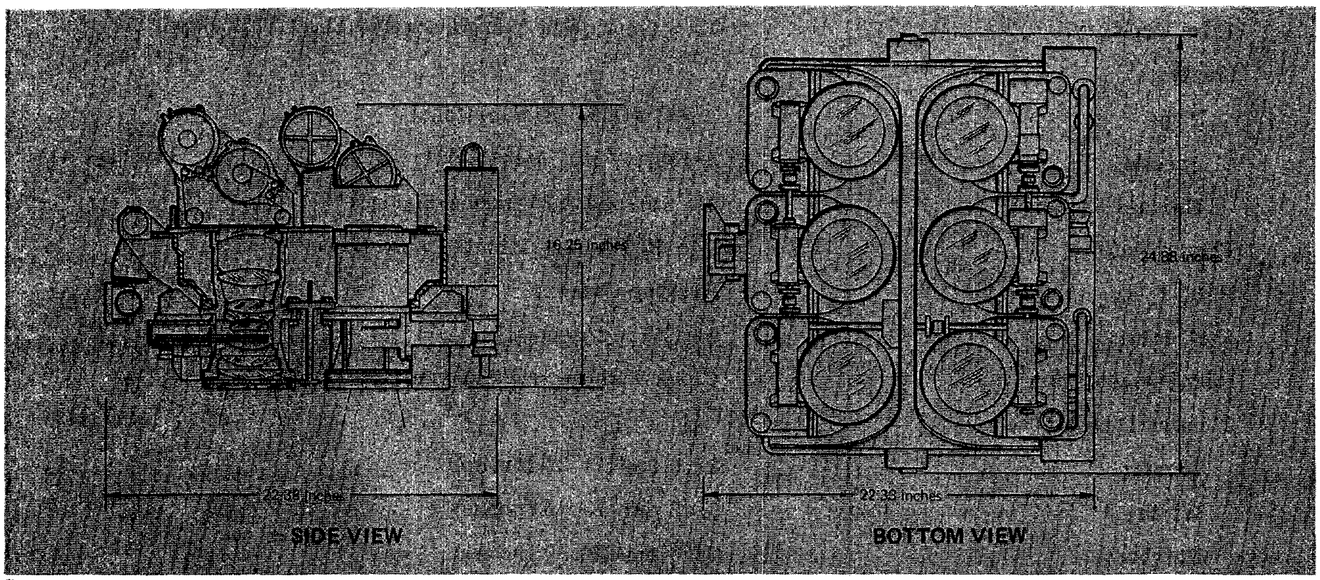
63.2 by 56.7 by 41.30m (24.88 by 22.33 by 16.25 inches)

WEIGHT

Including film	89.5 Kg (197 pounds)
Without film	87.2 Kg (192 pounds)

POWER REQUIREMENTS

119 watts average



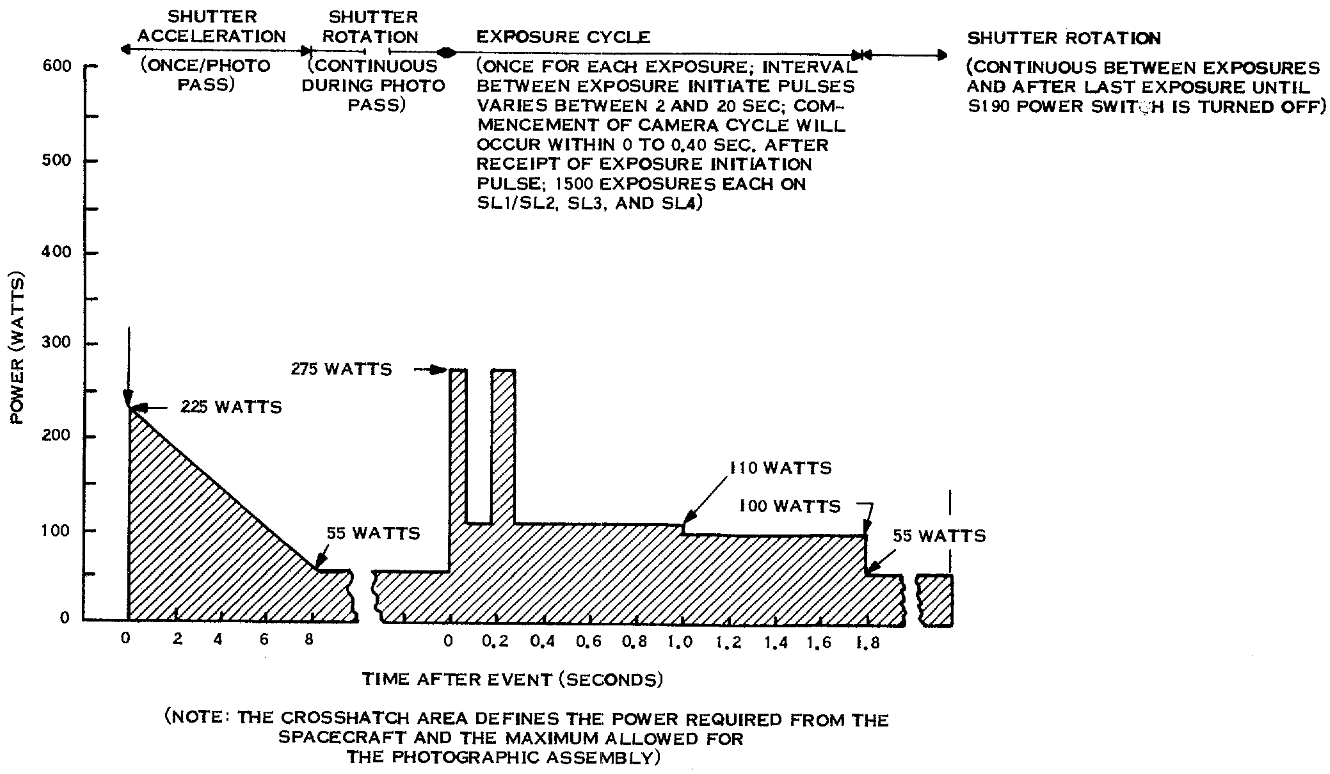


Figure 3-8. Maximum Allowable Power Profile, 5 msec Shutter Speed

Table 3-7. Particulars of Earth Terrain Camera, S190B

Type	Framing
Format Size	11.4 x 11.4 cm (4.5 x 4.5 Inches)
Film Capacity	12.7 cm x 61 m (5 Inches x 200 Feet) Thin Base)
Shutter	
Type	Focal Plane, Bidirectional
Speeds	1/100, 1/140, and 1/200
Curtain Velocity	292 cm/sec (115 Inches/Second)
Frame Rate	0 to 25 Frames/Minute, Auto Mode
FMC Type	Rocking Camera
FMC Rate	0 to 25 mr/Second
Data Presentation	Clock With Second Hand And Day Count
Camera Dimensions	
Length	28.6 cm (11.25 Inches)
Width	3.42 cm (13.45 Inches)
Height	71.6 cm (28.20 Inches)
Camera Power Requirements	115 vac, 400 Hz, 3 Phase, +28 vdc
Camera Weight	36.4 kg (80 Pounds) Without Film And Lens Protector

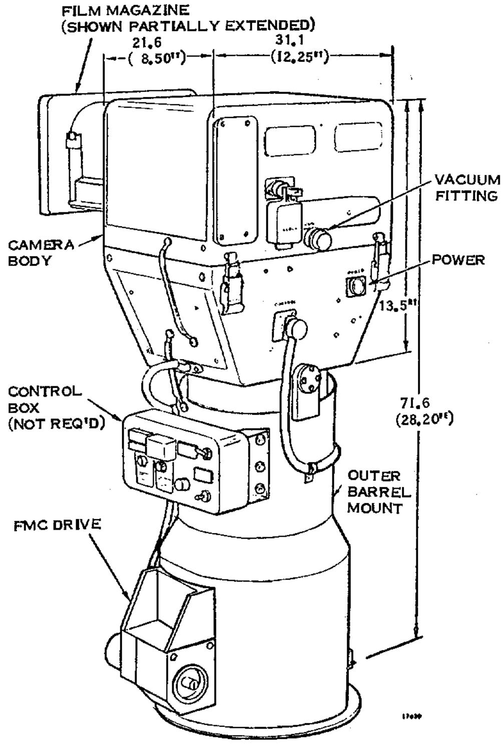


Figure 3-9. S-190B Earth Terrain Camera (Pressurization Container Not Shown)

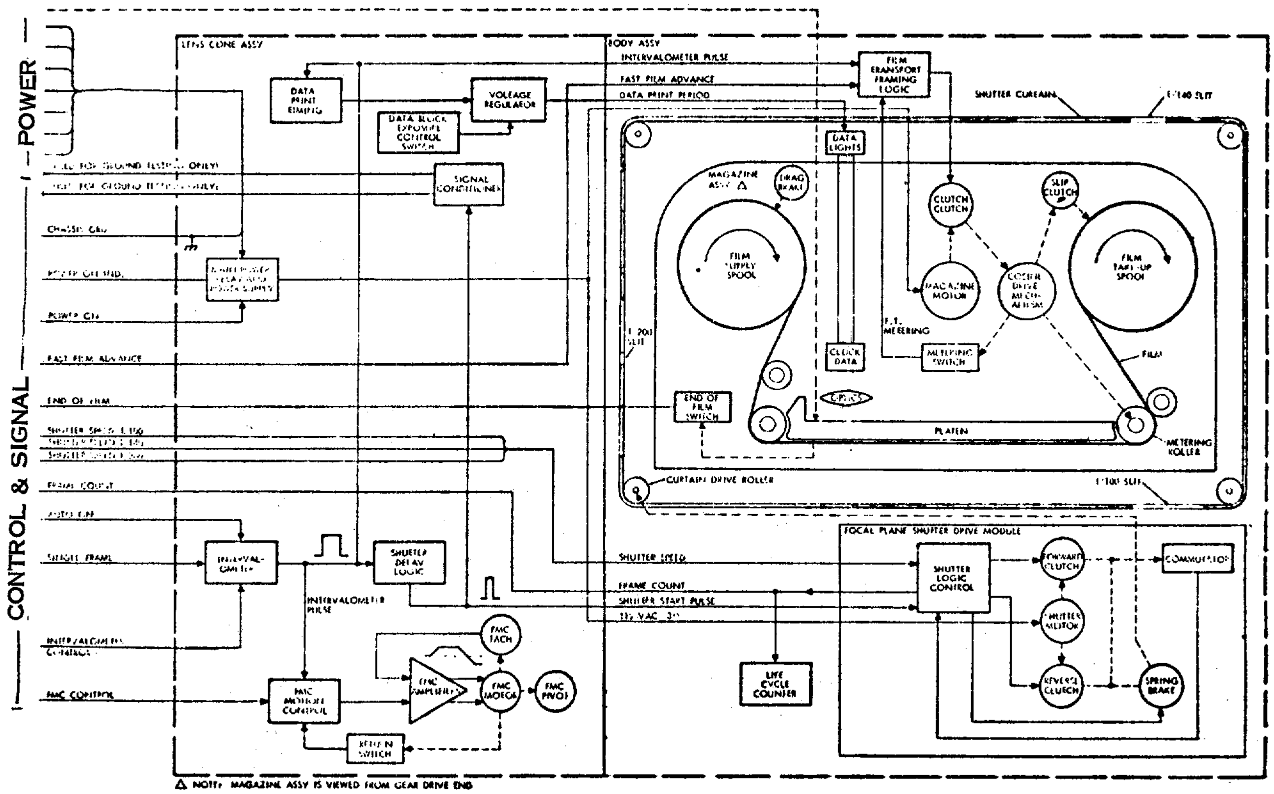


Figure 3-10. S-190B Schematic

The resolution of this camera, at best about 6 m from 442.6 Km (239 nm), is such as to allow delineation of all urban areas and location of new roads and developments will be sufficient to allow the identification and location of new homes. Table 3-8 gives the principle characteristics and Figure 3-11 shows the general configuration. Figure 3-12 shows a typical power profile

Table 3-8. S163 Principal Characteristics

Lens	61 cm (24-in) focal length, f/3.5 relative aperture
Coverage	2.09 rad (120-deg) scan angle
Stereo convergence angle	0.35 rad (20 deg) or monoscopic
Overlap	10 percent stereo, 55 percent mono
Film type	
Primary	3404, 12.7 cm (5-in) width
Alternate	Any Mylar or Estar thin base film whose base-plus-emulsion thickness does not exceed 0.1 mm (4 mils)
Film capacity	165 m (6,500 ft) of thin base film
Filter	Interchangeable Wratten gelatin, inserted in focal plane area
Format	11.4 by 127.7 cm (4.5 by 50.26 in)
Data recording	24-hour clock, frame count, data card, stereo indicator lights
Mode of operation	Autocycle with constant overlap along track
Frame rate	1 every 17.5 seconds to 1 every 3.5 seconds
V/h	0.005 to 0.025 radian per second
Slit width range	0.38 to 6.4 mm (0.015 to 0.250 in)
Exposure control	Automatic from 100 to 3,000 foot-lamberts
Exposure time	0.35 to 29 milliseconds
Resolution	135 lines per millimeter at 2:1 contrast at 0.002-second exposure over 80 percent of format 80 percent of time on 3404 film
Lens transmission	In spectral range defined by filter and primary film characteristics, transmission exceeds 55 percent at any part of format
Mean cycles between failure	20,000 cycles
Operation life span	200,000 cycles
Temperature control	Lens temperature controlled to $\pm$ 5°F ($\pm$ 2.5°C)
Power requirements	28 vdc and 400 hz, three-phase, 115 volts
Dimensions	140.2 x 63.5 x 49.8 cm (55.2 by 25 by 19.6 in)
Weight (including film)	116 Kg (255 pounds)

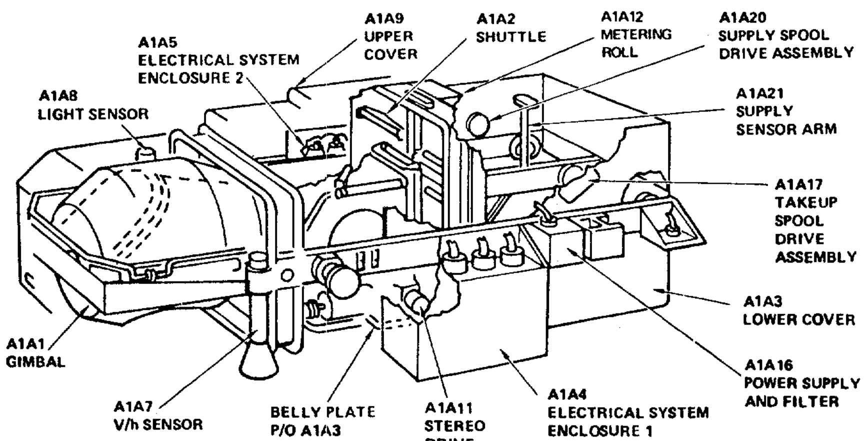


Figure 3-11. Location of Major Camera Assemblies, S163

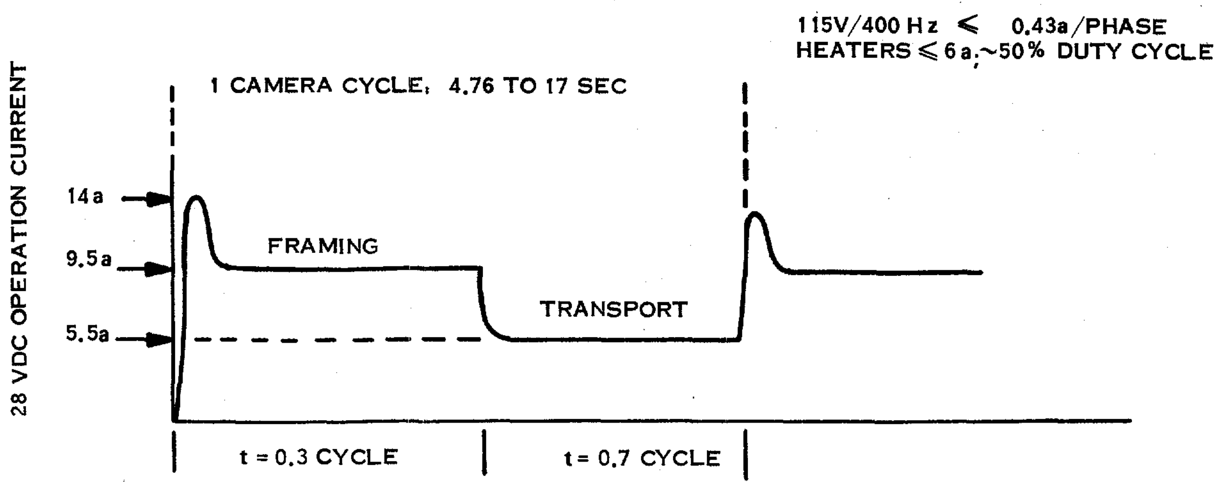


Figure 3-12. S163 Power Requirements

3.2.3 FILM SENSOR MODIFICATIONS

Two significant sensor modifications are required for the TERSSE Pallet film cameras: provision of pressurization to the S190 A and S190 B cameras to permit their operation on the unpressurized pallet.

Pressurization of S190 A and B will be accomplished by constructing individual gas-tight enclosures over the camera backs. Since no access to the cameras after launch is required, these containers will be permanently attached before flight and not removed until return. Pressurization will be provided by the igloo environmental control system. The igloo itself is pressurized to 1 atmosphere; either direct lines or regulated pressurant will be routed from the igloo to the camera backs.

3.2.4 THE THEMATIC MAPPER

The development status of the Thematic Mapper, in contrast to the film cameras just discussed, is much less mature. Several concepts for this sensor are now under study for the EOS program. We have, somewhat arbitrarily, selected one of the concepts for the TERSSE Pallet and redesigned it for this use. The selected design, based on the Hughes EOS sensor, is used as an example to illustrate concepts and does not imply preference for this design over others which are also in the process of development. Because of the less mature status of the TM design, we have included a more comprehensive description of it then provided for the well-known film cameras.

The design concept is shown pictorially in Figure 3-13. The TM utilizes object plane scanning obtained by directing the ground scene from an oscillating scanner miror through a telescope and relay optics to a series of detectors located at the focal plane. Spectral definition is obtained by a series of bandpass filters with spectral separation into the seven spectral bands obtained by spatial separation. Bands 1-6 have 14 elements per array and Band 7 has 4 elements. Data is taken on each half cycle of the scanning mirror oscillation by use of an image motion compensation dual mirror arrangement located in the optical system. The non-linear scan is monitored by an optical scan monitor defining start of scan, end of scan, and an insertable mid-scan indication in the data. Table 3-9 summarizes the sensor and system performance parameters.

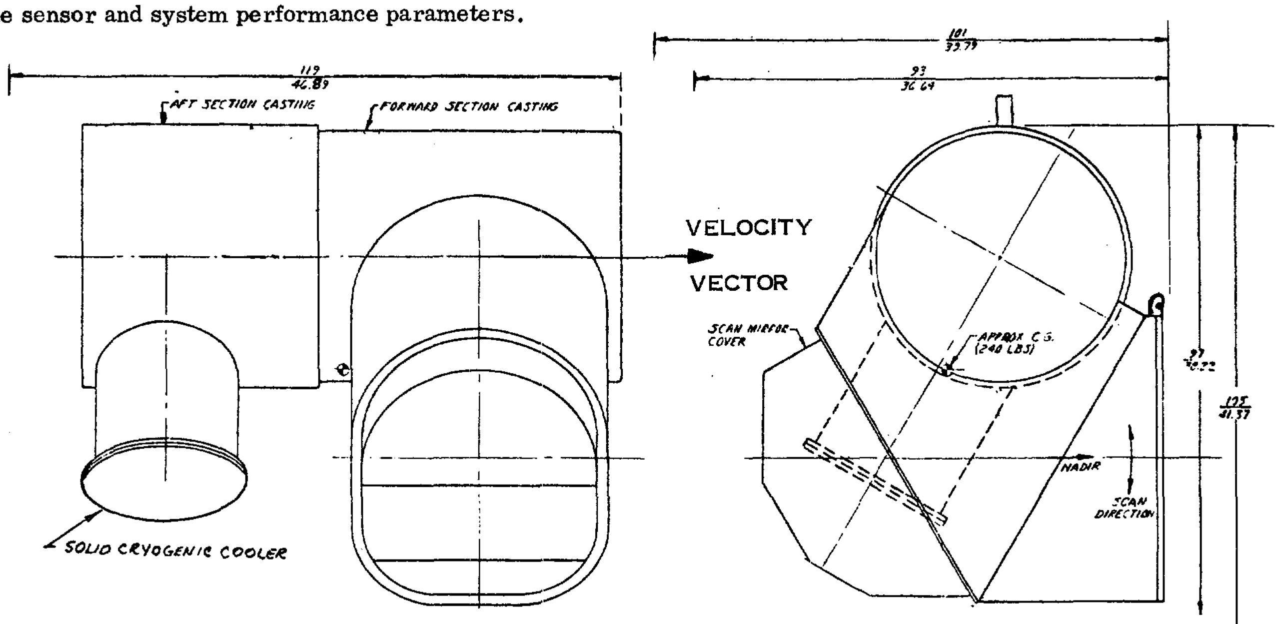


Figure 3-13. General Configuration of TM

Table 3-9. Hughes Thematic Mapper System Performance Parameters Baseline System

Band	Detector Type	Spectral Interval	Vertical Detector Array	Specified W/cm^2 Min - $\Omega \times 10^{-5}$	Specified S/N	Calculated S/N
1	PMT	.5 - .6	14	22	10	17.4
2	PMT	.6 - .7	14	19	7	13.5
3	PMT	.7 - .8	14	16	5	9.6
4	Silicon	.8 - 1.1	14	30	5	6.1
5	In Sb	1.55 - 1.75	14	8	5	5.2
6	In Sb	2.1 - 2.35	14	3	5	2.7
7	HgC_dT_e	10.4 - 12.6	4	300^oK	0.5^oK	0.55^oK

The optical system can be divided into the scan mirror subassembly, the telescope assembly, and the aft optics assembly. The scan mirror assembly has been designed to meet the requirements summarized in Table 3-10.

The scan mirror causes the IFOV to sweep across the swath. It needs to scan only half of the angle of the full field of view because of the angle doubling effect that occurs at reflection. The mechanism has nearly symmetrical scan pattern; i.e., the west to east forward scan and east to west reverse scan occur in nominally equal time intervals. The departure of the scan from the ideal sawtooth must be known and repeatable in order to correct for geometric accuracy. The fact that the actual shape is different in the forward and reverse directions adds complexity to the ground processing

Table 3-10. Scan Mirror Assembly Functional Requirements

Scan efficiency	80%
Scan frequency	8.4 Hz
Scan amplitude	± 0.050 rad (± 2.89 deg)
Scan to scan repeatability	3 μrad rms
Cross-scan jitter	4.5 μrad rms

A scan assembly is used to produce signals at start, center, and end of scan. This system consists of a gallium arsenide laser diode emitter, an optical projection system, a series of reflectors, and a pair of detectors. The accuracy in measuring the scan position is 0.5 μsec. which corresponds to one-tenth of an IFOV.

The telescope assembly includes the 48 cm (18.9 in) diameter primary mirror, the secondary mirror, a folding mirror for directing the beam into the aft optics assembly, and the telescope structure, which provides stable, accurate support of the optical elements and the Image Motion Compensator (IMC). The IMC mechanism must produce an offset of the optical beam in the direction of the spacecraft travel by an amount related to the IFOV, the telescope focal length, and the number of detectors per array. The net effect is to compensate for the tilt in the uncompensated ground scan pattern due to spacecraft motion (Figure 3-14).

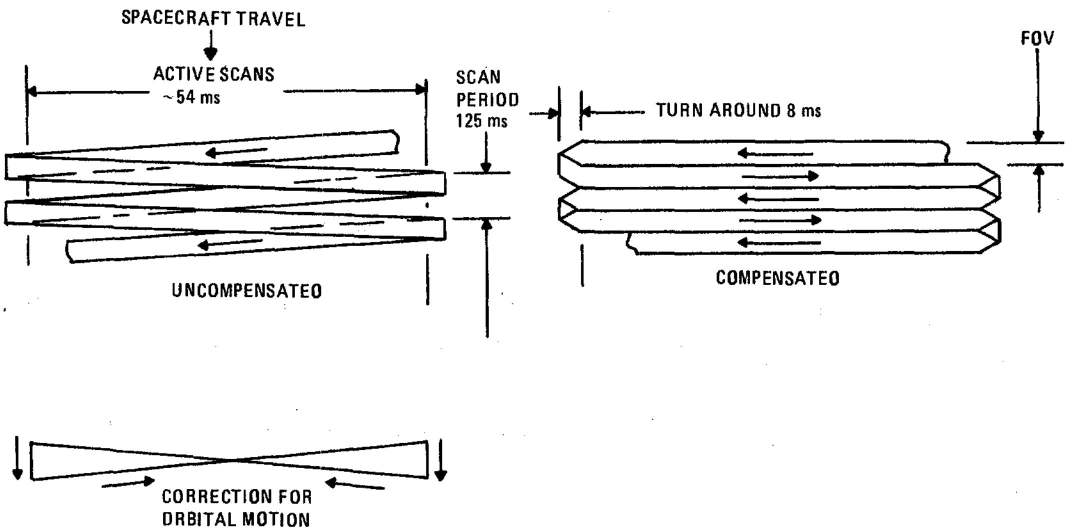


Figure 3-14. Uncompensated and Compensated Ground Patterns

Several requirements are placed on the mechanism chosen to provide IMC, such as minimal change in optical path length and constant angle of incidence on the detector plane. The design concept for the IMC uses two rotating flat mirrors in the convergent beam of energy located near the image plane to minimize the magnitude of the scanning motion. These mirrors are driven by a function generator and servo control to compensate for the spacecraft v/h motion during each scan, and resetting at the end of each scan in preparation for the next.

The aft optics assembly contains a number of optical/electronic components. These components must be accurately positioned relative to one another and to the telescope structure, and yet movable by the two commandable focus drives (if commandable drives are found necessary). The configuration at the focal plane is illustrated in Figure 3-15.

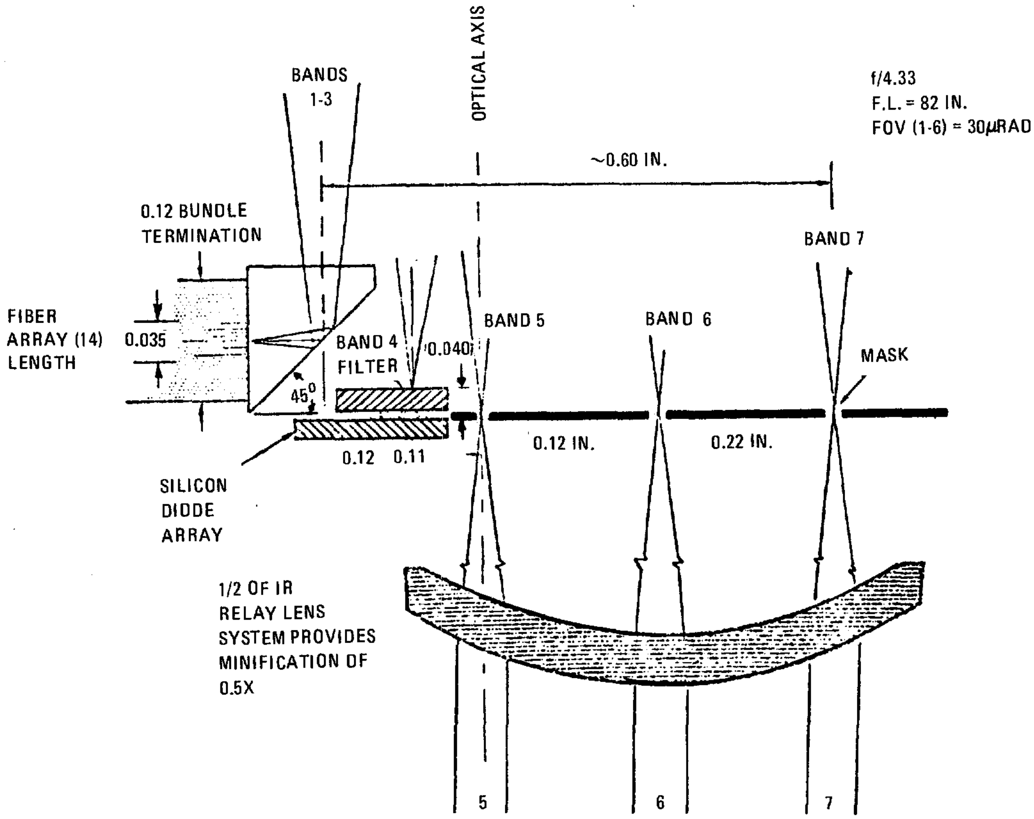


Figure 3-15. Focal Plane Arrangement

Bands 1 through 3 are folded 90 degrees by internal reflection in a prism. The fiber optic array originates at the exit face of the prism and then fans out to the individual detectors and filters. The fiber ends form the field stops.

Band 4 is detected by a filter and staggered silicon photodiode array. The diode elements provide the individual (14) field stops.

Energy for Bands 5 through 7 passes through a focus at the respective IR mask opening and then is reimaged by the relay lens system. The detector elements provide the field stops. The relay accomplishes the transfer of energy from the telescope plane to the location of the radiative cooler and reduces the field SNP sizes so that detector area and hence noise can be reduced.

Each of the spectral bands is physically separated from each other in image (and therefore object) space. Thus, they are not simultaneous, and coincidence in achieved by the scanning motion and subsequent matching of samples.

For radiation calibration, a lamp source is available and is reflected onto the detectors by moving a small mirror into the field of view. Issuing a radiation calibration command causes the lamp to be powered by a constant current supply, regulated to ± 0.2 percent. A continuously variable neutral density filter is included to provide a number of power input levels to the detectors.

A 1024 level staircase may be injected into each preamplifier to calibrate the electronics for gain and linearity.

3.2.5 THEMATIC MAPPER MODIFICATIONS

The present baseline Thematic Mapper design is compared in Table 3-11 with two possible modifications to adjust the instrument to an orbit in the Shuttle range rather than that of EOS-A.

Mod B appears to be more desirable from the standpoint of fewer modifications; i.e., mirror scan only rather than both the electronic system and the optical system as Mod A (see Table 3-12).

The operational advantage that Mod A has over Mod B is the greater swath width. The operational advantage that Mod B has over Mod A is the resolution.

There is a question on the stability of the scan mirror on the Mod B with its higher scan frequency. The only available data from Hughes is shown in Figure 3-16.

These two cases indicate the frequency of approach to instability is above the 13.9 Hz in Mod B plus the fact that Mod B has smaller accelerations due to the smaller scan angle. The baseline aperture is 40 cm which lies between the 38 cm case and the 43 cm case shown.

There is therefore confidence that this modification will be straightforward.

The second area for modification and one which must be done on any of the possible Thematic Mappers is the change of the detector cooling system from a passive radiative type to one which does not have a view black space for operation (an impossibility in the TERSSE Pallet configuration.) The potential thermal control approaches considered initially included passive, liquid and solid cryogens, thermoelectric, and refrigeration. General Electric has consistently found that passive, multi-stage, radiators severely restrict spacecraft configurations and, in many

Table 3-11. Comparison of Baseline Thematic Mapper Design with Modifications

Parameter	EOS Baseline System	Mod A	Mod B
Altitude, km	775	458	458
S/C Velocity, km/sec	6.66	7.12	7.12
Ground Resolution, m	27.1	20	16.3
Angular IFOV, μrad	35	43.7	35
Scan Angle, deg.	13.6 (0.238 rad)	13.6 (0.238 rad)	7.62 (0.133 rad)
Scan Rate, Hz	7.67	11.1	13.9
Ground Swath, km	185	109	60.8
Signal Bandwidth, kHz	65.8	75.7	65.8
Data Rate, Mbps	89.4	102.7	89.4
Clear Aperture, cm^2	990 (40 cm dia)	990	990
Focal Length, cm	206	165	206
F-Number	5.2	4.1	5.2
S/N - Band 1	22.8	33.2	22.8
2	25.6	37.2	25.6
3	25.2	36.7	25.2
4	27.4	39.9	27.4
5	7.0	10.2	7.0
6	3.5	5.1	3.5
7	$0.36^{o}K$	$0.25^{o}K$	$0.36^{o}K$

Table 3-12. Summary Mod A vs Mod B

Mod A	Mod B
1. 20 m ground resolution	1. Angular IFOV constant
2. Scan angle constant	2. Optic focal length constant
3. Scan mirror rate increased	3. Signal bandwidth and data rate constant
4. Signal bandwidth and data rate increased	4. Scan angle reduced
5. Optic focal length decreased	5. Scan mirror rate increased

cases, require prohibitive costs to accommodate. In addition, thermoelectric concepts are generally limited to about -190^{o}F (150^{o}K), refrigeration systems are not considered near term space hardware, and liquid cryogen systems are larger and heavier than solid cryogens with potential two-phase venting problems. It was therefore decided that a stored, solid cryogen system was the proper choice.

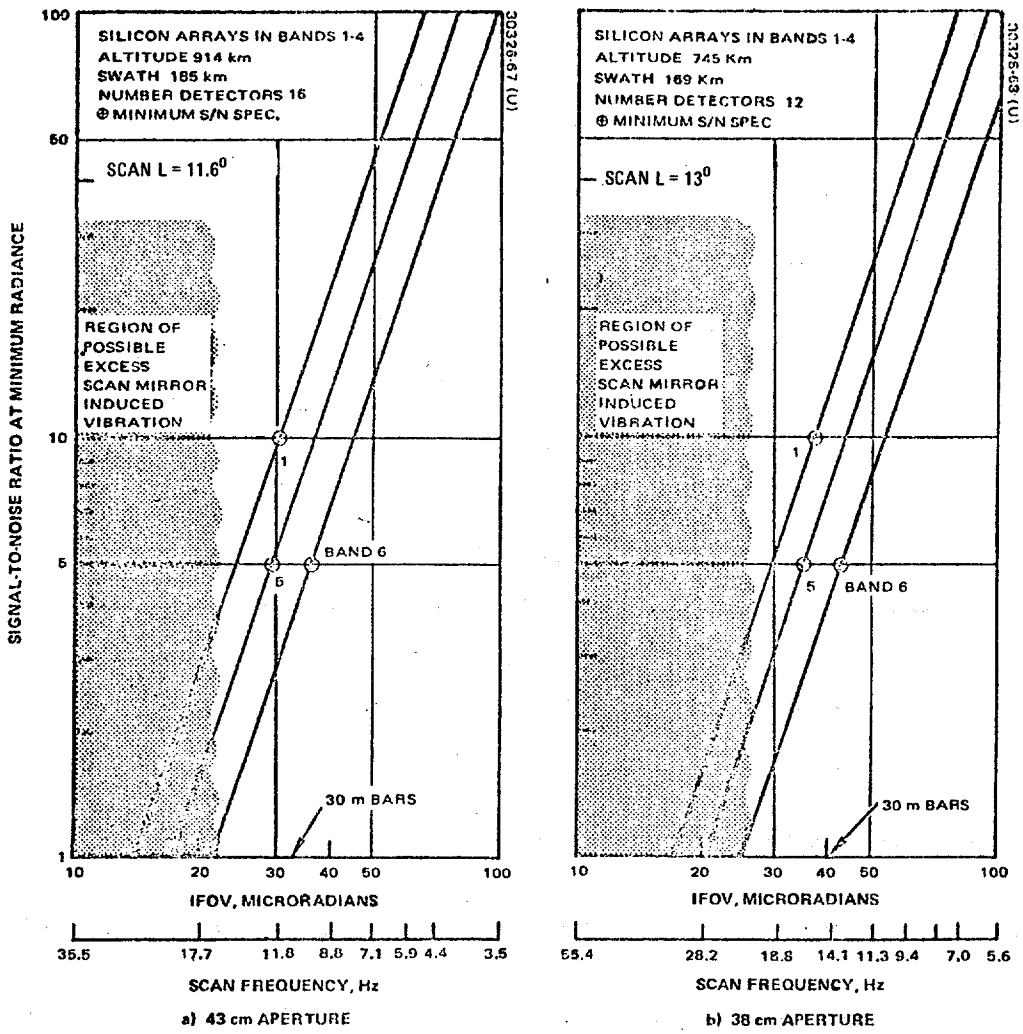


Figure 3-16. Silicon Array Performance

Two types of stored cryogen systems were considered; namely, single cryogen and staged cryogen systems. A staged cryogen system utilizes a higher temperature cryogen to act as a heat leak guard for a low temperature cryogen which, in turn, maintains the sensor temperature (e.g., 90°K). The single cryogen system concept includes a spherical tank for storing a solid cryogen, a surrounding region of multi-layer thermal insulation, and an outside vacuum shell. The inner shell is supported from the vacuum shell by compressively loaded, glass fiber reinforced epoxy posts. The payload sensor is coupled to the tank by a metallic tube which also carries away the gas that sublimes from the solid cryogen. This tube is vacuum sealed to the vacuum shell by low conductance stainless steel bellows. It should be noted that when the same payload contains sensors with different temperature requirements (e.g., 90°K and 180°K), it is possible to cool both sensors with one system by mounting both sensors to the same tube with the higher temperature sensor further from the solid cryogen than the lower temperature sensor such that the vapor leaving the system cools the higher temperature sensor.

Figure 3-17 shows the results of a computer analysis that was made for a longer life system. An 80°K methane systemfor 6 months weighs approximately 9.1 Kg (20 pounds), therefore a one week to one month system will be on that order or smaller.

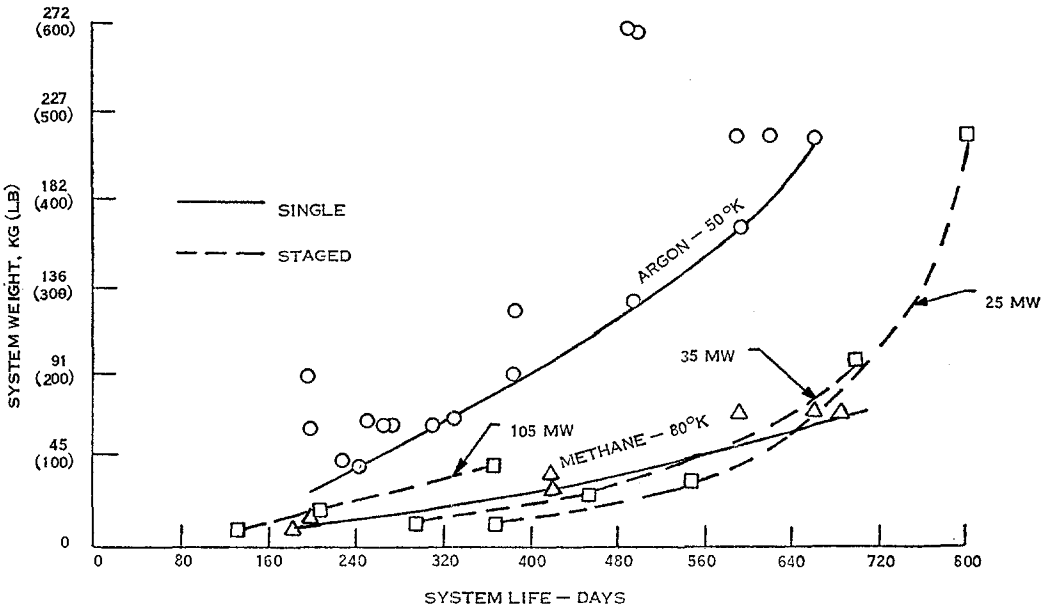


Figure 3-17. Weight vs. Life for Selected Solid Cryogen Systems

3.2.6 SENSOR POINTING

Sensor Pointing must be considered under four basic areas:

1. Boresight adjustment or the static alignment of the sensors so that they have nearby parallel centerlines of their fields of view.

2. Thermal distortion or the possibility that the thermal variations in orbit will bend the orbiter or the pallet in some unknown fashion so that the preset boresight and the orbiter's attitude reference are offset by some unknown amount.

3. Attitude control or the capability of the basic attitude control system, in this case the Orbiter, to assume and hold a known attitude with reference to nadir and the perpendicular to the orbital plane.

4. The ability of the actual sensor pointing system to point where desired at the time required.

The four problems are discussed in the following paragraphs.

Boresight Adjustment

Boresight alignment of the cameras on the pallet is required to 0.0017 rv (0.1°). This can be readily achieved by standard collimation methods and the adjustments made by shims under the mounting brackets, thereby eliminating the need for sophisticated leveling jacks, etc. Since the areas to be imaged are urban with many prominent features, there is no need to have a certain place in the format precisely match the position of the same element of another sensor's image. The only photographs that must be accurately registered from image to image are those formed by the Multispectral camera (S190A) and they are preboresighted in the camera manufacturing and assembly. The electronic readout of the Thermatic Mapper must have its images registered pixel by pixel but that also is insured in the Manufacture of the mapper.

Thermal Distortion

The larger question relating to the general question of boresighting is that of thermal distortion of the pallet and of the orbiter.

Paragraph 10.5 of JSC 07700 Vol XIV change I indicates the design of the Orbiter is not yet firm enough for definitive numerical answers but examination of ERNO data on probable pallet temperatures indicates temperature differentials of no more than 10°C to 30°C, (see Figure 3-18). Such temperature differentials will probably yield thermal deflections in the range of small fractions of a degree.

The thermal deflection of the pallet may be small compared to the thermal deflection of the orbiter itself. A rough estimate of the effect of heating the bottom of the Orbiter while simultaneously keeping the longerons cool indicated a possible deflection of perhaps 0.0052 r (0.3°). That deflection however would be such as to change the along track timing and is not important. The images will all be located by reference to ground control points with presurveyed coordinates.

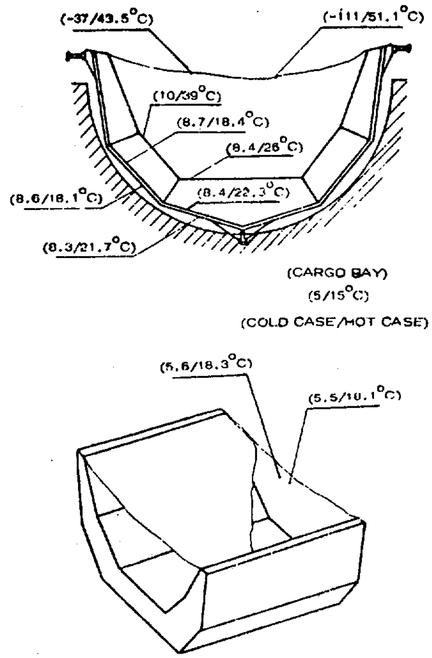


Figure 3-18. Pallet Thermal Model (Fully Covered)

The question that can be important and is still unresolved is the possibility that the open U-shaped payload bay may react to heat on one side by twisting. Such twisting would distort the coplanar characteristic of the longerons and would result in a rotation about the Orbiter roll axis. Such a twist about roll could misalign the optical line of sight in a serious manner. The effect would be to point the Thematic Mapper in a slightly unknown direction across track.

The practical effect of an unknown roll twist will be to require more overlap when two 0.133 r (7.62°) swaths are to be taken so as to cover one of the larger cities.

As a practical goal to prevent the loss of data, a roll deflection of 0.0087 r (0.5°) thermal twist in the orbiter 0.0017 r (0.1°) thermal bend on the pallet, and 0.0027 r (0.16°) error in the Orbiter navigation and control subsystem is desired. These errors will give 0.013 r (0.76°) total (worst case sum) which is one tenth of the swath width.

Since the swath width is 60 km, two swaths deflected in opposite directions if laid down with intentional overlap would miss by 12 km. The intentional overlap therefore should be 12 km if detailed analysis indicates these estimates are appropriate.

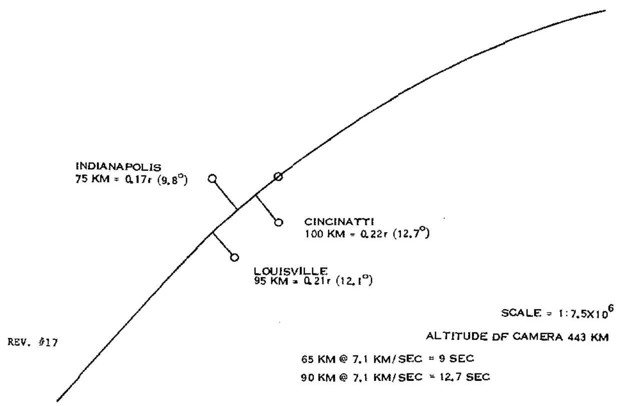
According to JSC 07700 the position error might be as much as 740 meters at 442.6 km (239. nm) altitude that would give a pointing determination error of 0.0017 r (0.096°) which is roughly comparable to the expected 0.028 r (0.16°) pointing error of the orbiter control system. Of course the orbiter pointing error might be increased by the thermal deflection, etc., of the orbiter. In any case neither of these errors is expected to be significant from the standpoint of geometric corrections to the data.

Therefore, it will not be necessary to provide any additional means to measure pointing or to control pointing.

3.2.7 OPERATIONAL ROLL POINTING

To accomplish this chosen mission of Urban Land Use Inventory, the sensors must be able to be pointed in roll while the axis of the orbiter is aligned along the velocity vector. The maximum roll angle has been tentatively set at ± 0.26 r (± 15°) from nadir. The rapidity of the roll maneuver, the consequent fuel consumption, and the reaction of such maneuvers on the crew and orbiter operations, must be traded against other solutions.

This roll pointing problem is illustrated by a pass between Indianapolis, Ind.; Louisville, Ky.; and Cincinnati, Ohio. The roll should first be to the right 0.21 r (12.1°) but only 12.7 seconds later to the left 0.17 r (9.8°) and then 9 seconds later 0.22 r (12.7°) to the right.



Let us assume that for each city the Thematic Mapper is operating for four seconds (± 2 seconds around the geographical center). To switch from Louisville to Indianapolis and to settle down at the proper roll angle can take no more than 8.7 seconds. Assuming that the sum of acceleration time and settling time on the new target is 2.7 seconds we have 6 seconds to rotate in roll 0.38 r (21.9°). The minimum roll rate for this maneuver that is 0.06 r (3.65°) per second. The fuel consumption tables in JSC 07700 imply a normal rate of 0.017 r/sec (1°/sec) about each axis but verbal information indicates a maximum programmed roll rate of 0.052 r/sec (3°/sec). Using the 0.052 r/sec (3°/sec) maximum roll rate to get 0.38 r (21.9°) requires 7.3 sec leaving 1.4 seconds to settle on target.

Moving onto the next sequence rolling from Indianapolis to Cincinnati we again deduct 4 seconds of operating time and find we have only 5 seconds to roll 0.39 r (22.5°); even with zero acceleration and settle time 0.052 r (3°) per second is inadequate. This means that if the orbiter is to perform the roll maneuvering function the particular city in this case must be observed on some other pass or the sensors must have some means of independently rolling or otherwise extending the angular coverage of their lines of sight.

Data from JSC 07700, Volume XIV, Change 1, (Table 3-13), indicates 7.6 kg (16.7 pounds) of RCS fuel to produce 0.017 r/sec (1^o/second) roll. There must be some additional consumption of pitch and yaw fuel to overcome gyroscopic cross coupling caused by the steady orbital pitch rate. There must also be a like amount of fuel to stop the roll and stabilize on the target. This mission may require executing this roll maneuver 100 to 150 times.

Table 3-13. Fuel Usage for Orbiter Sequential Three-Axis Automatic Maneuvers as a Function of Maneuver Rate

Manuever Rate, r/sec (deg/sec)	Fuel, kg (lb)			
	Roll	Pitch	Yaw	Total
.0044 (0.25)	1.7 (3.8)	3.6 (8.0)	4.8 (10.5)	10.1 (22.3)
.0087 (0.5)	4.1 (9.0)	5.3 (11.6)	6.8 (15.0)	16.2 (35.6)
.0131 (0.75)	5.9 (13.0)	7.3 (16.0)	13.3 (29.2)	26.5 (58.2)
.0.175 (1.0)	7.6 (16.7)	12.1 (26.6)	19.7 (43.4)	39.4 (86.7)

If we estimate that the pitch and yaw control fuel is two thirds of the roll, 24.5 kg (54 pounds) per observation are required or from 2454 to 3683 kg (5400 to 8100 pounds) of RCS fuel for the mission. The programming of a number of cities close enough together to require 0.05 r/sec (3^o/second) rolls would really drive the fuel consumption up. But even 100 rolls at 0.017 r/sec (1^o/second) cannot be supported by 1636 kg (3600 pounds) of RCS fuel. Therefore, other solutions to this problem must be sought.

Mechanical rotation is utilized in the case of these instruments because of the very large mirrors involved. In the case of the S190A the mirror would be a large rectangular one to be able to cover the fields of view of all six lenses. The Thematic Mapper would also require a very large mirror and the preferred method is therefore mechanical tilting.

Since the Thematic Mapper takes data serially rather than almost instaneously as a film camera does, there is less time between data periods. This requires a higher speed tilt and settle. Until further very detailed analysis a time from 0.26 rad to -0.26 rad ($+15^o$ to -15^o) of 3 sec (including settling time) is believed adequate. The configurations are shown in Figure 3-19.

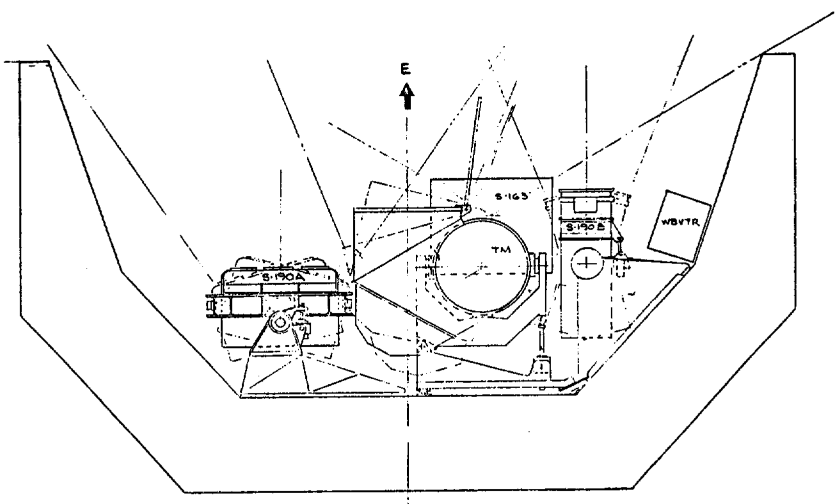


Figure 3-19. Sensor Pointing Configurations

If the estimates are proven to be overly optimistic when detailed analysis provides hard numbers, remedial action can be taken. For example, a closed circuit television camera mounted on the pallet and boresighted with the data cameras could be used to sight specific geographical targets while the orbiter roll angle was controlled by the navigation and control and computer system. A bias can then be manually set into the system by the Mission or Payload Specialist.

Attitude Control

The question of attitude control for the sensors can be evaluated by determining the pointing requirements and how the pointing requirements are to be achieved.

The pointing requirements for the sensors on this pallet are broken into two facets -- need to point and need to know. The need to point is governed by the desire to reduce the overlap required to prevent gaps. Until firm details on Orbiter errors are known an operational requirement of 0.028 r (1.6°) overlap is specified - 20% of the 0.133 r (7.62°) swath width of the modified Thematic Mapper. This will allow a possible 0.013 r (0.76°) total Orbiter error on one pass and an opposite 0.013 r (0.76°) error on the next pass.

The requirement to know the pointing at the instant of data taking is determined by the necessity to know the view angle of the pixel to the sensor so that geometric corrections can be applied. This view angle can be determined, in the case of urban land use mission imagery by either recording the Orbiter attitude at the moment of data taking or, since the geographical coordinates of some clearly visible features of any large city must be well known, a post flight computation can be made using the orbital position (ephemeris data).

3.2.8 DATA HANDLING AND STORAGE

The data acquired by the TERSSE Pallet is of three types. The three film cameras each have individual film supplies and the existing film cassettes hold sufficient film for performing the mission. However, the possibility of expanding the cassettes to allow complete coverage of the U.S. on a single Orbiter flight can be considered as the mission matures.

The second type of data requiring storage is the digitized data stream from the Thematic Mapper. Information will be generated at about 90 Megabits per second. The most advanced tape recorder now known to be under consideration which will be flight ready in 1979 is the GSFC development recorder. Table 3-14 gives the preliminary specifications for that recorder.

Note that by cutting the speed its nominal record time can be increased to 24 minutes. However the Thematic Mapper and recorder will be operational for only short periods of time in order to conserve space on the tape. Although the GSFC contractor (RCA) has not yet developed parameters for start/stop operation timing they have suggested the possibility of a 5 second turn around time. Considering a tape acceleration rate of 63.5 cm^2/sec (25 inches per sec^2) and a tape speed of 50 IPS for 90 MBPS (rather than 100 IPS for 240 MBPS) a start/stop sequence would use 254 cm (100 inches) - a 3 second data run, 380 cm (150 inches).

Table 3-14. 240 M Bit/Sec Preliminary Recorder Specifications

Item	Specification
Size:	
Recorder	74 x 53 x 46 cm (29 x 21 x 18 in)
Power Supply	20 x 20 x 24 cm (8 x 8 x 9.5 in)
Weight	
Recorder	90.9 kg (200 lb) max
Power Supply	11.4 kg (25 lb) max
Input Voltage	28 $\pm$ 1.5 VDC
Input Power	
Record	$\approx$ 200 W
Playback	$\approx$ 270 W
Rewind	$\approx$ 60 W
Storage	12 Minutes - (24 minutes at 50 IPS)
Total Bits	1.728×10^{11}
Angular Momentum	0.5 in-lb-sec
* Input Data Rate	240 MBPS (120 MBS at 50 IPS)
Life	5000 cycles
Bit Error Rate	10^6
Density	20 KBPI
Number of Tracks	120 DATA + 14 EDAC + 12 SPARES
Tape Speed	100 IPS (Modify to 50 IPS)
Tape Width	2 inches
Data Format	NRZ - L plus clock

With a 1930 m (76,000 inch) tape this mode would record 304 cities averaging 21 Km long x 60 Km wide. A single recorder has thus been included in the TERSSE Pallet design; dual recorders could be accommodated without difficulty.

3.2.9 COMMAND AND CONTROL

The ERNO pallet system contains, as optional support equipment, up to three experiment computers to be housed in the igloo. The characteristics of the computer are not firmly established, but sufficient capability will exist in the machine and its associated mass memory to carry out the sequencing and command generation for the TERSSE Pallet, thus greatly simplifying both the crew function and the TERSSE Pallet Distribution Box.

Sequence initiation will be manual from the PSS. Detailed sensor pointing sequencing commands will be generated by the computer using stored programs in conjunction with shuttle clock, ephemeris, and attitude data and fed to the TERSSE Pallet Distribution Box via the Remote Access Unit in the igloo.

The Distribution Box will function as the single point power and signal interface with the TERSSE Pallet and will provide hardwired controls which are not feasible to be allocated to the experiment computer, such as experiment heaters.

3.2.10 ELECTRICAL POWER

All sensors and support subsystems will receive power from the ERNO pallet. Unregulated 28 VDC and 115V-400 Hz power will be provided by the Igloo to the Distribution Box where it will be conditioned and fed to the sensors, tape recorder, and sensor pointing drives. Table 3-15 presents a system power bedget which is an average during data collection. Momentary peaks over these values will occur. A peaking battery option is planned by ERNO for inclusion in the igloo; it will be requested for the TERSSE Pallet Mission if the momentary peaks exceed the finally-defined igloo capacity.

Table 3-15. Operating Power Requirements

Thermatic Mapper	100 W
S190 A	120 W
S190 B	75 W
S163	200 W
Recorder	300 W
Control, Telemetry C&W & Margin	200 W
	995 W

3.3 MISSION SEQUENCE AND INTERFACES

This section describes the mission sequence and interfaces and the modifications of Shuttle Mission No. 4 which are necessary to accommodate the TERSSE Pallet and the Census Mission.

3.3.1 SHUTTLE MISSION NO. 4

The original Shuttle Mission No. 4, as described in "Integrated Mission Planning - First Two Years of Shuttle Mission, MSFC, March 1, 1974," had as its objective the demonstration of Shuttle's capability to launch and deploy a satellite. The Long Duration Exposure Facility (LDEF) was selected as the satellite to be deployed because it is a passive low-cost satellite whose launch time is not critical. A second original objective of the flight was the monitoring of the environment in and around the Shuttle using Integrated Real-Time Contamination Monitor Packages, which monitor the presence, amount, and rates of disposition of contaminents. These original objectives will both be met with the new Mission No. 4 and, in the case of the contamination objective, be expanded and enhanced by the inclusion of the TERSSE Pallet Mission.

The original and new cargo bay configurations are shown in Figures 3-20 and 3-21, respectively. The new layout contains the LDEF in its original position with an added Orbital Maneuvering System Kit located aft and the TERSSE pallet and igloo forward. The original mission contained a 1.5 m (5 ft.) pallet in which one IRTCM was mounted. This pallet is no longer necessary, as the 3 meter TERSSE pallet has sufficient area for the IRTCM and can profit from contamination measurements being made near the Census sensors.

Tables 3-16 and 3-17 contain the original and new mission weight summaries. Additions to the original weight list include the 3-meter pallet and attach fittings, sensors and support equipment and the OMS kit. The total launch weight of the new mission is 11,153 kg (24,538 lb).

Figure 3-22 illustrates the approximate original and new center of gravity locations for the configuration shown in Figure 3-2. The new launch c.g. is in the extreme aft position; some forward relocation of the LDEF and pallet may become desirable as the configuration matures.

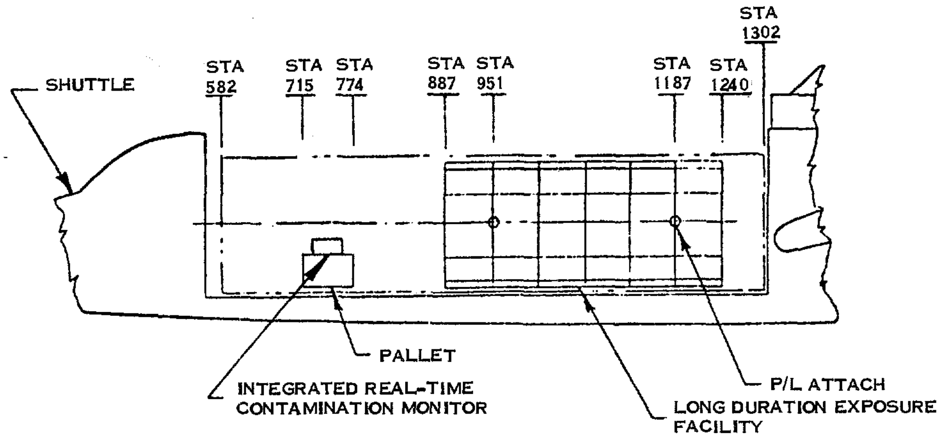


Figure 3-20. Original Configuration

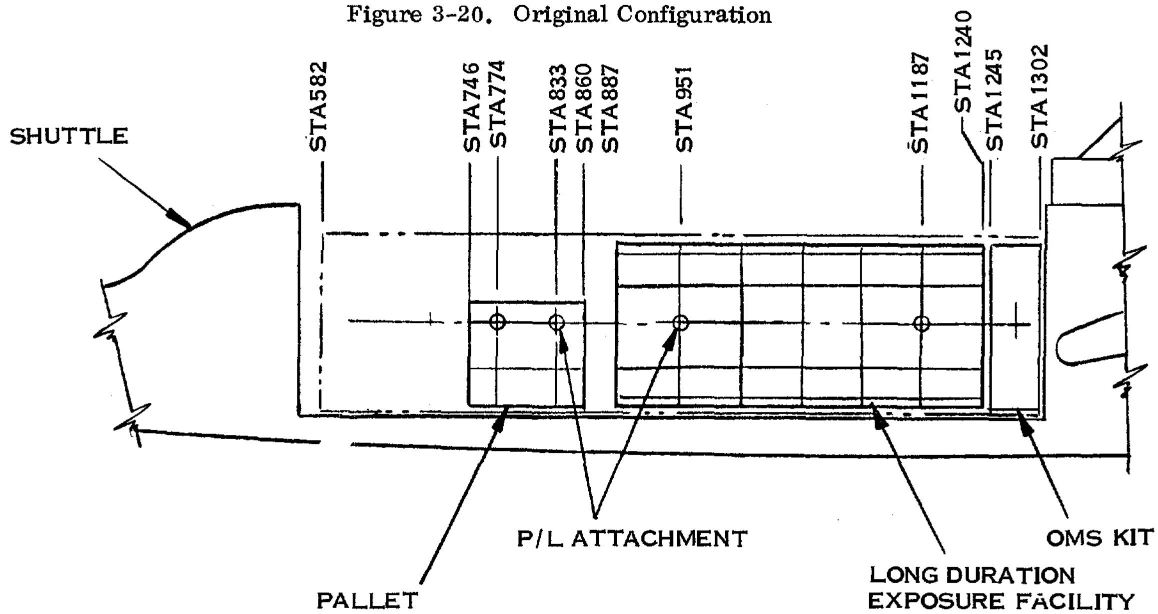


Figure 3-21. Mission No. 4 New Configuration

Table 3-16. Original Mission No. 4 Weight Summary

	Weight - kg (lbs) Launch	Weight - kg (lbs) Down
Pallet	181 (399)	181 (399)
Shuttle Attach Structure	205 (450)	205 (450)
Support Structure	36 (79)	36 (79)
Subtotal	422 (928)	422 (928)
Contingency (10%)	42 (93)	42 (93)
Research Equipment	4023 (8851)	160 (351)
LDEF	3864 (8500)	0
IRTCM'S	160 (351)	160 (351)
Total Payload Weight	4487 (9872)	624 (1372)

Table 3-17 New Mission No. 4 Weight Summary

	Weight - kg (lb) Launch	Down
Pallet	364 (800)	364 (800)
Igloo	182 (400) (EST)	182 (400) (EST)
Pallet Attach Fittings	205 (450)	205 (450)
LDEF Attach Fittings	205 (450)	205 (450)
Sub Total	956 (2100)	956 (2100)
Contingency (10%)	95 (210)	95 (210)
OMS Kit	5415 (11912)	1071 (2356)
Research Equipment		
Thematic Mapper	193 (425)	193 (425)
S-190 A	136 (300)	136 (300)
S-190 B	68 (150)	68 (150)
S-163	114 (250	114 (250)
WBVTR	114 (250	114 (250)
Power Dist. & Control	30 (65)	30 (65)
TM & Command	11 (25)	11 (25)
IRTCM'S	160 (351)	160 (351)
LDEF	3864 (8500)	0
Total Payload Weight	11156 (24538)	2948 (6482)

The original Shuttle Mission No. 4 was planned for launch at a 28.8° inclination to an altitude of 500 km (270 nm). The original mission profile is shown in Figures 3-23 and 3-24. In the 24-hr. original mission duration, the LDEF was to be checked out and deployed and contamination measurements made for the remaining time.

The new Shuttle Mission No. 4 profile is illustrated in Figure 3-25. The original part of the mission remains unchanged with the exception of the inclination, which is increased to 48.1°. Following LEDF deployment, the orbit is lowered to 443.1 km (239.5 nm) and the Census imagery portion of the flight carried on for a full six days. A timeline of the new mission is shown in Figure 3-26. The time line shows 33 data passes in Day 1 activity; 7 passes in Day 2; 6 passes in Day 3; 6 in Day 4; 6 in Day 5; 7 in Day 6; and 3 in Day 7. Crew involvement is relatively low level and is to insure that the equipment is turned on and that the computer commanded functions are properly occurring by monitoring the control panels. A typical pass over the CONUS takes from 4 to 15 minutes. There will also be a minimum number of other data taking times, such as a data pass over Hawaii in the middle of the second day's activity (pass 7A). Table 3-18 summarizes the interface requirements of the original and new missions for comparison.

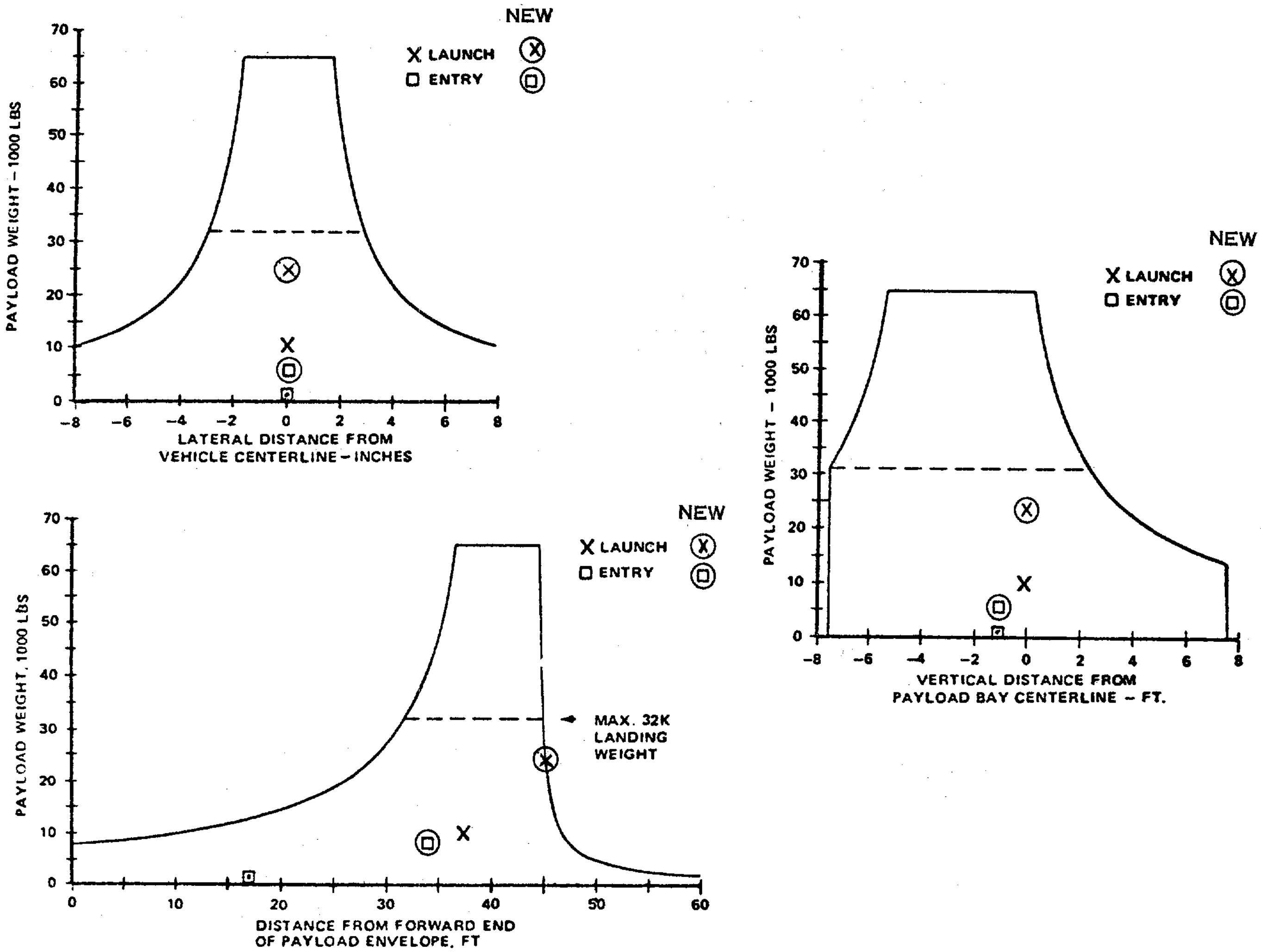
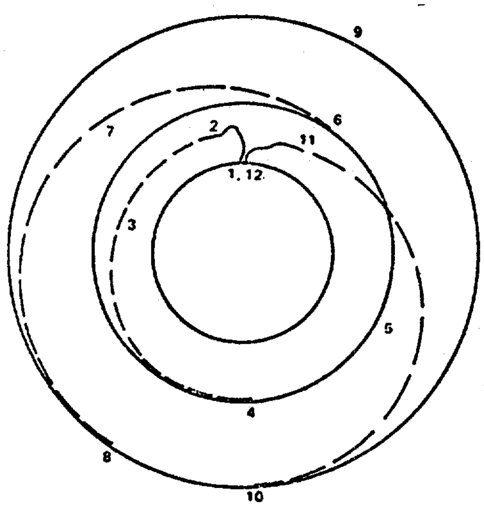


Figure 3-22. Center of Gravity



1. LAUNCH, AUGUST 1979
2. INJECT INTO 92 X 185 KM (50 X 100 NM), 28.8-DEGREE INCLINATION ORBIT
3. COAST TO APOGEE
4. CIRCULARIZE AT 185 KM (100 NM)
5. COAST 3 REVOLUTIONS*
6. INJECT IN 185 X 500 KM (100 X 270 NM) ORBIT
7. COAST TO APOGEE
8. CIRCULARIZE AT 500 KM (270 NM)
9. DEPLOY LDEF
10. DEORBIT
11. ATMOSPHERIC ENTRY
12. LANDING AT KSC

* R&D TEST PROGRAM MAY ALTER MISSION PROFILES, TIMES OR SEQUENCE

Figure 3-23. Original Mission No. 4 Payload

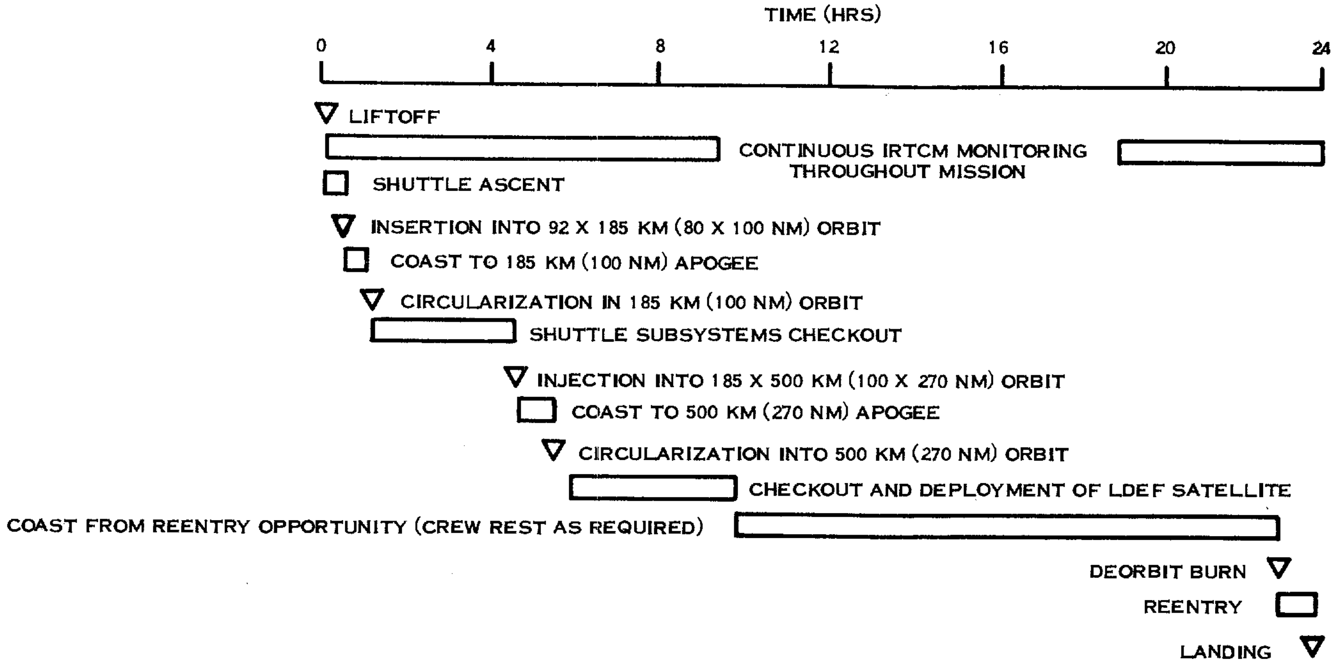
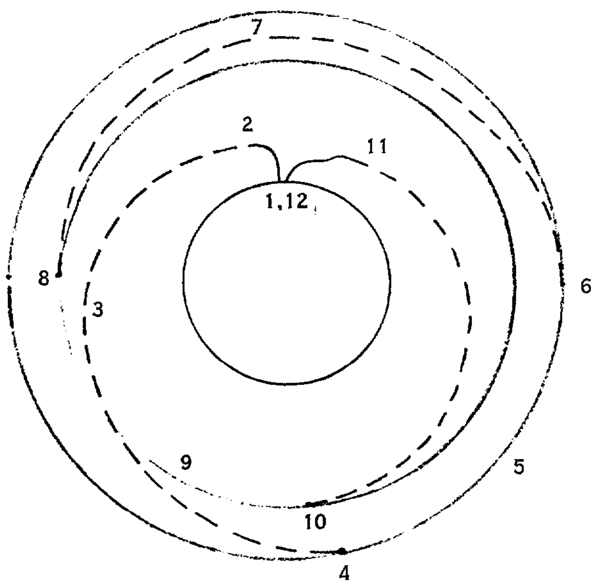


Figure 3-24. Original Mission No. 4 Timeline



1. LAUNCH FROM KSC
2. INJECT INTO 92 X 500 KM (50 X 270 NM), 48° INCLINATION ORBIT
3. COAST TO APOGEE
4. CIRCULATE AT 500 KM (270 NM)
5. LDEF ACTIVITIES (≈ 2 REVOLUTIONS)
6. OMS BURN FOR 500 X 443 KM NMI ORBIT
7. COAST TO PERIGEE
8. CIRCULATE AT 443 KM (239 NM)
9. CENSUS ACTIVITIES (≈ 90 REVOLUTIONS)
10. DEORBIT
11. ATMOSPHERIC ENTRY
12. LAND AT KSC

Figure 3-25. New Mission No. 4 Profile

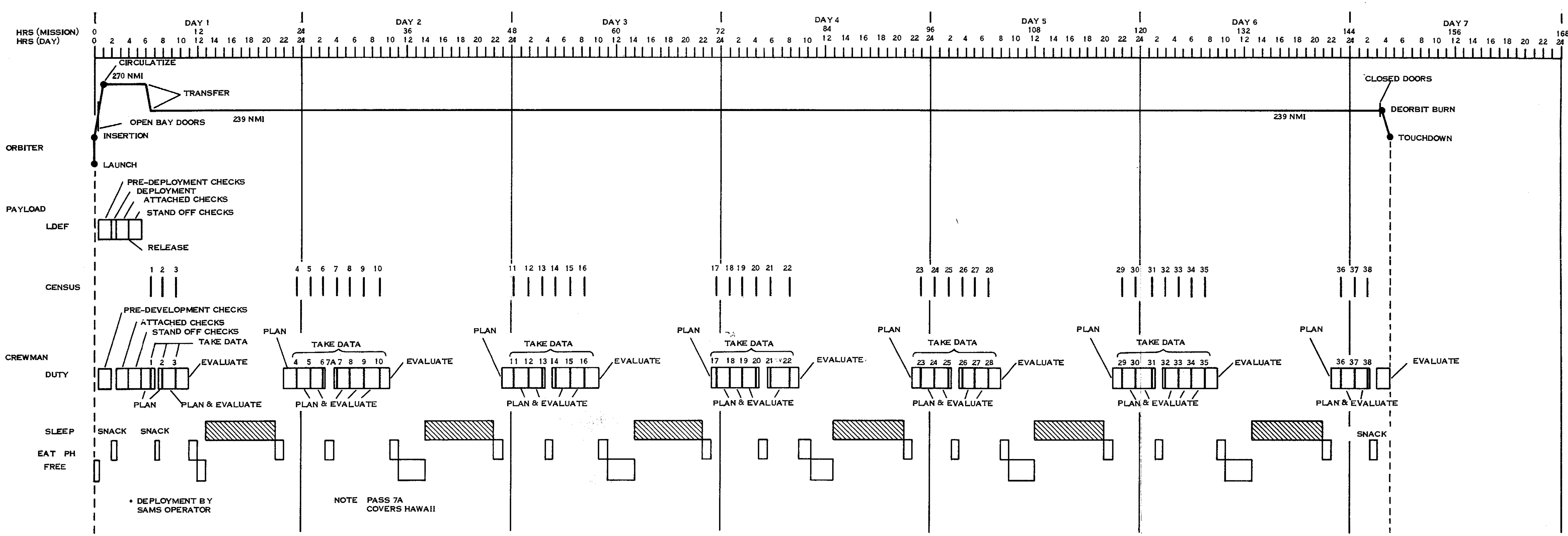


Figure 3-26. New Mission No. 4 Timeline

Table 3-18. Comparison of Original and New Interface Requirements

Payload Support Item	Original Mission No. 4 Requirement	New Mission No. 4 Requirement
Mission Data		
Altitude	500Km (270 nm)	500Km (270nm) initial; 4431cm (239 nm) final
Inclination	28.8°	48.1°
Duration	2 Days	7 Days
OMS Propellant	10818Kg (23,800 lb)	TBD
OMS Kits Required	None	One
RCS Propellant	1659Kg (3650 lb)	TBD
Mechanical		
Structural Support	Payload retention system/ support fittings for LDEF and IRTCM pallet	Same
Equipment Volume (Internal)	TBD	Same
Work Stations	0	Same
Experiment Area (External)	$0.84M^2 (9\ ft^2)$ + LDEF $38.3M^2 (412ft^2)$	Same + 3M Pallet + IGLOO
Manipulator	1 (Deployment)	Same
Electrical		
Power	462 W avg. 475 W peak	Same + 1kW during TERSSE Pallet OPS
Voltage	28VDC	Same + 115V/450 cycle
Energy	11kWH (24 hrs;)	11kWH (24 hrs) + TBD
Power Conditioning	No	Same
Additional Capability	Activation of LDEF sensor	Same
Data Handling		
Recorders	Digital 3456bps (continuous)	Same
Film Storage	None	Same
Computer Support	Yes	Yes
Control/Display	Yes	Same + TERSSE C&D
Checkout	No	Yes
Monitoring	Experiment output data (10%)	No additional
Environment (Non-Operating)		
Temperature	Shuttle payload bay is acceptable	Same
Cleanliness		
Acoustics		
Humidity		
Acceleration		

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