JANUARY 1972

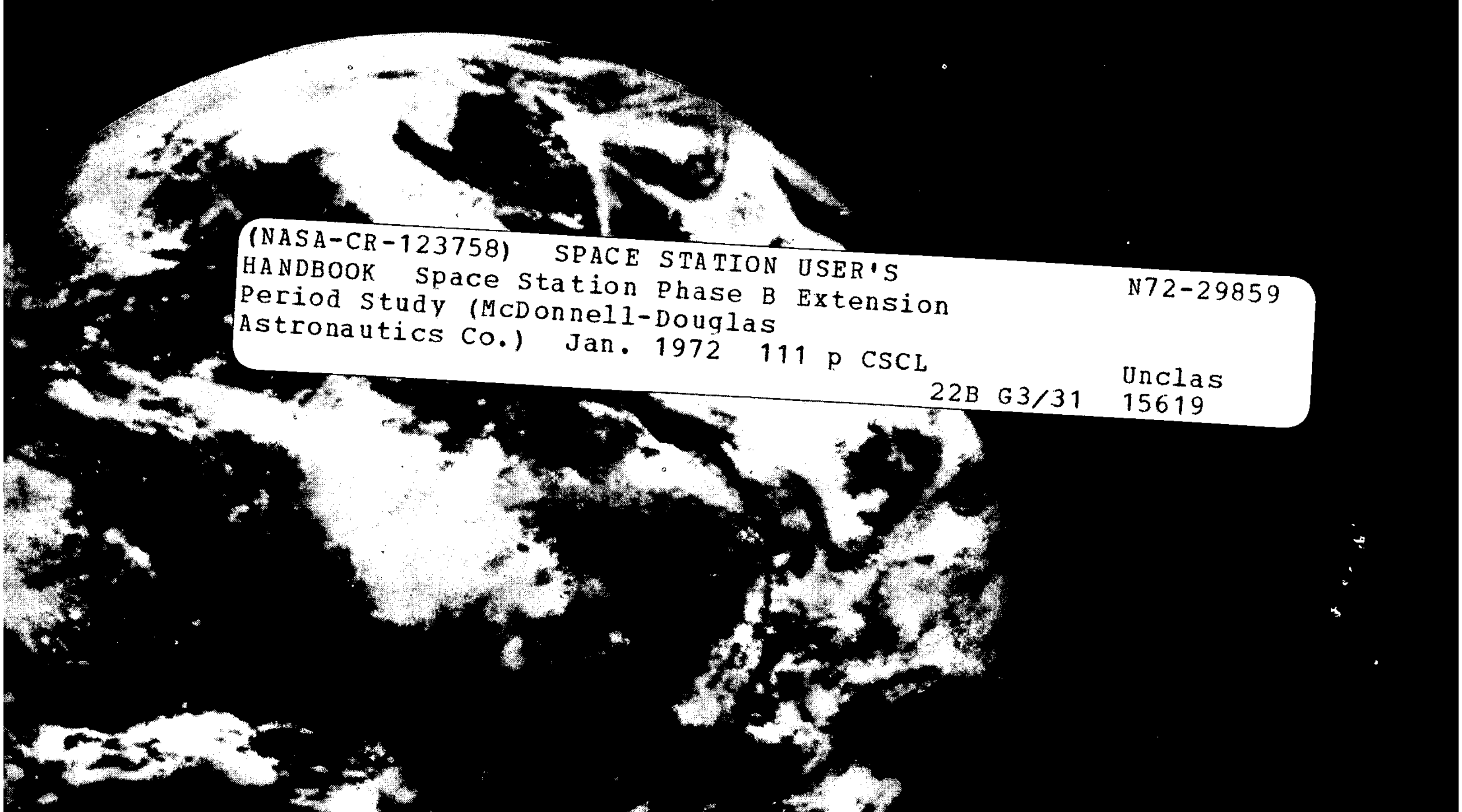
MDC G2580

SPACE STATION

MSFC-DPD-235/DR NO. SE-08

USER'S HANDBOOK

CONTRACT NAS8-25140



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Details of illustrations in this document may be better studied on microfiche.

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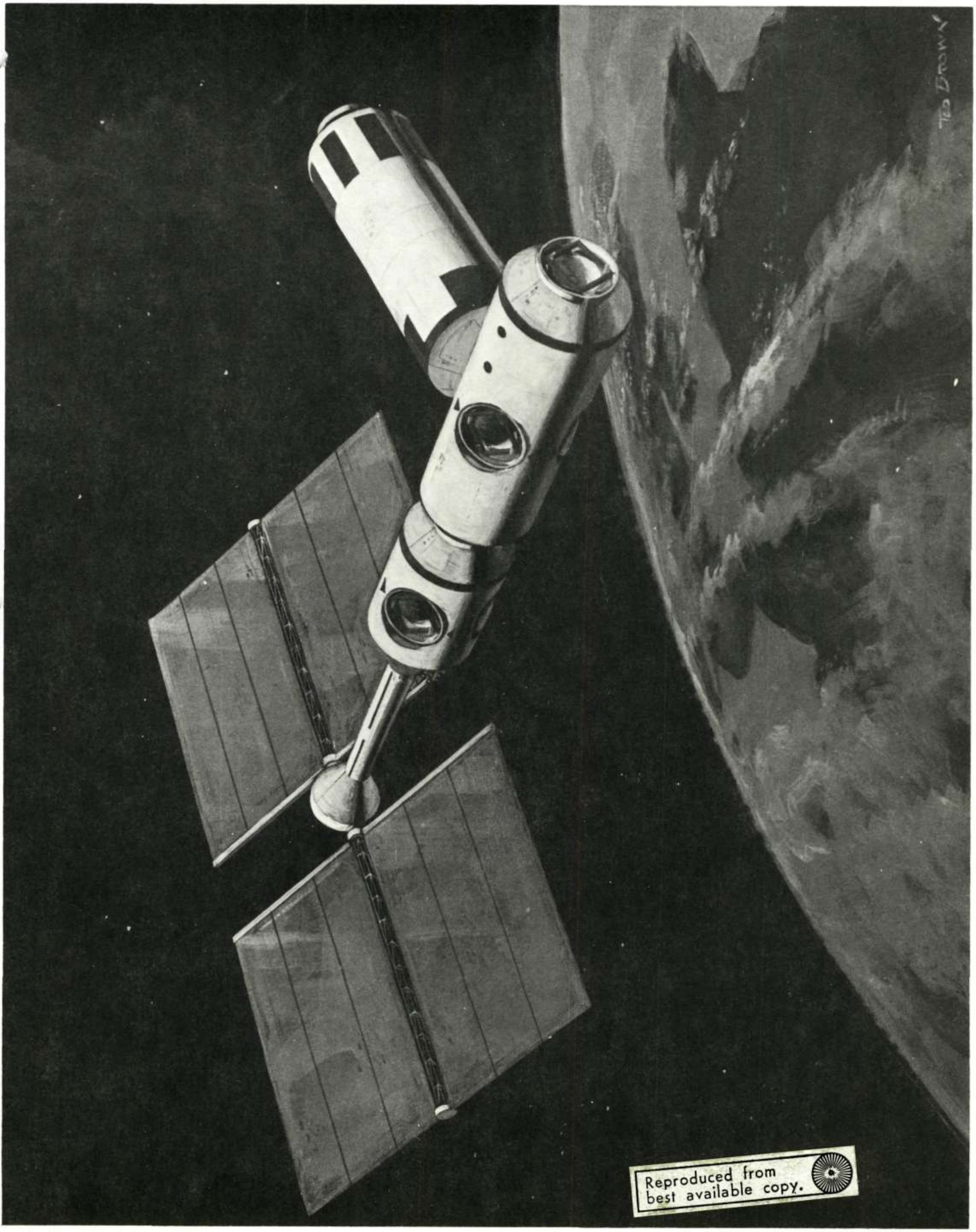
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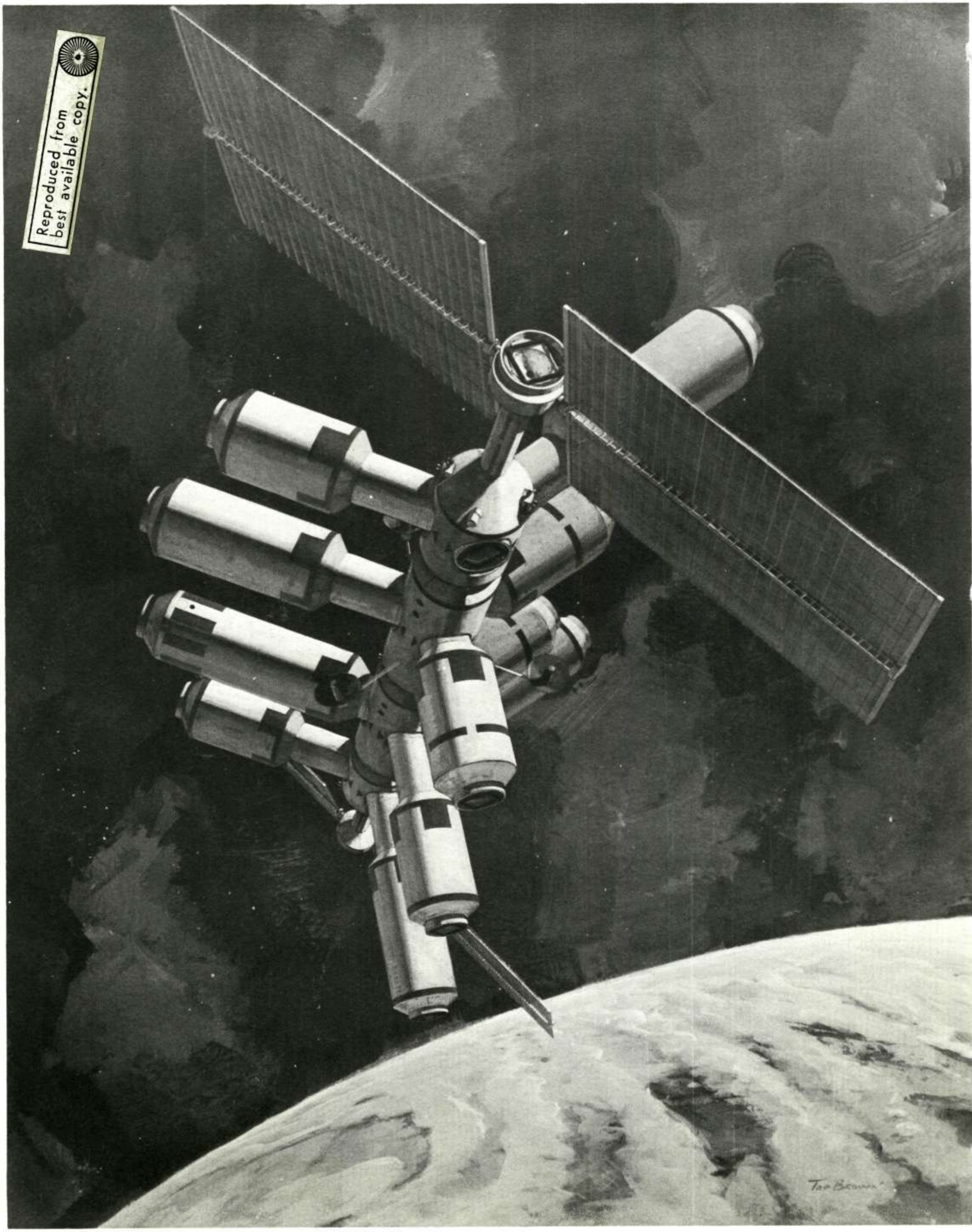
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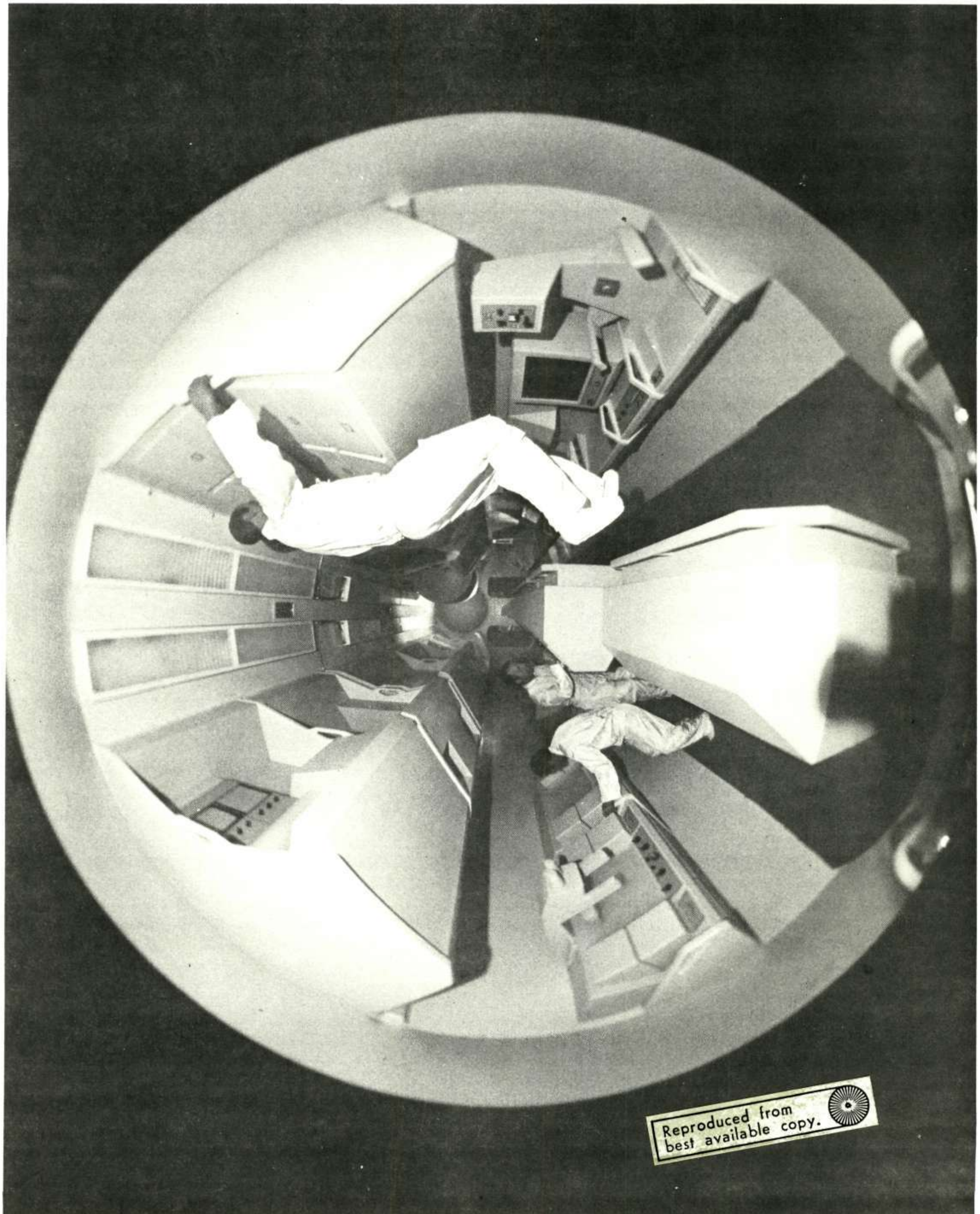

PREFACE

The work described in this document was performed under the Space Station Phase B Extension Period Study (Contract NAS8-25140). The purpose of the extension period has been to develop the Phase B definition of the Modular Space Station. The modular approach selected during the option period (characterized by low initial cost and incremental manning) was evaluated, requirements were defined, and program definition and design were accomplished to the depth necessary for departure from Phase B.

The initial 2-1/2-month effort of the extension period was used for analyses of the requirements associated with Modular Space Station Program options. During this time, a baseline, incrementally manned program and attendant experiment program options were derived. In addition, the features of the program that significantly affect initial development and early operating costs were identified, and their impacts on the program were assessed. This assessment, together with a recommended program, was submitted for NASA review and approval on 15 April 1971.

The second phase of the study (15 April to 3 December 1971) consists of the program definition and preliminary design of the approved Modular Space Station configuration.

A subject reference matrix is given (page v) to indicate the relationship of the study tasks to the documentation.

This report is submitted as part of Data Requirement SE-08.

DATA REQUIREMENTS (DR's)
MSFC-DPD-235/DR NOs.
(contract NAS8-25140)

Category	Designation	DR Number	Title
Configuration Management	CM	CM-01	Space Station Program (Modular) Specification
		CM-02	Space Station Project (Modular) Specification
		CM-03	Modular Space Station Project Part 1 CEI Specification
		CM-04	Interface and Support Requirements Document
Program Management	MA	MA-01	Space Stations Phase B Extension Study Plan
		MA-02	Performance Review Documentation
		MA-03	Letter Progress and Status Report
		MA-04	Executive Summary Report
		MA-05	Phase D/D Program Development Plan
		MA-06	Program Option Summary Report
Manning and Financial	MF	MF-01	Space Station Program (modular) Cost Estimates Document
		MF-02	Financial Management Report
Mission Operations	MP	MP-01	Space Station Program (Modular) Mission Analysis Document
		MP-02	Space Station Program (Modular) Crew Operations Document
		MP-03	Integrated Mission Management Operations Document
System Engineering and Technical Description	SE	SE-01	Modular Space Station Concept
		SE-02	Information Management System Study Results Documentation
		SE-03	Technical Summary
		SE-04	Modular Space Station Detailed Preliminary Design
		SE-06	Crew/Cargo Module Definition Document
		SE-07	Modular Space Station Mass Properties Document
		SE-08	User's Handbook
		SE-10	Supporting Research and Technology Document
		SE-11	Alternate Bay Sizes

FOLDOUT FRAME 1

FOLDOUT FRAME 2

SUBJECT REFERENCE MATRIX

LEGEND:
- CM Configuration Management
- MA Program Management
- MF Manning and Financial
- MP Mission Operations
- SE System Engineering and Technical Description

	CM				MA		MF	MP						SE					
	CM-01 Space Station Program (Modular) Specification	CM-02 Space Station Project (Modular) Specification	CM-03 Modular Space Station Project Part 1 CEI Spec	CM-04 Interface and Support Requirement Document	MA-05 Phase C/D Program Development Plan	MA-06 Program Option Summary Report	MF-01 Space Station Program (Modular) Cost Estimates Document	MP-01 Space Station Program (Modular) Mission Analysis Document	MP-02 Space Station Program (Modular) Crew Operations Document	MP-03 Integrated Mission Management Operations Document	SE-01 Modular Space Station Concept	SE-02 Information Management System Study Results	SE-03 Technical Summary	SE-04 Modular SS Detailed Preliminary Design	SE-06 Crew/Cargo Module Definition Document	SE-07 Modular Space Station Mass Properties Document	SE-08 User's Handbook	SE-10 Supporting Research and Technology	SE-11 Alternate Bay Sizes
2.0 Contractor Tasks																			
2.1 Develop Study Plan and Review Past Effort (MA-01)																			
2.2 Space Station Program (Modular) Mission Analysis								●											
2.3 Modular Space Station Configuration and Subsystems Definition														●					
2.4 Technical and Cost Tradeoff Studies							●												
2.4.4 Modular Space Station Option Summary											●								
2.5 Modular Space Station Detailed Preliminary Design														●					
Mass Properties																●			
2.6 Crew Operational Analysis									●										
2.7 Crew Cargo Module															●				
Mass Properties																●			
2.8 Integrated Mission Management Operations										●									
2.9 Hardware Commonality Assessment													●						
2.10 Program Support					●														
2.11 Requirements Definition																			
Space Station Program (Modular)	●																		
Space Station Project (Modular)		●																	
Modular Space Station Project–Part 1 CEI			●																
Interface and Support Requirements				●															
2.12 Plans					●														
2.13 Costs and Schedules							●												
2.14 Special Emphasis Task Information Management (IMS)												●							
Modular Space Station Mass Properties																●			
User's Handbook																	●		
Supporting Research and Technology																		●	
Technical Summary													●						
MOD 29																			●
MOD 40						●													

FOREWORD

This handbook has been prepared under Contract NAS 8-25140 by McDonnell Douglas Astronautics Company as part of the Modular Space Station Program performed for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center.

This handbook describes a currently completed modular Space Station concept that furnishes facilities which investigators may use for experimentation and application if this Space Station is approved for final design and implementation. It should be recognized and understood by investigators using this handbook that alternate Space Station concepts may continue to be developed. ~~In fact, this~~ handbook supersedes a similar document published in March 1971 under Contract NAS 8-25140, in which the Space Station structural concept was monolithic rather than modular. Further alternate concepts may depend in part on the response received from the users of the book, the purpose of which is to acquaint investigators with the resources and opportunities currently available. The user is invited to assist NASA in defining candidate payloads and assessing the suitability of current Space Station designs for such payloads and experimentation.

Comments and suggestions should be addressed to:

NASA-Marshall Space Flight Center
Huntsville, Alabama 35812
Attention: Space Station Task Team, PD-SS

Mr. Vern D. Kirkland or Mr. B. E. Garlich
McDonnell Douglas Astronautics Company
5301 Bolsa Avenue
Huntington Beach, California 92646

SPACE STATION RESOURCES
RESERVED FOR EXPERIMENTS

Item	Capability
Laboratory Facilities	200 M^3 (7000 cu ft)
Power for Experiments	4.8 kwe (average) during ISS, including support equipment operation
	12.1 kwe during GSS
Pointing and Stabilization	All-attitude capability; inertial and Earth-centered data available
	0.25-degree accuracy, able to hold position with drift of 0.005 degree per second or less
Navigation	Ground based
Data Management	Computer-managed for both experiments and Space Station operations
	Quick-look capability
	Able to process 9072 kg (20,000 lb) of film and tape per year
Communications	Multichannel voice transmission and two-way color television
	Relay satellite capability 10^{12} bits per day
Experiment Checkout	Monitoring, caution and warning, and troubleshooting functions
Gravity	Nominally 10^{-5}-g
Crew Availability	4-5 during ISS
	9-10 during GSS
Payload to Orbit	73,000 kg (160,000 lb) per year at approximately 30-day intervals

CONTENTS

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FIGURES

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INTRODUCTION

BACKGROUND

With the advent of the Space Shuttle in the late 1970's, a long-term, manned scientific laboratory in Earth orbit will become feasible. Using the shuttle for orbital buildup, logistics delivery, and return of scientific data, this laboratory will provide many advantages to the scientific community and will make available to the United States a platform for application to the solution of national problems such as ecology research, weather observation and prediction, and research in medicine and the life sciences. It will be ideally situated for Earth and space observation, and its location above the atmosphere will be of great benefit to the field of astronomy.

This orbiting laboratory can take many forms and can be configured to house a crew of up to 12 men. The initial study of the 33-foot-diameter Space Station, launched by the Saturn INT-21 and supporting a complement of 12, has been completed to a Phase B level and documented in the DRL-160 series. Recently completed studies are centered around a Space Station comprised of smaller, shuttle-launched modules. These modules could ultimately be configured to provide for a crew of the same size as on the 33-foot-diameter Space Station, but buildup would be gradual, beginning with a small initial crew and progressing toward greater capability by the addition of modules and crewmen on a flexible schedule.

The Modular Space Station Phase A—level study results are documented in the DRL-231 series. Recent Modular Space Station Phase B study results are documented in the DPD-235 series, of which this is a volume.

The Space Station will provide laboratory areas which, like similar facilities on Earth, will be designed for flexible, efficient changeover as research and

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experimental programs proceed. Provisions will be included for such functions as data processing and evaluation, astronomy support, and test and calibration of optics. Zero gravity, which is desirable for the conduct of experiments, will be the normal mode of operation. In addition to experiments carried out within the station, the laboratories will support operation of experiments in separate modules that are either docked to the Space Station or free-flying.

Following launch and activation, Space Station operations will be largely autonomous, and an extensive ground support complex will be unnecessary. Ground activities will ordinarily be limited to long-range planning, control of logistics, and support of the experiment program.

The Initial Space Station (ISS) will be delivered to orbit by three Space Shuttle launches and will be assembled in space. A crew in the Shuttle orbiter will accompany the modules to assemble them and check interfacing functions.

ISS resupply and crew rotation will be carried out via round-trip Shuttle flights using Logistics Modules (Log M's) for transport and on-orbit storage of cargo. Of the four Log M's required, one will remain on orbit at all times.

Experiment modules will be delivered to the Space Station by the Shuttle as required by the experiment program. On return flights, the Shuttle will transport data from the experiment program, returning crewmen and wastes.

The ISS configuration is shown in the frontispiece. The Power/Subsystems Module will be launched first, followed at 30-day intervals by the Crew/Operations Module and the General Purpose Laboratory (GPL) Module. This configuration will provide for a crew of six. Subsequently, two additional modules (duplicate Crew/Operations and Power/Subsystems Modules) will be mated to the ISS to form the Growth Space Station (GSS) (shown in the second frontispiece), which will house a crew of 12 and provide a capability equivalent to the 33-foot, INT-21-launched Space Station. GSS logistics support will use a Crew Cargo Module (CCM) capable of transporting a crew of six.

During ISS operations, five Research Applications Modules (RAM's) will be assembled to the Space Station. Three of these will be returned prior to completion of the GSS. In the GSS configuration, 12 additional RAM's will augment the two remaining from the ISS phase. Three of the RAM's delivered to the GSS will be free-flying modules.

During the baseline 10-year program, the Space Station will be serviced by Shuttle-supported Logistics Module or Crew Cargo Module flights.

SCOPE OF THIS VOLUME

The NASA Modular Space Station is being designed to offer the broadest possible range of resources for scientific and technological investigation. The specific ways in which these resources will be applied depend upon the individual researchers and experimenters who will use this laboratory in space. The researchers will conceive the work to be carried out, assist in the planning and engineering necessary to make it a reality, and participate in its performance on orbit. The user's creativity, his specialized knowledge, and his insight into the needs and potentials of his field are, therefore, crucial to the success of the Space Station Program.

This handbook has been prepared to furnish the potential Space Station user with a framework within which to consider his requirements and goals. The contents are designed to acquaint him with the overall Modular Space Station Program, the general nature and capabilities of the station itself, some of the scientific opportunities presented by the Station, the general policy governing its operation, and the relationship between the program and participants from the scientific community.

Section 1
THE MODULAR SPACE STATION PROGRAM

NASA plans to launch its first large space station in the late 1970's to provide the world with an international facility wherein man can truly begin to take advantage of the space environment. On board, scientists and engineers will live and work in shirtsleeve comfort. They will conduct experiments, make observations, and collect data over a broad spectrum of technical and scientific disciplines. They will cook their meals, bathe, and relax much as men do now in a modern submarine.

The researchers and crewmen will travel to and from the orbiting Space Station in a shuttle vehicle that will provide accommodations similar to those of a jet airliner. Once aboard the station, they will find laboratories equipped much as their laboratories were on Earth. They will move around freely and will work in a temperature-controlled, well-lighted, well-ventilated atmosphere. The overall profile of orbital operations during the planned 10-year program is shown in Figure 1-1.

As conceived by NASA, the Space Station is intended to serve both national and international interests. In addition to scientific and technological research and development, its use will include commercial applications. Experiments will be designed and operated on board by members of the academic and scientific community and by people from industry. International participation will be encouraged.

The Space Station will be operated much like a government-owned laboratory, wind tunnel, accelerator, or observatory on Earth.

During the operational life of the station, the Space Station will be used by investigators in the fields of astronomy, astrophysics, medicine, biology, material processing, Earth sciences, communications and navigation, and space physics. Thus it is being designed to be as versatile as possible, indicated by the range of possible research areas listed in Table 1-1.

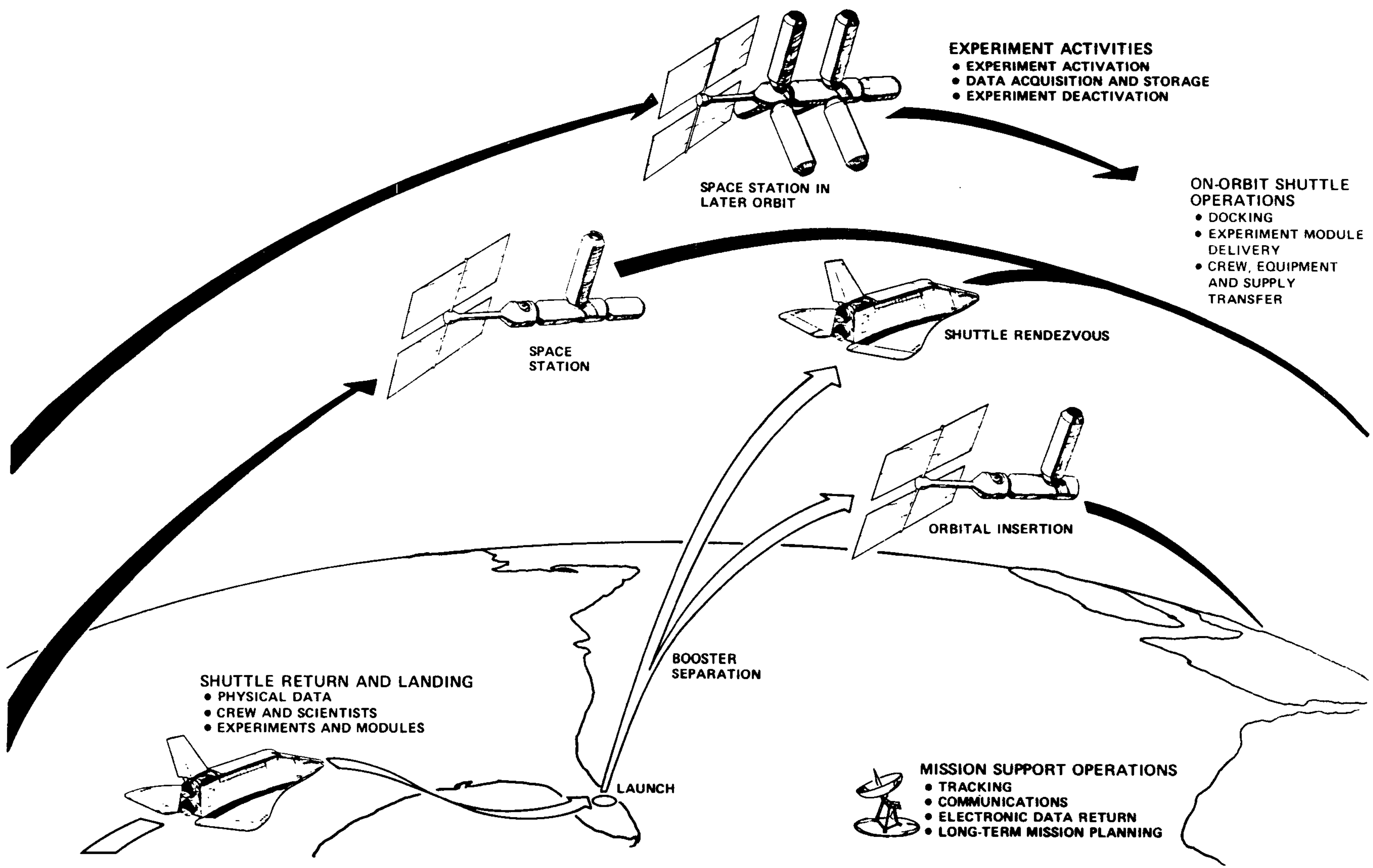

Figure 1-1. ISS Profile of Mission Activities for Five-Year On-Orbit Program

Table 1-1

POTENTIAL RESEARCH AREAS

Disciplines and Objectives	Research Areas
Astronomy	
Improved understanding of strong galactic x-ray sources and search for new sources	Grazing incidence x-ray telescope
Increased knowledge of the spatial structure of astronomical objects and detection of faint objects	Advanced stellar astronomy
Understanding of solar processes through high-resolution observation of the sun's granular structure and areas of high solar activity	Advanced solar astronomy
Mapping of the entire sky in the ultraviolet region of the spectrum, with concentration on strong ultraviolet sources	Ultraviolet stellar astronomy
Determination of the characteristics of x-ray and gamma-ray sources	High-energy stellar astronomy
Infrared survey of the sky to determine the sources of infrared radiation and their characteristics	Infrared stellar survey
Life Sciences	
Understanding of the fundamental roles of gravity and a cyclic environment in biological processes on Earth	Primates Small vertebrates Plant specimens Microbiology Invertebrates
Enhancement of man's capabilities in space and advancement of medicine through use of environmental factors of space flight for applied research	Biomedical research and man-system integration
Earth Observations	
Development of the technology for remote sensing of the Earth's resources and improvement of the knowledge of the Earth and its atmosphere	Earth surveys Remote maneuvering subsatellites

Table 1-1

POTENTIAL RESEARCH AREAS (Continued)

Disciplines and Objectives	Research Areas
Communications and Navigation	
Support broad research programs by conducting performance testing of candidate configurations and techniques under actual operating conditions.	Extended space structure development Component test and sensor calibration Noise measurement Propagation measurement Communication systems Navigation systems
Space Physics	
Improved understanding of the space environment and the induced environment surrounding the Space Station	Space physics airlock experiments Contamination measurements Exposure experiments Fluid physics in microgravity Physics and chemistry
Materials and Processes	
Establish the technology of processing materials in the zero-gravity and vacuum environment of space for scientific and potential commercial purposes	Material science, processing, and manufacturing

The Modular Space Station uses a buildup of modules and crew to arrive at full capability. The buildup initially consists of three modules (Power/subsystems, Crew/operations and GPL) which provide the capability for supporting a six-man crew and extensive experiment program. Additional modules, as well as experiment modules, can be added to achieve a 12-man capability. Of primary interest to the potential experimenter is the GPL, which is discussed in detail in Subsection 3.1.

The Space Station will operate in a circular, 55-degree-inclination orbit with a range of 445 km (240 nmi) to 500 km (270 nmi) that affords good coverage for space and Earth observations. Once the station is in orbit, its operations will be largely autonomous, making an extensive ground support complex unnecessary. The station will be resupplied every 45 to 90 days, and the crew will be rotated every 90 days.

Three types of personnel will make up the Space Station crew. Normally, there will be experiment scientists, principal investigators, and astronaut-engineers.

Experiment scientists are professional crew members who make repeated flights on the Space Station. Their primary function is to control or perform the experiments, but they will also assist in station maintenance.

Principal investigators are occasional crew members who may visit the station for a special purpose, but whose main function would normally be carried out on the ground.

Finally, there are the astronaut-engineers, whose job is to operate the station and assist in the conduct of the experiments.

The crew is organized in a manner similar to the pattern found on oceanographic research ships. The experimental scientists or principal investigators are responsible for the scientific mission. The scientific crew is under the direction of a chief scientist, who is an organizational equal of the station commander. The chief scientist has the final authority for all activities associated with completion of the experiment program, so long as these activities do not conflict with safe operation of the Space Station. The flight crew, consisting of the station commander and other astronaut-engineers, is responsible for operating and maintaining the station. The Station Commander has final authority over all matters concerning the safety and operation of the facility.

Section 2
RESEARCH AND APPLICATIONS OPPORTUNITIES

The basic purpose of the Space Station is to conduct research and applications that can be accomplished best from manned, Earth-orbital spacecraft. The benefits offered by such research have been fully explored by NASA, on a continuing basis, through studies, symposia, and conferences, as well as by participation in science and Government advisory councils, both domestic and international.

Presented here is an overview of the broad spectrum of Space Station research opportunities. The intention is to indicate the many areas of participation that may be considered by interested members of the scientific and technical communities, and to stimulate suggestions of additional areas of research that may be included in the Space Station Program.

The design of the Space Station facility has evolved according to the needs of its potential users. Reflected in the design is the program objective of providing a general-purpose facility. Not only is there consolidation of common demands, but the design includes functional laboratories and provisions for multipurpose installations that can be reconfigured from time to time over a 10-year operational period. In addition, a modular add-on capability is provided for growth and for special requirements not anticipated in the initial design. Thus the facility will have the viable capability of accommodating new requirements generated by knowledge gained from a research program while it is still in progress.

2.1 ASTRONOMY

The opportunity to carry out certain research from space platforms is of significant advantage to the science of astronomy, more than to any other discipline. The principal benefit to be derived is in regions of the electromagnetic spectrum where radiation is not transmitted through the atmosphere and is therefore denied to ground-based observatories. As shown in Figure 2-1, only the visible range (wavelength 4, 000 to 8, 000 Å) and portions of the radio region of the spectrum (wavelength 1 centimeter to about 10 meters) are essentially unattenuated, while the infrared region (upwards of 1 micron) is transmitted ONLY in fragmented bands. Thus, by means of an Earth-orbital spacecraft, the ultraviolet, x-ray, and gamma-ray regions of the spectrum, as well as portions of the infrared and radio regions, are open to research not previously possible. Additional benefits are available from orbital astronomy caused by the inherent ability for avoiding interference resulting from man-made signals (such as lights and radio transmissions).

Advantages may also be found in regions of the spectrum where observations have traditionally been made from the ground. Figure 2-2 shows the effect of the atmosphere in limiting the resolution of ground-based observations. This distortion causes a loss of definition in imagery and smearing in interferometry and other high-resolution operations, so much so that resolution on Earth is limited to 0.5 to 1.5 arc-seconds (5, 500Å), regardless of the size of the telescope. By comparison, a 1-meter-aperture telescope in space has a potential resolution capability from 2.5 to 7.5 times greater than that of the 5.08M (200-inch) Hale telescope at Mount Palomar. In addition, the available seeing time for the space-based telescope is some seven times that of its Earth-based counterpart because of such factors as the absence of clouds and moonlight. This means that the space astronomy program will derive higher-resolution photographs of double stars, star clusters, planets, comets, and the sun than are possible from terrestial observations.

Sky surveys in ultraviolet, x-ray, and gamma-ray wavelengths can be made with wide-angle equipment. These surveys may be followed by other on-orbit experiments for the high-resolution examination of selected sources, as is being done with Earth-based facilities at Mounts Palomar, Hamilton, and Wilson. Data in the visible, x-ray, ultraviolet, and H-alpha regions of the electromagnetic spectrum are expected from the solar experiments.

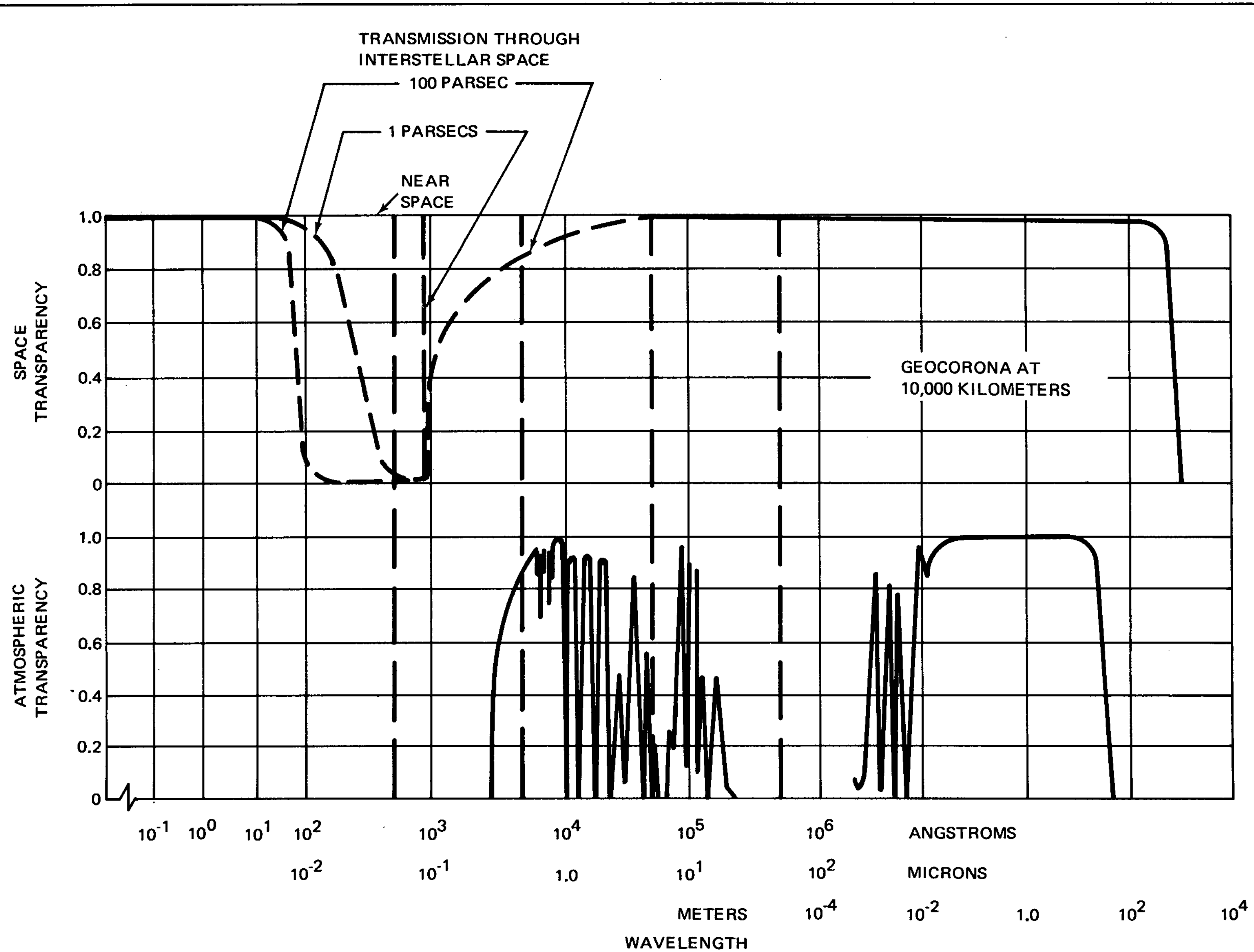

Figure 2-1. Electromagnetic Energy Transmission Through the Earth's Atmosphere and Through Space (Vertical Path)

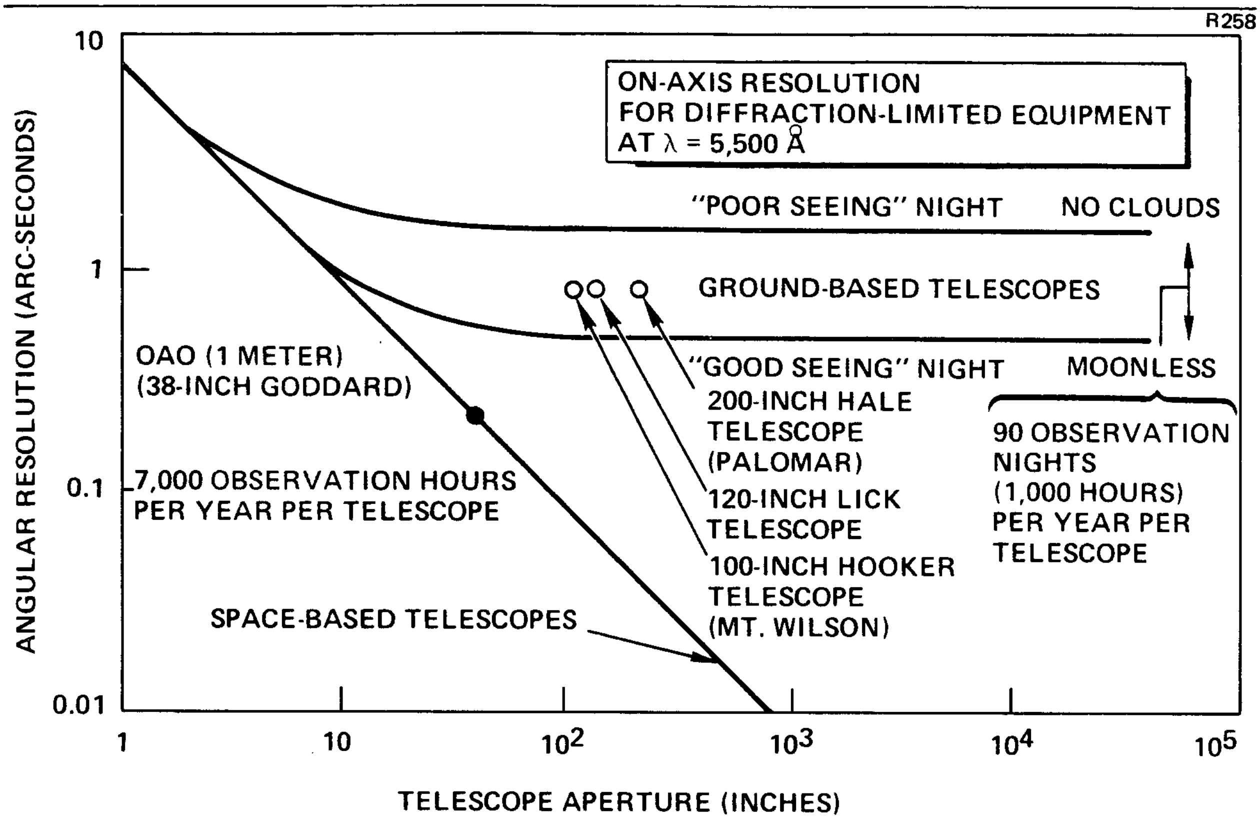

Figure 2-2. Effects of Atmosphere in Limiting Resolution

In conjunction with free-flying and attached experiment modules, the Space Station will provide astronomy research facilities that permit not only manned participation, but also more reliable and diversified operation than is possible from existing unmanned astronomical satellite programs. Contemplated is a series of observatory-type instruments that will provide for the attachment of individual experiments from different investigators. Module lifetimes of 10 years require that the design be flexible enough to allow for replacement and upgrading of the instruments.

The following types of equipment are candidates for the space astronomy program:

A. Large-aperture Cassegrainian telescope (ultraviolet, visible, and infrared — selected sources).

B. Miscellaneous gamma and x-ray detectors.

C. Solar telescopes of large aperture-81 cm (32-in.).

D. Infrared telescopes (special Cassegrainian type with low thermal threshold).

Separate free-flying modules, periodically visited by man, are candidates for astronomy experiments that require precision pointing and stabilization.

2.2 LIFE SCIENCES

Man's physical welfare has always benefited profoundly from significant increases in knowledge of himself as a biological entity and of the underlying biological sciences that facilitate this understanding. Research in Earth-orbital facilities provides a dramatic opportunity to expand the entire spectrum of biological research in a dimension heretofore unavailable. Every life process known to biology is subject to significantly increased understanding by the expanding of existing Earth-based research experience into the realm of partial and near-zero gravity. In addition to this truly unique capability, the ability to examine the influence of cyclic factors in the environment (such as circadian rhythms) by establishing different environmental cycles is vastly facilitated.

A broad range of biological research that may take advantage of this environment was identified by the National Academy of Sciences at the Woods Hole Summer Study of 1970. These research areas are listed in Table 2-1.

Plans for Earth-orbiting spacecraft include provisions for many types of biological experimentation. The program has provided for meaningful research to take place under a broad spectrum of conditions, with each research project carried out under its own optimal conditions. This research opportunity will serve as an impetus for the generation of new ideas aimed toward the further understanding of life processes on Earth.

Many experiments have been proposed that seek information related to man's performance both on Earth and in space. Animals that possess comparable systems, whether enzymatic, biochemical, immunological, or organismic, can be used for this type of study.

2.3 EARTH OBSERVATIONS

Viewing of the Earth from orbit promises great practical benefits to mankind. The ability to manage the resources of the Earth in a more effective manner than ever before, as a result of the global point of view that can be developed

Table 2-1

RESEARCH AREAS IN SPACE BIOLOGY

(Developed at Woods Hole Summer Study, 1970)

1. Role of gravity in cellular processes
   a. Mitosis and meiosis (cogenesis)
   b. Metabolic functions
   c. Response to ionizing radiation
2. Role of gravity in morphogenesis (including embryogenesis)
   a. Animals
   b. Plants
   c. Evolutionary selection
3. Role of gravity (lack of) in function of specific organ systems.
   a. Animals
      (1) Orientation systems (vestibular, proprioceptive, and central nervous system)
      (2) Circulatory system (including fluid balance)
      (3) Weight-bearing systems (bone and muscle)
      (4) Metabolic processes (including endocrine responses)
   b. Plants
      (1) Orientation mechanisms for particular organs
      (2) Metabolic control processes
      (3) Influence on reproduction processes
      (4) Effect on weight-bearing tissues (lignification)
4. Effect of space environment on behavior of animals (including man)
5. Influence of isolation from cyclic geophysical changes
   a. Earth rotation (day-night cycle)
   b. Lunar interaction (tidal effects)
   c. Solar interaction (seasonal effects)
6. Biological effects of particle radiation of high charge and atomic number
7. Role of gravity in infectious disease processes

through frequent observational access to any area, however remote, can be applied in such fields as agriculture, the location of mineral deposits, availability of fresh water, marine ecology, and the location of fish and other ocean resources.

Although these fields represent the needs of groups of users who have specialized information requirements, different disciplines may use similar sensors to produce their raw data, or they may use the same raw data different ways. The Space Station provides the opportunity to develop both common and unique instruments, together with the techniques necessary to enable these instruments to satisfy the needs of many users. As part of an integrated program involving surface studies, aircraft, and automated satellites, the Space Station will make it possible to pursue this research on a global basis. Thus, the research role of the Space Station in Earth observation calls for development of instrumentation, sensors, and operational techniques that may be used on either automated or manned spacecraft, as well as sharing in day-to-day operational observing programs with automated satellites and aircraft.

In the past decade, the objectives of Earth physics have shifted toward an understanding of the mechanisms that determine the state and the change of state of the Earth. This shift in emphasis resulted from the use of satellites, which made possible more accurate measurements of the shape, gravitational field, and motions of the Earth, and thus opened the theory of Earth physics to comparison with measured data. Researchers testing global theories can now look forward to support in the areas of long-term dynamics of the solid Earth, general circulation of the oceans, earthquake mechanisms, global heat balance, nature of the geomagnetic dynamo, energy dissipation in the oceans, and rotational dynamics of the Earth.

Observations related to agriculture and to forest and range resources will make it possible to increase and improve the supply of food, clothing, and housing. Knowledge is needed on how much land is being used to produce food, fiber, and wood, and on how efficiently these lands are used. The agronomist needs information on the current and future yield and vigor of crops as well as on potential and incipient stress conditions and threats. As demands for agricultural products increase beyond the limit of current production, new land areas must be identified and dedicated to agricultural purposes.

Developing the sciences of geography and cartography from space requires knowledge of spatial patterns and the interrelations of natural and cultural phenomena; geographic data on a large and synoptic scale to aid planned management of natural and cultural resources; and a base of observations for interrelated studies of resource utilization, settlement and population dynamics, urbanization, transportation, and historical geography.

Five major research areas in geology and mineral resources include surficial geologic mapping, deep-seated geologic formations, use of the Earth's crust to store commodities and to condition waste, warning and avoidance of geologic disasters, and utilization of geothermal energy sources.

Management of fresh-water resources is hindered by large gaps that exist in the theory of hydrology, especially in terms of a physical-mathematical model of the general hydrologic cycle (Figure 2-3). Limited data are available for defining the discharges of major rivers, and the world's total water budget is not known with sufficient accuracy. The problem of pollution of ocean water and beaches, as well as pollution of streams, rivers, lakes, and estuaries by industrial and other sources of effluents, is now recognized as a major concern. Observations of the Earth from orbit can provide data on a global scale that cannot otherwise be obtained economically. Major research activities include investigations concerned with rainfall forecasts, stream flow, snow-water content and rate of melting, and detection and monitoring of water quality and pollution. The economic benefits to be derived from the ability to forecast — and eventually control — sources of flood, drought, and pollution are enormous.

The oceans represent about 70 percent of the surface of the Earth. The scientific goals in oceanography that can be addressed from the Space Station contribute to man's welfare in two broad categories: (1) increased utilization of the oceans for transportation, recreation, and food and mineral production (Figure 2-4); and (2) improved understanding of the effects of the

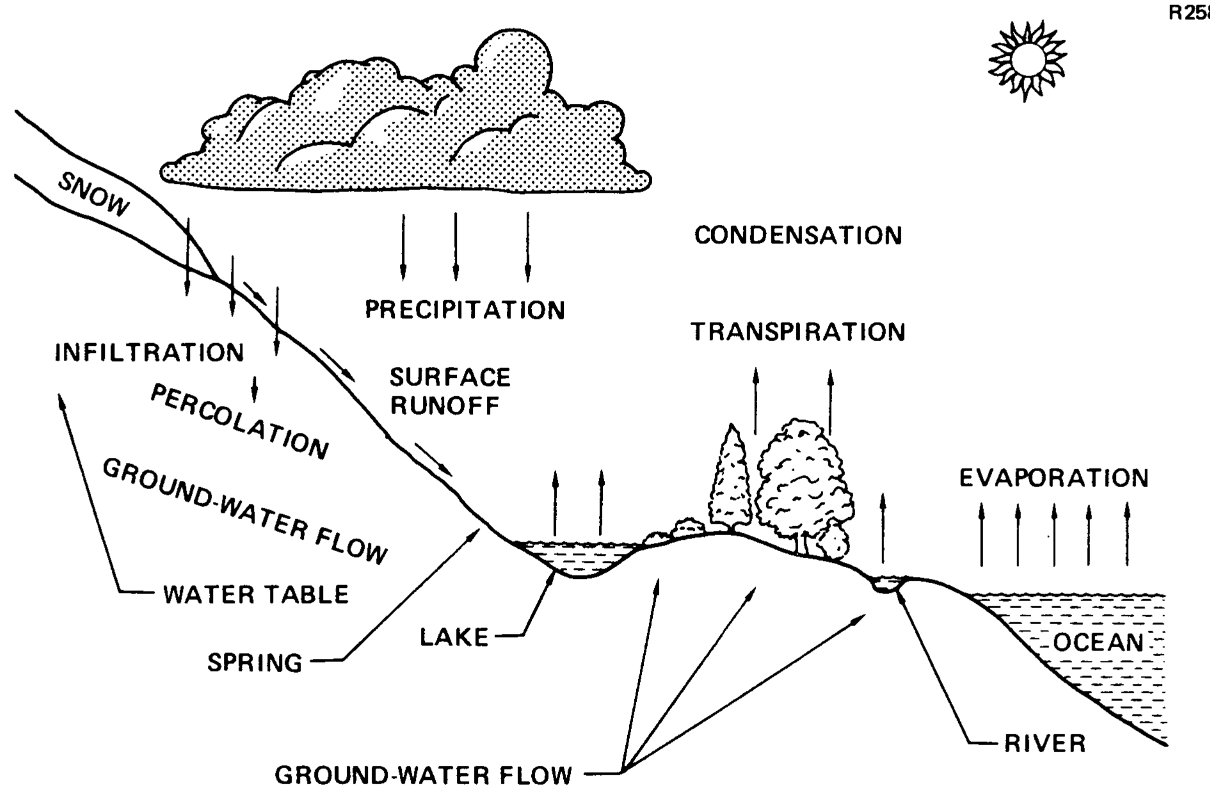

Figure 2-3. The Hydrologic Cycle

oceans on weather and climate. Fisheries are concentrated in about 10 percent of the ocean area. The other 90 percent (nearly three-quarters of the Earth's surface) produces only a negligible fraction of the world's catch and has little potential for increased yield. Fish cultivation, protection, and harvest are therefore primary resource goals, as are pollution identification and control, ocean motions and forecasting, erosion control, and understanding of photosynthesis and other life-cycle phenomena.

Automated satellites have already given meteorologists timely data on global cloud cover. However, progress has been paced by a series of individual flights (TIROS, NIMBUS, etc.), each carrying a different complement of sensors. The Space Station can assist in more rapid pursuit of these investigations by offering the capability to change sensor parameters during a given mission.

A fundamental area of research is found in the specialized discipline of cloud physics. Meteorologists have observed the clouds for many years,

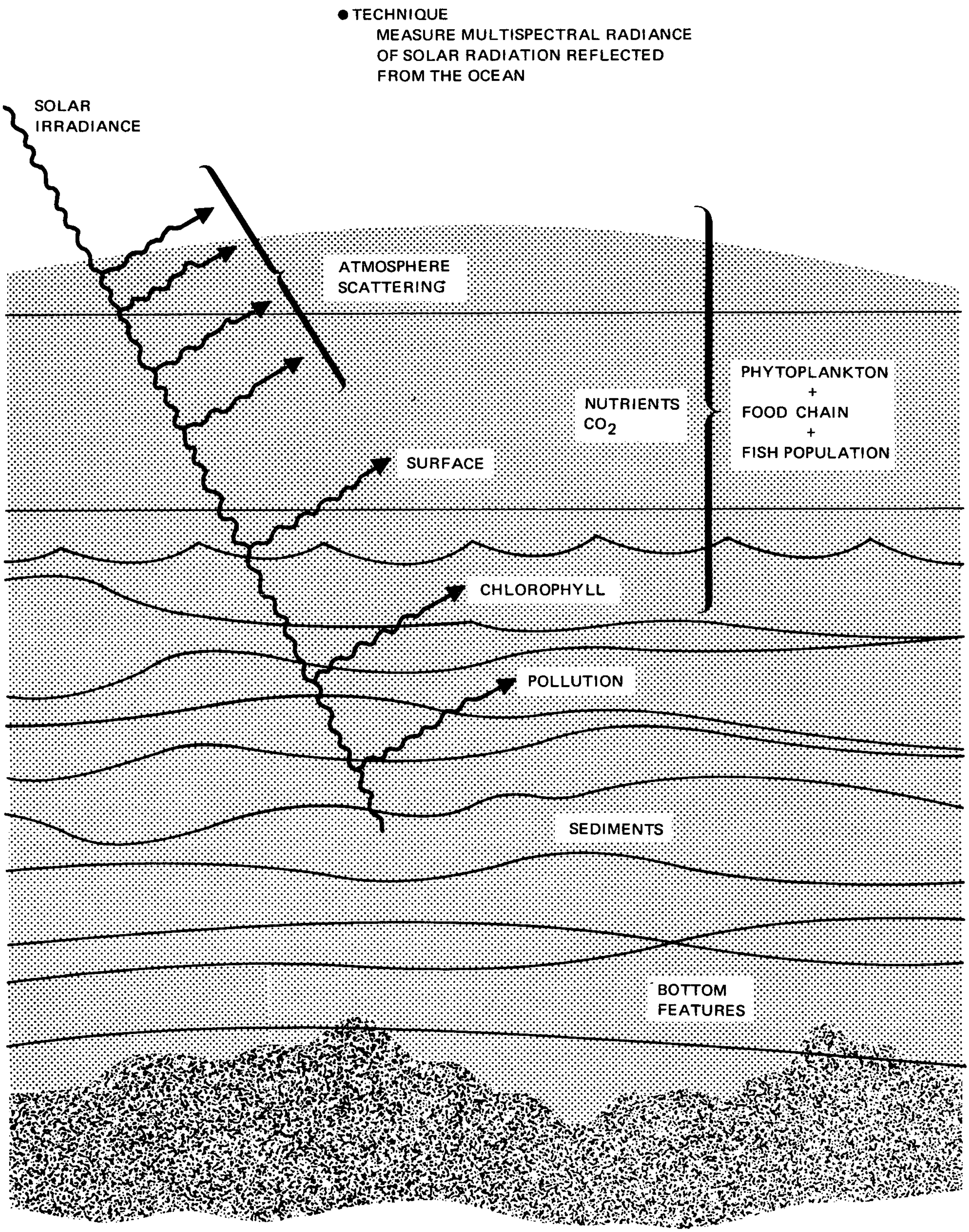

Figure 2-4. Possible Areas of Oceanographic Study

and yet very little is known about the basic physical mechanisms and processes involved in cloud formation and dissipation. Increased knowledge of these mechanisms is the key to eventual weather modification and control. Ground-based researchers have conducted laboratory investigations with limited success. Problems are encountered with experiment chamber setups caused by wall effects and convective currents disturbing the controlled environment. A zero-gravity cloud chamber aboard the Space Station can thus offer investigators a new dimension in research with which to further the understanding of cloud physics.

2.4 COMMUNICATIONS AND NAVIGATION

Under the sponsorship of military and commercial activities, the advantages of space have been well exploited in recent years in the field of relay communications. Operational systems have relied principally on unmanned space platforms. However, a manned research facility can provide for more mature development of feasible space communication techniques that are yet untried in operational systems. A laboratory in space will support broad research programs by permitting performance testing and evaluation, under actual operational conditions, of experimental configurations and techniques selected from candidate systems. The capabilities that can be provided include functional testing, development system simulation, and demonstration of components and advanced system concepts. Specifically, the scientific capabilities inherent in a controllable test bed in space can permit:

A. Noise Measurement — Preparation of noise maps of the Earth's surface on a global scale, with selected noise fields spectrally defined and geographically located.

B. Propagation Measurements — Determination of the Earth-space parameters, such as phase-path length, length change, refraction, frequency change, group-path delay, polarization rotation effects, and atmospheric absorption, at frequencies from 0.1 to 100 GHz. Investigations may include multipath studies employing cooperating ground calibration sites and test aircraft, and the study of plasma effects on space transponders.

C. Communication Systems — Qualification testing of millimeter and laser components and pre-operational evaluation of wideband and narrow-band transmission techniques at the shorter wavelengths. The reconfiguration capabilities of a manned facility will allow broad experimentation leading to future expansion of the usable radio-frequency spectrum.

D. Navigation Systems — Qualification testing of position-fixing and surveillance techniques for surface and near-surface transportation vehicles, leading to precision national or global navigation capabilities employing satellites. Modeled systems employing manned station facilities will provide broad opportunities for testing the wide variety of proposed system concepts.

2.5 SPACE PHYSICS

Figure 2-5 indicates some of the accomplishments in space physics since 1958.

The unique opportunities offered by the Space Station will benefit physics research in several ways. Primary among these is the unlimited availability

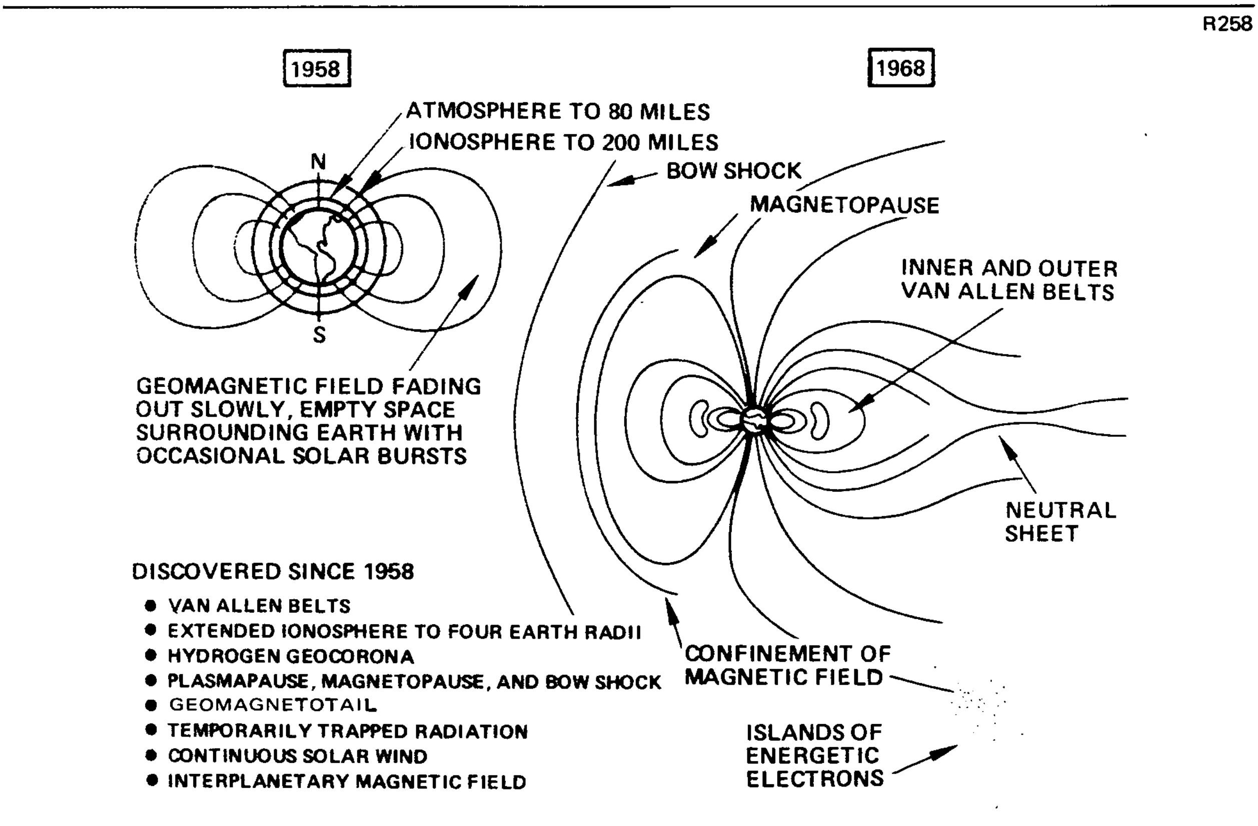

Figure 2-5. Discoveries in Space Physics, 1958 to 1968

of the space environment, which is itself the subject of many potential experiments on airglow and the zodiacal light, interplanetary dust, solar radiation, cosmic rays, ionospheric phenomena, and wave-plasma interactions in the geomagnetic field.

An effective observatory for high-energy particle studies will require equipment to measure flux, composition, energy, and direction. The Space Station could support a large cosmic-ray laboratory for the long durations required to obtain statistically significant data. Such a laboratory would contain devices similar to those used in high-energy accelerator installations on the ground, such as superconducting magnets, ionization and total absorption spectrographs, scintillators, Cerenkov detectors, spark chambers, and emulsions. This array of devices could be flexibly reconfigured and modified with additional equipment to meet new measurement objectives, and investigations in particle interaction physics could be performed at energies greater than those available from ground-based accelerators.

Subsatellites can be flown from the station to place receivers at electrically remote positions or to locate particle sensors in the return path of a reflected particle beam injected from sources on the station. Airlocks and booms on the station can also be used for such experiments. The wake of the station or of an inflatable body ejected from the station can be studied using subsatellites. While the station can support a limited number of plasma physics experiments in a serial manner, an attached RAM, supported by the station, is envisioned as the appropriate accommodation for a complete plasma physics laboratory.

Light produced by changes in the molecular excitation level of upper atmosphere constituents, scattered from interplanetary dust or the near-space micrometeoroid flux, can be studied with an array of collectors and electro-optical devices. The energy, size, and composition of the micrometeoroid flux can be determined from measurements of the light.

A number of gravity-dependent phenomena can also be studied, both to determine basic scientific data and to test the feasibility of possible manufacturing operations. Of particular interest are fluid behavior, combustion, and phase transitions, especially as related to casting and crystal-growing applications.

2.6 MATERIALS AND PROCESSES

Within the broad scientific discipline of physics, consideration is needed for ways to perform productive tasks in space that will have a direct and immediate effect on the industrial and economic strength of society. The Space Station can contribute to this goal by developing the technical basis for commercial use of manned space facilities to produce economically viable products for use on the ground, by solving critical experimental problems in material science and technology, and eventually, by carrying out manufacturing operations in space.

Pursuit of these objectives should lead to development of materials or finished products with properties superior to, or not obtainable in, terrestial products. While the materials and products may be liquids or solids, the important part of the processing cycle will involve the fluid state of matter and will employ such zero-gravity phenomena as mixture stability, the absence of thermal convection, or the lack of disturbance of intermolecular forces. Weightlessness also permits the contact-free (containerless) processing and solidification of liquids.

While all of the environmental factors present in space can be simulated to some degree on Earth, zero gravity can only be produced during free fall. While a few rapid processes, such as the drop-casting of lead shot, have been developed to exploit zero-gravity effects, the full potential of this environmental factor will be realized only when long-duration exposure such as that permitted by the Space Station is possible.

In the absence of gravity, processes sensitive to buoyancy and thermal convection are basically changed. Molecular forces come into play and become the major processing factors. Thus, sand mixed into water does not sink, and a candle does not continue to burn because there is no convective air movement to resupply oxygen.

Before the possibilities for processing in the absence of gravity can be exploited, the implications must be understood. For instance, when metals are melted in Earth gravity, the low-density comes to the top. This phenomenon is an advantage in purifying metals, but it complicates the production of vaccines, where the growth rate decreases as stratification occurs. It is estimated that vaccine growth rates on orbit may be up to four times as fast as on Earth.

It is well known that a drop of liquid tends to become spherical in shape when in free fall because of the molecular forces of surface tension. In the space environment, with the absence of gravity and buoyancy, it should be possible to produce nearly perfect metal or glass spheres of uniform density and composition. In addition, absence of the thermal and gravitational forces that are exerted upon molten glass by container walls or substrates allows for the formation of perfect crystals of clear amorphous glass.

Section 3

THE MODULAR SPACE STATION FACILITIES

The manned space missions of the Mercury, Gemini, and Apollo programs were flown primarily as explorations and to prove the principle that man can survive and perform useful work in the space environment. In essence, the missions—and the spacecraft themselves—were experiments.

In contrast, the Modular Space Station is not an experiment in itself. Rather it is a vantage point from which to carry on needed research that can be performed nowhere else. It is a manned, virtually permanent laboratory in space.

The Space Station is incrementally assembled in orbit from modules of 4.3M (14 ft) diameter and up to 17.7M (58 ft) in length delivered by the space shuttle transportation system. Growth to full capability is planned in two phases, the Initial Space Station (ISS) and the Growth Space Station (GSS).

The first three incrementally launched modules, together with Research and Applications Modules (RAM's), form the ISS. The GSS is achieved with two additional modules. Additional RAM's supplement this facility.

The ISS modules are, in order of launch, (1) Power/Subsystem, (2) Crew/Operation, and (3) the General Purpose Laboratory (GPL) (Figure 3-1). The GPL is, of course, of primary interest to the potential users of the Space Station. Also shown in Figure 3-1 is the GSS buildup.

Seven docking ports are located about the three modules. These ports are used for transfer of crew and cargo bound to and from the Earth, for docking of modules carrying experiments that cannot be performed inside the station, and for storage. The experiment modules are of two types: those that remain attached to the station during operation, and self-propelled, free-flying modules that operate under remote control.

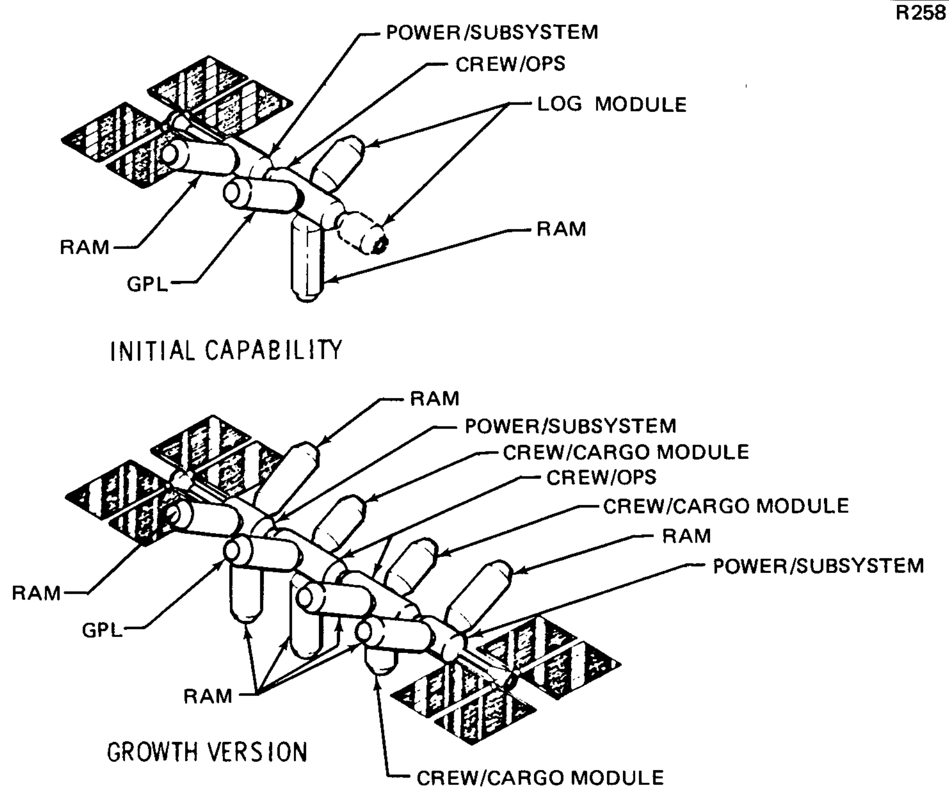

Figure 3-1. Modular Space Station Buildup

Approximately one third of the station's internal volume is allocated to laboratory space, and over 40 percent of the electrical power produced is available for experiments. The stabilization and attitude reference system used for station control is also designed to orient and control experiment sensors, and the on-board checkout system offers many calibration, measurement, and verification functions for experiment support. On-board facilities can process up to 9,072 Kg (20,000 lb) of film and video tape per year. Microwave links to the Earth are used for two-way television, voice communication, experiment control, and high-capacity data transfer. Data Relay Satellites will be used to ensure timely radio frequency (RF) data return. Approximately 73,000 kg (160,000 lb) of experiment cargo can be transported to and from the Space Station each year for the first five years; thereafter 42,000 Kg (92,000 lb) each year.

3.1 GENERAL PURPOSE LABORATORY

The Space Station General Purpose Laboratory (GPL) provides a series of facilities to support space experiments and operational systems. It contains the major equipment and facilities required to support, service, and maintain internal and modular experiments in the Space Station Program, as well as equipment and facilities to do physical testing, repair, and maintenance of Space Station subsystems.

An analogy to the GPL's is that of the operation of an oceanographic research vessel. There are individual laboratories to support scientific research, as well as shops and laboratories to support both research and operational seaworthiness of the vessel. The Space Station is arranged in a similar manner, with facilities to conduct experimentation, as well as facilities to support experimentation and operations.

The GPL is a dynamic entity that allows full support of a wide range of experimentation and operations, without limiting the type or breadth of the program. The GPL, as its name states, is flexible and can be responsive to program changes while on the ground, in the fabrication phase or in operation on-orbit.

A requirement for the GPL stems from the need to support a Space Station research program in which experiment activities have been defined only in board terms. The primary functions of the GPL have been organized into functional laboratories, based on technological disciplines. These disciplines encompass the wide range of experimentation noted by users throughout the research and applications community as candidates for space flight.

In addition to the support provided by the GPL for research and experimentation, the facilities also support the Space Station systems and subsystems.

The nature of support for experiments and subsystems provided by the GPL is:

A. Analytical or test.
B. Disassembly, assembly, and repair.
C. Storage of parts, equipment, in-flight spares, operational consumables, and procedures.
D. Component replacement from on-board stores.
E. Calibration.

F. Work area and restraints.

G. Physical accommodation for the performance of experiments.

H. Equipment for the performance of experiments.

3.1.1 Facilities

The GPL is functionally and physically subdivided into laboratories and facilities (Figure 3-2) combining related technology activities. The facilities are permanent throughout the operational mission life, but the test, calibration alignment, etc., equipment contained therein will change as the experiment program evolves and changes. Primary performance characteristics of these facilities and some of the basic equipment (such as power supplies, work benches, and storage facilities) are expected to remain throughout the full mission. Replacement parts and components are stored on board and in the logistics module, and resupplied from logistic deliveries. The GPL has a free docking port on the end away from crew quarters module, allowing logistics deliveries directly to the GPL. Clear access 1.5M (5 ft) in diameter is provided along the whole length of the GPL.

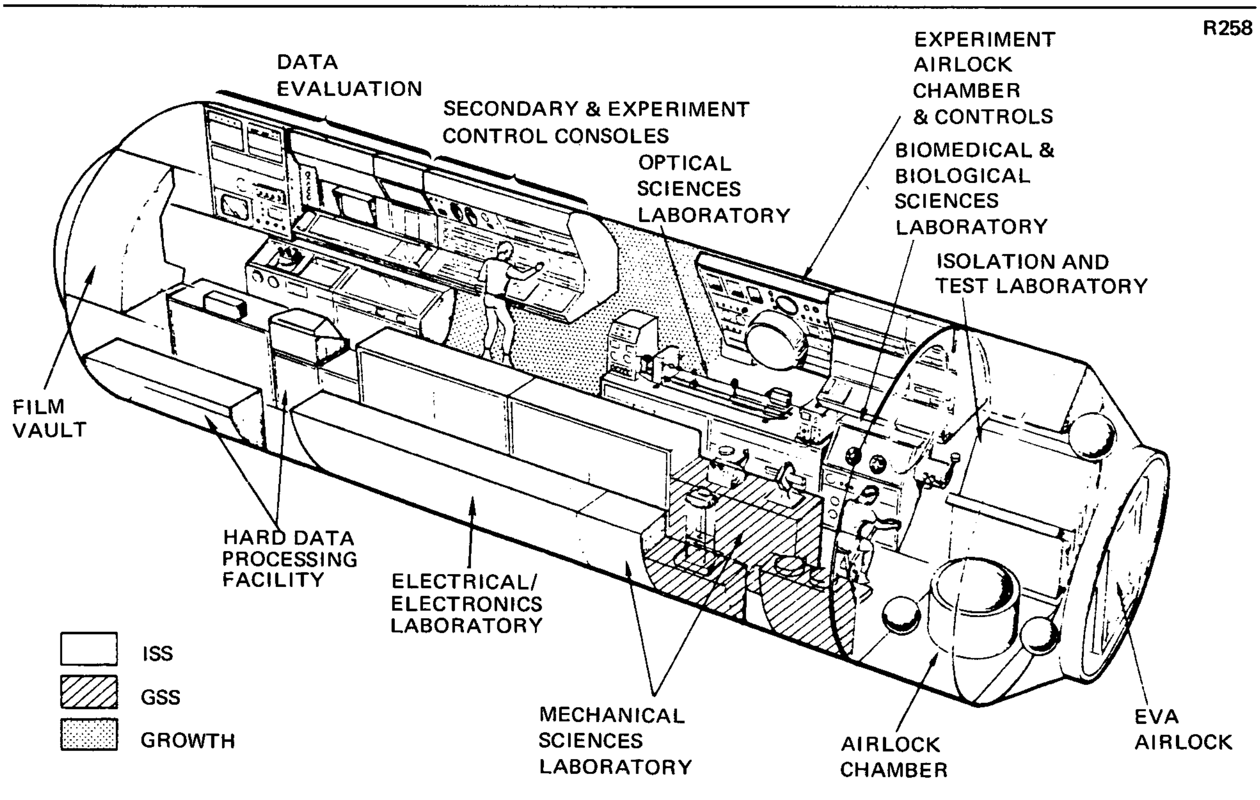

Figure 3-2. Baseline General Purpose Laboratory

A rail, serving as a track for a small trolley to move and restrain large items being moved from one area to another, runs along the top of the 5-ft diameter access to provide controlled movement in the aisle. Each piece of equipment has foot restraints to allow "hands free" operation of the equipment, and all work station tables have restraining or holding devices to keep experiment items and tools in place. Attachments for emergency suit pressurization and breathing, as well as communication facilities, are strategically located in work areas. An emergency first aid station is located in the GPL, and all work areas have appropriate fire fighting equipment.

The laboratories and facilities are:

A. Electrical/Electronics Laboratory.
B. Mechanical Sciences Laboratory.
C. Experiment and Test Isolation Laboratory.
D. Hard Data Process Facility.
E. Data Evaluation Facility.
F. Optical Sciences Laboratory.
G. Biomedical and bioscience Laboratory.
H. Experiment/Secondary Command and Control Center.

The facilities are located in the GPL module as shown in Figure 3-1. Table 3-1 (at the end of subsection 3.1) contains a listing of the types of equipment used in each laboratory or facility.

3.1.2 Data Evaluation Facility

The data evaluation facility (Figure 3-3) contains equipment to analyze, reconstruct, mensurate, store, and retrieve experimental and operational data. The data evaluation facility works in conjunction with the Space Station data management system to make up a complete complement of hardware and software for Space Station data handling capability. Significant portions of the data management system are physically located in the data evaluation facility.

The data evaluation facilities include those functions or capabilities that are logically related or associated with the availability of film, video, analog, and digital data, and the handling, processing, and evaluation of such data.

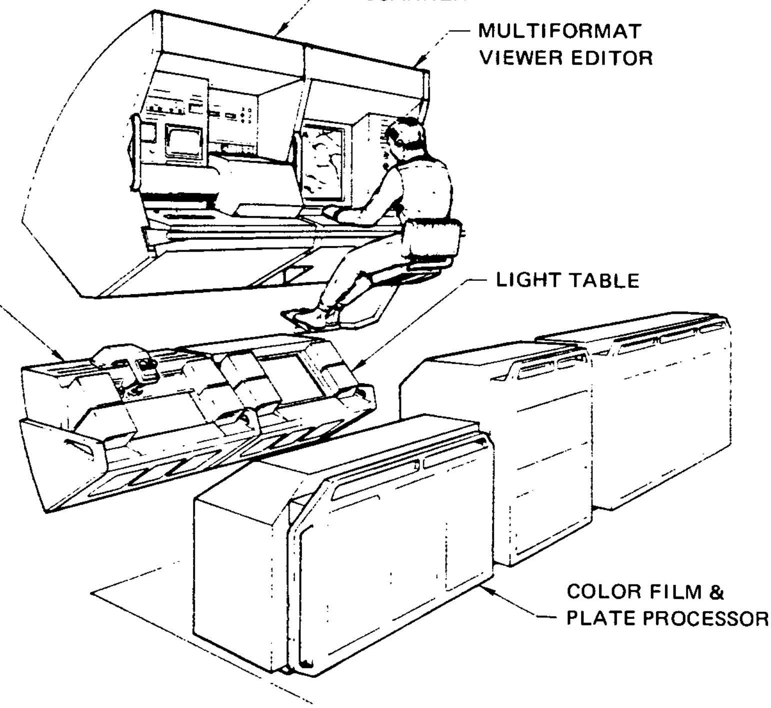

Figure 3-3. Data Evaluation Facility

This facility is both an experiment and operations support facility and as such provides services to all experiments and subsystems. A folding screen and controllable rheostat for light control is provided for the data evaluation area.

3.1.3 Optical Sciences Laboratory

The optical sciences laboratory contains optical test, calibration, and alignment equipment. This equipment supports a wide range of experiments, and experiment and operational equipment, such as contamination equipment, telescopes, cameras, scanners, navigation equipment, attitude stabilization equipment, electronic imagers, rendezvous and tracking equipment, and any other gear that requires optical or spectral alignment, calibration, troubleshooting, or setup.

The optical sciences laboratory contains a scientific airlock chamber for performance and deployment of experiments. The airlock is a pressurable cylinder with a hemispherical dome closing the interior end and a mechanically operated door in the outer wall that allows the experiment package to be exposed to the space environment. The experiment package can be mounted on a stable platform within the airlock chamber.

Associated with the airlock chamber is an optically flat, broad spectrum transmission window that permits viewing and photography of deployed experiments and external phenomena. The scientific airlock chamber can accept a 0.61M (24-in.) diameter experiment package. An airlock chamber extension is also provided which also provided which allows the chamber to accommodate experiment packages up to 2.1M (7 ft) in length. A small experiment and airlock display and control unit is mounted adjacent to the airlock with the appropriate interfaces provided.

Figure 3-4 illustrates the optical sciences laboratory. A specimen is being evaluated. The specimen is a coated lens that has been exposed to the environment outside the space station. The crewman is checking and recording the spectral transmission characteristics of the lens that has been exposed. Calibrated white light is transmitted through the lens, and the resulting spectral characteristics are recorded. The spectral record is compared with

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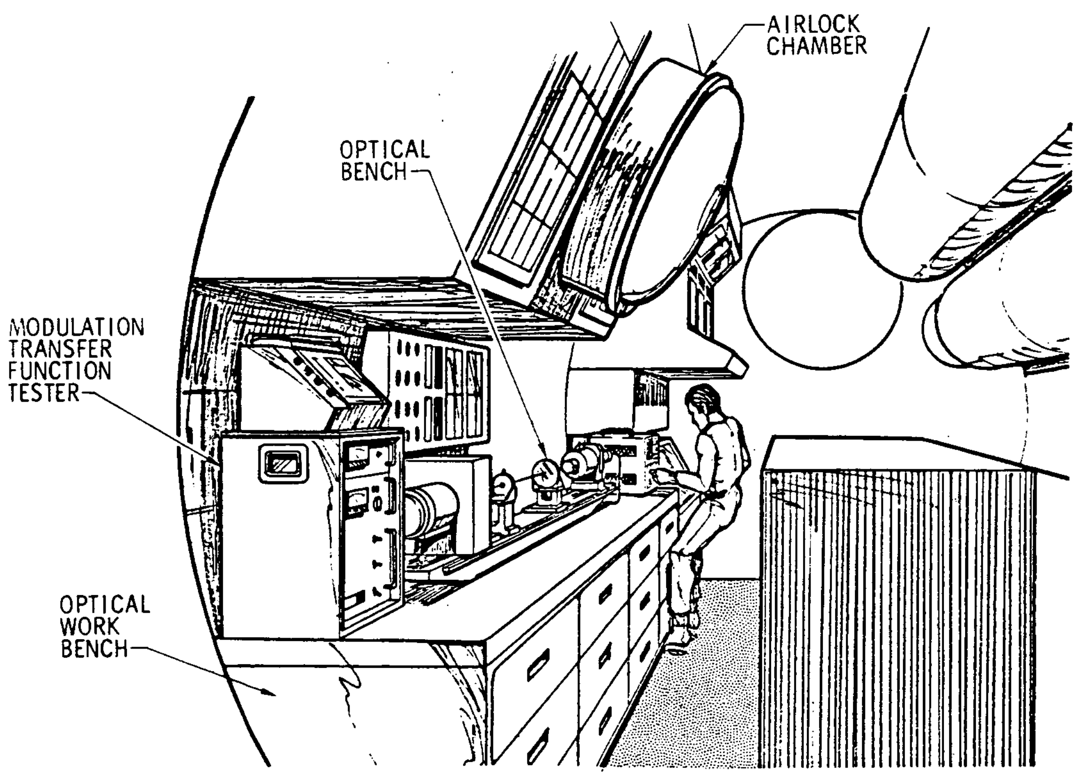


Figure 3-4. Optical Sciences Laboratory

a record made before the lens was exposed, to determine the extent of the spectral change.

Also shown on the optical bench in Figure 3-4 is a modulation transfer function tester. The lens will be tested for resolution degradation by transmitting a monochromatic light source (laser) through a grating and slit to the lens, and recording the ability of the lens to pass frequencies generated by the grating and slit. The resultant recording is then compared with the modulation transfer function of the unexposed lens to determine extent of resolution degradation.

3.1.4 Electronic/Electrical Laboratory

The electronic/electrical laboratory (Figure 3-5) provides all the instrumentation, test gear, stimuli, controls, and displays necessary for testing, electronic calibration, and maintenance of experiments and Space Station subsystems. As in all other GPL laboratories and facilities, the equipment is built modularly so that carry-on equipment can be used and the laboratory reconfigured.

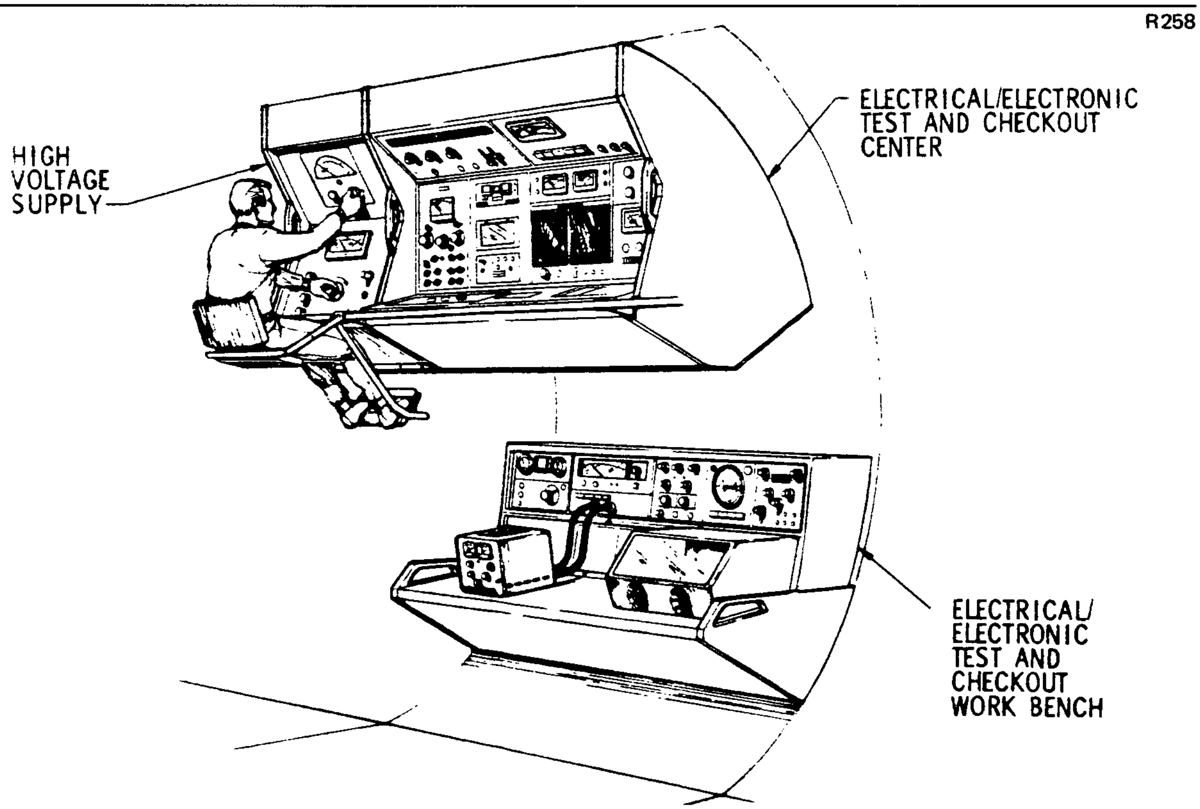


Figure 3-5. Electronic/Electrical Laboratory

The main service facility in the electronic/electrical laboratory is the multi-instrument test bench and console providing the capability for bench checkout, calibration, and contingency repair of electronics and electrical equipment. The instruments in the multi-instrument test bench can be unplugged and used in a remote location as portable test equipment. Built into the bench is a miniature laminar flow glove box for cleaning, assembling, disassembling, and soldering. The multi-instrument test bench also contains storage for hand tools required for contingency bench level work on electronic equipment. As a minimum, the laboratory will include the following items: oscilloscope; hardcopy data recorders; voltmeter; power supplies; signal generator; signal analyzer; test sets; small patch panels and test connectors; continuity checkers; multimeter; timers; frequency counters; transducer calibration units (vacuum, pressure, and temperature); special hand tools; and mounting fixtures.

3.1.5 Experiment and Test Isolation Laboratory

The experiment and test isolation laboratory includes the facilities for conducting experiments, maintenance, and operations isolated from the Space Station environment. It provides the capability to isolate toxic liquids, gases, molten solid materials, and high pressures. An airlock chamber of 1.25M (4.1-ft) diameter is contained in the laboratory for experiments involving exposure to environment other than that in the Space Station. A chemistry and physics glove box with a storage and analysis console is located in the laboratory to provide enclosed work stations for experiments and operations involving chemical handling and other similar functions. A heat exchanger is provided as part of the airlock chamber for heat transfer to the space station radiator from high-temperature experiments. Temporary storage and utilization capability is included for high-pressure gases, cryogenics, toxic fluids, and similar materials for use during experiments. Experiments are operated remotely from a monitor and display console after they have been set up, and the experiment and test and isolation laboratory has been sealed.

Figure 3-6 is an example of an experiment being set up in the experiment isolation and test laboratory. This view shows a materials science levitation casting experiment being positioned in the airlock chamber. The crewman has taken the experiment out of its canister, made a final visual check on the integrity of the experiment, and is now inserting it into the chamber. When the experiment is in the chamber, all necessary plumbing and electrical connections will be connected, and the chamber door will be closed and locked. At this point,the crewman leaves the experiment and test isolation facility and proceeds to the isolation facility console where all subsequent operations on the experiment will be controlled. After the seals are tested for integrity, the chamber is purged to vacuum and resealed.

When the chamber has been resealed, the crewman provides the necessary resources to the experiment while monitoring and controlling from the remote console.

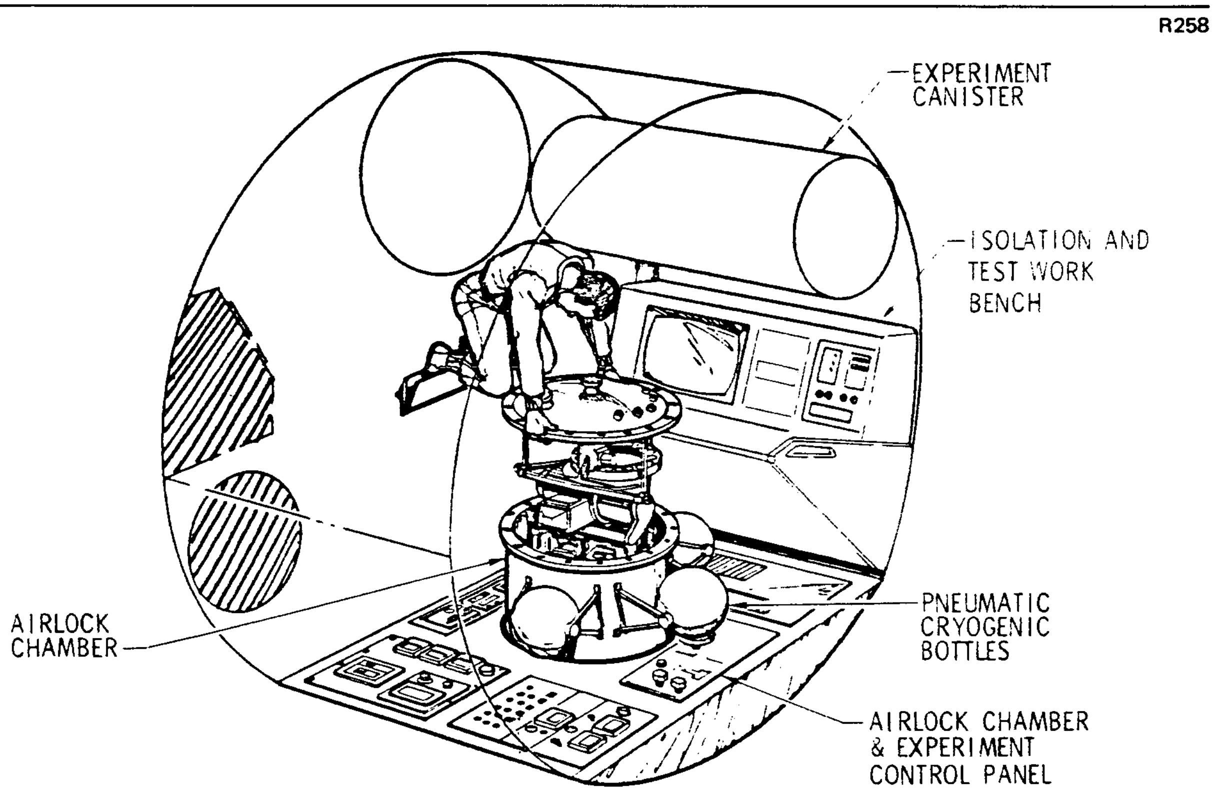


Figure 3-6. Experiment and Test Isolation Laboratory

3.1.6 Mechanical Sciences Laboratory

The mechanical sciences laboratory (Figure 3-7) supports a wide range of experimental and operational functions. Many types of mechanical, electro-mechanical, and chemical functions must be accommodated by the equipment in this laboratory. The mechanical sciences laboratory features laminar flow glove boxes with chemical and gas capabilities for heavy duty, light duty, and specialized functions. The glove boxes are used for assembly, disassembly, repair, replacement, purging, cleaning, lubricating, and calibration of items of subassembly size. These glove boxes provide zero-g holddown for items subject to disassembly. Work benches provide for the stowage of hand tools and maintenance consumables most frequently used, and stowage is provided in this facility for shop tools and specialized spares.

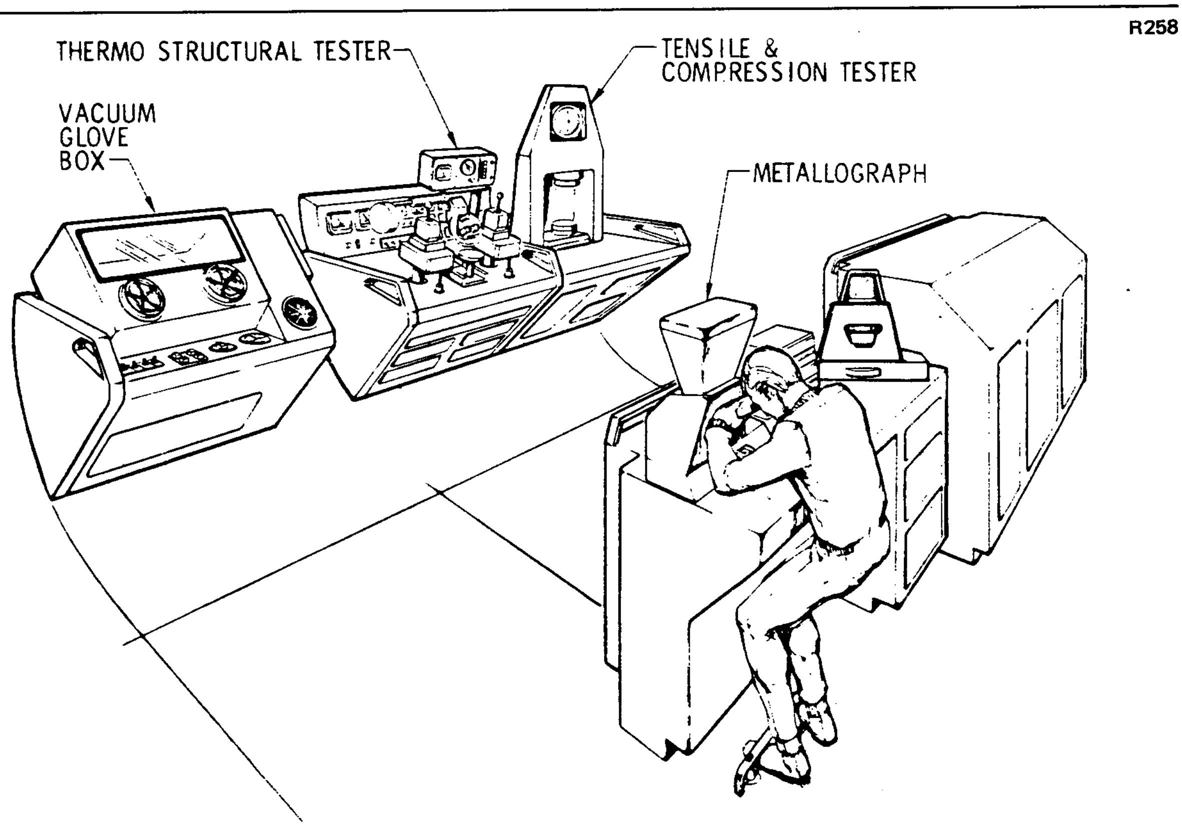


Figure 3-7. Mechanical Laboratory

A "precision work fixture" is also supplied in the mechanical laboratory, which can also be used on the optical bench in the optical sciences laboratory.

The mechanical laboratory also contains a metallograph tester, thermo-structural tester, x-ray diffraction unit, x-ray generator, and specimen structural tester for performance and analysis of materials science experiments.

3.1.7 Hard Data Processing Facility

The hard data processing facility (Figure 3-8) includes the capabilities and all the equipment related to film availability, film handling and processing, preliminary film calibration, and "quick look" film data evaluation. Each item of equipment in the facility which has the potential of emitting toxic fluids or gases will have a double barrier built into the equipment. Waste products from the equipment will be collected in reservoirs and returned to Earth.

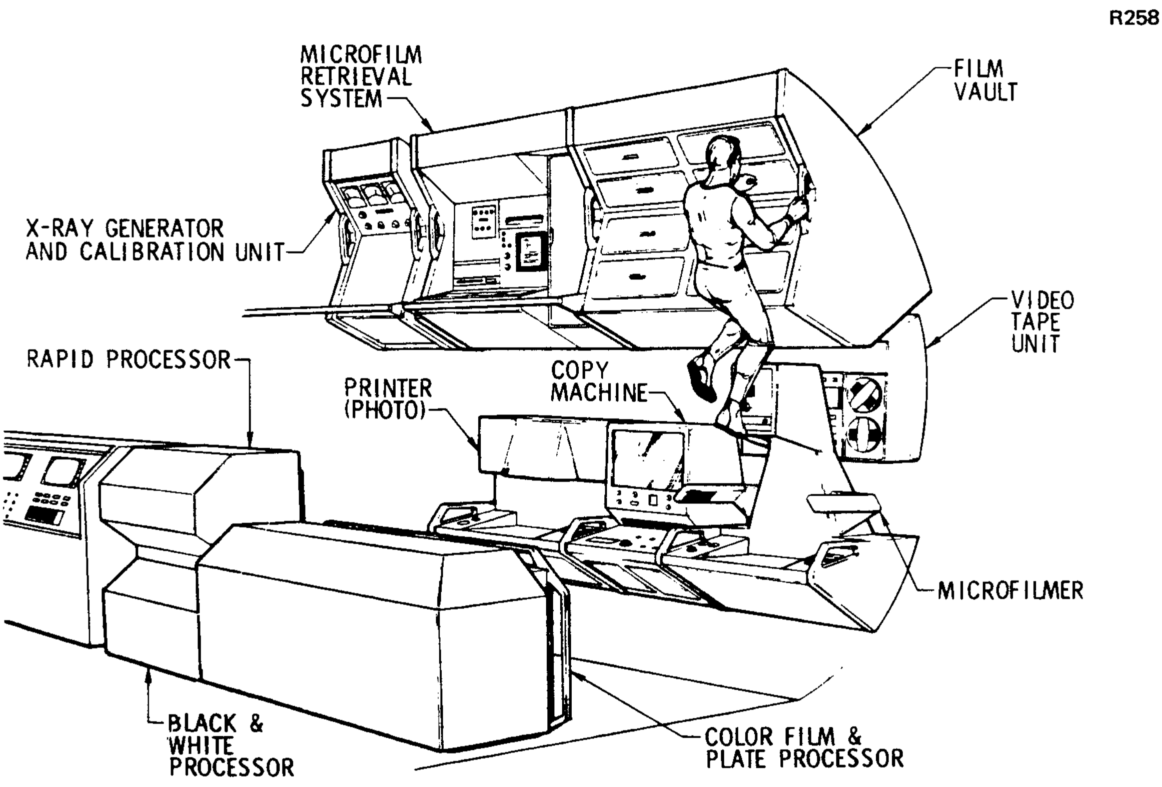


Figure 3-8. Hard Data Processing Facility

Film is stored in the hard data processing facility. The film storage cabinet will provide radiation protection as well as temperature stabilization. Predictable, consistent, and satisfactory film quality will be maintained through the use of the storage cabinet.

The hard data processing facility provides the equipment to develop film, produce microfilm, calibrate developed film, and perform basic analysis of test strips. The hard data processing facility will contain equipment of the following type: Plate and film processors (black and white, and color; high resolution and quick access); a microfilming facility; a spectrometer; a densitometer; and a light table. The light table with integral densitometer and spectral color analyzer will take the film test strip data. Processed film will be archival quality. As such, it can either be stored, microfilmed (with either the microfilm or original copy sent to Earth), copied, scanned, and sent to Earth electronically.

3.1.8 Biomedical/Bioscience Laboratory

The research objectives of a bioscience program and the astronaut "well being" monitoring have been combined into a single laboratory (Figure 3-9) because of some commonality of equipment. The equipment for bioscience consists of plant lighting, photo/TV coverage, time and specimen identification, plant and cell chemistry, and special holding devices, flight launches, and optics for invertebrate research. The biomedical equipment will have the capability to measure heart functions with an electrocardiogram and a vectorcardiogram, work performance with a bicycle ergometer, body mass with a body mass measurement device, and effects on the physiology of using a lower body negative pressure device. Equipment is also available in a biochemical and biophysical analysis unit for "zero-g" blood and urine analysis. A biological glove box is provided for biological work requiring isolation or separation from the space station environment caused by either toxicity or contamination.

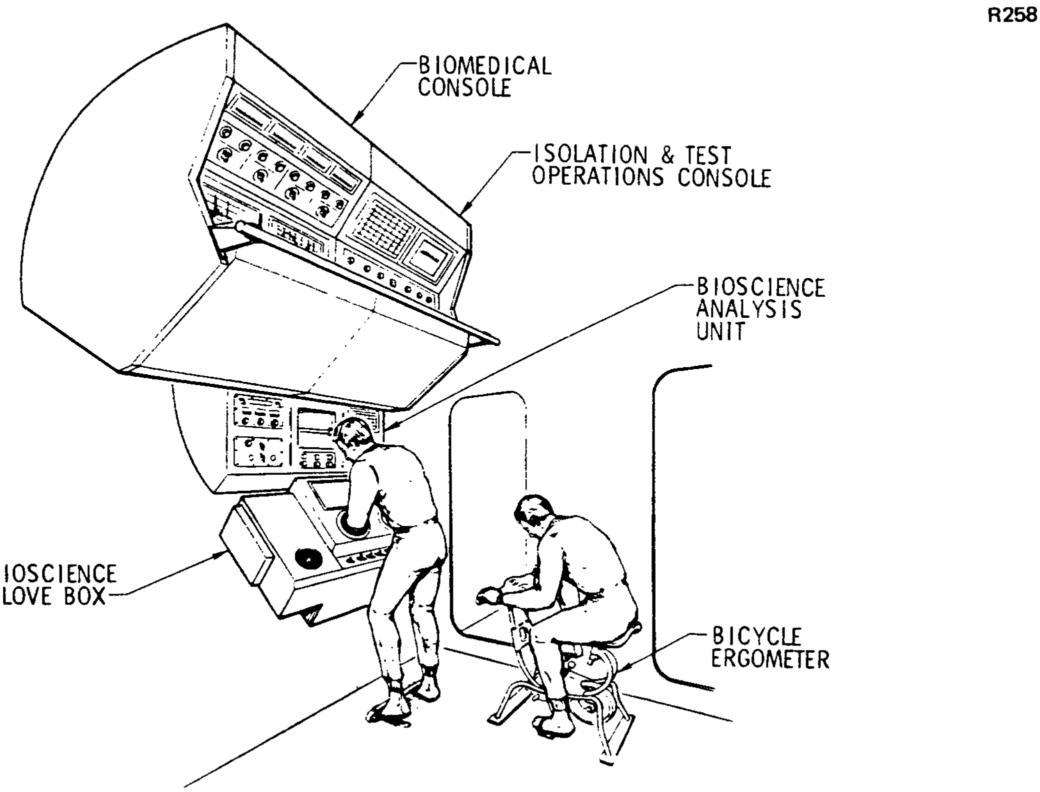
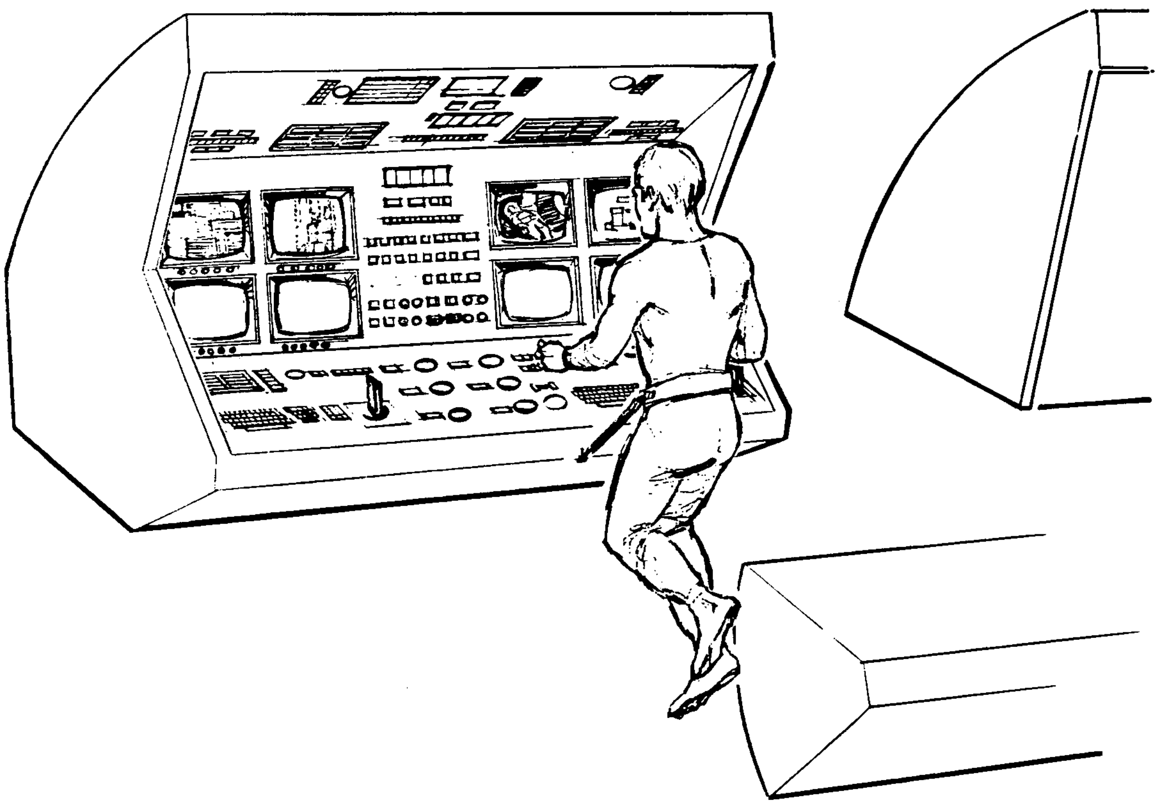


Figure 3-9. Biomedical/Bioscience Laboratory

3.1.9 Experiment/Secondary Command Control Center

The Experiment/Secondary Command and Control Center is a centralized operation center for monitoring and management of the experiment program of attached modules, free-flying modules, and experiment operations located within the GPL as required. In addition, this station is capable of providing emergency/backup vehicle and subsystem control capability in the event the crew is forced to evacuate the Primary Command and Control Center (located in the Crew/Operation Module) because of a major contingency condition. Displays and controls located at the Experiment/Secondary Command and Control Center are basically the same as those required at the Primary Command and Control Center with additional dedicated experiment displays and controls to permit monitoring and control capability over the experiment program. The center is designed in such a way that fully independent two-man operation is possible. Thus, one operator can concentrate on one set of experiments (see Figure 3-10) without interference from the other operator.



F igure 3-10. Experiment/Secondary Control Center

The major assemblies on the Experiment/Secondary Command and Control Center are as follows:

Multipurpose Display and Input Devices—The primary display element is a computer-driven CRT device that interfaces with the computer facility via the data bus, permitting information to be displayed upon a single time-shared device as requested or through cycling procedures. The CRT display is capable of presenting computer-generated data such as characters, vectors, and tabular data, as well as dynamic, real-world TV imagery provided by Vidicon cameras and other analog sensors. These two sources of data can be shown independently, adjacent to each other, or be super-imposed to provide complete flexibility and visibility of computer processing and data control operations.

Video Surveillance Monitor—A surveillance monitor is included at the Command and Control Centers to provide internal and external surveillance capability over designated areas of the Space Station. This display may also be used to monitor incoming vehicles during docking phases and for monitoring experiment data, programs, and parameters that are available within the system on a real-time basis or from stored memory as directed by the operator. These displays are compatible with 525-line, commercial color TV standards and are interchangeable with the recreational TV's within the crew quarters.

Color Discriminator—Color discriminator capability is provided to enhance data comparison operations, and/or highlighting those parts of the data in a particular spectral range. This feature may be used to highlight data that would otherwise be difficult or impossible to visualize.

Alphanumeric Displays—Alphanumeric readouts are used to continuously display selected parameters that are considered critical to Space Station integrity or important to certain mission phases, and to provide information of general interest in the form of computer-generated digital data. These readouts are liquid crystal cell displays that incorporate the advantages of high reliability/lifetime, wide-angle viewing having little or no parallex, continuous brightness independent of ambient lighting, microwatt power, low voltage, and relative low cost.

Warning Matrix—Continuous monitoring of subsystem critical parameters is performed as part of the on-board checkout subsystem (OCS) with a matrix of annunciators at the command centers to display and alert the crew to failed or out-of-tolerance conditions. The warning functions consists of an array of dedicated light annunciators that are "hard-wired" to the OCS detection equipment.

Caution and Display—Display of caution level functions is effected by a liquid crystal cell display that indicates a message(s) determined by the multiprocessor. This display interfaces with the multiprocessor via the data bus and operates in a manner similar to the alphanumeric displays. The lower portion of the display permits storage of past caution alerts and allows recall capability of functions that have not been corrected. In this manner, status of caution functions can be determined by activating a switch to call up the message for uncorrected caution conditions.

Voice Message Generation Unit—The voice message generator permits spoken voice messages to be generated by computer control. This unit supplements the caution and warning functions as well as provides operational and experiment information through its internal vocabulary. The unit is capable of composing phrases of up to four discrete words from code words supplied by the computer using individual words stored within the internal vocabulary.

Status Lights—Status lights and monitors are provided to show subsystem and experiment assemblies operating conditions. These monitors are used to indicate active or passive conditions, depict normal or alternate modes, provide positive control feedback response, and, in general, indicate subsystems status and experiment conditions.

Microfilm Viewer—A microfilm viewer assists the crew member in trouble shooting procedures, maintenance techniques, control operation procedures, and other related information.

Dedicated Displays—Several dedicated meters and other display devices are required for unique and emergency/contingency conditions. It is expected these will be used in the event of emergency response, power failure conditions, and other contingency conditions as well as for subsystems and experiment control.

A series of illuminated pushbutton selection switches allows the operator to select the desired Space Station Module for display of these parameters.

Programmable Function Keyboard—A programmable function keyboard is supplied at each operator's station as an input device for access to the computer. This keyboard-display-computer loop allows one operator to sequentially select from a computer-listed "menu" and progressively construct command code for computer initiation of the required operation. Through a series of fixed-programmed select keys and a series of function keys associated with a display of computer generator variable nomenclature listings, the operator can select the desired operation. The fixed program keys are typically pushbutton switches while the display function keys are activated by the operator "touching" the nomenclature with his finger. This technique allows the operator to implement control capability without requiring a dictionary of the computer command codes.

Dedicated Switches—Rotary and toggle switches are provided to supplement the previously described control devices. These controls may be used for specific subsystem and experiment functions as well as for emergency and contingency capability. Critical control functions and backup functions are "hard-wired" for maximum reliability.

Hand Controller—The hand controller, depending on mode selection, is used to perform manual steering operations, operate attitude and translation thrustors, and aim sensors/cameras to track landmarks and targets. The hand controller provides emergency direct attitude control capability through hard-wired interfaces.

Printer—A printer provides a record of ground communications in the event that the console is not manned during a ground contact period. The printer can be used as a means of producing a hard-copy record of instructions, computer programming changes, and subsystem data.

Typical parameters to be displayed on these alphanumeric displays are:

Mission time	vehicle longitude	attitude pitch
GMT time	vehicle latitude	attitude yaw
Cabin pressure	vehicle altitude	attitude roll

GPL High-Fidelity Mockup

A high-fidelity mockup of the GPL has been constructed in order to evaluate the functional and spatial relationships of the facilities and individual equipments.

It is recommended that interested potential users of the Modular Space Station contact the Program Development Space Station Task Team of the NASA-Marshall Space Flight Center to make arrangements for viewing the mockup. Photos of the GPL mockup are shown in Figure 3-11.

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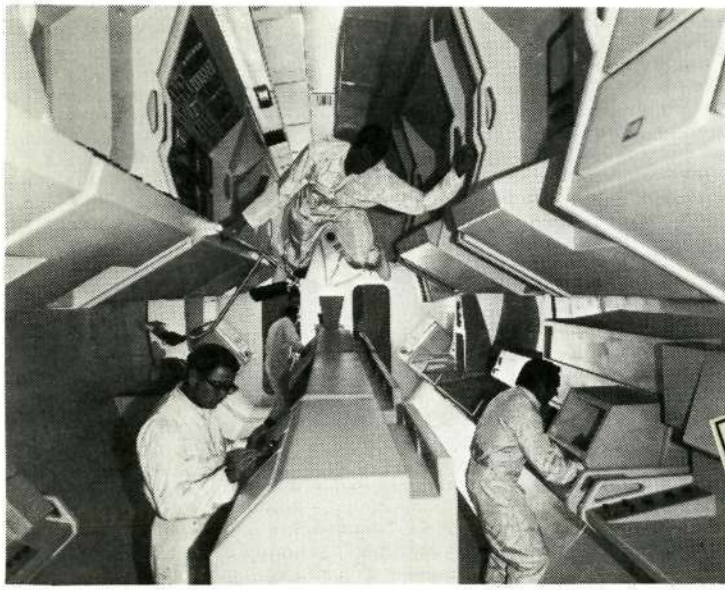
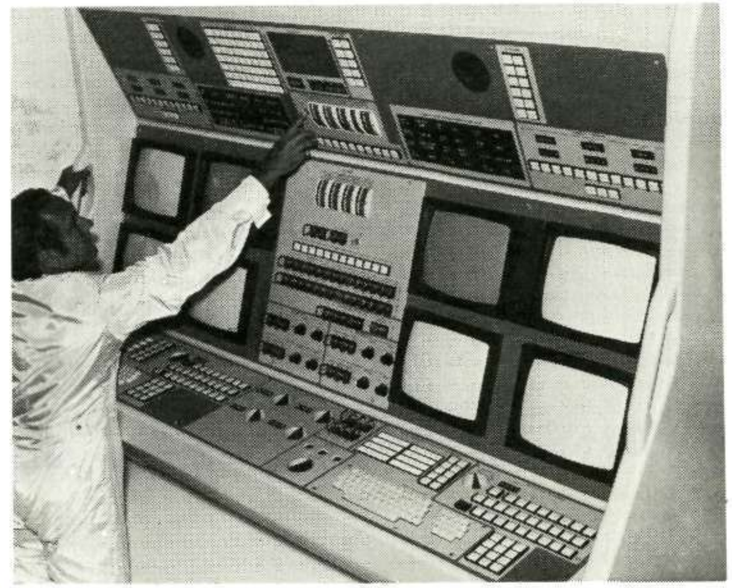
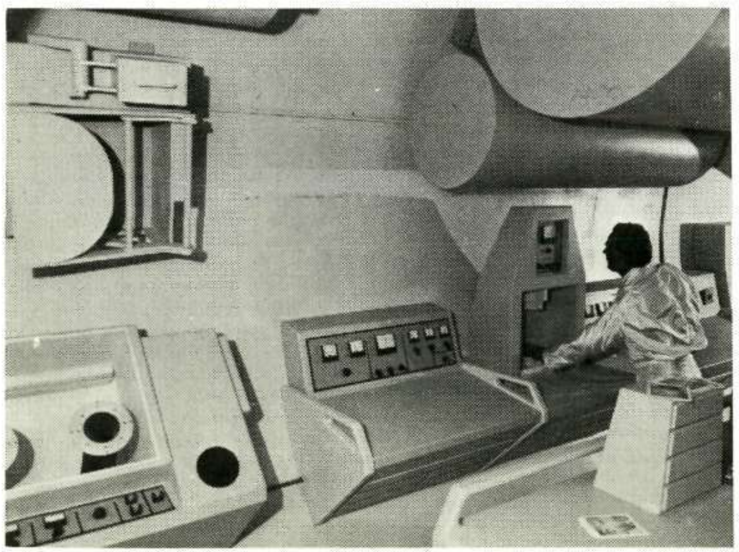


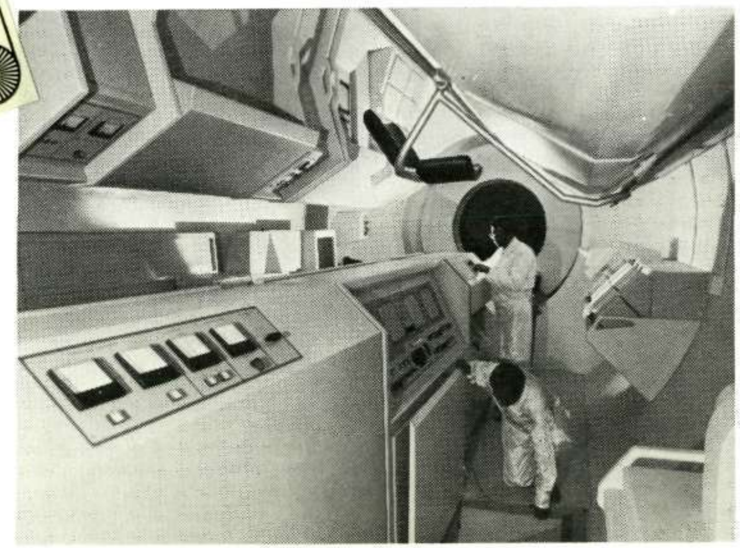
A. GPL VIEWED FROM CREW/OPERATIONS MODULE



B. EXPERIMENT COMMAND/CONTROL CONSOLE



C. MECHANICAL SCIENCES LABORATORY



D. DATA PROCESSING AND EVALUATION FACILITIES

Figure 3-11. General Purpose Laboratory Mockup Photos

Table 3-1

GENERAL PURPOSE LABORATORY MAJOR EQUIPMENT

1. Hard Data Processing Facility
   - Film and Plate Processors
   - Film Storage
   - Video Data Display and Control Console
   - Microfilmer
   - Light Table
   - Spectro Photometer
   - Densitometer
   - Operations Console
   - Display and Control Unit
2. Electronic/Electrical Laboratory
   - Electronic All Duty Work Station
   - Multi-Instrument Test Bench
   - Battery Charger
   - High-Voltage Source
   - High-Energy Counter Calibration Equipment
   - Miniature Glove Box
3. Experiment and Test Isolation Laboratory
   - Hazard Detection System
   - Electrical and Vacuum Power Center
   - Hydraulic/Pneumatic All-Duty Work Station
   - Cryogenic and Fluid Storage
   - High-Pressure Gas Storage
   - Airlock/Environmental Chamber
   - Chemistry and Physics Glove Box
   - Chemistry and Physics Analysis and Storage Unit
4. Optical Sciences Laboratory
   - Optical All-Duty Work Station
   - Optical Bench
   - Precision Work Fixture
   - Microdensitometer
   - Monochromator Spectrometer
   - Modulation Transfer Function Measurement System

Table 3-1

GENERAL PURPOSE LABORATORY MAJOR EQUIPMENT (Continued)

	Optical Spectrum Analyzer
	Scientific Airlock Chamber
	Precision Optical Window
5.	Mechanical Laboratory
	Mechanical Workbench
	X-Ray Diffraction Unit
	Experiment and Isolation Test Laboratory Monitor Panel
	Laminar Flow Glove Box
	Specimen Structural Tester
	Metallographic Tester and Microscope
	Thermostructural Test Equipment
	X-Ray Generator
6.	Biomedical/Bioscience Laboratory
	Biochemical and Biophysical Analysis Unit
	Bioscience Glove Box
	Bicycle Ergometer
	Lower Body Negative Pressure Device
	Body Mass Measuring Device
	Biomedical Display and Control Unit
7.	Data Evaluation Facility
	Multiformat Viewer Editor
	Microfilm Retrieval System
	Automatic Film Reader
	Copy Machine
	Stereo Viewer
	Image Processing and Data Management Control Station
	Working Image Storage
	Permanent Video Storage
	Permanent Digital Storage
	Time Reference Unit
	Printer
	TV Camera Control Unit
	Video Tape Unit
	Scientific Computer

3.2 RESEARCH AND APPLICATIONS MODULE (RAM) SUPPORT

Experiments that cannot be performed inside the Space Station because of their size or specialized needs can often be accommodated externally in attached or free-flying modules. Attached modules are mounted at the docking ports for the duration of their experiments. Free-flying modules, which are self-propelled and remotely controlled by the Space Station, operate at ranges up to 1,850 km (1,000 nmi) and periodically return to the station for servicing (see Figure 3-12 and Figure 3-13).

Except in special cases, RAM modules consist of two sections, a system chamber and an experiment chamber. The system chamber houses equipment for attitude stabilization, power supply, thermal control, data acquisition, communications, etc., as necessary, to meet the requirements of individual experiments in its attached or free-flying modes. The RAM module may be up to 4.3M (14 ft) in diameter and can vary in total length up to 17.7M (58 ft) while remaining compatible with shuttle cargo bay dimensions. When the modules are attached to the Space Station, both sections can be pressurized to permit access for servicing or repair (see Table 3-2).

3.3 FACILITY SUPPORT

The Space Station is of interest to the potential user as a facility in which to work and live for extended periods of time (up to 90 days).

Subsection 3.3.1 provides details of the crew accommodations the user can expect, a discussion of the logistics support the space station, information about the space station orientation capability, and a summary of the functional and support characteristics of the space station and its subsystems.

3.3.1 Crew Accomodations

Accommodations for the six-man crew are concentrated in the Crew/ Operations Module. The general arrangement is a zero-g longitudinal configuration as shown in Figure 3-14. Each of the crewmen has individual private quarters that serve not only as a sleeping facility and place for storage of personal items, but also as a private office and place for relaxation,

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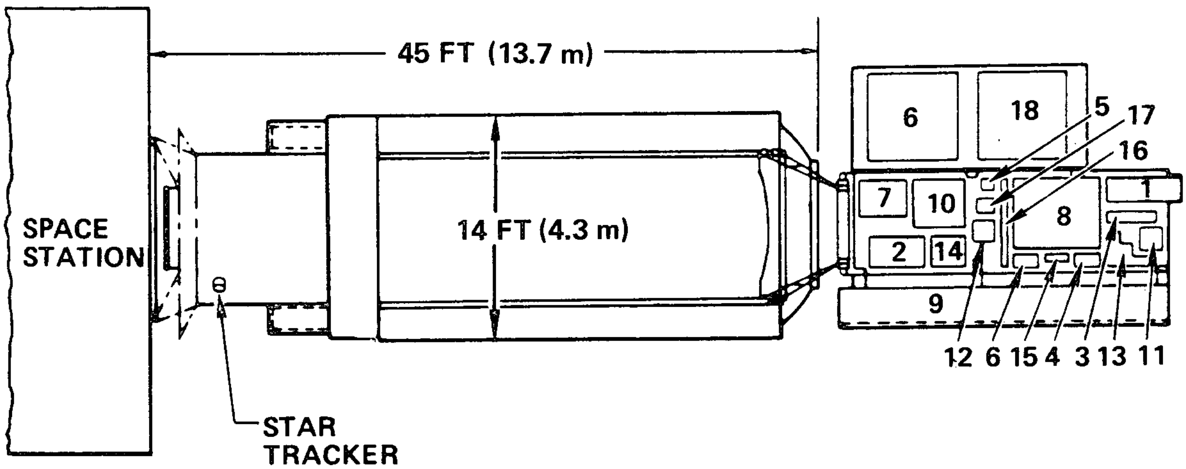

1. METRIC CAMERA
2. MULTISPECTRAL CAMERA
3. MULTISPECTRAL INFRARED SCANNER
4. INFRARED INTERFEROMETER SPECTROMETER
5. INFRARED ATMOSPHERIC SOUNDER
6. INFRARED SPECTROMETER RADIOMETER
7. MICROWAVE ATMOSPHERIC SOUNDER
8. MULTIFREQUENCY MICROWAVE RADIOMETER
9. RADAR IMAGER
10. ACTIVE-PASSIVE MICROWAVE RADIOMETER
11. VISIBLE-WAVELENGTH POLARIMETER
12. ULTRA-HIGH-FREQUENCY SFERICS
13. ABSORPTION SPECTROMETER
14. LASER ALTIMETER
15. ULTRAVIOLET IMAGER SPECTROMETER
16. RADAR ALTITUDE SCATTEROMETER
17. PHOTO-IMAGING CAMERA
18. DATA COLLECTION

Figure 3-12. Typical RAM Attached for Earth Surveys (Sensors Deployed)

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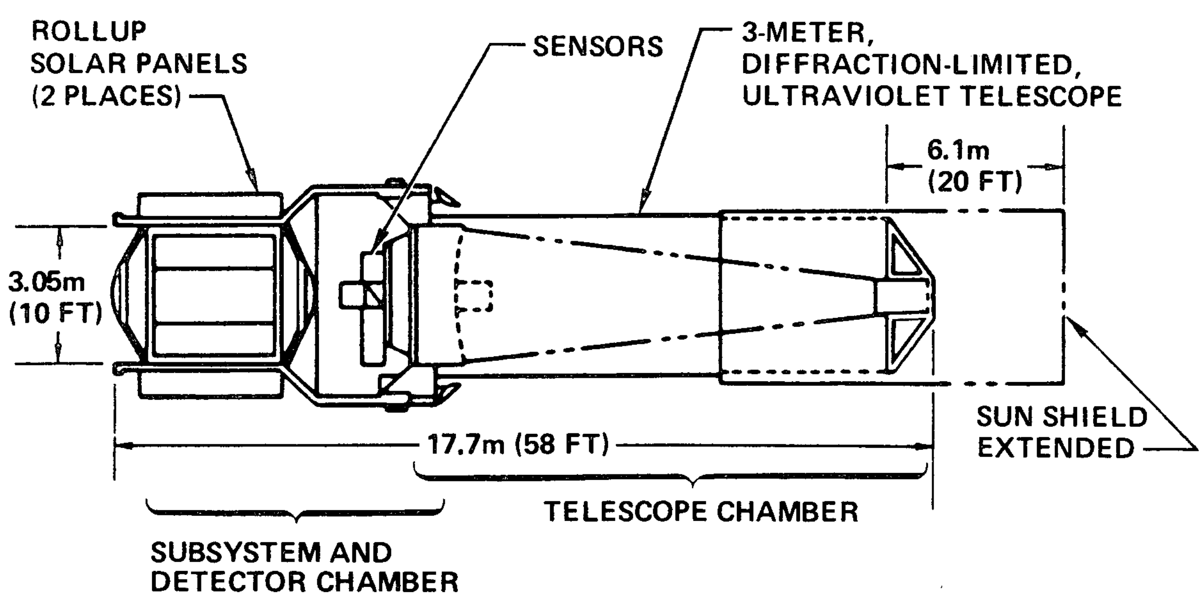

Figure 3-13. Typical Free-Flying RAM for 3-Meter Stellar Astronomy Telescope

Table 3-2

SERVICES AVAILABLE TO ATTACHED MODULES

Structural attachment	**On-board checkout**
Module docking system	Stimuli, command, and control from Space Station computer
1.5M (60-inch) diameter access	Portable control and display unit supplied by Space Station
Electrical power	**Propulsion**
ISS	Liquid-transfer coupling for hydrazine
115 ± 3 vdc / 2.4 kWe (24-hr avg)	Gas-transfer coupling for nitrogen
115/200 vac, 400 Hz / 0.5 kWe (24-hr avg)	**Attitude Reference**
Data transfer and control	Inertial system started and aligned by station
Signal multiplexing, demultiplexing, and display	Pointing command by station
Automatic or manual remote control	Star tracking offset furnished by station
Voice communications	**Navigation**
Station computer and data services	Data supplied by station
Environment	**Maintenance service**
Oxygen and nitrogen at 69 kn/M^2 to 104 kn/M^2 (10 to 15 psia), and 292° to 303°K (65° to 85°F) (selectable)	Space Station shops and personnel

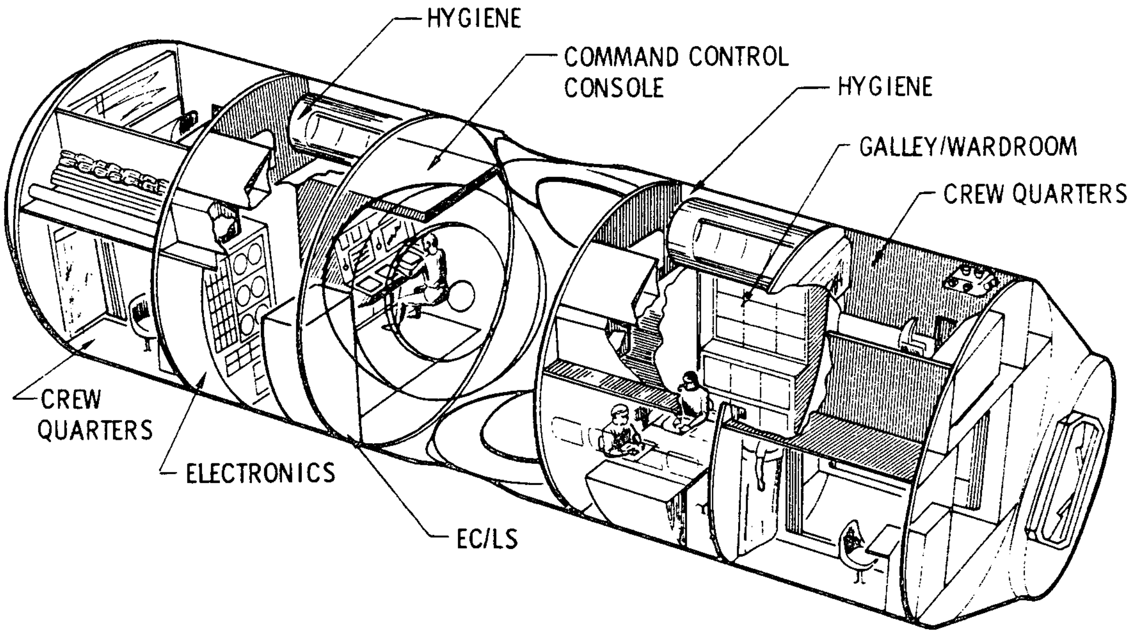

Figure 3-14. Crew/Operations Module

recreation, and study. Three of the quarters are located at either end of the module. The volume of the quarters is approximately $5.66M^3$ (200 ft^3).

A Skylab-type sleep restraint is provided which can be removed when not in use. The office capability includes the equivalent of a desk with a writing surface, storage facility, individual lighting, and restraints. Storage for personal clothing (clean and soiled) is included. Other provisions include intercom system, tape deck, reading material, hobby supplies, and personal items. An emergency oxygen mask with a portable, rechargeable oxygen bottle is stored in the crew quarters. A 30.5-cm (12-in.) viewport is also provided in each of the quarters.

Two identical hygiene facilities, $7.05M^3$ (250 ft^3) each, are located adjacent to the private quarters, one above the wardroom/galley and the other above the command-control console. Both can be accessed from the docking port area. The location of the hygiene facilities provides privacy for mixed crews and minimizes traffic through the module. The control center, $8.05M^3$ (285 ft^3), is located so the operator can view any part of the module from this work station and internal and external docking operations as well.

Each hygiene center is an enclosed area that contains a shower for fullbody wash, chamber sink for hand and face wash, complete waste management system, separate urinal, and laundry (for cleaning and drying clothing, bedding, etc.). Additionally, each crewman is provided with a personal hygiene kit containing small equipment items and supplies needed for routine personal hygiene and grooming. The kit includes an electric razor, comb, hair brush, nail clipper, toothbrush or forced-water cleaning head, deodorant, shave lotion, etc., depending on personal needs.

The wardroom/galley is located between the docking port area and one set of crew quarters with the control center between the docking port and the other set of crew quarters. The docking port area, approximately 22.6m^3 (800 ft^3), is used to augment the wardroom/galley area of 28.3m^3 (1,000 ft^3) for gymnasium purposes. Thus, the wardroom galley area is capable of accommodating six crewmen engaged in the same or different activities. The galley is designed for the storage, preparation, serving, and cleanup of meals and snacks. It includes a microwave-infrared oven for heating frozen or rehydrated food; hot and cold water dispensers for rehydration of food and beverages; a dishwasher for cleaning, disinfecting and drying utensils for eating, cooking, and serving. A 15-day supply of food is stored in the galley in controlled (freezer refrigerator) and ambient temperature cabinets. A 30-day contingency food supply is located in the GPL. The remainder of the food stores remain in the Logistics Module until needed. An eating area, opposite the galley, consists of an eating surface which when fully extended, accommodates six men and includes appropriate seat restraints. When partially extended it can be used by one to three men. In either case, it doubles as a recreation table.

Fixed and portable restraints and locomotion aids are located throughout the station to ensure safe and efficient crew operations. Standard and special tools are located at the various work stations together with portable lighting for both EVA and normal operation. A cargo handling system aids the crew in transporting packages that weigh more than 91 kg (200 lb) to ensure proper control.

A medical support assembly is provided for first aid, resuscitation, and supportive measures for Earth-return of crewmen in the event of injury or illness. The assembly includes equipment for diagnosis, therapeutics, urinalysis, hematology, and microbiology. The equipment is designed for use by a specially trained crewman rather than a physician. This assembly is located in the GPL.

3.3.2 Logistics Support

Crew and cargo are delivered to and returned from the Space Station by the Space Shuttle. Crew are transported in the passenger cabin of the Shuttle orbiter while cargo is housed in a logistics module carried in the cargo bay. This module is 4.3M (14 feet) in diameter and 8.6M (28 feet) in length. It provides for the stowage of cargo in standardized container modules measuring 0.61 by 0.61 by 0.61M (2 by 2 by 2 ft) and multiples thereof, as well as a large volume for stowing outsized items of Space Station and experiment equipment. The allowable equipment size is limited only by the size of hatches, 1.5M (5 ft) in diameter, through which the equipment is transferred. Essentially unlimited capability exists from a weight standpoint to transport experiment equipment, supplies, and support equipment.

Logistics flights to and from the Space Station occur approximately every 30 days. Transport of experiment-related supplies to the Space Station and return of data and specimens would be accommodated on these flights as required by the experimenters. After docking to the Space Station, experiment supplies can be either transferred immediately to the Space Station (film, for example) or used from the logistics module on demand (spare parts, for example).

While the logistics module is in the cargo bay, the atmosphere is maintained at 101 kn/m^2 (14.7 psi) and conditioned by the orbiter environmental control system. The internal temperature of the logistics module is not expected to exceed the range of 283^o to 311^{o}K (+50^o to +100^{o}F) during a return mission; the range is less during all other mission phases. On-orbit, while attached to the Space Station, the module atmosphere is conditioned to the same as other Space Station modules. Electrical power and monitoring of systems/ cargo parameters are also available from the Shuttle while the module is in the cargo bay.

3.3.3 Orientation Capability

The Space Station has an all-attitude capability and can therefore provide an Earth-centered, inertial or solar orientation for the users demands. The duration of these orientations other than the long-term orientation may be limited by the logistics capability to meet the resupply demands for attitude control propellant.

The primary orientation of the Space Station is trimmed horizontal (see Figure 3-15). To implement the trimmed horizontal orientation, the Space Station is initially aligned so that the roll or X-axis is aligned to the orbital velocity vector, the yaw or Z-axis toward the Earth aligned to the vertical, and the pitch or Y-axis aligned with the normal to the orbit plane. This orientation is the horizontal orientation. The trimmed horizontal orientation is obtained by an angular deflection about the pitch axis so that the bias gravity-gradient and aerodynamic torques about the pitch axis are zero. This orientation minimizes the attitude control propellant and is anear-minimum orbital drag configuration. The horizontal orientation can also be

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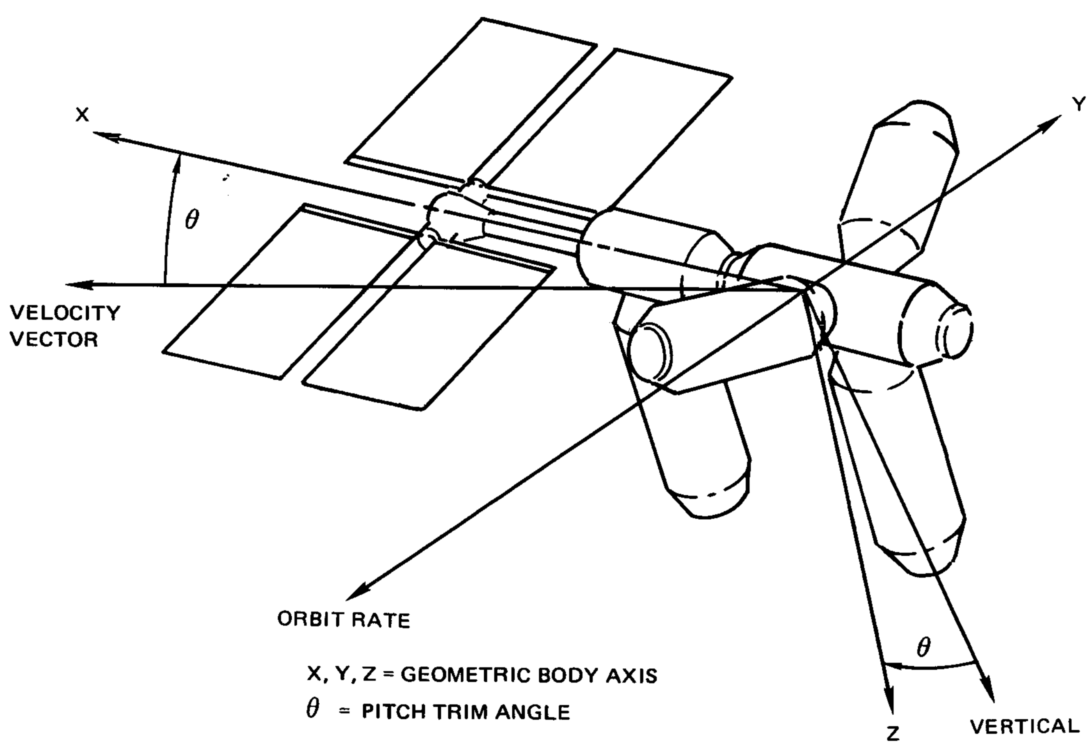


Figure 3-15. Trimmed Horizontal Orientation

trimmed with an angular deflection about the yaw or Z-axis. This case of trimming produces a near-maximum drag configuration and can be implemented subject to experiment program requirements. Such an orientation is referred to as Z-axis, trimmed horizontal.

The GNC subsystem has an all-attitude capability and can accommodate any inertial orientation subject to experiment program requirements for an indefinite time period. The restriction to maintaining indefinite operation in the alternate attitudes is the required propellant expenditures and potential contamination associated with the use of the high-thrust jets. The attitude control propellant and equivalent impulse penalties associated with several Space Station orientations are shown in Table 3-3.

In the long-term orientation, the orbit-keeping and bias attitude control requirements are provided by the resistojet system. The bias attitude control, or CMG desaturation, is performed concurrently with the orbit-keeping function. The biowaste resistojet capability for the six-man crew is 6.35 kg/day, which is sufficient for the long-term orientation.

Table 3-3

ISS ATTITUDE CONTROL PROPELLANT PENALTIES

Orientation	Attitude Control Requirements: Impulse (n-m-sec/orbit)	Attitude Control Requirements: Propellant* (kg/day)
Trimmed Horizontal (Long-term)	315	0.23
Untrimmed Horizontal	24,100	17.2
Worst Case Earth-Centered	50,000	204.0
Inertial		
Average	19,500	18.6
Worst case	28,700	118.0

*Propellant I_{sp} = 180

The user's requirement for a different orientation also imposes attitude control maneuver requirements of the Space Station as given in Table 3-4.

Table 3-4

ATTITUDE CONTROL MANEUVER REQUIREMENTS

	Maneuver Propellant Kg (lb)/event	
Maneuver (0.1 deg/sec)	ISS Configuration	ISS Configuration
Pitch	1.8 (4)	3.6 (8)
Yaw	1.8 (4)	3.6 (8)
Roll	6.8 (15)	14.4 (32)

An increase of propellant expenditure also increases the contamination level, which may degrade the level of performance for optical experiments.

The user with different orientation requirements from those of the normal long-term orientation of the Space Station must consider gimballing the experiment with respect to the station as well as placing the entire experiment gimbal requirement on the Space Station attitude.

Table 3-5 presents the Modular Space Station support characteristics.

3.4 ORBITAL ENVIRONMENT

This section contains information useful in the design of experiments that are sensitive to characteristics of the orbital environment, such as acceleration, radiation, or contamination, or that depend on relationships between the space station, earth, sun, and deep space (pointing orientation, sun angle, field of view, ground swath, etc.) for their performance.

3.4.1 Earth-Orbital Environment

The environmental criteria for the NASA Space Station Program are documented in NASA TM X-53865, Natural Environment Criteria for the NASA Space Station Program, second edition, August 20, 1970, and in NASA TM X-53857, Space Environment Criteria Guidelines for Use in Space

Table 3-5

MODULAR SPACE STATION SUPPORT CHARACTERISTICS

Characteristics	ISS	GSS
BASIC CHARACTERISTICS		
Altitude Capability	445 to 500 km (240 to 270 nmi)	445 to 500 km (240 to 270 nmi)
Inclination	55 deg	55 deg
Mission Duration	5 years	10 years
Consumables	30 days beyond planned resupply (includes logistics module)	30 days beyond planned resupply (includes logistics module)
RAM's Supported	4 attached (maximum) + GPL	7 attached (maximum) + GPL and 4 FF RAM's (maximum)
RAM-Deployment and Retrieval	Shuttle Docking	Shuttle docking and MSS/RAM docking maneuver using laser docking for F. F. RAMS
CREW RESOURCES		
Crew Availability for Experiment	4.6	9.5
Station Crew Size	6	12
Experiment Man-Hours/Day (Available)	46	95
Maximum Man-Hours/Day (Available)	60 (10 hr/day, 6 days/wk)	120 (10 hr/day, 6 days/wk)

Table 3-5

MODULAR SPACE STATION SUPPORT CHARACTERISTICS (Continued)

Characteristics	ISS	GSS
ELECTRICAL POWER		
Average Power	4.8 kwe (total of RAM's and integral experiment)	12.1 kwe (total of RAM's and integral experiment)
Load Bus Characteristics	115 ± 3 VDC	115 ± 3 VDC
	2.4 kwe (24-hr avg/RAM)	4.0 kwe (24-hr avg/RAM)
	3.6 kwe (1-hr avg/RAM)	6.0 kwe (1-hr avg/RAM)
	115/200 vac, 400 Hz	115/200 vac, 400 Hz
	0.5 kwe (24-hr avg/RAM)	0.5 kwe (24 hr avg/RAM)
	0.75 kwe (1-hr avg/RAM)	0.75 kwe (1 hr avg/RAM)
	2.8 kwe (5-min peak, total of RAM's and integral experiment)	7.1 kwe (5-min peak, total of RAM's and integral experiment)
DATA MANAGEMENT		
Data Acquisition/ Storage	10-MBPS data bus (2nd and 3rd data bus available for limited time)	Same as ISS
Support to Experiment	Data acquisition Computation Data storage Data distribution Display and control Timing	Same as ISS

Table 3-5

MODULAR SPACE STATION SUPPORT CHARACTERISTICS (Continued)

Characteristics	ISS	GSS
ON-BOARD CHECKOUT		
	Attached RAM checkout	Attached and FF RAM
	Controlled from station	Controlled from station
	Test sequencing	Same as ISS
	Fixed and portable control and displays	Same as ISS
	General purpose stimuli	Same as ISS
COMMUNICATIONS		
Primary Mode	Attached RAM's	Attached and FF RAM's
	Communication with SS (data bus)	Communication with SS wide band
	Communication with ground (via Space Station and DRSS)	Same as ISS
Interruptions	Near full-time wide-band capability	Same as ISS
Backup Mode	S-band to MSFN	Same as ISS
Attitude Constraints (Imposed by Comm)	None	Same as ISS
Voice - Full Duplex (SS to GND)	3 channels max (for experiment)	Same as ISS
Exp TLM to Gnd	2 channels 10.0 MBPS (real time)	Same as ISS
Exp TLM from FF RAM	N/A	6 channels 10^3 to 10^7 BPS

Table 3-5

MODULAR SPACE STATION SUPPORT CHARACTERISTICS (Continued)

Characteristics	ISS	GSS
COMMUNICATIONS (Continued)		
Digital Data	2 channels (maximum) 10 MBPS (maximum)	Same as ISS
TV B&W or Color (MSS to Ground)	2 channels (maximum)	Same as ISS
Video from FF RAM	N/A	2 channels (maximum)
Digital Data from FFM	N/A	6 channels (maximum)
Internal Communications		
Voice	36 channels	48 channels
Video	8 channels	14 channels
GUIDANCE, NAVIGATION, AND CONTROL		
G&N Accuracy	±1,850M (±1 nmi)	Same as ISS
Attitude Orientation Preferred	Trimmed horizontal (all attitude capability exists)	Same as ISS
Attitude Control Pointing Error	±0.25 deg (pointing error)	Same as ISS
Attitude Reference	±0.02 deg attitude reference	Same as ISS
Attitude Stability Angular Rate Limit	±0.005 deg/sec	Same as ISS
Attitude Rate Reference	±0.001 deg/sec	Same as ISS
Ranging	None	±0.1% to 1,000 nmi

Table 3-5

MODULAR SPACE STATION SUPPORT CHARACTERISTICS (Continued)

Characteristics	ISS	GSS
ENVIRONMENTAL CONTROL/LIFE SUPPORT		
Habitable Areas	Shirtsleeve environment	Same as ISS
Airlock-Pumpdown/ Repressurization	Supports any requirement to access RAM's	Same as ISS
RAM Pumpdown/ Repressurization	Up to 23.2 m^3 (820 ft^3) (power limitation determines frequency)	Same as ISS
Pumpdown and Repressurization Flow Rate	23.2 m^3 (820 ft^3) in 4.85 hr	Same as ISS
RAM Atmospheric Circulation	3.84 m^3/min (136 cfm)	Same as ISS
Thermal Load (Atmospheric)	None (crew only)	Same as ISS
Atmospheric Pressure	101 kn/m^2 (14.7 psia) $0_2/N_2$	Same as ISS
Humidity Control	0.45 kg (1.0 lb)/day (not crew)	Same as ISS
Water Coolant (RAM's and Integral Experiment)	4.8 kwe	12.1 kwe
Contamination—	Real-time monitoring	Same as ISS
Waste Management	None (except for crew)	Same as ISS
CREW HABITABILITY		
Hygiene	None (except for crew)	Same as ISS
Food Management	None (except for crew)	Same as ISS

Table 3-5

MODULAR SPACE STATION SUPPORT CHARACTERISTICS (Continued)

Characteristics	ISS	GSS
STRUCTURAL/ MECHANICS		
RAM Docking Ports	2 on nadir	7 attached
	2 at 60° from zenith	2 FF (One of these is backup normally used for CCM.)
Windows	One window adjacent to:	
	Primary control station	Same as ISS
	Secondary control station	Same as ISS
	Small scientific airlock	Same as ISS
	Large scientific airlock	Same as ISS
	On window in each docking port	Same as ISS
Experiment Airlocks		
Earth Viewing	One, 1.25M dia x 1.2M (4.1-ft dia x 7 ft)	Same as ISS
Celestial Viewing	One, 0.61M dia x 2.14M (24-in. dia, extendable to 7 ft)	Same as ISS
EVA/IVA Airlocks		
Primary	One in each Logistics Module (2 man capability) 1.6M dia x 1.5M (64-in. dia x 60-in.)	Same as ISS
Secondary	Test and Isolation Cell 3.97M dia x 1.5M (13-ft dia x 5 ft) (approximately) with docking port	Same as ISS
PROPULSION		
Propellant Interface	Hydrazine Liquid Transfer	Same as ISS
	GN_2 Transfer	

Vehicle Development, second edition, August 26, 1970. Information from these publications of interest to potential space station users is summarized here.

Vehicle-induced environments that have a major influence on the design, packaging, and operation of potential experiments are also defined here. Both the launch and orbital environments are considered. In addition, the acceleration level within the space station and the contaminant cloud surrounding the station are discussed.

3.4.1.1 Launch Environment

The launch environment will impose acceleration, vibration, shock, and acoustic loads upon the payloads. However, the space station systems will not involve the high acceleration loads previously encountered with expendable launch vehicles, since all payloads will be delivered to orbit by the space shuttle.

The launch environment created by the space shuttle system is tentative at present. The preliminary design references acceleration limits are shown in Table 3-6.

3.4.1.2 Radiation

The space station radiation environment is defined in NASA TM X-53865. The ability of the space station to protect the crew, film, and equipment from this environment was expressed by a calculational model that evaluated the effective structural shielding of the space station and defined the radiation environment in various regions within the station. In the region of minimum effective shielding, the doses expected to be received by a typical crew man is shown in Table 3-7. As seen, these are within the NASA-specified allowable also shown.

For film protection, the radiation dose rate is plotted against vault thickness and vault weight in Figure 3-16 for a spherical vault located within the GPL. The allowable dose for typical films is also shown in Figure 3-15 for the case where the films were allowed to remain undeveloped for 90 days in the suggested storage mode. The data shown in Figure 3-15 assume film

Table 3-6

STEADY-STATE FLIGHT ACCELERATIONS

Condition	Rigid Body Loads		
	X(g)	Y(g)	Z(g)
Launch	1.6	±0.5	-0.5
High Q (Booster Thrust)	1.9	±1.0	1.0
End Boost (Booster Thrust)	3.0	±0.6	-0.6
End Burn (Orbiter Thrust)	3.0	±0.5	-0.5
Entry	-0.5	±1.0	-2.5
Flyback	-0.5	±1.0	+1.0 -2.5
Landing	-1.0	±0.5	-2.7

Table 3-7

RADIATION ENVIRONMENT INSIDE

Receptor Point	90 Day Dose (rem)	
	Dose	Allowable
Skin	44	105
Eyes	28	52
Blood-Forming Organs (BFO)	9	35

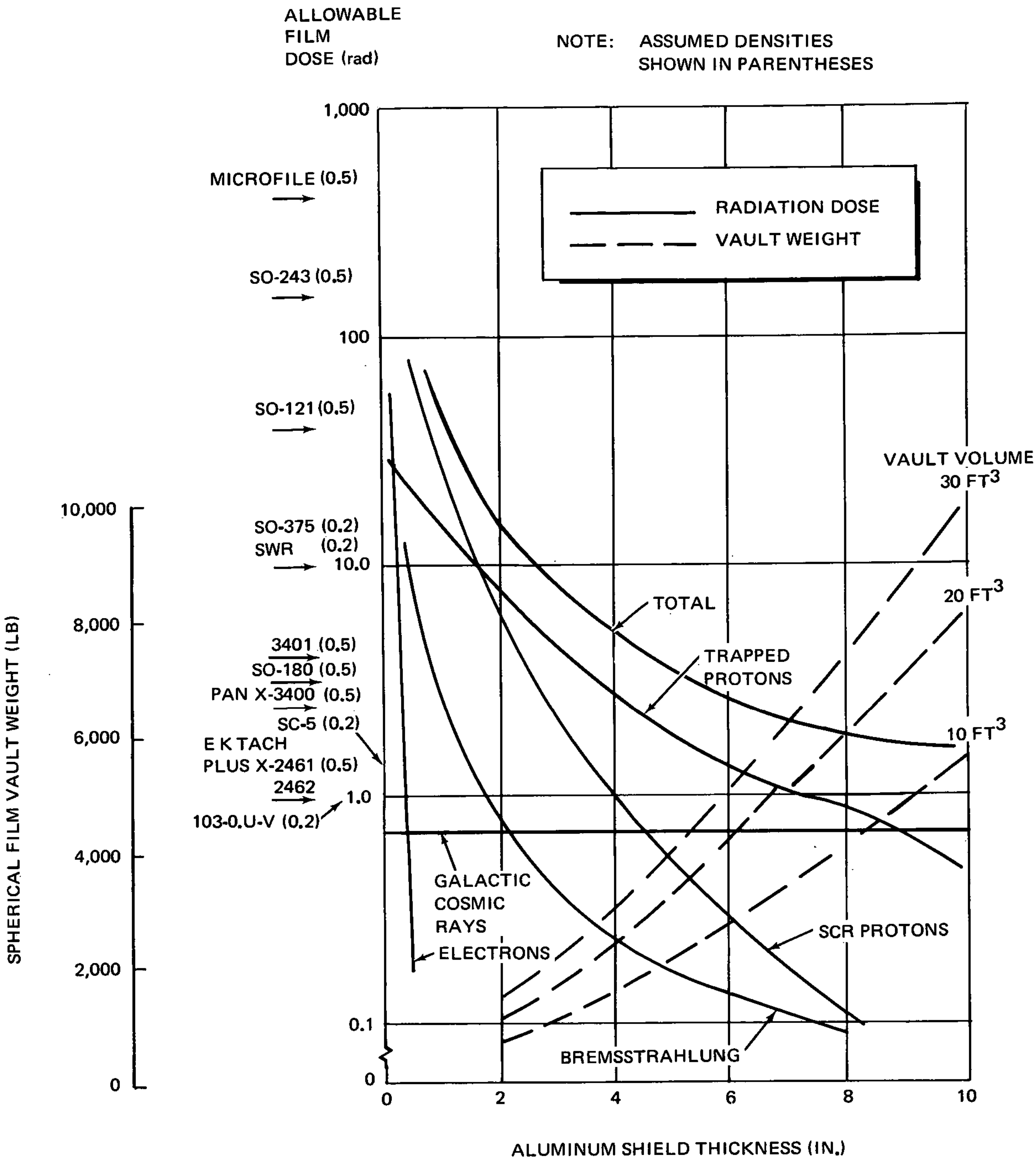


Figure 3-16. Film Vault Shield Requirements—90-Day Dose

applications limited to fogging densities associated with film types as shown. Each individual user must set his own allowable density requirements in order to establish shielding requirements.

Another method of film protection is to lower the storage temperature. This, in effect, reduces the film sensitivity so that at cryogenic temperatures, significant reduction in fogging may be achieved. This reduction, however, precludes applications in which film is exposed at shorter intervals than the time required to bring it from storage temperature to ambient temperature.

Probably as important, if not more so, are the effects of thermal radiation on film. The chemical changes that certain photographic materials undergo with age are of a chemical nature and have a high temperature coefficient. Therefore, all films intended for scientific work would be kept refrigerated from at least 277° to 284°K (40 to 50°F). For optimum results, these films should be brought to 294° ± 6°K (70 ± 10°F) with a relative humidity between 40 and 60 percent during exposure. The following films are particularly susceptible to thermal radiation: Kodak spectroscopic plates and films, I-M, I-Z, I-N, IV-N, and Kodak SWR.

3.4.1.3 Acceleration Disturbances

The acceleration levels present aboard the space station in the zero-gravity configuration are the result of drag, gravity gradient, venting, crew motion, stabilization, orbit-keeping, and docking. The maximum linear, radial, and tangential accelerations imposed on the space station by these disturbance sources are shown in Figure 3-17, as a function of probable frequency of occurrence.

The large acceleration spectrum covered by the orbit-keeping function reflects the dependence of these disturbances upon the type of propulsion system used. The resistojet used on the space station, for example, operates nearly continuously, canceling the drag (10^{-7} g). On a near-continuous basis, accelerations of at least 10^{-4} g can be expected because of crew movements and control activation requirements. Thus, it may be necessary to consider revising the research protocols to relax the acceleration requirements, or perhaps isolation techniques will have to be provided to eliminate disturbances

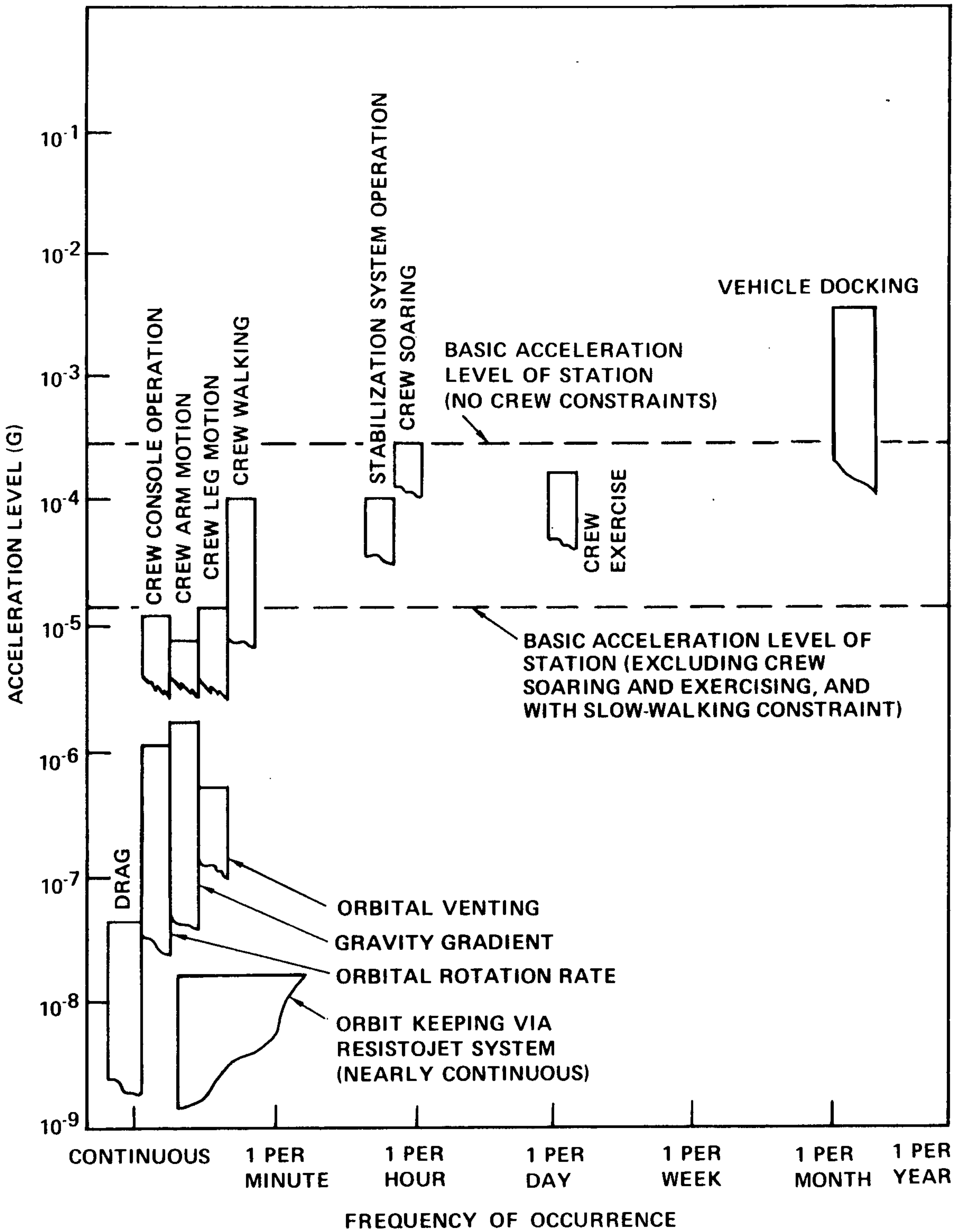


Figure 3-17. Acceleration Disturbances and Limits

on critical experiments. Accelerations resulting from major disturbances created by crew soaring or exercise can probably be operationally controlled for reasonable periods if a critical experiment imposes the requirement to do so.

3.4.1.4 Contaminant Cloud Environment

The contaminant cloud formed by effluents of the Space Station (Figure 3-18) must be considered in the planning of the experiment program because this cloud could degrade or invalidate some of the experiments. The potential cloud, depending on its constituents, would absorb or reflect energy in several portions of the electromagnetic spectrum and could form deposits on optical sensors, radiator surfaces, windows, etc. The magnitude and composition of this cloud are shown in Figure 3-19.

The effects of these effluents on specific materials and experiments will be determined when the design and test programs mature. In the meantime, the space station is being designed under a strict contamination control plan selected to minimize effluents and material outgassing, which are known to affect experimentation.

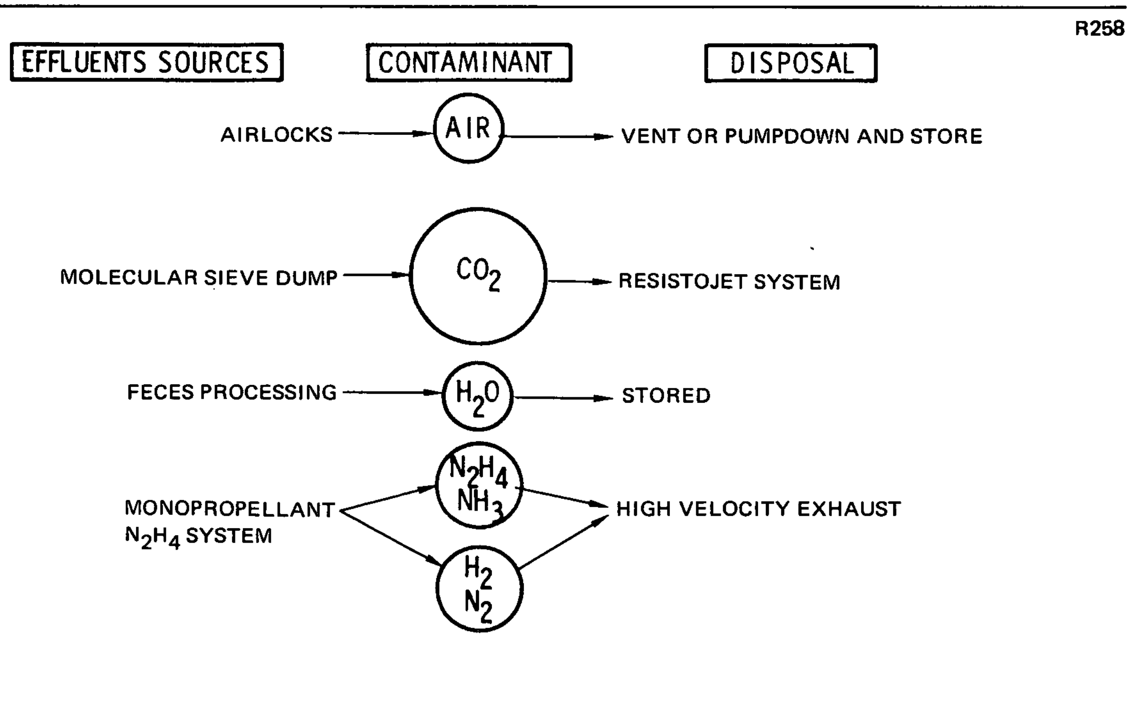
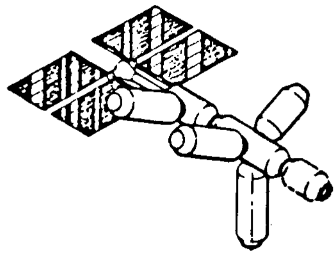
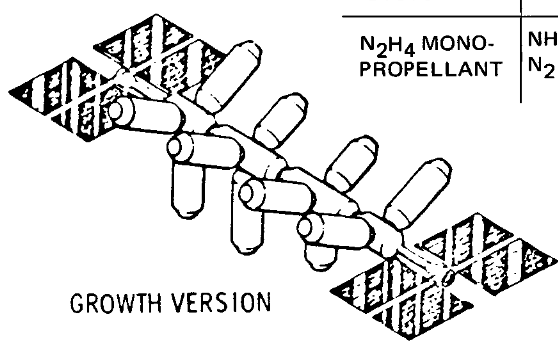


Figure 3-18. Space Station Effluent Sources



INITIAL CAPABILITY



GROWTH VERSION

POTENTIAL EFFLUENT DISCHARGE

SOURCE	EFFLUENT	METHOD OF EXPULSION	QUANTITY RATE	QUANTITY TOTAL
AIRLOCK	AIR	AIRLOCK VENT	0.32 LB/EVA	——
MOLECULAR SIEVE	CO_2	RESISTOJET SYSTEM	O	O
RESISTOJET SYSTEM	CO_2	NOZZLE DISCHARGE	CONTINUOUS OR PERIODIC	2.3 LB/MAN-DAY (1.5 LB/MAN-DAY)
N_2H_4 MONO-PROPELLANT	NH_3 & H_2 N_2 & N_2H_3	NOZZLE DISCHARGE	10-50 LB/ EVENT	~25 TO 250 LB/MONTH *

*ONLY CONTINGENCY USAGE PLANNED

Figure 3-19. Space Station Effluent Discharge

These figures are not representative of free-flying modules and would not apply to experiments that are susceptible to contamination or to degradation of data by scattering, attenuation, or distortion caused by plasma clouds, solid particles, or ice. Free-flying modules will probably operate without a significant atmosphere and, as no human wastes will be present, the only contaminants will be from attitude control thrustors (hydrazine) and from outgassing of masterials. In addition to the space station, the shuttle effluent discharge must also be considered.

Current shuttle studies are developing requirements for the shuttle effluent discharge. Resultant orbitor effluent characteristics are expected to have minimum interaction with experiment hardware.

The current Space Station design employs quartz crystal contamination sensors and a broad band mass spectrometer for routine external contaminating monitoring. The quartz sensors are distributed with four on each ISS module. The data are displayed on the Experiment Control Console, located in the GPL.

3.5 OBSERVATIONAL CHARACTERISTICS

3.5.1 Earth Observations

The orbit inclination for earth viewing is 90 degrees (polar). The cost of achieving polar orbit vs the additional ground coverage obtained does not appear necessary, since approximately 82 percent of the Earth's land mass and 88 percent of the population are located within the coverage of the space station's 55-degree orbit inclination. Complete coverage of this massive area is provided every five days. It is significant that the space station orbit does not provide for polar observations; however, as noted by the National Academy of Sciences publication on polar research, such observations can be made by unmanned satellites in polar or geosynchronous orbits.

The distribution of typical targets for earth observation is illustrated in Figure 3-20. A cumulative distribution of earth observation targets covered by various orbit inclinations is shown in Figure 3-21. This plot dictates the high percentage of Earth resources covered by the 55-degree orbit of the space station.

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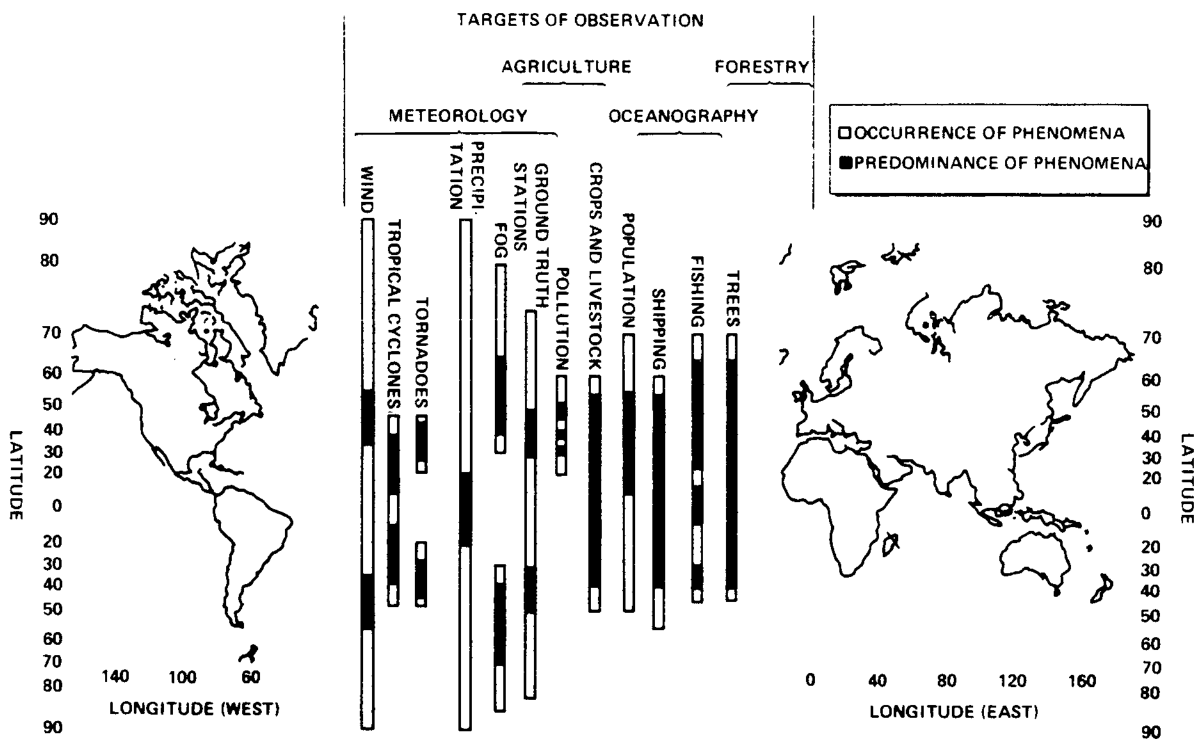

Figure 3-20. Distribution of Earth Observation Targets

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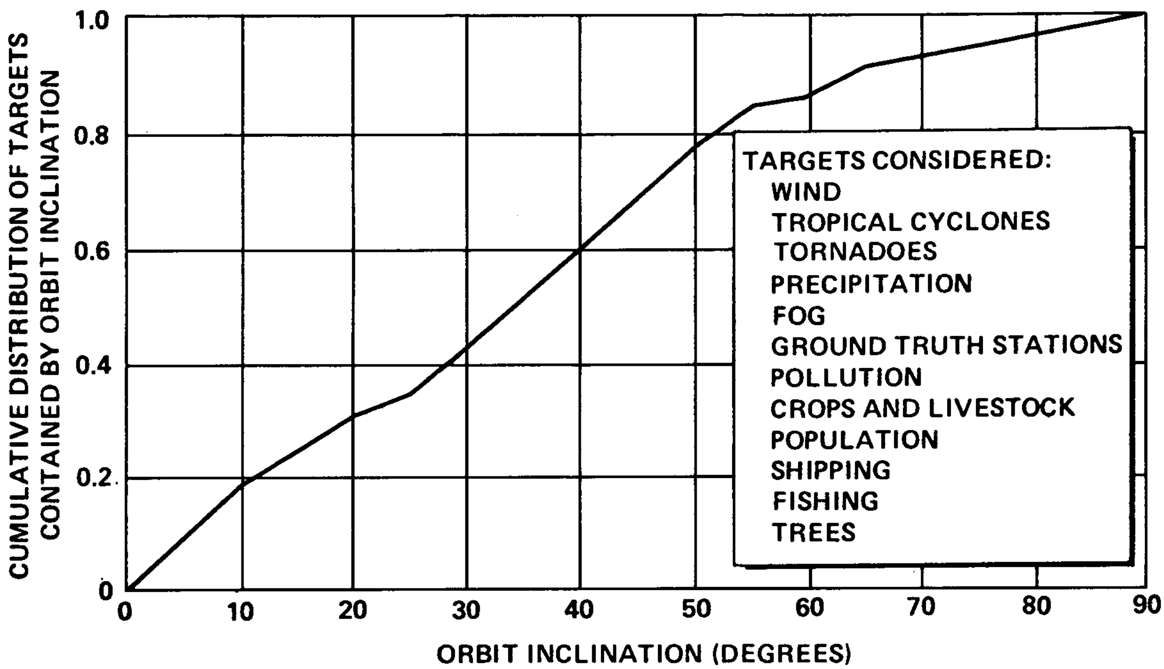

Figure 3-21. Cumulative Distribution of 12 Typical Earth Observation Targets vs Orbital Inclination

3.5.1.1 Geometry of Earth Viewing

The basic geometry of Earth viewing from orbit is shown in Figure 3-22. The data in Figures 3-23, 3-24, and 3-25 indicate the relationships between these geometric parameters. The term look angle (ψ), as used here, represents one-half the field of view, and the ground range to target (R_G) represents one-half the total ground swath (G_S) viewable. The horizon elevation angle (σ) is the parameter that limits communication range-to-ground stations and also the allowable range (usually expressed as minimum elevation angle) to a ground target. In the latter case, the target limit is expressed as degrees from the horizon where the phenomenon can still be observed.

The effect of sensor field of view on ground swath width is illustrated in Figure 3-26 for the Space Station altitude band of 370 to 555 km (200 to 300 nmi). As an example, a typical field of view of 44 degrees would result in a 370 km (200 nmi) ground swath width if viewed from a Space Station at an altitude of approximately 462.5 km (250 nmi).

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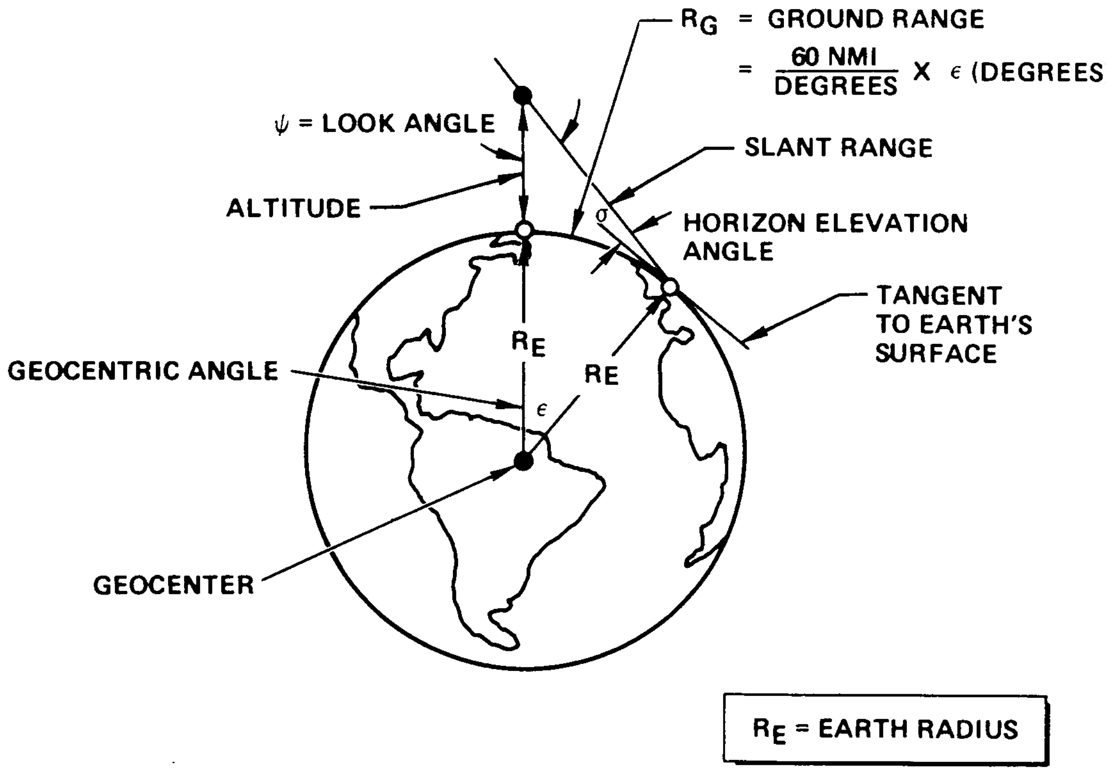

Figure 3-22. Earth Coverage Geometry

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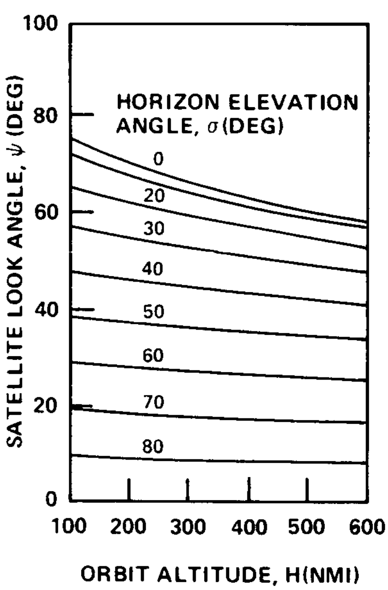

Figure 3-23. Satellite Look Angle, ψ

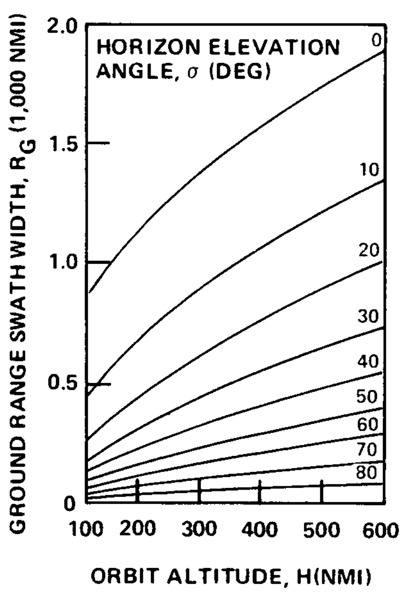

Figure 3-24. Ground Range Swath Width, R_G

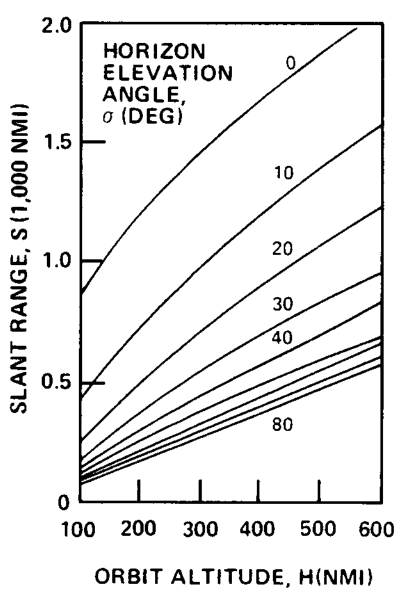

Figure 3-25. Slant Range, S

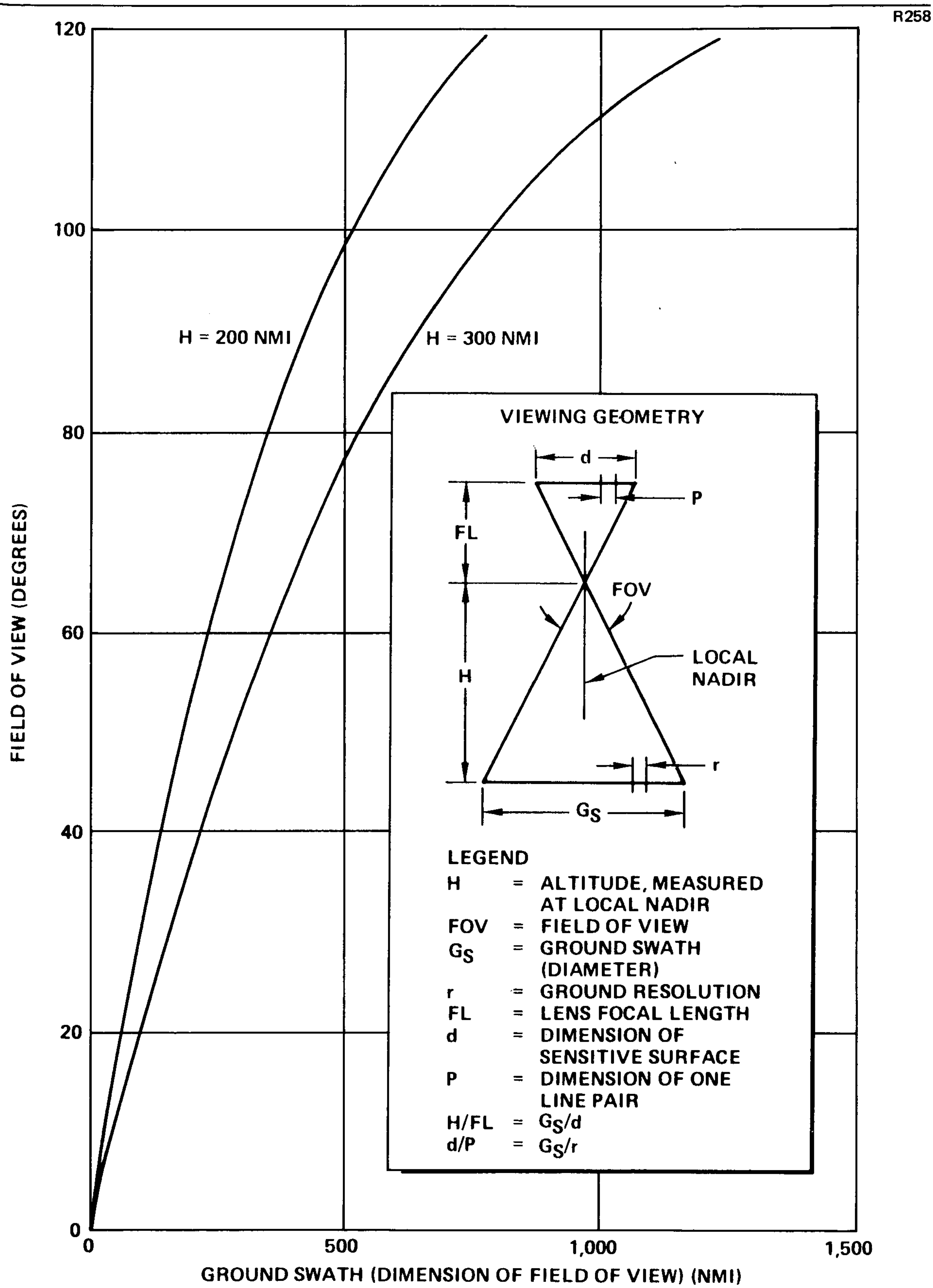

Figure 3-26. Ground Swath Viewing Geometry

Viewing geometry and resolution-focal length relationships, etc., are also indicated in Figure 3-26. As an example, the unit G_S width projected onto a 1-inch unit distance (d) of a photograph in a camera employing a 30.5-cm (12-inch) focal length (FL) from a 555-km (300-nmi) altitude (H) would be 25 nmi, or 2.54 cm (1 inch) equals approximately 46.25 km (25 nmi). The resolving power of a lens-film combination is defined as the reciprocal of the smallest observable separation of adjacent lines in a photographic test pattern consisting of parallel black lines of equal width separated by white lines of the same identical width, expressed as lines (or line pairs) per millimeter. Ground resolution limit is therefore equivalent to one line of resolving power. If the resolving power (1/P) of the lens-film system is 30 lines/mm, the ground resolution (r) for this example would be 61.6M (202 feet) (the minimum distance between two objects on the ground that are just resolvable).

Typical fields of view of candidate earth survey sensors are listed in Table 3-8.

3.5.1.2 Film Format and Ground Coverage

One of the prime sensors considered for the earth resource mission is the photographic camera operating in the visible and near-infrared wavebands. The specifications for ground view and operating orbit altitude are critical in establishing the physical characteristics of the camera. The relationship between film format, camera focal length, field-of-view angle, spacecraft altitude, and ground view is presented in Figure 3-27. If there is but one fixed camera in the system, then it is convenient to consider the ground view as swath width. Additional data presented in Figure 3-27 are film mass vs film format and number of pictures, and area covered vs number of pictures and ground view. Points are indicated for the area of the continental United States and the land mass of the earth (see the lower lefthand plot).

As an example, consider film with a 9-inch format. Assume a 20-inch focal length and a Space Station altitude of 250 nmi. By constructing a line connecting 9 inches to the 20-inch focal length line, then dropping the perpendicular to the 250 nmi altitude allows the user to construct a line to the left

Table 3-8

TYPICAL FIELDS OF VIEW OF CANDIDATE EARTH SURVEY SENSORS

Candidate Sensor	Typical Field of View (degrees)
Metric camera	70
Multispectral camera	41
Multispectral infrared scanner	20
Infrared interferometer spectrometer	3
Infrared atmospheric sounder	12.5
Infrared spectrometer-radiometer	0.2
Microwave scanner radiometer	100
Multifrequency microwave radiometer	120
Microwave atmospheric sounder	120
Radar imager	8.6
Active-passive microwave radiometer	10
Visible-wavelength polarimeter	3
Very-high-frequency sferics	120
Absorption spectrometer	1 for spectrometer, 18 for imager
Laser altimeter	6×10^{-8} steradian
Ultraviolet imager-spectrometer	1 for spectrometer, 15 for imager
Photo-imaging camera	Less than 16
Radar altimeter-scatterometer	1
Data collection	20

which gives the ground view. Also, if the vertical line is extended downward, the field-of-view is obtained.

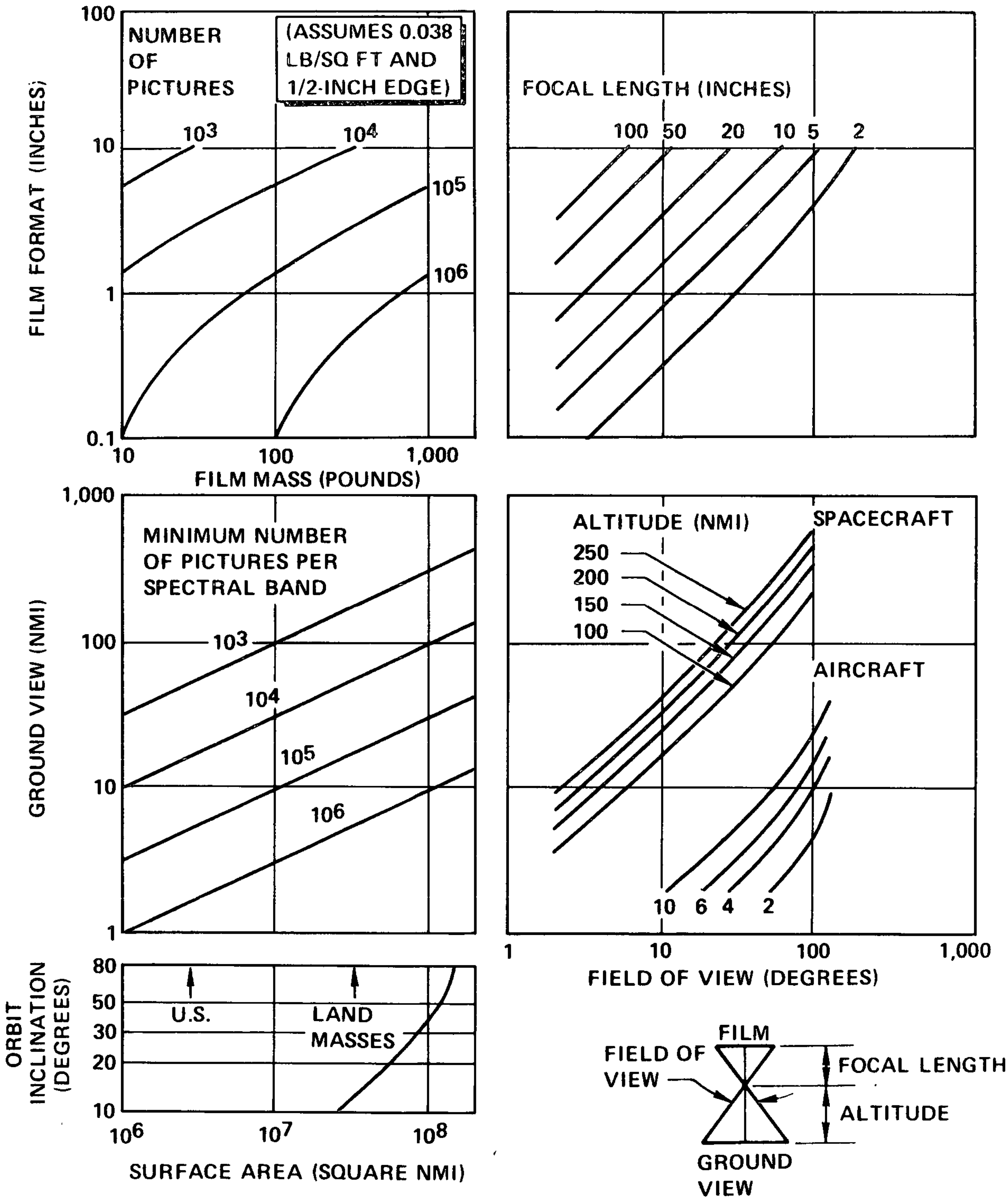

Figure 3-27. Nomograph for Film Weight Estimation

The orbit inclination uniquely determines the surface area. By extending a vertical line upward until an intersection is made with the horizontal altitude-ground view line, an estimate of the number of pictures results. For the previous example, if a 55-degree inclination is used, the number of pictures is approximately 10^4. Finally, if from the intersection of the 10^4 line and the line connecting film format and focal length a vertical line is dropped, the film mass is determined.

3.5.1.3 Resolution Capability

The film format-area coverage solution must also consider the requirement that the target area be viewed with a given resolution. The parametric plots of Figure 3-28 were prepared to relate this ground resolution value to the resolution capability of the camera system. Additional parameters of these plots include spacecraft altitude and the focal length of the optics, which are common parameters with the plots of Figure 3-27. It should be noted that the linear resolution varies with the contrast of the subject, the f/ratio of the optical system, and the field of view. Plots of these variables are shown in Figures 3-29, 3-30, and 3-31 for a representative combination of aerial camera lens and fine-grain film.

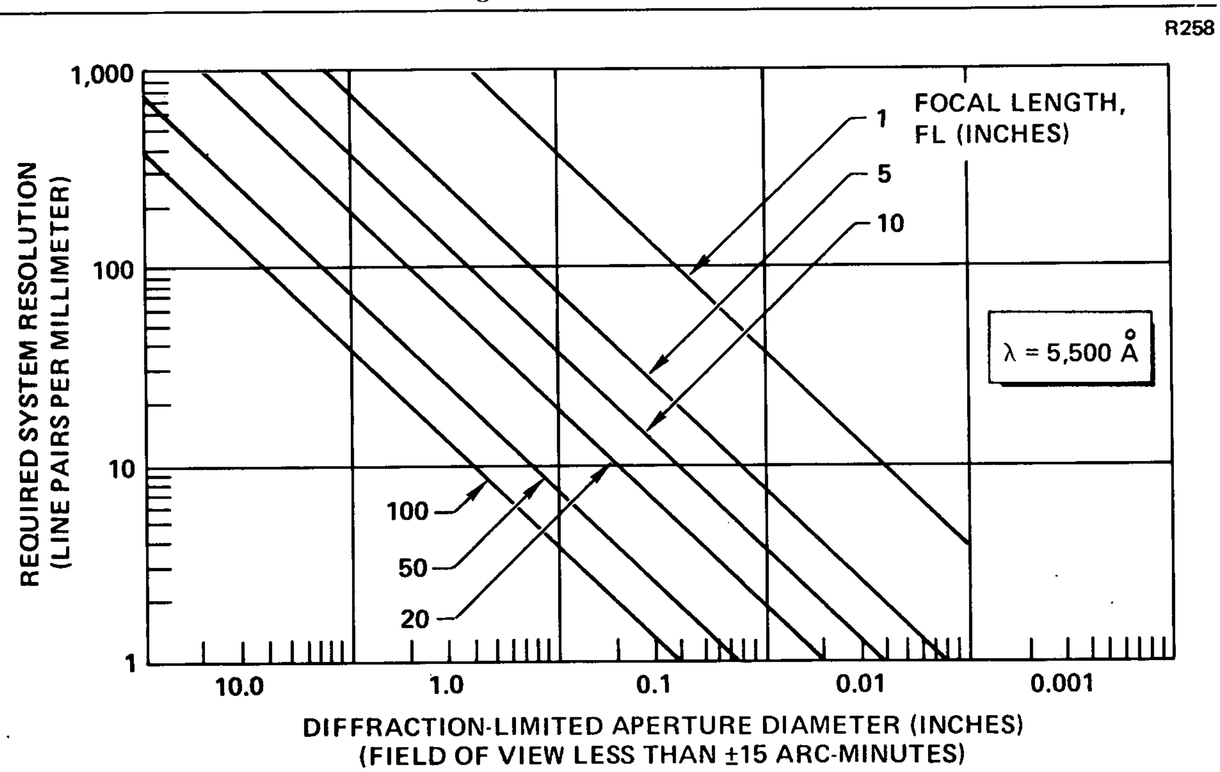

Figure 3-28. Optical Resolution Nomograph

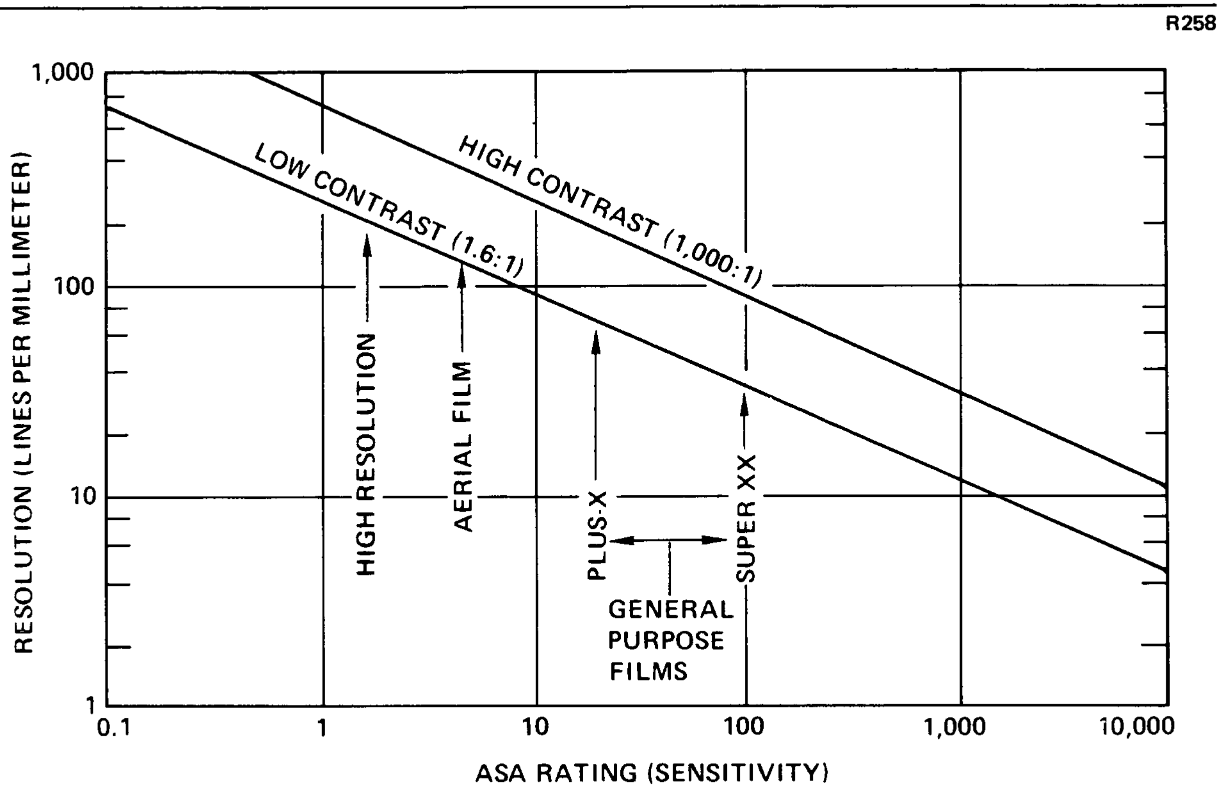

Figure 3-29. Photographic Film Resolution vs Sensitivity and Contrast

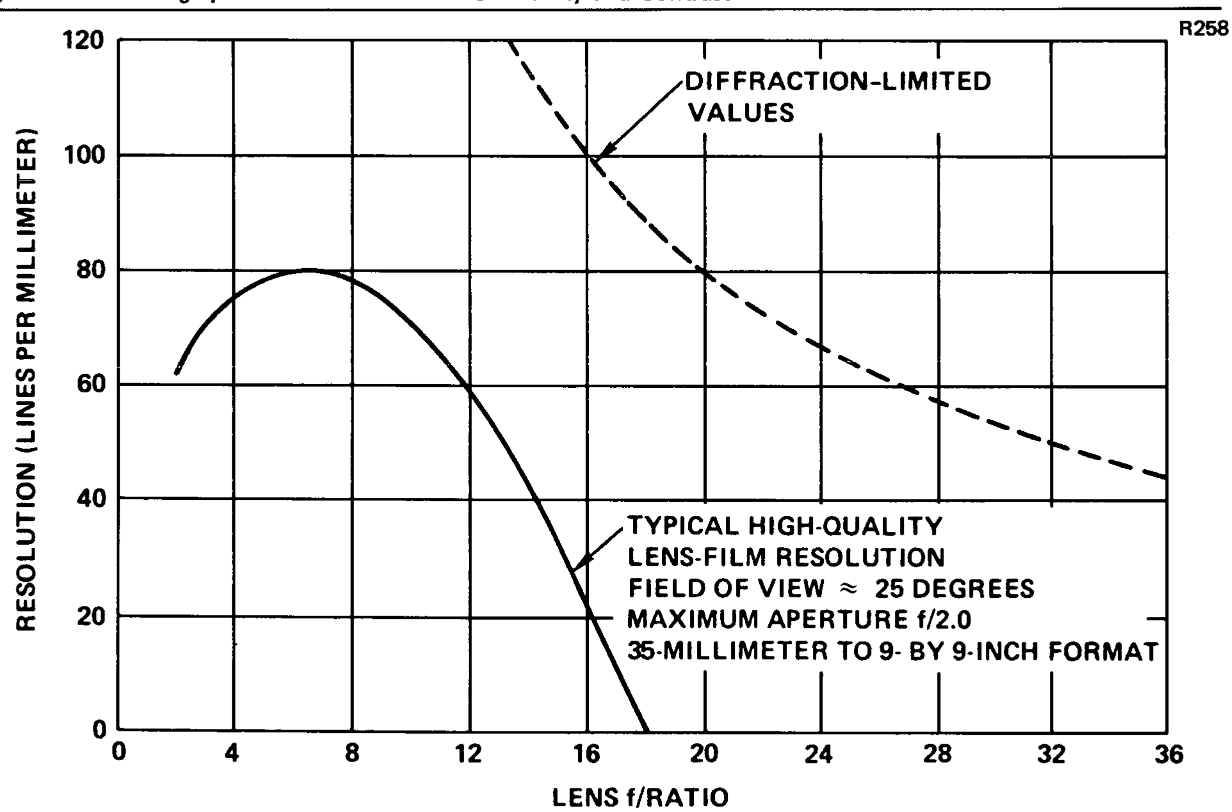

Figure 3-30. Typical Lens Resolution vs f/Ratio

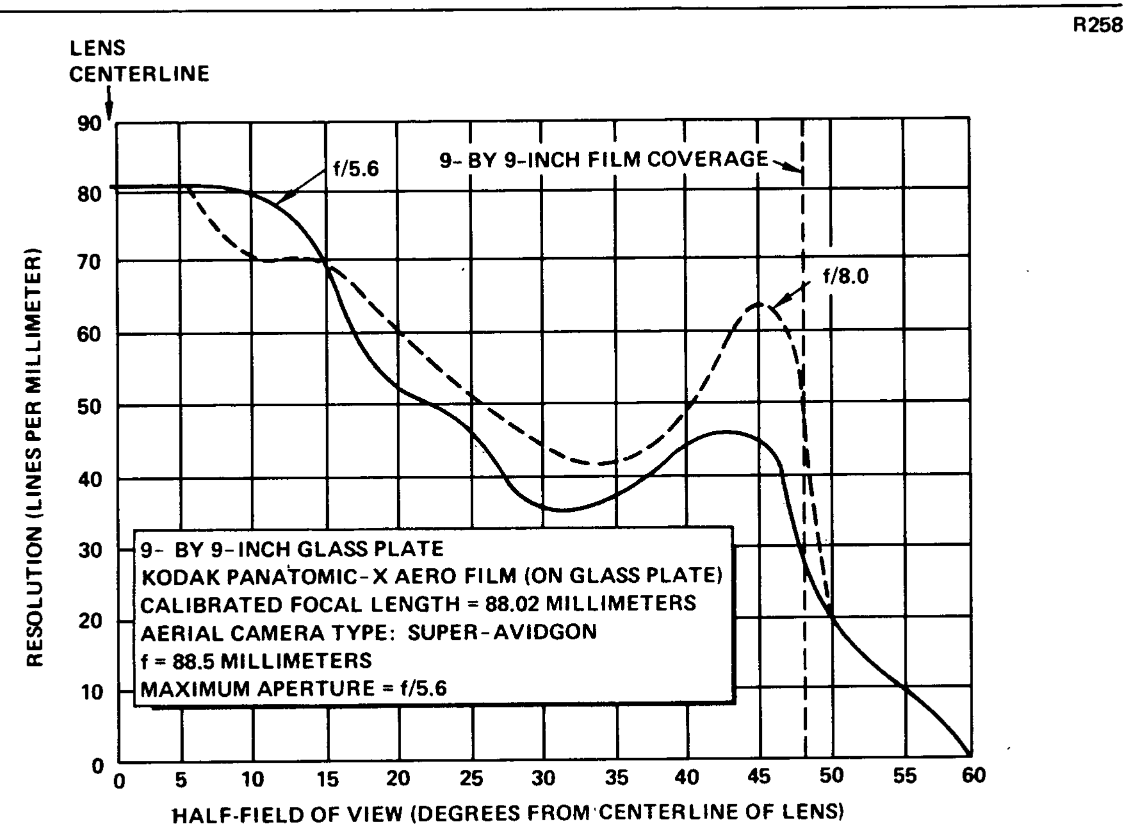

Figure 3-31. Typical Lens Resolution vs Field of View

Table 3-9, which was extracted from military handbook TM 30-245/NAVAER 10-35-610/AFM 200-50, indicates typical scales for identification and technical analysis of various subjects. These scales may prove more useful, in many instances, than study of resolution parameters, for they allow quick evaluation of altitudes, lens focal lengths, and other details. However, they are subject to alternation, owing to the many variables in atmospheric conditions and film processing to which aerial photos are exposed. The scales are based on average-quality photography currently being produced. Improvements in such factors as image-motion compensation, camera mount vibration, and edge gradient will permit the use of smaller scales.

Column 1 of the table indicates scales required for recognition of an object class (e. g., motor vehicles, multiengine aircraft, etc.). Column 2 indicates scales necessary for detailed analysis of specific objects within an object class. All scales refer to vertical stereo photo coverage. Low-level oblique photography and continuous-strip photography are noted as being helpful in specific instances.

Table 3-9

MINIMUM PHOTOGRAPHIC SCALES FOR INTERPRETATION AND IDENTIFICATION

Subject Class	Constituents of Subject Class	1 Minimum Scale Identification	2 Minimum Scale for Technical Analysis
Transportation	Rail	1/30,000	1/8,000
	Road (Road surface conditions cannot be reliably determined from aerial photography)	1/30,000	1/5,000
	Inland waterways	1/30,000	1/10,000
	Bridges (over 30.5M (100 ft))	1/30,000	1/10,000, oblique helpful
Utilities	Sewage	1/20,000	1/10,000
	Water purification	1/20,000	1/10,000
	Gas plants	1/20,000	1/8,000
	Municipal thermal power plants	1/30,000	1/10,000
	Industrial thermal power plants	1/15,000	1/8,000
	Central heating plant (typical)	1/15,000	1/6,000
	Hydroelectric power plant	1/30,000	1/10,000
	Power lines (to trace)		1/6,000
Terrain	Major land forms	No limit	1/20,000
	Minor land forms	1/20,000	1/8,000

Table 3-9

MINIMUM PHOTOGRAPHIC SCALES FOR INTERPRETATION AND IDENTIFICATION (Continued)

Subject Class	Constituents of Subject Class	1 Minimum Scale Identification	2 Minimum Scale for Technical Analysis
Vegetation	Scales given are applicable to optimum season only	1/20,000	1/8,000, low-level oblique and continuous-strip helpful
Shipping	Merchant vessels		
	Above 61M (200 ft)	1/25,000	1/12,000
	Below 61M (200 ft)	1/15,000	1/5,000
Shipping facilities	Ports	1/25,000	1/12,000
	Docking facilities (piers, wharves, etc.)	1/20,000	1/8,000
	Services (cranes, wharf trackage, etc.)	1/12,000	1/6,000
	Individual personnel	Unknown	1/1,000, low-level oblique and continuous-strip helpful
Structures	Structural analysis	1/12,500	
	Urban area analysis	1/12,500	
Photogrammetry	Tri-met (for air navigation charts)	1/60,000	
	Vertical (for mapping)	1/40,000	
	Supplemental (for air navigation charts and mapping)	1/20,000	

3.5.2 Solar Illumination and Occultation

Earth- and space-viewing experiments are severely affected by the sun. Experiments that depend upon detection of incipient energy in the object under investigation (for example, galactic sources, earth thermal measurements, and space physics) generally need to have the sensors and the object occulted from the sun. In this case, the period of the orbit during which the space station is on the dark side of the earth is most important and should be as long as possible, compared to the duration of the measurement. Conversely, many other experiments require that the sources be irradiated by the sun (earth photography, solar astronomy, lunar observations, etc.). In these cases, the "day" side of the orbit is required.

The seasonal variation of the Earth-sun system in the ecliptic plane is presented in Figure 3-32 to help visualize the geometry of the system. Figure 3-33 shows the interrelationships between the space station, the rotating Earth below it, and the sun in its apparent rotation about both.

The key to the solar effects on the space station is the beta (β) angle, which is the angle between the Earth-sun line and the orbit plane. Once the space

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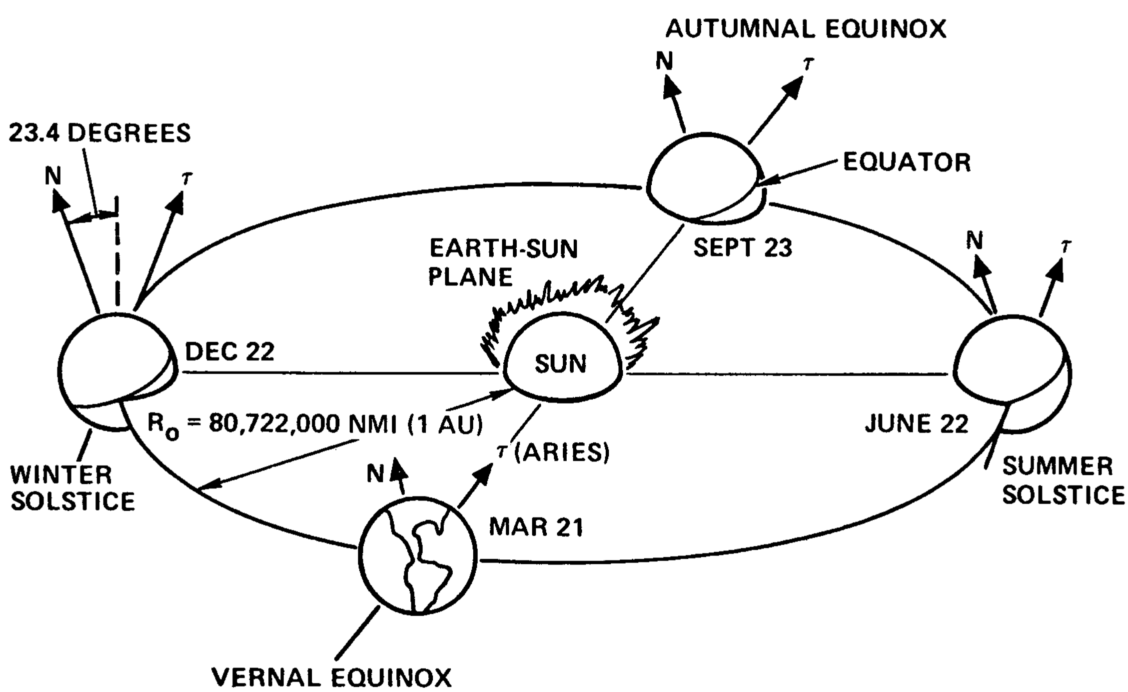


Figure 3-32. Seasonal Variation in Ecliptic Plane

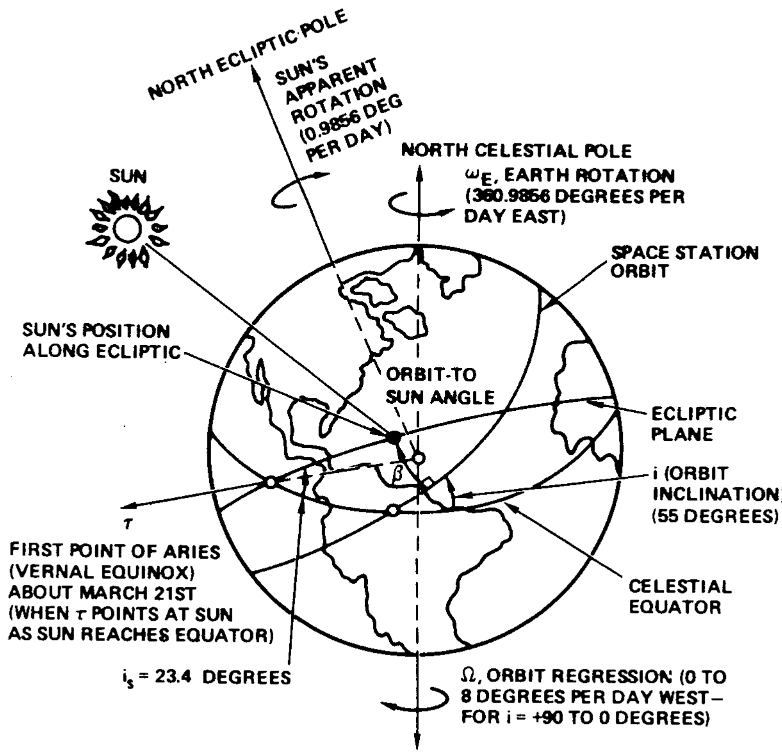


Figure 3-33. Relationship of Earth and Sun to Earth Orbit

station is injected into orbit, β angle can be calculated for each day of the year, and the periods of daylight and darkness for the space station and the Earth can be specified. The dark line of Figure 3-34 indicates the repetitive annual cyclic variation in β angle for a July 4 launch.

Figure 3-35 privides a plot of the time per orbit that the space station is in the Earth's shadow (umbra), as calculated from Figure 3-34. The typical orbit data shown in Figure 3-35 indicate that the space station is completely in sunlight throughout each orbital revolution for a period lasting between 3 and 5 days. This condition exists two or three times a year near the solstices, when β angle is greater than ±69 degrees. The condition when the sun enters the plane of the space station orbit, resulting in the maximum percentage of an orbital revolution being in the darkness of the Earth's umbra, occurs once every 27 days. The space station is in the umbra a maximum time of 36.4 minutes per orbit during these periods, and the ground track point on the earth below the space station is in total darkness for 47 minutes per orbit.

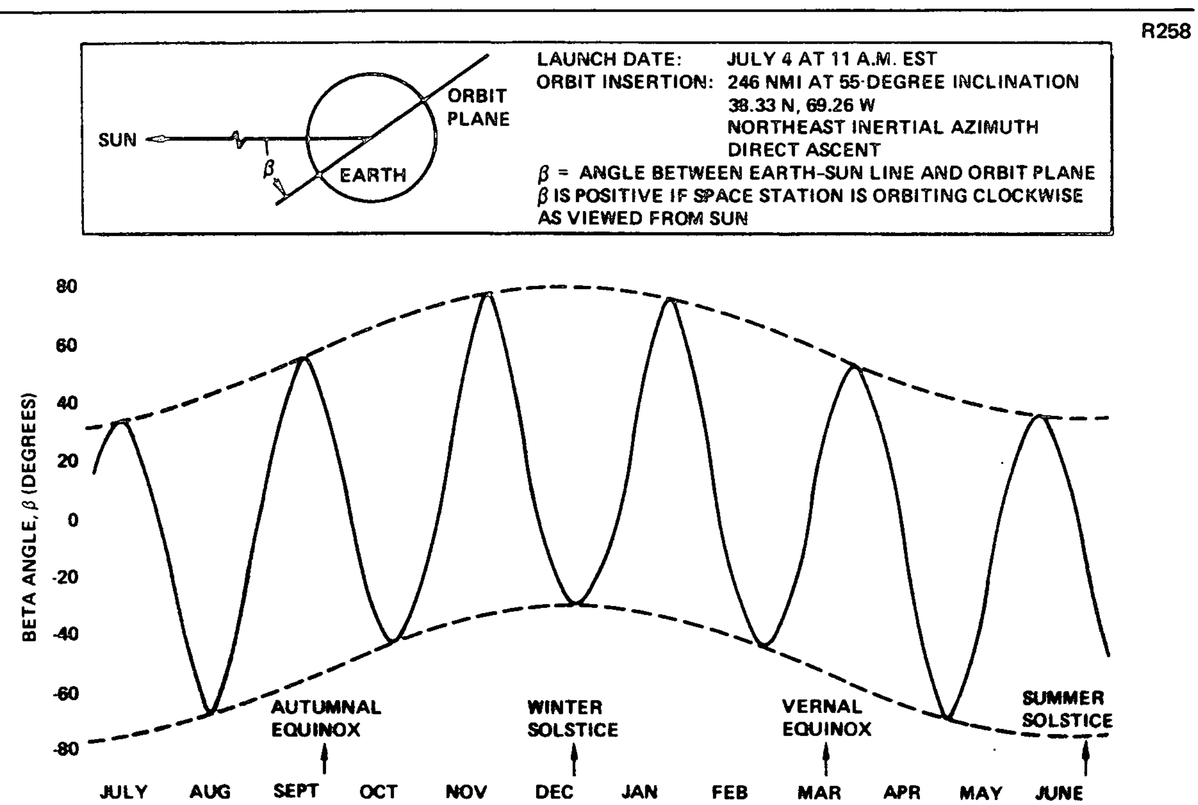


Figure 3-34. Beta Angle History

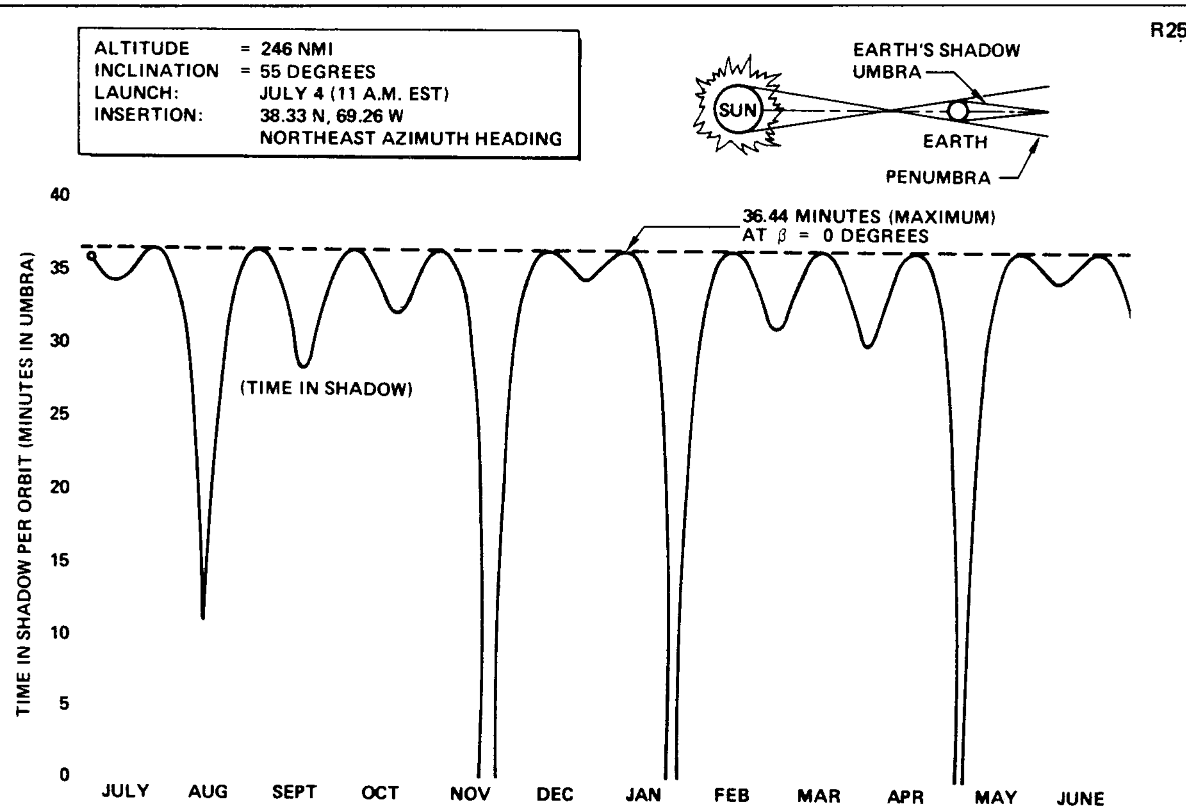


Figure 3-35. Space Station Time in Earth's Shadow

Figure 3-36 indicates a typical application of the fact that the β angle definition fixes the ground illumination cycle for earth observation experiments requiring a specified sun angle (α) at the Earth sites. High noon occurs when α is 90 degrees.

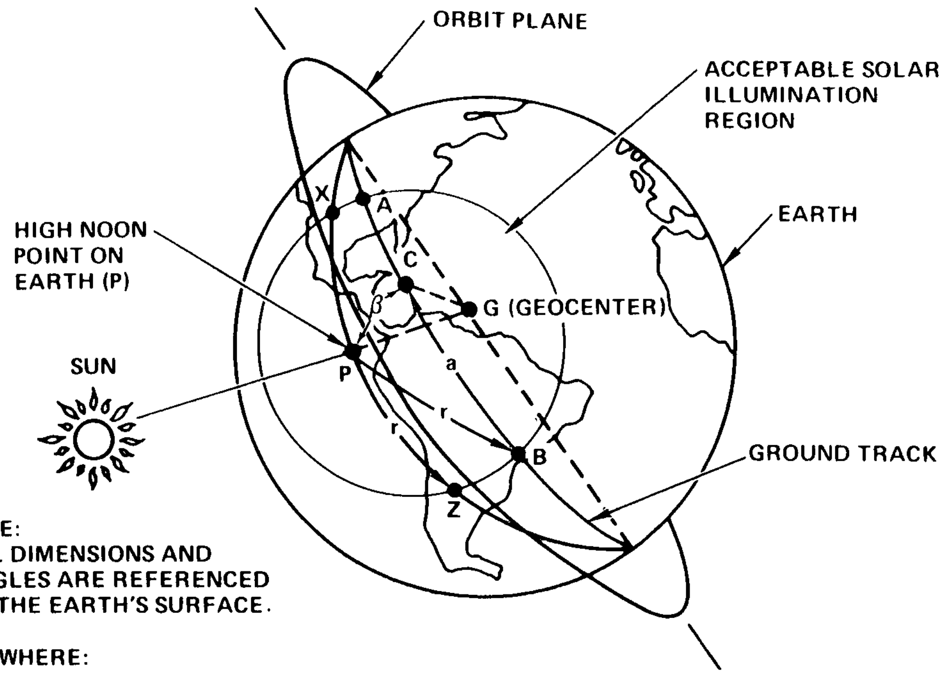
Figure 3-37 provides data that define the duration that the ground track below the space station is illuminated, as a function of β angle taken from Figure 3-34. The data in Figure 3-37 show, for example, that a ground track illumination with a sun angle greater than 30 degrees (typical viewing constraint for geological and geographical mapping, and for mineral and petroleum surveys) is possible for a maximum of 31.2 minutes per orbit, 13 times a year, for periods of one to three days. Figure 3-37 also shows that the ground track is not illuminated with a sun angle of 30 degrees or greater four times per year for periods of eight to ten consecutive days. It may be also noted that the yearly average opportunity for the 30-degree sun angle is 24 minutes per orbit. Sun angles of 60 to 90 degrees are considered typical viewing constraints for crop identification, and for timber and rangeland surveys.

3.5.3 Astronomy

This subsection summarizes some of the more pertinent aspects of the natural orbital environment that may degrade scientific equipment and limit the performance of astronomy observations, and presents some astronomical viewing considerations that may affect experiment design.

3.5.3.1 Natural Optical Environment

Part of the natural optical environment is produced by airglow and aurorae from the earth, earthlight, moonlight, and zodiacal light. All of these functions vary with the time, position, and direction of interest. The interstellar gas absorbs radiation from stars at discrete wavelengths (spectral lines), principally in the visible and ultraviolet bands, and produces continuous absorption shortward of 912 Å. Interstellar dust scatters stellar radiation, resulting in increasingly strong continuous attenuation from the near-infrared to the ultraviolet wavelengths. Neither the dust nor gas has any measurable effect on solar observations, but the attenuation of ultraviolet radiation from all other stars by the dust and hydrogen Lyman lines (1,216 Å to 912 Å) and the continuum (less than 912 Å) is expected to be



NOTE:
ALL DIMENSIONS AND ANGLES ARE REFERENCED TO THE EARTH'S SURFACE.

WHERE:

α = SUN ANGLE ON THE GROUND (SUN ELEVATION FROM HORIZON)

θ_{AB} = GROUND TRACK RANGE OVER ACCEPTABLE ILLUMINATION REGION (60 NMI PER DEGREE)

β = BETA ANGLE BETWEEN EARTH-SUN LINE AND ORBIT PLANE

θ_{XZ} = SOLAR ILLUMINATION REGION WITHIN SPECIFIED SUN ANGLE (2r)

r = RADIUS OF ILLUMINATION REGION MEASURED FROM SUBSOLAR POINT P ($90^o - \alpha$)

a = HALF OF GROUND TRACK (θ_{AB}) MEASURED FROM POINT C

$$= \cos^{-1}\left(\frac{\cos r}{\cos \beta}\right)$$

ΔT_{AB} = DURATION OF COVERAGE FROM ORBIT OVER ILLUMINATED GROUND TRACK

$$= \frac{2a}{\dot{\theta}_{ORBIT}}$$

$\dot{\theta}_{ORBIT}$ = ORBITAL REVOLUTION RATE ($360^o/\tau$), WHERE τ = ORBIT PERIOD (AT 246 NMI ALTITUDE, τ = 93.5 MINUTES, $\dot{\theta}_{ORBIT}$ = 3.85 DEGREES PER MINUTE)

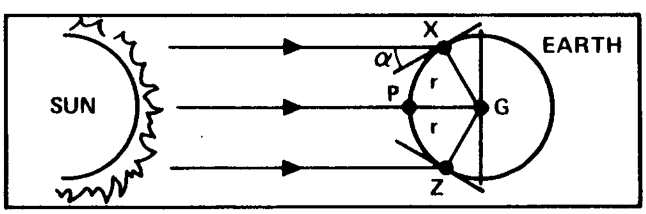


Figure 3-36. Ground Track Illumination Geometry

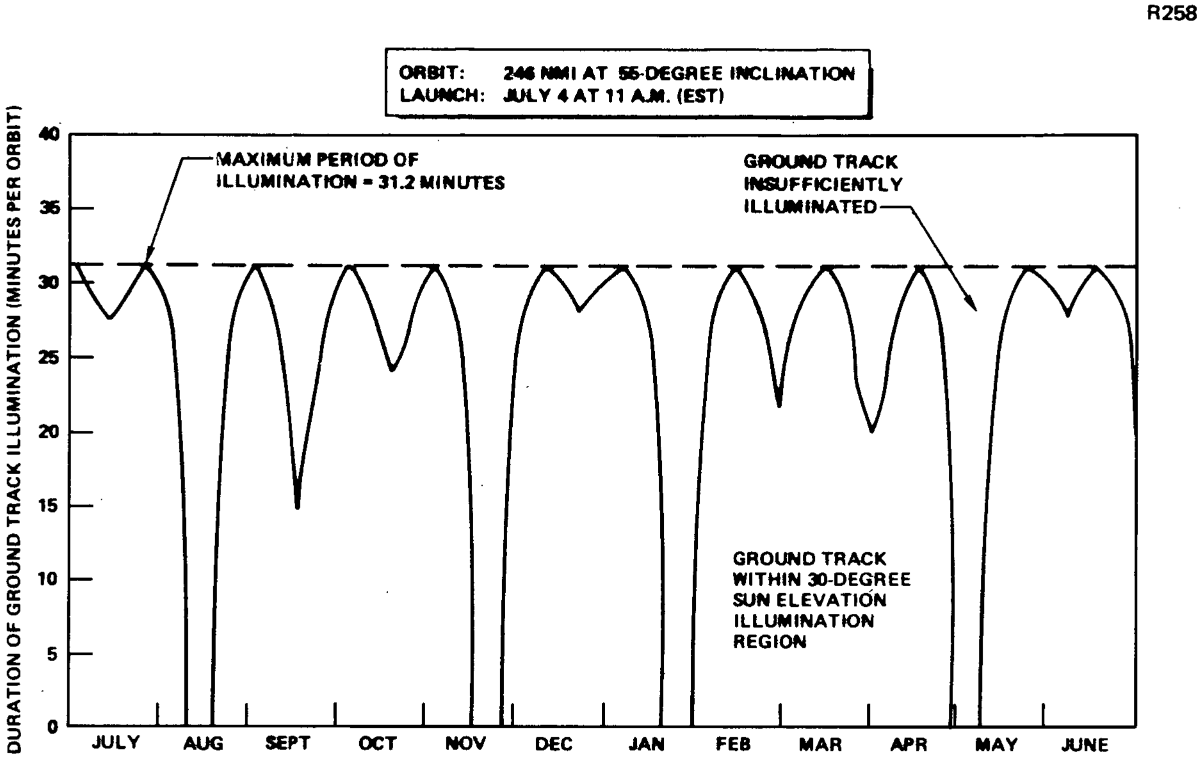


Figure 3-37. Typical Illumination Time History

significant in low-level stellar observations for those measurements in which the star, sky, and ambient noise combine to approach the energy level of the target object.

Airglow, aurorae, and zodiacal light are diffuse sources and, as a whole, have a relatively high background energy level in certain parts of the sky. As this light can be seen by the human eye, its integrated level is less that a +6 magnitude star. However, as a diffuse source, its unit energy (energy per square degree) is exceedingly small—less than a specular (star) source of +26 mv. This is a ratio between diffuse and specular energy levels of at least 10^8 times, and in most cases, stellar observations at a reasonable angular distance from the sun (10 degrees or greater) will be essentially unaffected by these "noise" sources. For long exposures, surveys (imagery covering large sections of the sky), and nonvignetted optical apertures, these sources and their effects on the final result must be considered.

Since most of the airglow, aurorae, and atmospheric attenuation, together with the possibility of liminance from meteor showers, occur at altitudes below 200 km, observation of stellar objects should be limited to horizon elevations from orbit that do not penetrate the atmosphere below that altitude. For the space station mission scheduled for 445 to 500 km (240 to 270 nmi), the zodiacal and coronal light, earthshine, moonlight, and possible occasional auroae will have significant effects on the background brightness. Radiation flux levels in the day and night skies from various sources are shown in Table 3-10 for comparison. During the daylight portions of the orbit, the zodiacal and coronal light will be the major natural contributors to background light. During the nighttime portions of the orbit, the zodiacal light (elongation will be greater than 90 degrees) will be important. Regions of interest will be beyond the umbra of the earth [more than 1,600,000 km (860,000 nmi)] and will therefore be in sunlight for nighttime observations. Lesser, though still significant, nighttime contributors to background brightness will be earthshine, moonlight during the brighter phases of the lunar cycle, and occasional aurorae.

3.5.3.1 Visibility of Celestial Objects

Some astronomy observations require visibility of the whole celestial sphere. Gamma, x-ray, ultraviolet, infrared, and radio-wave measurements of the entire sky are desired to prepare maps of each region for the whole electromagnetic spectrum. Observational requirements for our solar system range

Table 3-10

RADIATION SOURCES IN THE DAY AND NIGHT SKIES

Source	Flux (ergs cm^{-2} sec^{-1})
Sun	1.4×10^{6}
Full moon	$3,000 \times 10^{-3}$
Total starlight	1.8×10^{-3}
Airglow (visible)	16.0×10^{-3}
Infrared	19.0×10^{-3}
Lyman α (1,216 Å)	10.0×10^{-3}
Celestial sources (1,230 to 1,350 Å)	0.1×10^{-3}
Cosmic rays	3.8×10^{-3}

from durations of a few seconds up to hours for the planets and hundreds of days for the sun. These objects all lie near the ecliptic plane and define a band of interest on the celestial sphere.

A map showing the celestial sphere as it would appear from a geosynchronous orbit (35,748 km (19,323 nmi) altitude) and a typical space station orbit (456 km (246 nmi) altitude) is shown in Figure 3-38 with the ecliptic and galactic planes plotted on it. Also indicated on this figure are some star clusters, associations of interest, and the distribution of the Milky Way.

The remaining observations do not specify a particular star or object, but rather classes of objects. In general, these classes can be categorized as best observed either near the galactic plane or removed from it because of attenuation of electromagnetic radiation by intergalactic dust and hydrogen:

Near Plane of the Galaxy	Away From Plane of the Galaxy
Population I stars of the galaxy	Globular clusters
Open clusters	Galaxies
Novae	Quasars
X-ray sources	Halo (Population II) stars of the galaxy
Diffuse nebulae	Galactic corona
Interstellar dust	Pulsars

In performing astronomy observations from the space station, it is important to know the availability of objects for viewing. To determine representative availability, some 36 stars located within 20 degrees of the galactic plane were chosen for an observation program. An apparent solar occultation diameter of 60 degrees was also assumed. Figure 3-38 shows the locations of these stars and the sun. A computer simulation then examined star occultations during one complete orbit. The simulated orbit was at a 50-degree inclination and 370 km (200-nmi) altitude, with the ascending node initiated at 12:00 noon solar time on May 28. Eight stars were occulted by the sun, 35 were occulted for various periods by the earth, and one (Deneb) was visible continuously during the orbit, as can be seen from Figure 3-38.

R258

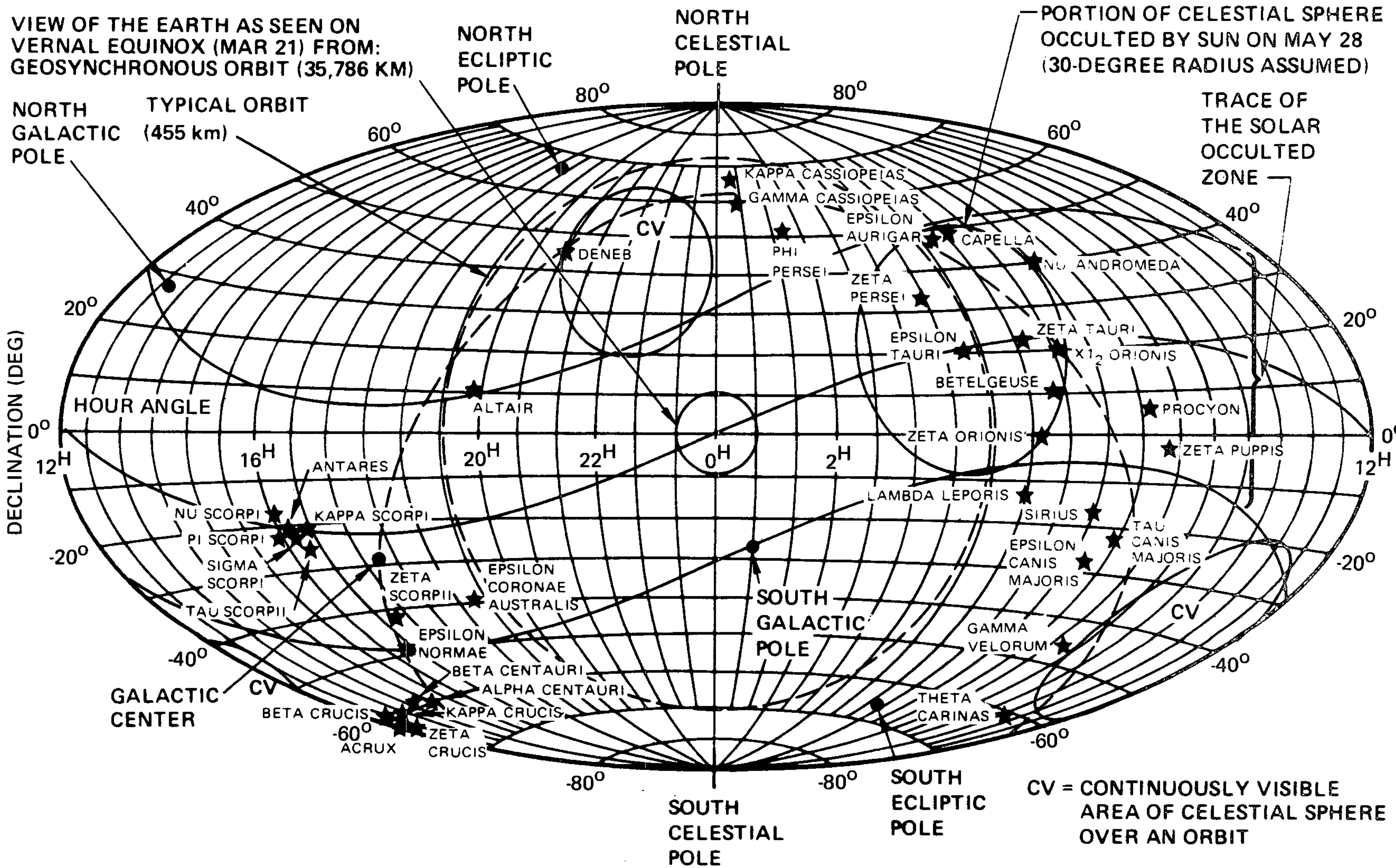


Figure 3-38. Celestial Sphere, Showing Some Areas of Interest

The average number of stars visible from particular star groupings is plotted in Figure 3-39.

Although all the celestial sphere is of interest, particularly the ecliptic plane and the plane of the galaxy, generalizations regarding observation-time opportunities are invalid because times for each observation-object combination must be determined separately.

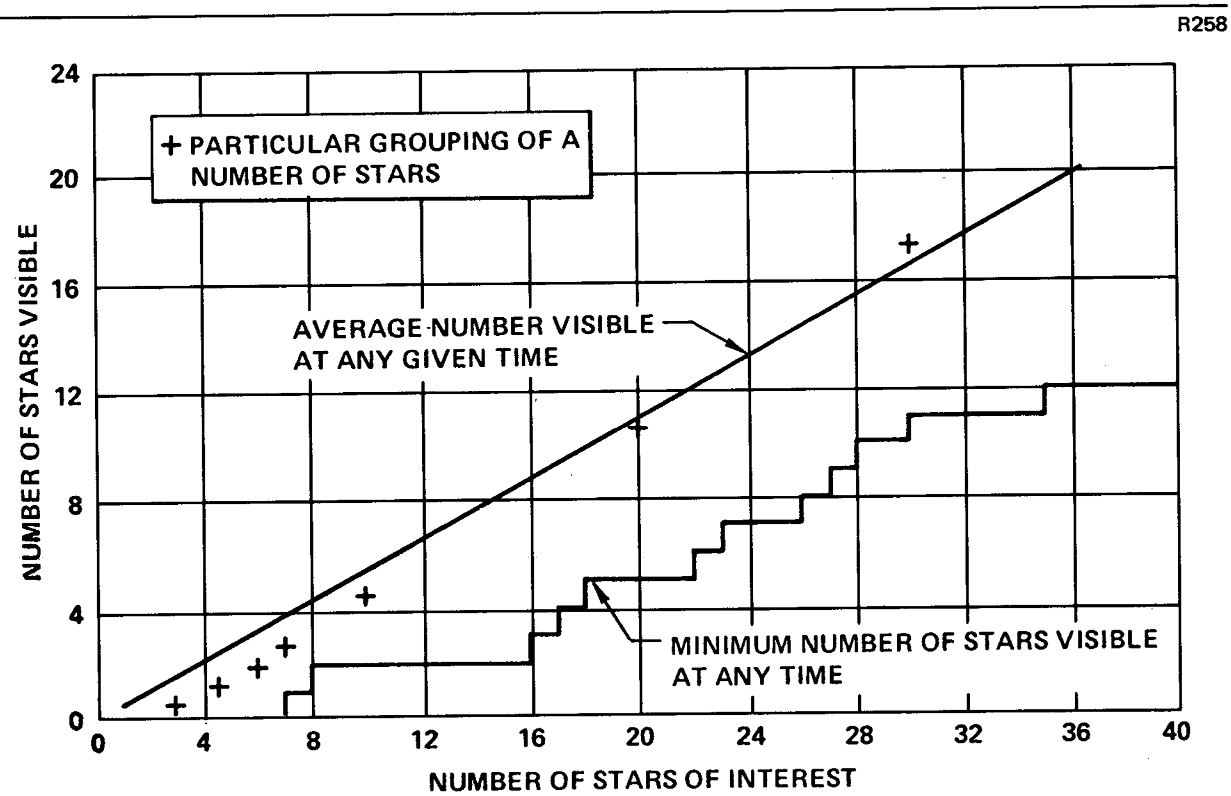


Figure 3-39. Star Availability

Section 4
USER PARTICIPATION

Prediction of the method of "doing business" in the 1980's is at best speculative, but some significant changes from the current procedures that have evolved over the period of manned space flights are apparent. These trends to streamline operations will result, in part, from the availability of low launch cost reusable launch vehicles coupled with on-orbit manned access and control of experiments.

Some of the candidate methods to take best advantage of the new capabilities include methods to:

A. Establish and maintain firm flight dates.
B. Solidify the space station design prior to issuing announcement of flight opportunity.
C. Hold experiment schedule from proposal to launch to 2 to 3 years; less if hardware is already available.
D. Define a minimum documentation tree (with content) at start.
E. Minimize length and distribution of documentation
F. Develop an accurate understanding of experiment design, cost, schedule, and data management requirements prior to final approval of experiment.
G. Publish and enforce control specifications.
H. Establish and hold standard interfaces.
I. Centralize responsibility and control of orbital facilities at discipline-oriented NASA centers with overall Space Station program control and coordination at NASA Headquarters.
J. Let the experimenter team retain responsibility for experiment success.
K. Not treat experiment as flight critical unless crew safety is affected.
L. Minimize hardware turnover between organizations.

The goal of these changes will be to provide increased experimenter involvement and responsibility, lower total cost, less documentation, fewer test articles and qualifications tests and shorter span times between the proposal and flight.

This section describes how these trends influence the investigator's involvement in the space station program from the proposal through operation of the experiment. Emphasis is placed on the scientific and R&D missions that will be the first to fly and have been studied in the most depth. Most of these scientific and R&D experiments will be conducted either in the GPL or in discipline-oriented experiment modules.

The GPL will support a wide range of carry-on experiments with the array of support equipment, scientific airlocks with boom-deployed platforms, and an isolation cell as described in subsection 3.1 of this manual. The discipline-oriented modules will provide national facilities equipped with a basic core of hardware that give a nucleus to be used with the investigator's specialized experiment hardware. Several examples include:

A. A module supporting the primary optical train of a 2 to 3 meter diffraction limited telescope.
B. An Earth-survey module with a basic sensor group and tracking telescope mounted on a large gimbal platform retractable into a pressurizable chamber.
C. A bioscience module with environmentally isolated subject holding facilities, an array of analytic equipment, and other laboratory hardware.

As hardware designs and data reduction capability progresses to the degree required for operational systems, users (other than the research scientist and development engineer) will assume a greater involvement in orbital facility development and utilization. The full potential of the Space Station will support a wide spectrum of users, including:

A. Scientific community.
B. US Government agencies.
C. International participants.
D. Industry.

Where the foregoing organizations need an entire module, the split of responsibility between NASA and the user will be defined in a Joint Operating Agreement. The working arrangements will result in alternate implementation techniques such as:

A. Joint NASA/user management team responsibility from design through data reduction.

B. User development, building and operation of the module with NASA liaison for technological information and interface requirements.

4.1 PAYLOAD SELECTION

Payload selection will be accomplished in several different ways, depending on the user financial support and responsibility. For example, the USAF or an industrial user who pays for the module will control the payload selection, subject to overall Space Station interface compatibility and safety. Ad hoc NASA steering committees will select the payloads of NASA-funded modules.

This subsection outlines a candidate procedure for the GPL and national facilities for scientific and R&D experiments. Proposals to use these facilities will be formally solicited by Announcements of Flight Opportunity (AFO's) starting in the late 1970's. Announcements will be made in both business and scientific journals to obtain wide dissemination. At that time, designs and schedules will be available for the Space Station, GPL, and the particular discipline-oriented modules associated with the AFO's. The accurate knowledge of the interfaces with these systems will greatly reduce subsequent experiment modifications.

The AFO's will typically include information on:

A. Organization and submission of the proposal.

B. Facility objectives, observational opportunities, and mission schedules.

C. Module interfaces.

D. Basic core experiment hardware, support equipment, and other resources available.

E. Launch and orbit environments encountered.

F. Qualification, reliability, and test requirements.

Much of the detailed information needed by the experimenter will be contained in the user manuals for the Space Station and the applicable modules. The latest update of these manuals will be supplied by the AFO.

Experiment proposals will be submitted to an Experiment Steering Committee composed by NASA and university scientists. When the experiment is approved as a candidate for a Space Station flight, the investigator will receive funding to work with the lead NASA center to prepare an Experiment Implementation Plan (EIP).

The EIP expands the proposal to include:

A. Preliminary designs for high-risk technology identified.
B. Cost and schedules.
C. Experimenter responsibility.
D. Management organization and interfaces.
E. Manufacturing, reliability, safety, and test procedures.
F. Data handling and analysis.

The money and effort expended to obtain accurate data at this point in the program will be a primary factor in meeting the goals discussed at the beginning of this section. Final approval of the proposed experiment will be made by the Experiment Steering Committee, based on this EIP information.

A NASA project scientist will be assigned to represent the experimenter team at the lead center. This will give the investigator representation and liaison in the office of the NASA Project Experiment Manager and in many of the day-to-day meetings where direct experimenter participation is not mandatory.

Where NASA funding is required for development of experiment hardware, NASA will be responsible for the procurement mode. Note that in many cases, the investigator will still be selected to build the hardware.

Documentation requirements will be related to experiment complexity, using the experimenter's formats where possible. A minimum documentation tree will be established and added to only as required for unusual experiment requirements. Documentation will be made as brief as possible and distribution limited to those that have justified need.

4.2 TESTING AND QUALIFICATION

One of the primary advantages of a manned space station program will be the ability to calibrate, maintain, and perform simple repairs on equipment in orbit. These functions, coupled with the possibility of returning experiments for repair or refurbishment on the ground, will relax reliability requirements to a degree consistent with the risk involved. In many cases, the use of high reliability parts and exhaustive qualification testing will not be necessary, allowing the use of only slightly modified "laboratory-hardware". This is consistent with the reduced launch costs that allow greater safety margins resulting in heavier payloads and lower packing densities with lower cost and greater maintenance accessibility. Reliability requirements will be imposed by NASA where there is a potential flight critical condition or hazard to man.

A Flight Integration Tool (FIT) will be available to verify experiment interface compatibility with the module. The ground simulation will be as realistic as feasible, including the computerized checkout systems used in the orbital operation. The FIT for the complete space station will be located at the launch site, but the module FIT's will be located at the lead NASA center for each discipline. This will aid in making easy access to the experimenter and will reduce hardware turnover.

4.3 ORBITAL OPERATION

In most cases, the experiments will be operated by the scientific crew complement of the space station. These crewmen will be trained primarily in a specific discipline, such as plasma physics, and cross-trained to support several other disciplines, e.g., astronomy and cosmic-ray physics. During training, the crewmen will work with the experimenter to ensure that he is an effective on-orbit representative. It will also be possible for the experimenter or nonastronaut representative of the experimenter to come on board for a limited duration, but this procedure will not be the normal operating mode.

The data management activity will be an important input to accurate estimation of overall experiment cost. Early identification of the scope and techniques to be used will be one of the most significant items in the experimenter's proposal.

The investigator will have access to the NASA control center for monitoring operation and obtaining data. Also, where data bandwidth permits economical transmission, remote monitors will be feasible at the experimenters' facility.

Where data is used in an operational system, the data will be supplied to User Data Centers in near-real time for rapid processing. Examples of such data include meterological and oceanographic information.

Near-real time transmission or in-orbit analysis will also be used where data observation or analysis is required for modifying experiment protocol in a timely manner. But where delay in the return of data does not significantly affect the experiment performance, hard data storage and return on the shuttle usually prove superior. This mode will be particularly useful where the experiment contains its own recording media, such as magnetic tape, photographic film, nuclear emulsions or material samples. This use of "carry-off" hard data significantly expands experiment capability. Furthermore, on-board processing and analysis or facsimile transmission will be accomplished for that hard-copy data needed prior to shuttle return. The facilities on-board the Space Station for this processing and interpretation are discussed in the section describing the General Purpose Laboratory.