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SPACE FLIGHT EVOLUTION

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Advanced Systems Analysis Office

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16. ABSTRACT

This report describes a possible comprehensive path of future space flight evolution. The material in part originated from earlier NASA efforts to define a space program in which earth orbital, lunar, and planetary programs are integrated. The material presented is not related to specific time schedules but provides an evolutionary sequence. The concepts of commonality of hardware and reusability of systems are introduced as keys to a low cost approach to space flight.

The verbal descriptions are complemented by graphic interpretations in order to convey a more vivid impression of the concepts and ideas which make up this program.

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PREFACE

This report, which is a set of briefing charts with text, has been prepared to describe the concepts and objectives of an evolutionary space program. With the exception of the early Skylab, the missions presented in this report are not approved but are in various study phases.

Any future mission implementation will certainly change the appearance given to them here; however, text and illustrations attempt to give typical interpretations of future space missions and operations.

ACKNOWLEDGMENTS

Many contributions and suggestions to this report were made by various elements of Program Development and Administration and Technical Services. Without the valuable critiques and comments of numerous individuals, this report would not be as complete and coherent as we hope it to be.

We are especially indebted to the advice and support provided by Dr. W. R. Lucas, Director, Program Development. Mr. W. G. Huber, Director, Advanced Systems Analysis Office, provided encouragement, guidance, and support during the entire program analysis phase and preparation of this report. Their guidance and support made this report possible.

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Recognition should also be given to the many illustrators who made significant contributions to the graphic portion of the report. Special recognition should be given to Mr. E. D. Cagle for his unique and creative contributions in chart definition and overall supervision, and to Mr. H. R. Melson of RCA for his untiring effort in chart layout and coordination of visual aids.

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INTRODUCTION

The many achievements of the space program during the decade of the 1960's culminated in the realization of one of man's greatest dreams: landing a man on an extraterrestrial body and returning his safely to this planet. The successful flight of Apollo 11 was the beginning of the exploration and exploitation of our solar system for the benefit of mankind. The nation now has the opportunity to capitalize on its space investment and continue a program that will maximize the practical benefits of space applications.

The information presented herein describes an integrated space flight program for the future which will accomplish recognized goals and objectives. The thesis of an integrated program is to utilize hardware in multiple applications in order to minimize the number of hardware developments and to reuse all major pieces of hardware for reduction of operational cost. With the experience that has been gained in the Apollo Program, the application of these concepts will permit a bold and aggressive approach to space flight.

APPROACH TO SPACE FLIGHT

The approach used in planning for space flight evolution is shown on the facing page.

The initial activity in both earth orbital and lunar missions will be to emphasize the use of existing Apollo capability for scientific returns as well as establish design and operational requirements for future systems and missions. The dominating criterion in the development of new systems is to reduce the cost of space flight. Progress toward economical space flight can be realized by designing major systems with multiple mission applications and systems of long life which will reduce the types and number of hardware items in the space inventory.

In an evolutionary space program, the evolution of systems and the time phasing of missions are impacted by two factors. It was influenced, first, by the goal of maximizing the benefits returned to mankind from space exploration and, second, by the goal of maximizing the quality and rate of knowledge obtained about the solar system. The secondary goal must be accomplished without compromising the primary goal.

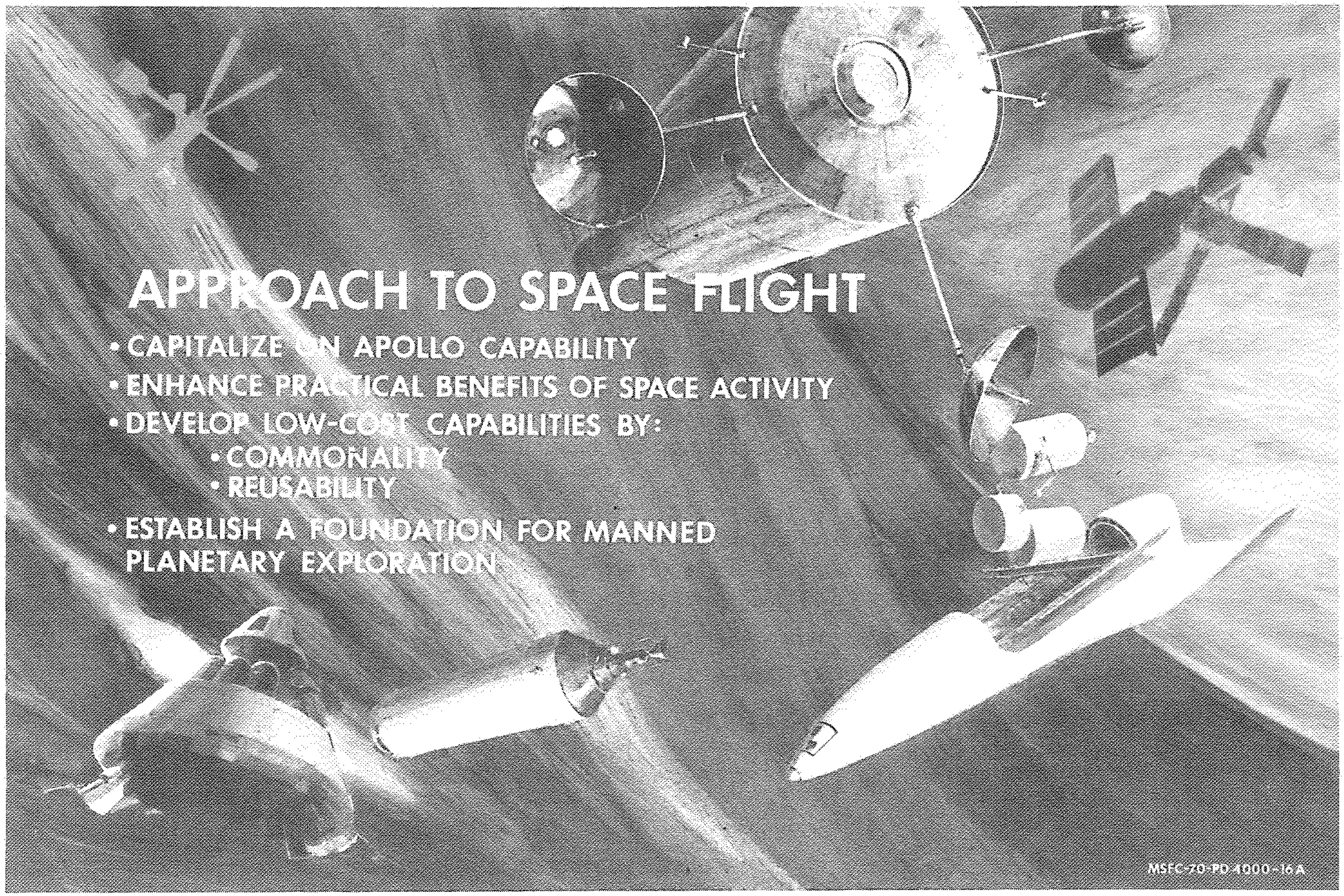

Figure 1. Approach to space flight.

UTILIZATION OF CURRENT HARDWARE

Systems developed and knowledge gained from the Apollo program in the 1960's provide the foundation for extended manned earth orbital and lunar missions with little additional investment.

Commitment of Apollo systems – Saturn V, Command and Service Module, and the Lunar Module – has been made to extend the lunar surface mission duration up to three days. This extended duration will allow astronauts more time to collect samples, make observations, and perform scientific experiments which will, in turn, provide scientists more insight into lunar history and establish operational requirements for more ambitious missions of still longer duration.

A Skylab, derived from Apollo hardware, will be placed in low earth orbit in the early 1970's. Its prime objectives are to establish physiological and psychological data for extended manned space flight missions and to support high resolution solar astronomy at short wavelength that is not directly observable from the surface of the earth. In addition to these two major activities, the Skylab will support a broad spectrum of experimental investigations in other scientific disciplines. Logistics support for the Skylab will utilize the Saturn IB launch vehicle and modified Command and Service Modules.

A second Skylab, utilizing backup hardware, is under study with mission profile and objectives similar to those for the first Skylab. There are, however, two important differences. This later station could have a lifetime of up to 2 years if desired and will make possible the extension of crew staytimes. The data and operational experience gained from these two missions will provide the information necessary to develop a station module with a lifetime of up to 10 years.

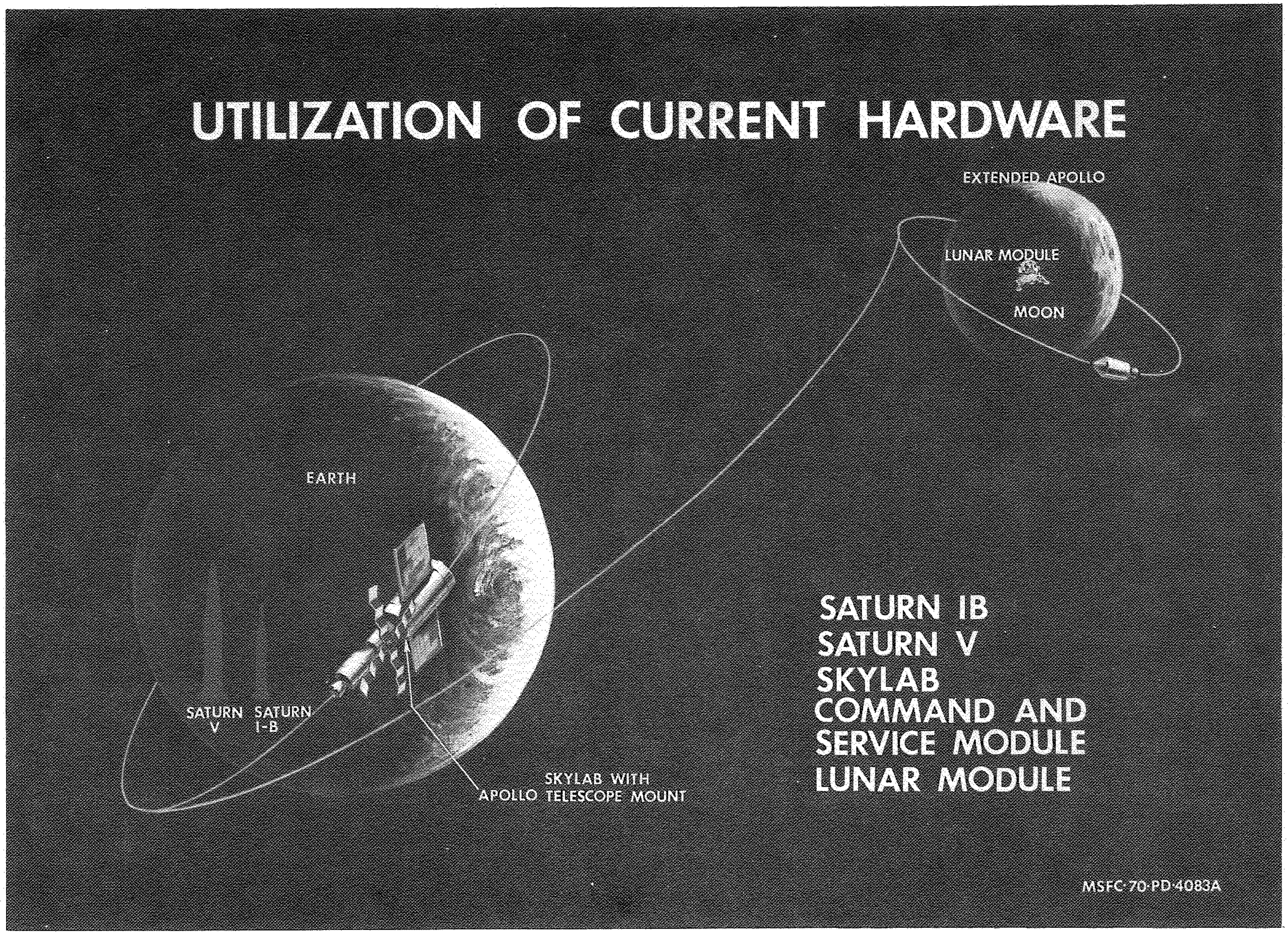

Figure 2. Utilization of current hardware.

SKYLAB

Following the Apollo Program, the Skylab Program is basically structured for extension and utilization of existing Saturn and Apollo systems. The missions planned are designed to accomplish the objectives of extending manned space flight duration to about 2 months and conducting a broad spectrum of experimental investigations.

This illustration shows modified versions of the Apollo CSM and Saturn S-IVB stage, in addition to new hardware such as the Apollo Telescope Mount. Specific objectives of the initial manned phase of the Skylab are: (1) establish a Skylab in earth orbit; (2) conduct a manned flight of up to 28 days duration to evaluate the effects of long duration space flight on the crew and spacecraft; (3) acquire sufficient biomedical data to allow subsequent missions of longer duration; (4) conduct other experiments as assigned; and (5) activate and verify operation of the Apollo Telescope Mount. Subsequent manned revisit missions to the Skylab have specific objectives to (1) visit and reuse the Skylab up to 56 days, (2) use the Apollo Telescope Mount to obtain high resolution solar astronomy data at the short wavelengths not directly observable from the earth surface, (3) obtain biomedical data on effects of long duration space flight, and (4) continue and complete the remaining complement of assigned experiments.

A second Skylab may be equipped with instruments for stellar, X-ray, and gamma ray astronomy; materials and process research equipment; and biomedical and human performance measuring and testing equipment. Crew rotation intervals ranging from 4 to 6 months are expected with nearly continuous manning. A total mission duration between 16 and 24 months could result. During this mission, the fundamental biomedical investigations concerning man's performance and physiological well-being in weightless environment should be completed. Important information concerning the operation of astronomical instruments by man also should be accumulated. This data will be used in the design of astronomical instruments for the space station/space base and geosynchronous station. Consideration is also being given to the feasibility of incorporating artificial gravity investigations in the second Skylab.

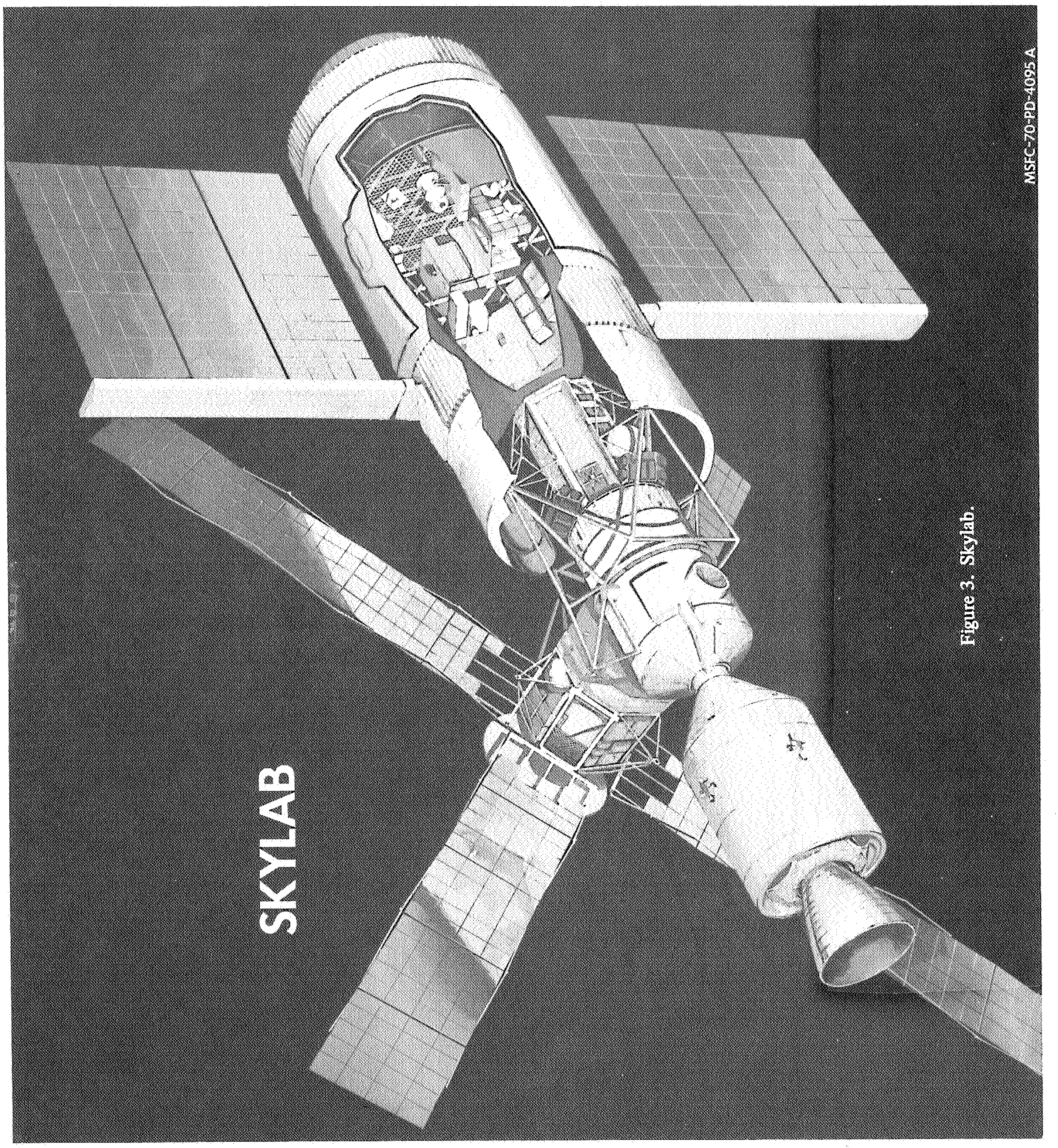

Figure 3. Skylab.

SPACE SCIENCE AND TECHNOLOGY – EARLY PERIOD

The early period will bring significant gains in space science and technology. Investigations will provide fundamental scientific knowledge in many disciplines and, at the same time, yield information necessary for development of sapce systems of the future.

Space observations will involve increasing applications to earth-based problems. Remote sensor development flights will be included for a wide range of potential applications in such areas as meteorology, oceanography, geology, and geography.

Prototype materials processing and manufacturing facilities will be placed in orbit. A wide diversity of technological experiments and developments will be tested to support future operations and systems development. In situ maintenance capabilities will be developed.

There will be a continuing effort to develop appropriate systems and techniques to enable long duration space flights required for manned exploration of the solar system. A program of biomedical and behavioral tests will be conducted on crew members during long duration space tests. Biological investigations on a variety of animals and plants will provide a better understanding of the effects of weightlessness on organisms and will support development of a unifying body of biological theory.

Astronomical systems, which will have the capability of manned service, repair, or refurbishment in space, will be operated in association with the space station. Telescopes will view the sun. Other telescopes will be used to make high resolution studies of Mars and other planets, as well as galactic and extragalactic observations of stars and nebulae.

The lunar exploration program will involve a close coupling between lunar orbit observations and lunar surface studies for obtaining knowledge about the moon – its environment, composition, and surface and subsurface features. Particular emphasis will be on the location of lunar resources, e.g., water, to support future exploration. Roving vehicles having manned and automated capabilities will be used to support the lunar surface exploration program.

The exploration of the solar system will continue with automated probes, orbiters, and landers. Emphasis will be placed on the mapping of Mars and obtaining knowledge about its environment and surface characteristics.

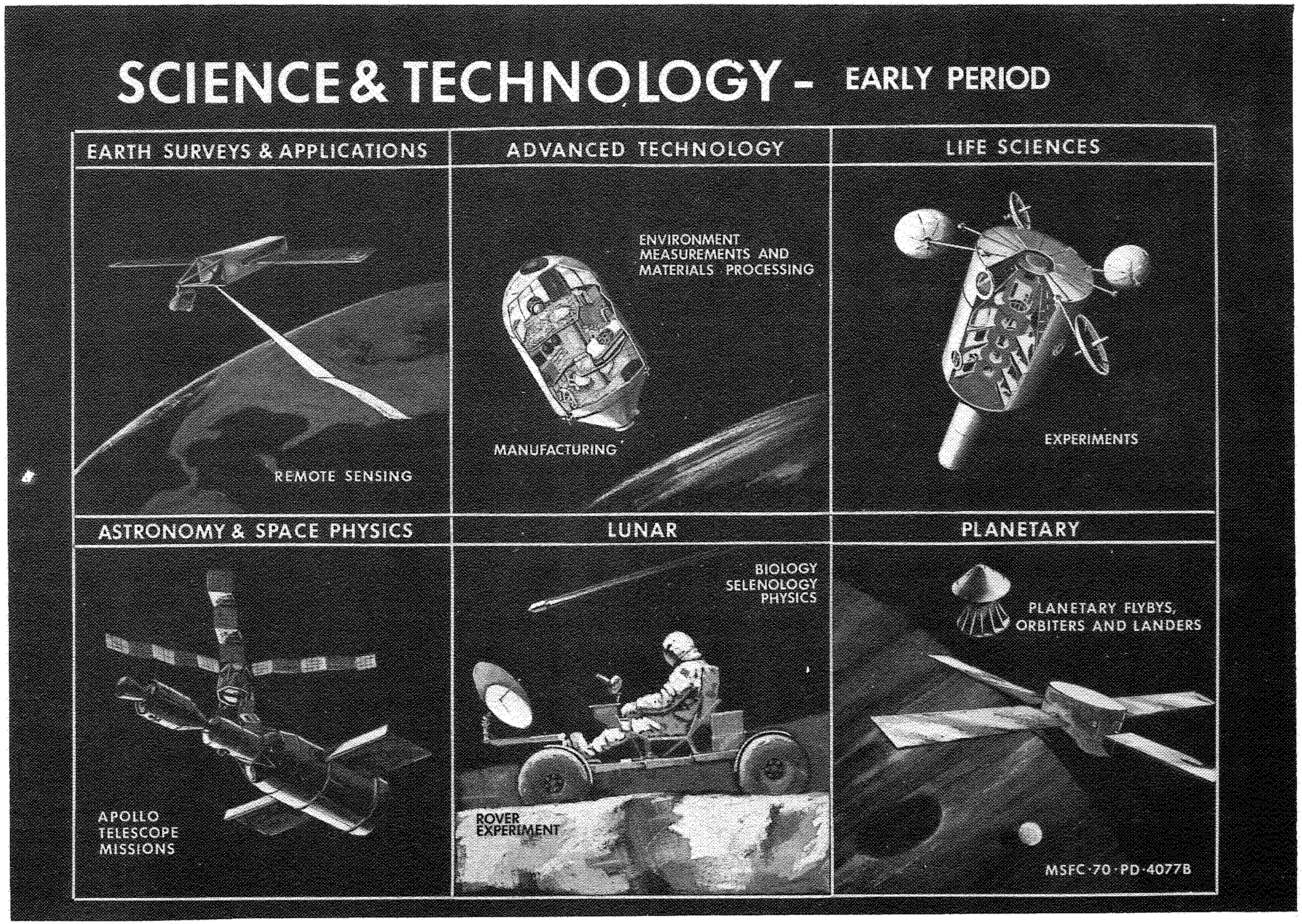

Figure 4. Science and technology – early period.

EARLY NEW SYSTEMS

One of the central objectives of a continuing space program is the development of improved space flight capability on an economical basis. If the nation is to pursue its goal of exploring the solar system, new systems must be developed with improved performance and reduced development and operations costs. These new systems will permit the nation to develop a capability to live and work in the space environment for extended periods of time.

The Skylab mission will do much to determine the characteristics and requirements of follow-on space stations. These stations must provide a living and working environment for 6 to 12 personnel for a decade or more. If the application of the station is to be economical, it must be designed so that it can be utilized in any manned mission of extended duration, be it earth orbital, lunar, or planetary. At a later time, the station would be utilized in both earth orbit and lunar orbit.

In order to reduce the operational costs for these long duration stations, a low cost transportation system must be developed to provide logistic support. At present, it appears that the system most likely to meet the requirements is a totally reusable space shuttle. Although this shuttle would primarily transport passengers, equipment, modules, and supplies to the low orbit space station, it would inherently provide the capability for delivery, inspection, and/or maintenance of automated payloads.

Extension of lunar surface mission duration beyond three days will require an additional new manned system, a space tug. With introduction of the space tug, 14 to 28 day surface missions are possible from the lunar orbit station. In addition to providing lunar orbit to lunar surface transportation, the tug can also be used in earth orbit to support the space station program and to launch and maintain automated satellites and probes.

These systems and missions are explained in detail in the following pages.

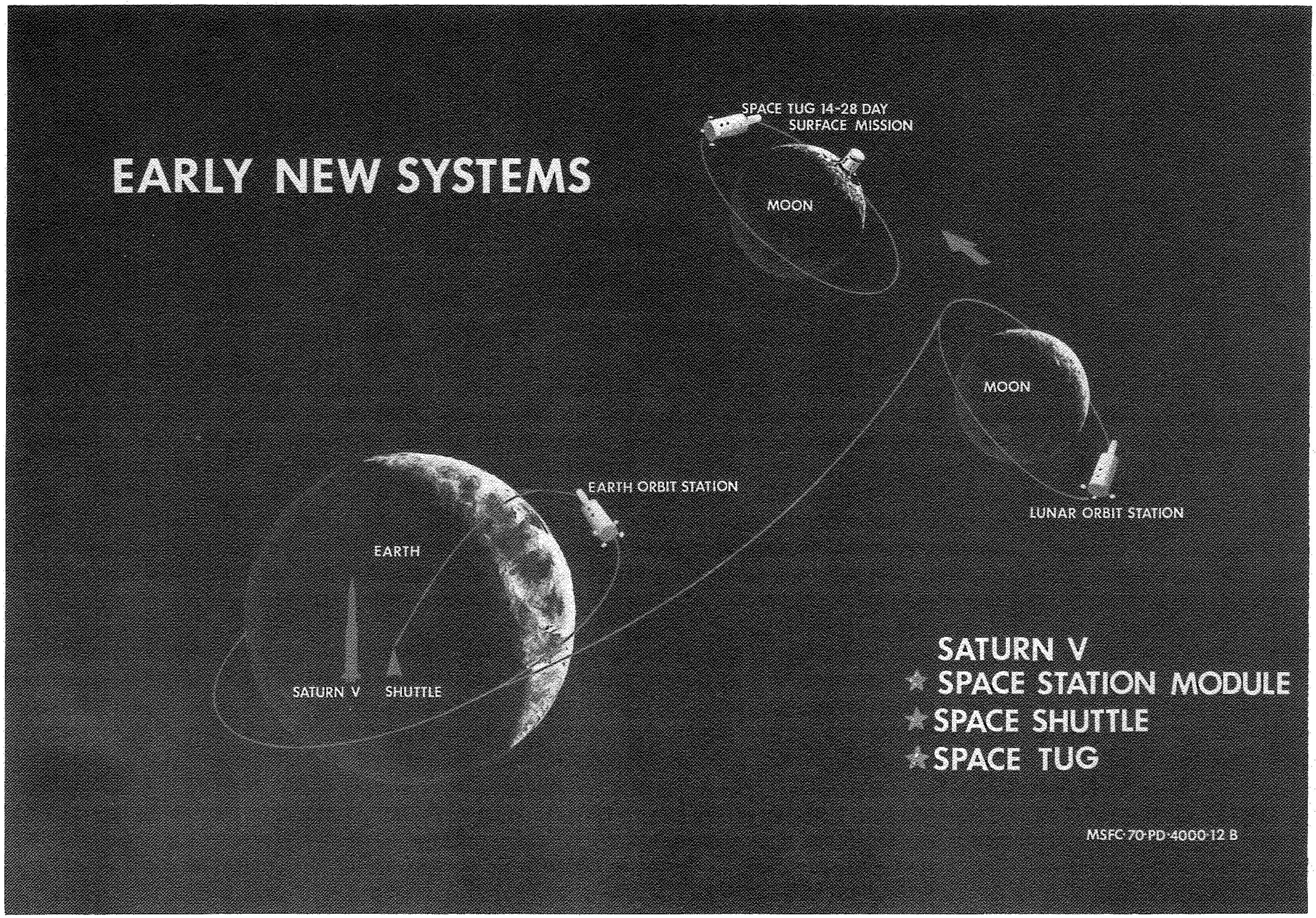

Figure 5. Early new systems.

SPACE STATION

The technologies developed and the extension of man's operational capabilities achieved as a result of the precursor Skylab program will provide a firm foundation upon which an advanced space station program may be initiated in the late 1970's. This space station will provide the next major advance in spacecraft design with new long duration maintainable subsystems capable of operation over a period of ten years in support of a comprehensive scientific, application, technology, and engineering experiment program. Specific objectives of this program are to continue and expand the acquisition of knowledge in the physical sciences, technology, and engineering; the life sciences, biomedicine, and behavior of man; and of man's role in space. Instruments and equipment will be provided for investigating phenomena of interest in a range of fields such as earth resources, oceanology, astronomy, solar physics, pathology, enzymology, botany, physiology, man machine relationships, communications, materials processing, and manufacturing. Integral laboratory facilities and data processing machines will be provided to support the orbital research operations as required. Most importantly, these investigations will be performed directly by skilled scientists and engineers.

While nominally operating in a circular orbit inclined 50 degrees at approximately 270 nautical miles altitude, this multi-purpose module, or portions thereof, will also provide alternate mission applications beyond the 1970's in support of earth orbital synchronous missions, lunar missions, and manned planetary missions. The space station is self-sustaining and will accommodate a maximum operational crew size of 12 to accomplish the planned scientific programs. As these program requirements expand even further, this module may become an integral part of a larger space base research facility. Comfortable crew accommodations, an earth-like atmosphere, and closed-cycle life support systems are provided. Functional elements of the space station include crew habitability and protection, command, control and data management, utility services, and docking/general work provisions. Logistics support for crew exchange and cargo transfer will be provided by the reusable space shuttle. In addition to onboard laboratory facilities, a capability to support separate experiment modules that are hard-docked, tethered, or detached in a station-keeping operating mode is provided. While nominally operating in a weightless mode, provisions for accomplishing an artificial gravity assessment experiment will also be provided.

Autonomy of operation is enhanced by provision of flexible onboard data management and checkout systems, two-way television, multiple voice channels, broad band experiment data transmission, extensive telephone inter-communications, and real-time continuous transmission paths to ground via data relay satellites. This capability provides the mission flexibility required for the wide range of applications planned for this multi-purpose module.

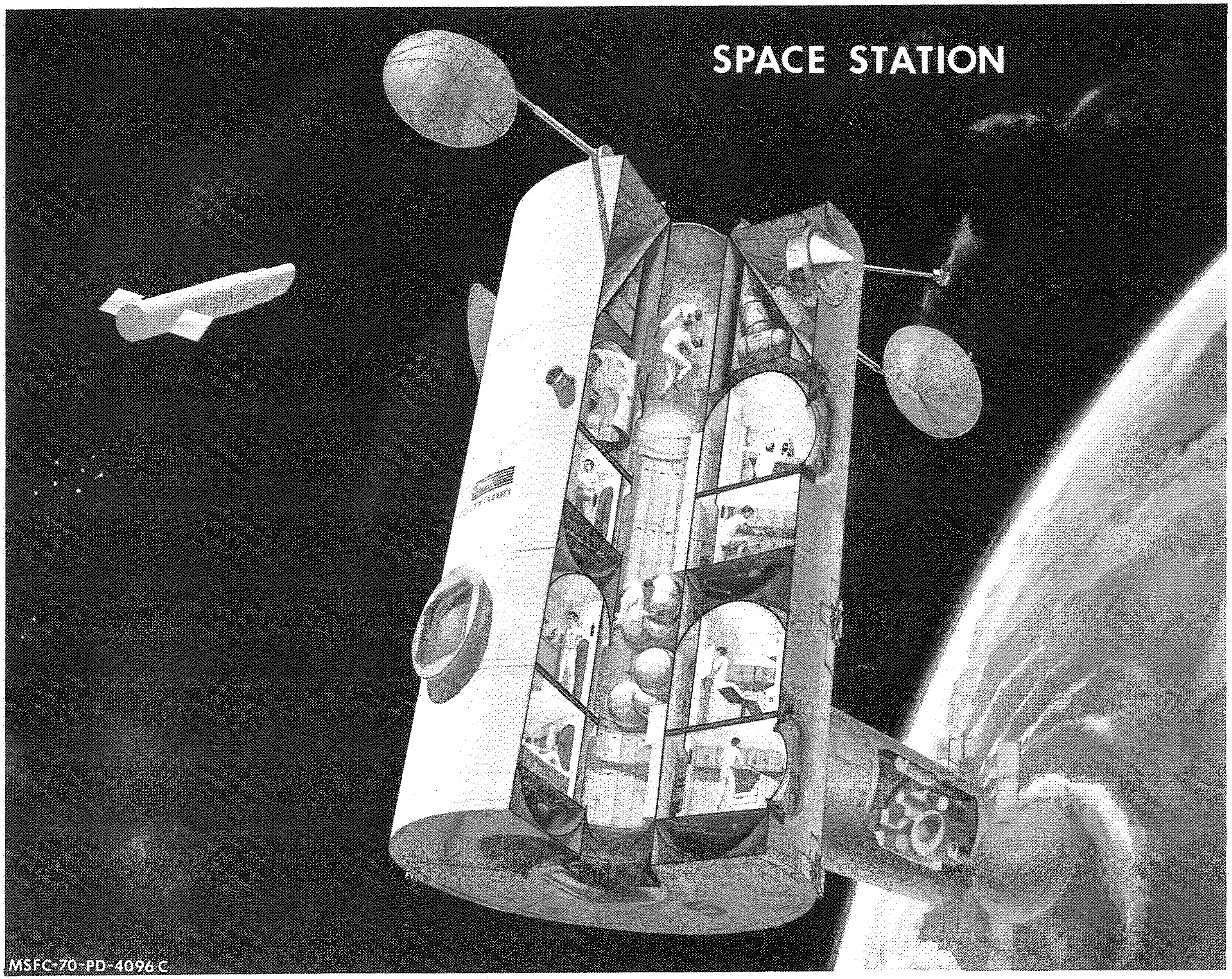

Figure 6. Space station.

SPACE STATION MODULE COMMONALITY

As described earlier, the basic earth orbital space station module, or portions thereof, will be designed to accommodate a variety of alternate mission applications as shown on the facing page. After initial utilization in low earth orbit, the basic common module may be utilized in lunar orbit to conduct extensive lunar orbital science/surveys and to support periodic exploratory landings on various areas of the lunar surface in the next decade. The space tug system will be used to make the landings and will be controlled and be monitored from the lunar orbital station. Later, the common module will be adapted for lunar base applications and delivered to the lunar surface by the propulsion module of the space tug.

Advanced earth orbital usage of this autonomous module will occur in the later period to accomplish selected synchronous orbit missions. As earth orbital mission requirements expand, a multi-purpose, 50- to 100-man space base research facility could be assembled to provide the necessary increased capabilities. The early space station module may become the initial modular element of this facility, which will consist of a number of both space station modules and specialized modules docked together via earth orbital assembly.

Additional applications will include use of the module as a mission module for manned planetary missions.

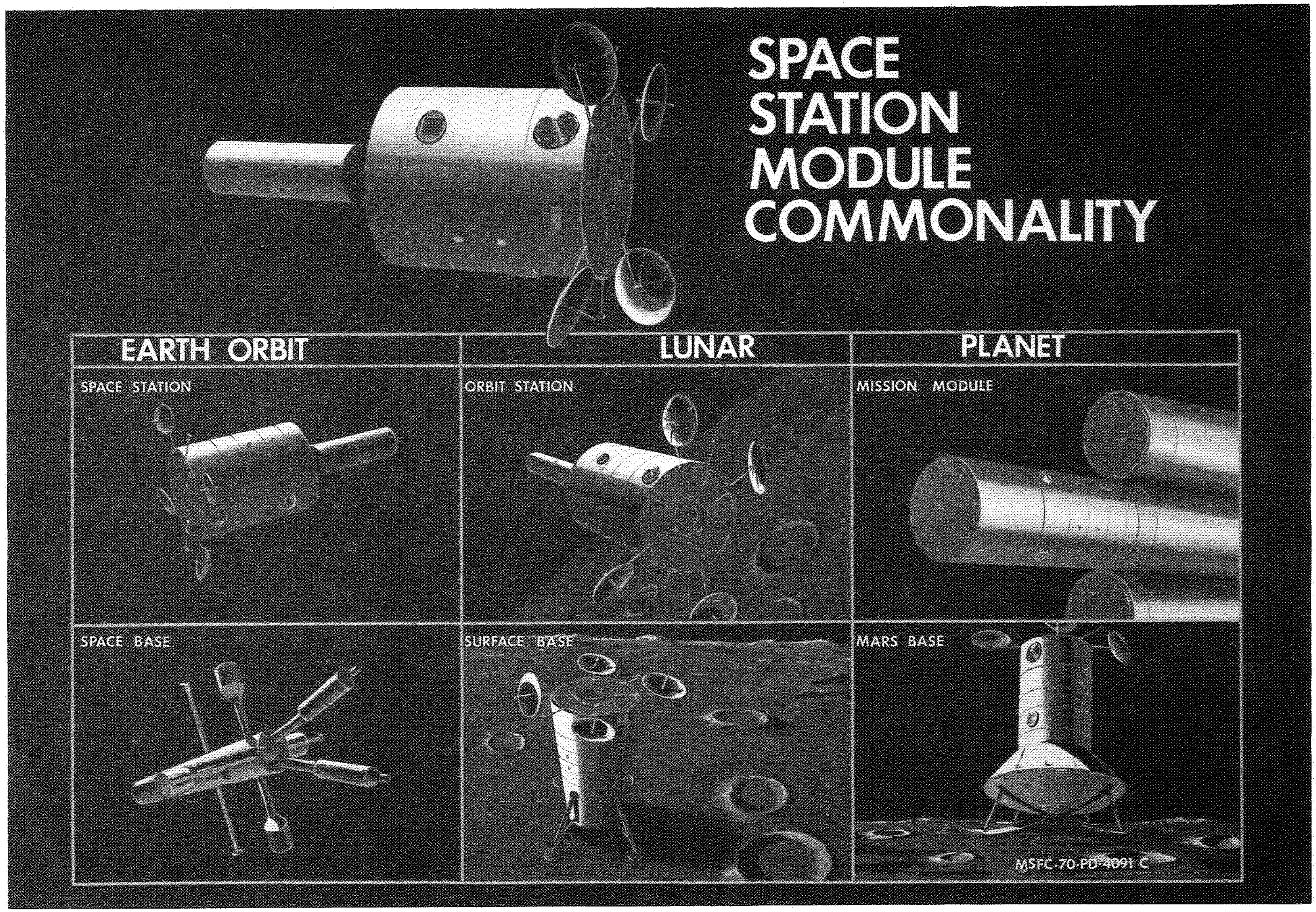

Figure 7. Space station module commonality.

SPACE SHUTTLE LAUNCH

The space shuttle is one of the major elements of the Integrated Program. This system will provide low cost transportation between earth and earth orbit for all personnel and most of the equipment and supplies required by the program. The versatility and economy of this system are obtained by utilizing aircraft design and operations procedures to the maximum extent. This results in a two-stage fully reusable system having long life subsystems, low maintenance and repair, quick turn-around times, onboard checkout and system monitoring, and minimum ground support equipment and personnel requirements. The orbiter is designed for maximum flexibility in accommodating a variety of payload/passenger mixes.

This illustration depicts a typical configuration prepared for launch. As other vehicles are phased out, present facilities can be modified to accommodate this vehicle, or new especially designed facilities can be provided at new launch sites as required.

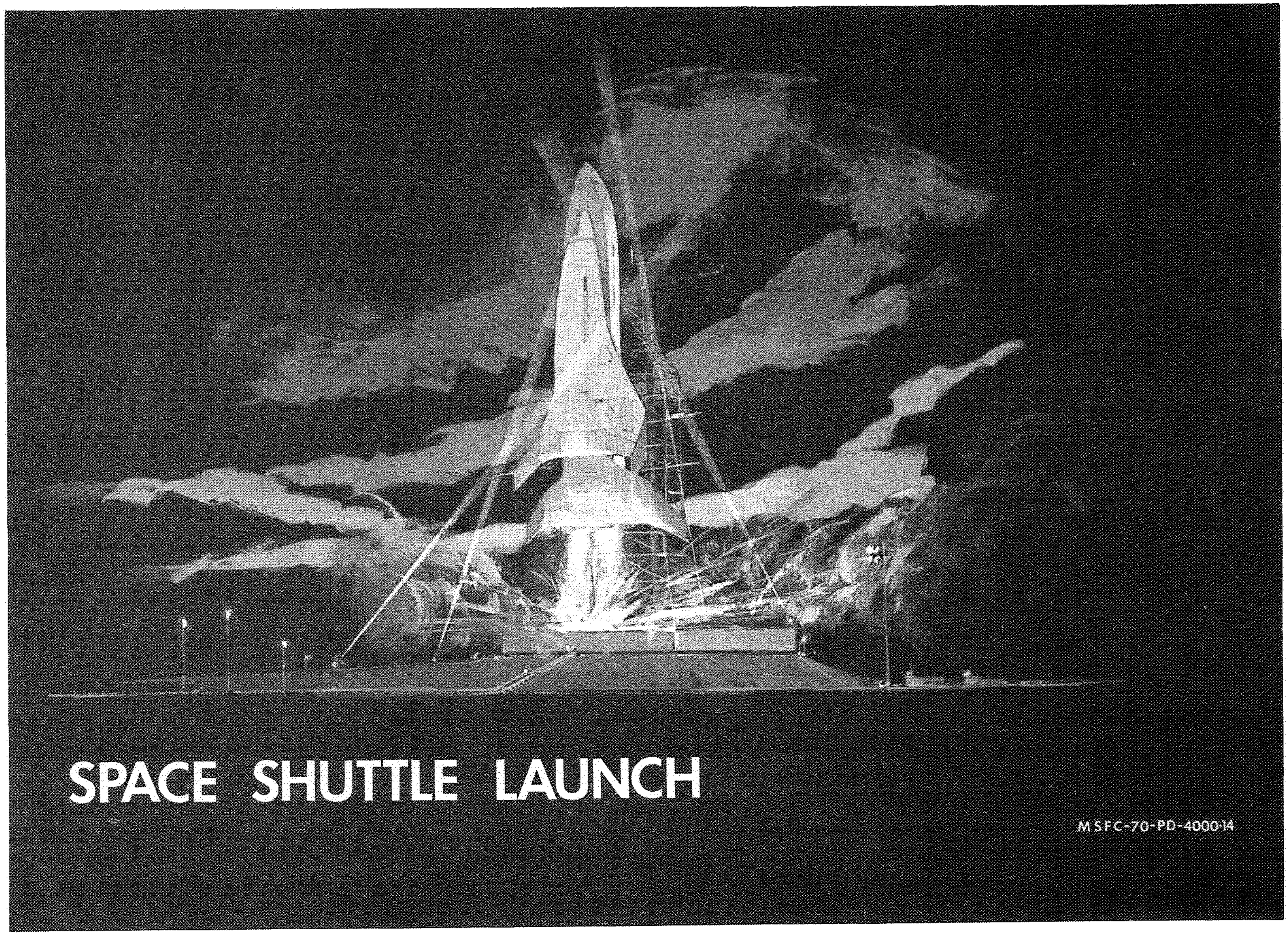

Figure 8. Space shuttle launch.

SPACE SHUTTLE LAUNCH/RECOVERY

Depicted here is the mission profile for the space shuttle. Both stages are powered by advanced oxygen-hydrogen engines and manned by a crew of two to provide the checkout, mission control, and flyback functions.

The booster engines ignite for liftoff. After about 5 minutes staging occurs, and the orbiter engines ignite for injection into an elliptical orbit. At this point, the booster maneuvers for reentry into the atmosphere, and after reaching subsonic velocity air-breathing jet engines are deployed for cruise back to the landing site. After the appropriate orbit phasing is obtained, the engines of the orbiter are restarted to reach the desired point in orbit for payload delivery. After completion of its orbital mission, the engines are ignited again for braking the orbiter for reentry and return to a landing site.

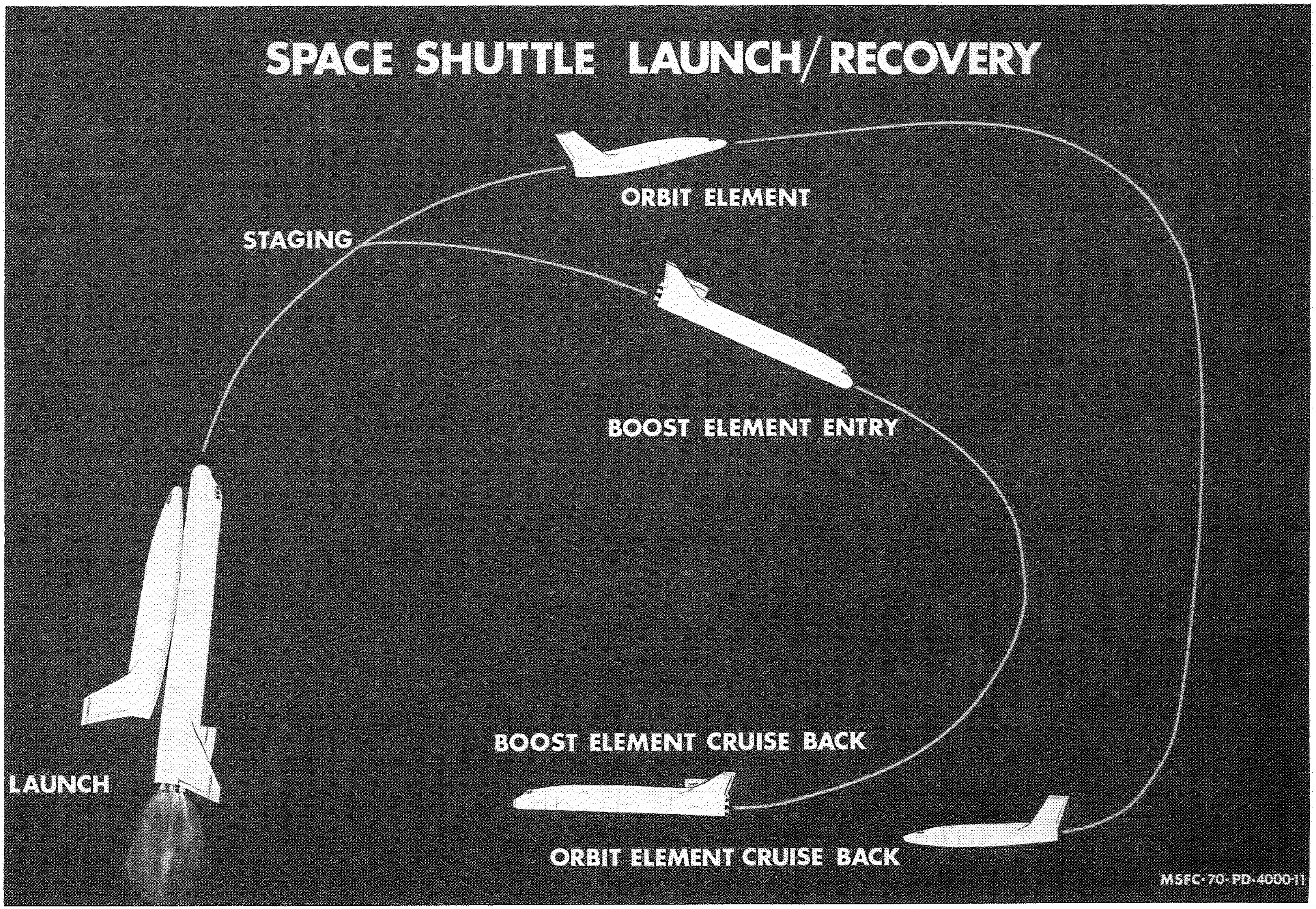

Figure 9. Space shuttle launch/recovery.

SPACE SHUTTLE ORBITER

The orbiting element of the space shuttle is a versatile spacecraft that can conduct various space missions. After accomplishing the desired orbital mission, the orbiter takes on a new payload to bring back to earth or, if the mission dictates, returns with the launched payload. De-orbit maneuvers are performed at the proper point to optimize the reentry trajectory. The orbiter utilizes an onboard guidance system for terminal maneuvers when approaching the landing site. The shuttle is designed so the orbiter can land at numerous airfields throughout the world. The orbiter can ferry itself back to a launch site where, after refurbishment, it can be mated to a booster for another orbital mission.

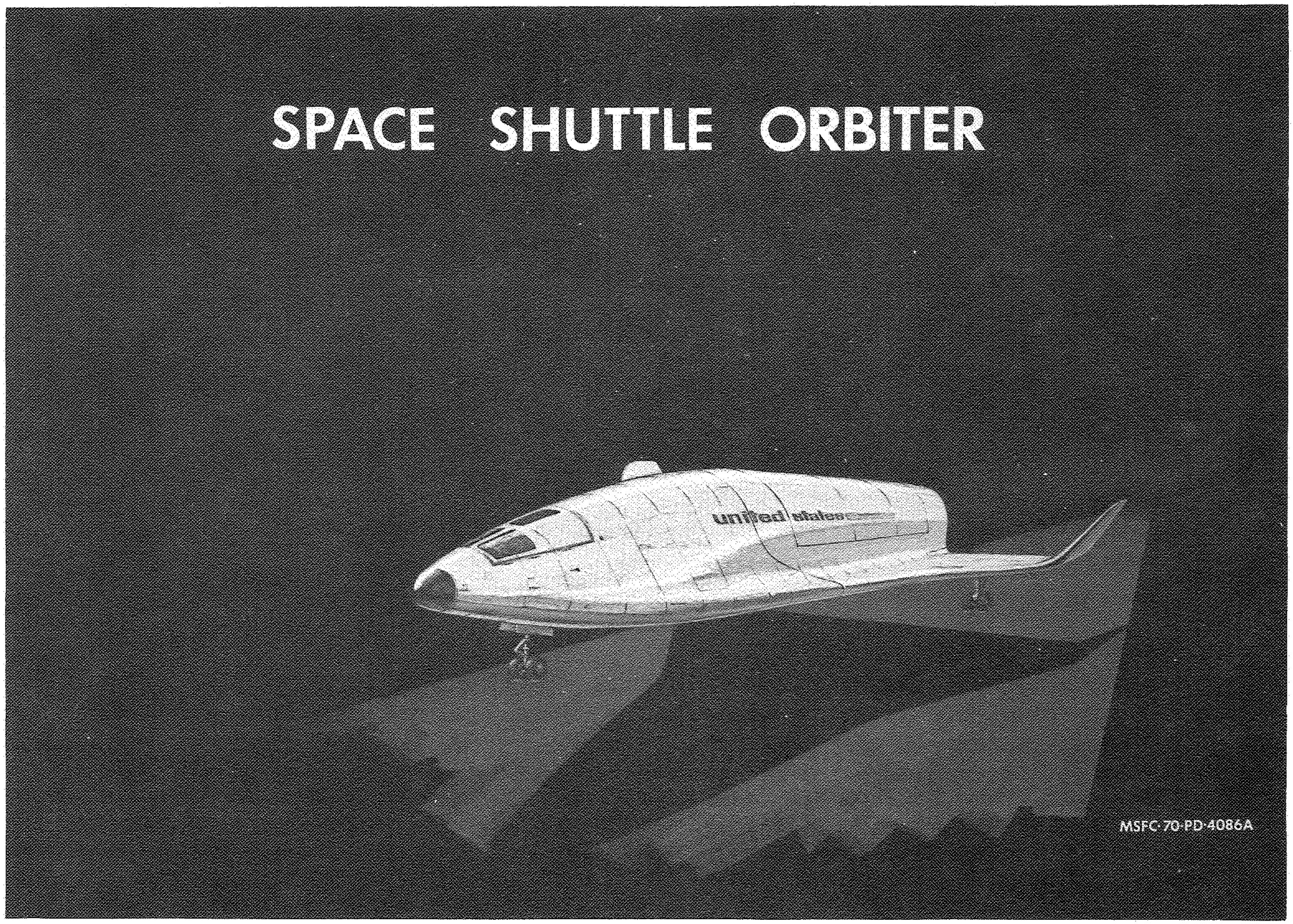

Figure 10. Space shuttle orbiter.

SPACE SHUTTLE APPLICATIONS

The space shuttle is a highly diversified cargo delivery and space operations vehicle. Illustrated on this chart are some of its typical applications:

- Crew transport for space station exchange or to conduct surveillance or other type manned missions on board the orbiter.
- Propellant delivery in transfer containers or tanks for the nuclear shuttle, space tug, or for additional mission propellants for another space shuttle orbiter.
- In-orbit satellite delivery, inspection, repair, or data retrieval.
- Logistics support for the space station.
- Space tug module delivery.
- Delivery of a spacecraft and propulsion stage. After unloading, the propulsion stage would accelerate the spacecraft to meet mission requirements such as an unmanned planetary probe.

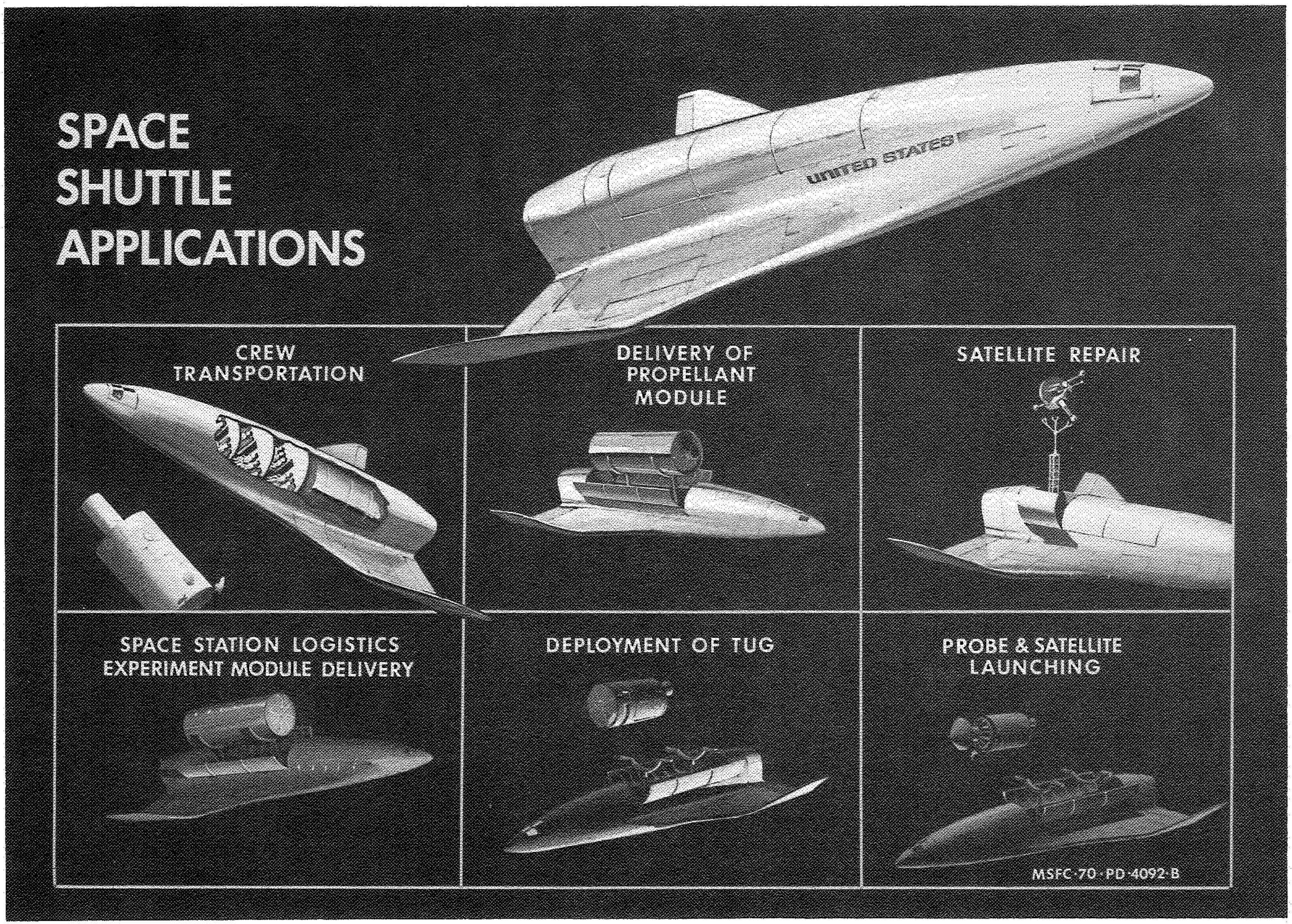

Figure 11. Space shuttle applications.

LUNAR ORBIT STATION

A new mode of lunar exploration will begin with the establishment of the lunar orbit station. The station is established by placing a space station module in polar orbit around the moon. In addition to performing orbital science, this station will make possible the observation and/or visitation of any point on the lunar surface every 14 days. The accomplishment of this mission will require a new system, the space tug, which is comprised of three major elements, a propulsion module, cargo module, and crew module.

A nuclear shuttle vehicle will be the delivery system for all payloads to the moon, both manned and unmanned. An unmanned launch will initiate this operating mode by transporting a space station module into lunar polar orbit at approximately 60 miles altitude. Manned launches will deliver command modules, space tugs, and support cargo to the orbiting station. The command module will be used for earth-to-moon-and-return crew delivery and will be modified to remain at the station for extended periods. The space tug, delivered by unmanned flights, will support the 14- to 28-day surface excursions that are flown from the station. Sufficient nuclear shuttle flights will be made to support the orbiting station and provide approximately six surface visits per year.

The lunar orbit station will provide a station from which many activities can be conducted. Surface roving vehicles will be used during the surface excursions to increase mobility on the lunar surface. Selenological samples will be collected from the surface and analyzed in lunar orbit. During the landings, the first major lunar surface farside radio telescope could be deployed. The polar orbit of the station will make possible the complete mapping and remote sensing of the lunar surface.

At the end of this mode of lunar exploration, enough surface experience will have been accumulated that a lunar surface base can be implemented if it is deemed desirable.

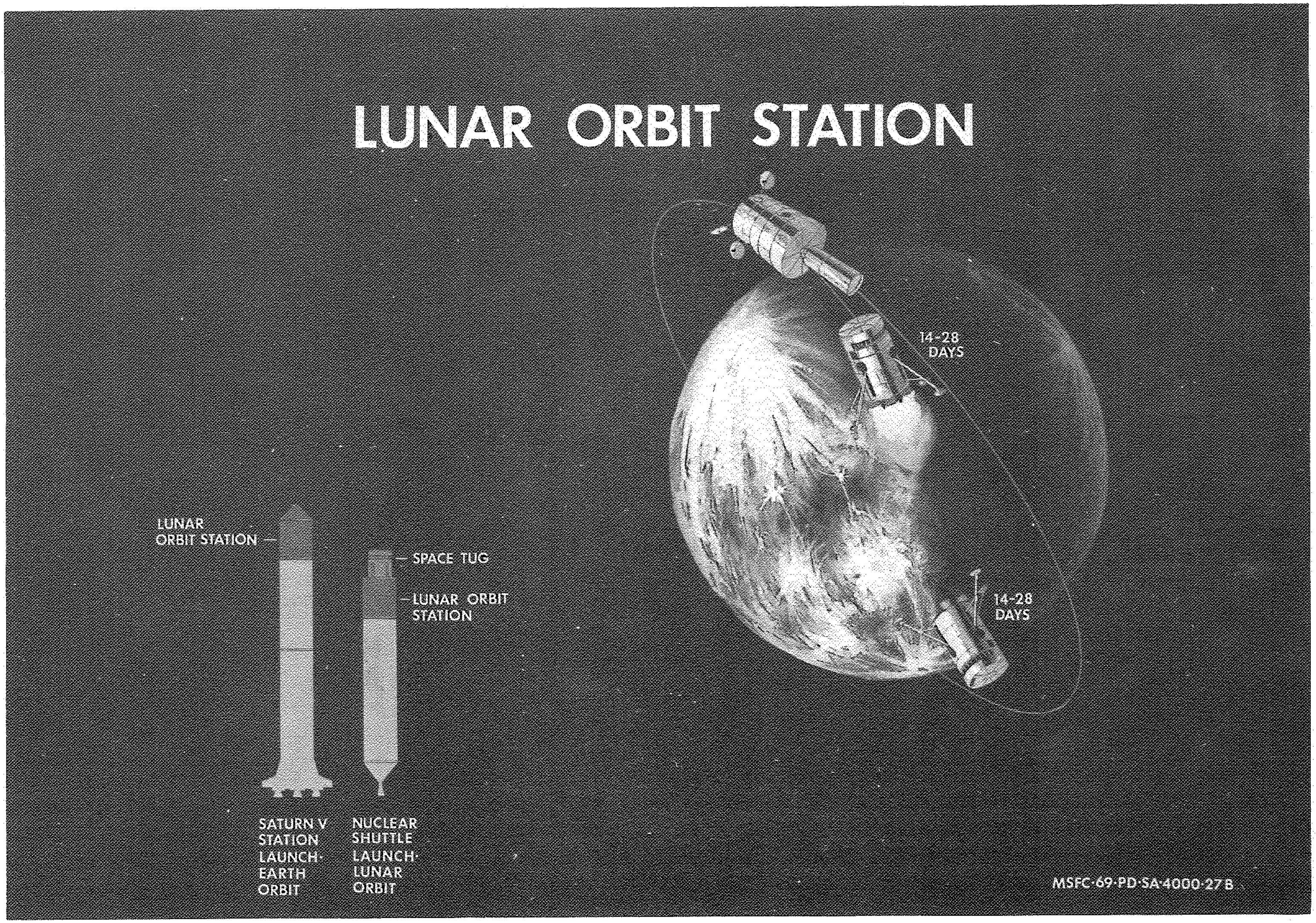

Figure 12. Lunar orbit station.

SPACE TUG/LUNAR APPLICATIONS

The tug is one of four major new pieces of equipment which are required in the Integrated Program. The space tug concept is a highly versatile multi-application system that utilizes three major modules – crew, propulsion, and cargo – which may be used separately or together with a variety of supplementary kits depending on mission support function required. These kits would be components such as landing legs, environmental control systems, power, guidance and navigation, and manipulatory arms. Each module will be recoverable and economically refurbishable.

Significant improvements in lunar exploration will be introduced with the advent of the space tug. For the lunar landing application, the propulsion module, crew module, landing legs, and other appropriate support kits will descend from a lunar orbit station to the surface for exploration missions of 14 to 28 days as illustrated on this chart. After surface mission completion, the tug will ascend to the orbit station to refuel and resupply for another surface sortie.

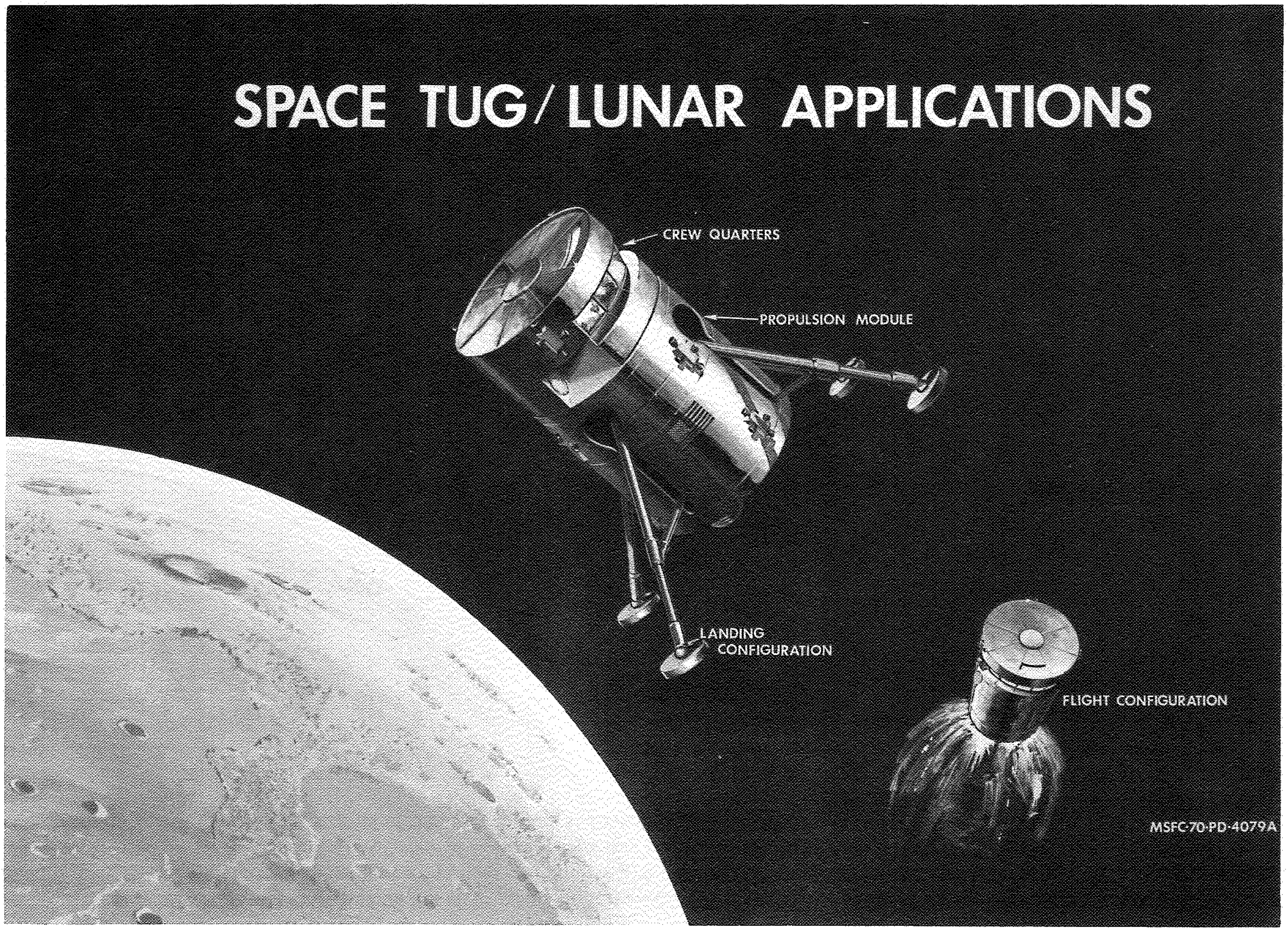

Figure 13. Space tug/lunar applications.

SPACE TUG/EARTH ORBIT APPLICATIONS

The versatile space tug illustrated on this chart represents a typical configuration for conducting operations and tasks in earth orbit. The crew module may house from one to six men to meet specific mission needs. A manipulator kit would be attached to allow the tug to conduct operations without the need for EVA. The space station would serve as a departure point for space tug operations, which includes movement of the station itself; movement of large payloads in the vicinity of the space station; and satellite placement, retrieval and maintenance services.

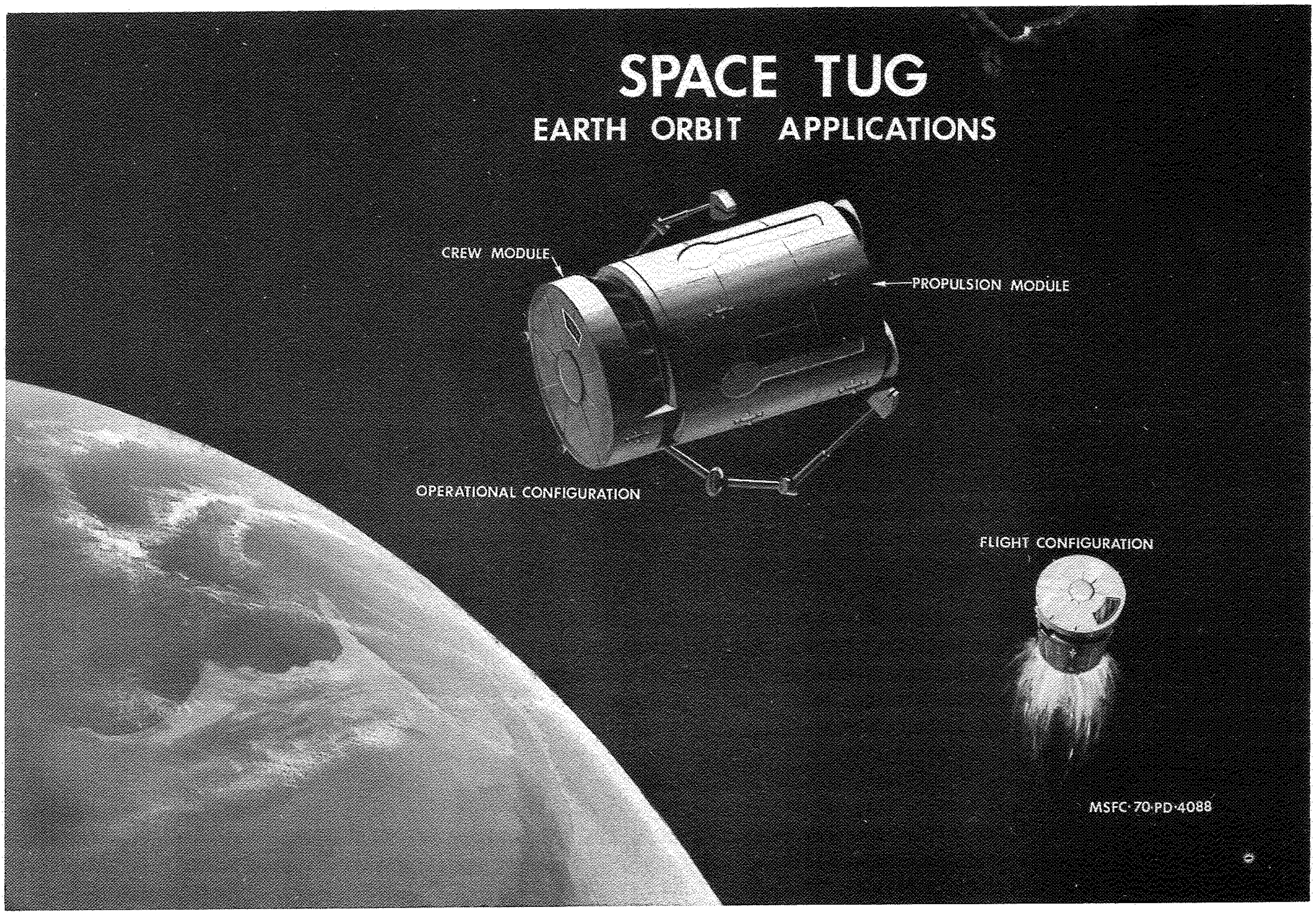

Figure 14. Space tug/earth orbit applications.

SPACE TUG REFUELING IN EARTH ORBIT

The anticipated size of the space tug would allow it to be refueled directly by a space shuttle, which carries cryogenic propellants and transfer equipment in its cargo bay. The propellants are transferred by direct docking of the space tug to the space shuttle.

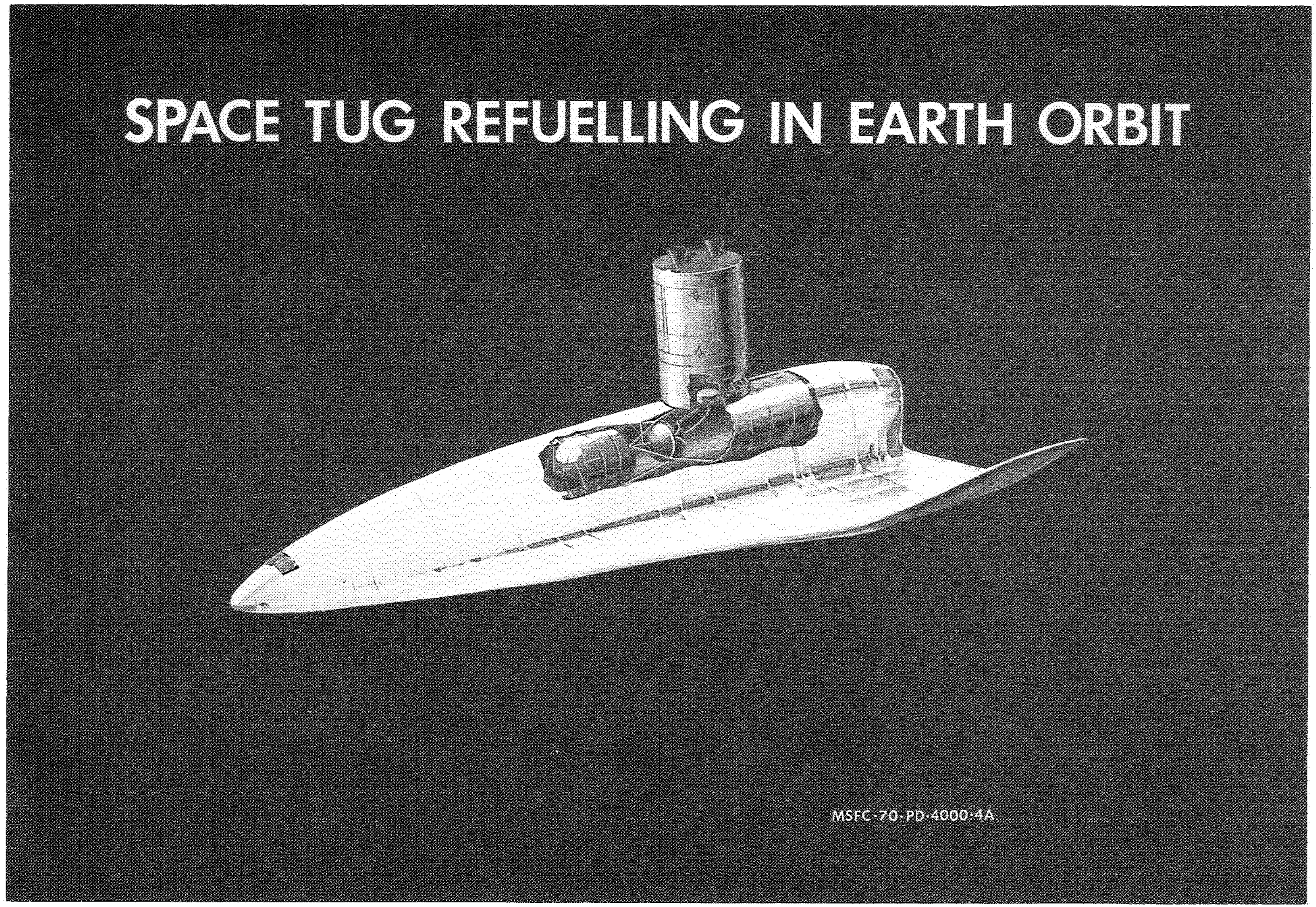

Figure 15. Space tug refueling in earth orbit.

SPACE TUG WITH PAYLOAD DELIVERY IN LOW EARTH ORBIT

The space shuttle will be capable of carrying a great variety of different space probes into orbits of various inclinations. The space probes use the space tug's propulsion module for insertion into the desired orbits.

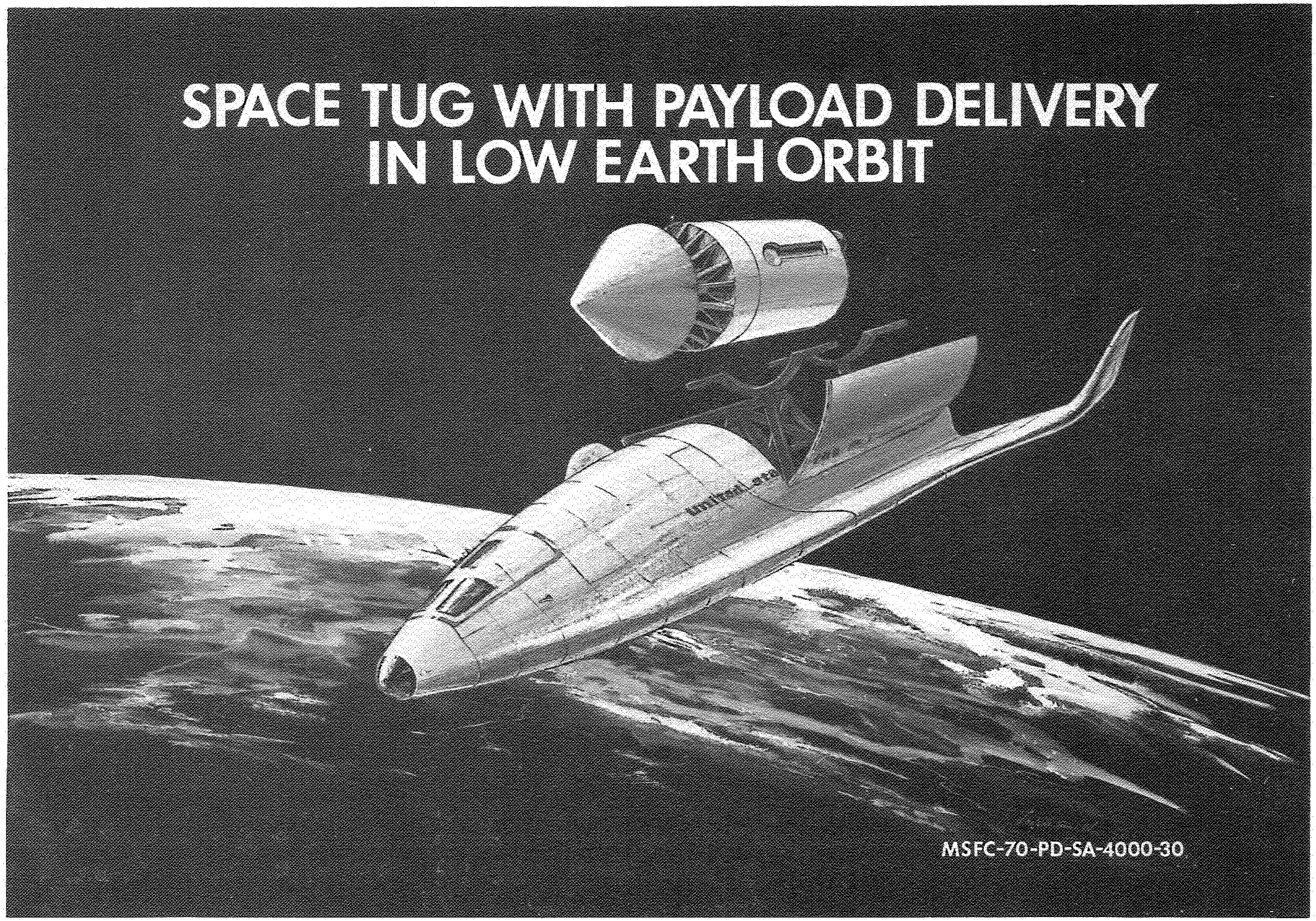

Figure 16. Space tug with payload delivery in low earth orbit.

SPACE PROBE LAUNCH

After launch into low earth orbit by a space shuttle, a space probe powered by a space tug's propulsion module and intelligence systems is inserted into its desired trajectory. Depending on the trajectory requirements, one or two propulsion modules can be used in tandem, with either one or both able to return for reuse after payload delivery.

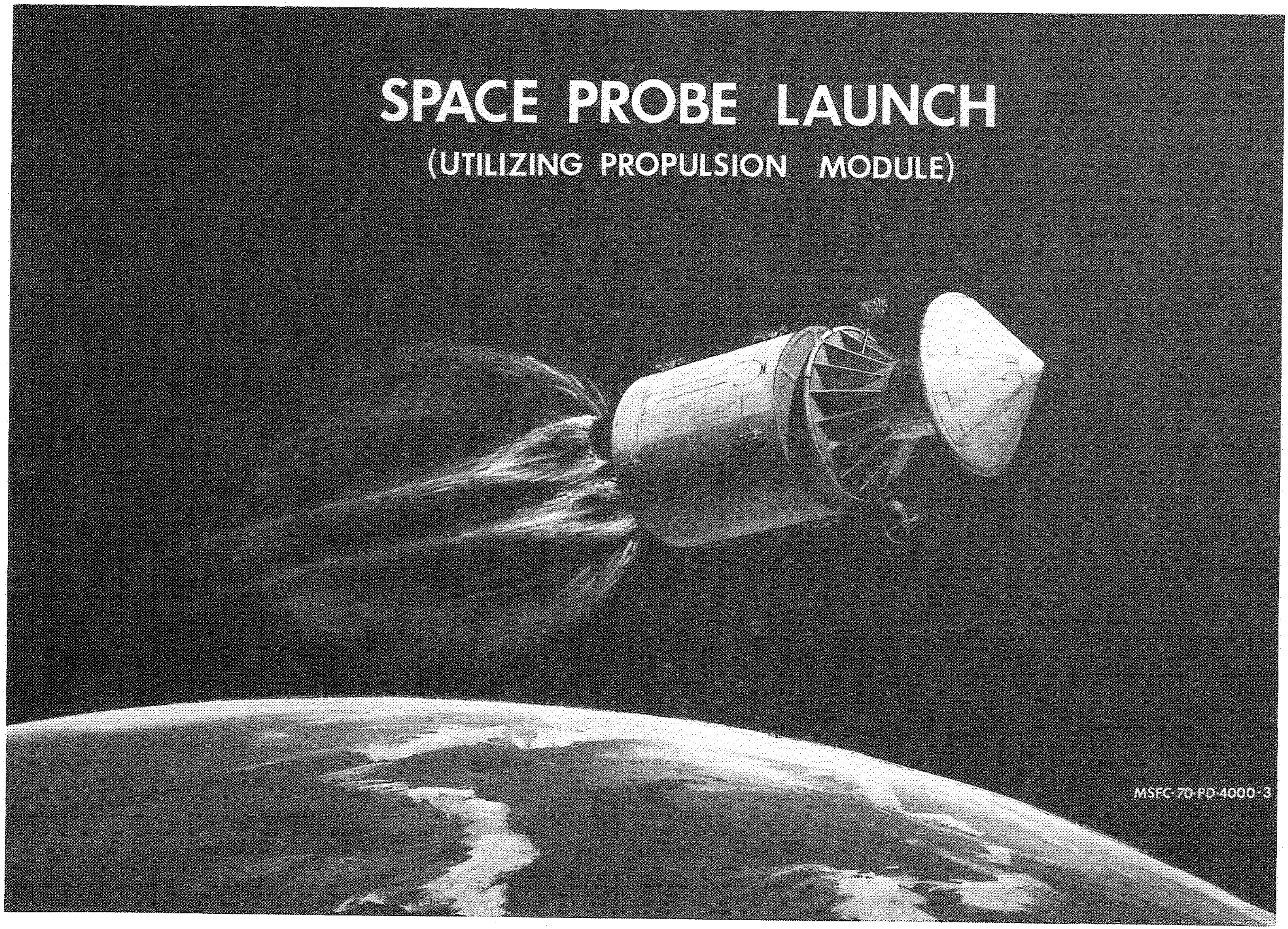

Figure 17. Space probe launch.

SPACE TUG/CREW MODULE

This module contains the space tug crew of three to six men and the necessary life support, intelligence, and maneuvering systems. It can be attached to the space tug's propulsion module for manned tug operations, or it can operate independently. Master/slave manipulator arms can be attached for orbital assembly operations.

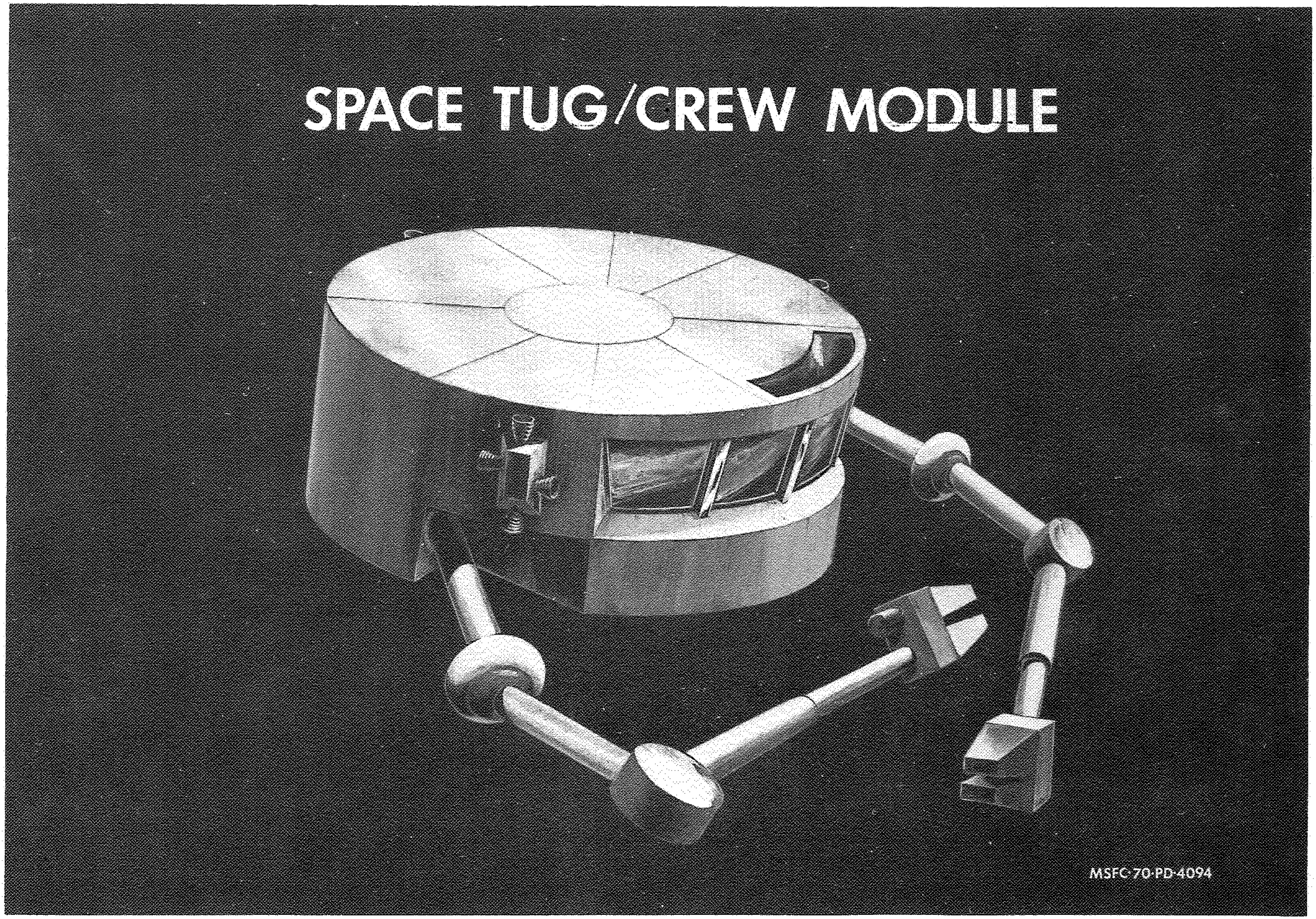

Figure 18. Space tug/crew module.

SATELLITE REPAIR

Special attachments to the space tug allow the servicing and repair of satellites in various orbits. The attachments would provide for de-spin of the spinning satellite, for anchoring the object and access by man. After servicing, the desired orientation and spin would be restored.

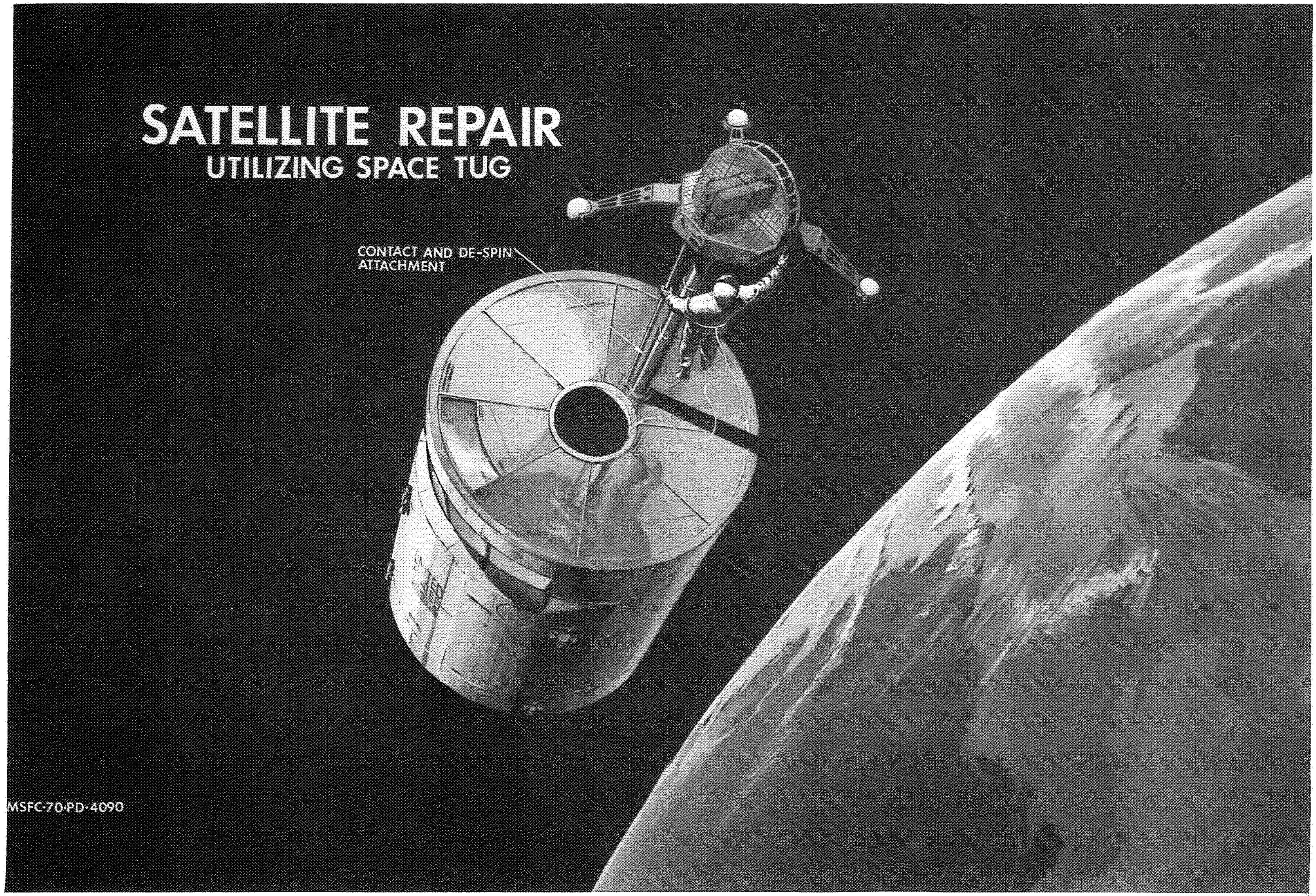

Figure 19. Satellite repair.

SPACE TUG MISSIONS

The basis of the space tug concept is the propulsion module. This module uses a cryogenic propulsion system with sufficient insulation to allow long-term storage of its propellants in space environment. Examples of a few of the applications of the propulsion module are illustrated on this chart. There is the landing of large payloads of men and/or material on the lunar surface and the returning of men and cargo to lunar orbit. One or more propulsion modules will also launch planetary probes from earth orbit depending upon energy requirements to meet specified missions. Space station support, one of the many and varied earth orbit applications, will be accomplished through movement of men and equipment, assembly and maintenance of items, and other activities requiring propulsive maneuver.

The propulsion module, like all other components of the space tug, is to be reused many times. After each mission, it would be refueled and refurbished and, if need be, have appropriate kits and other modules attached to conduct other missions.

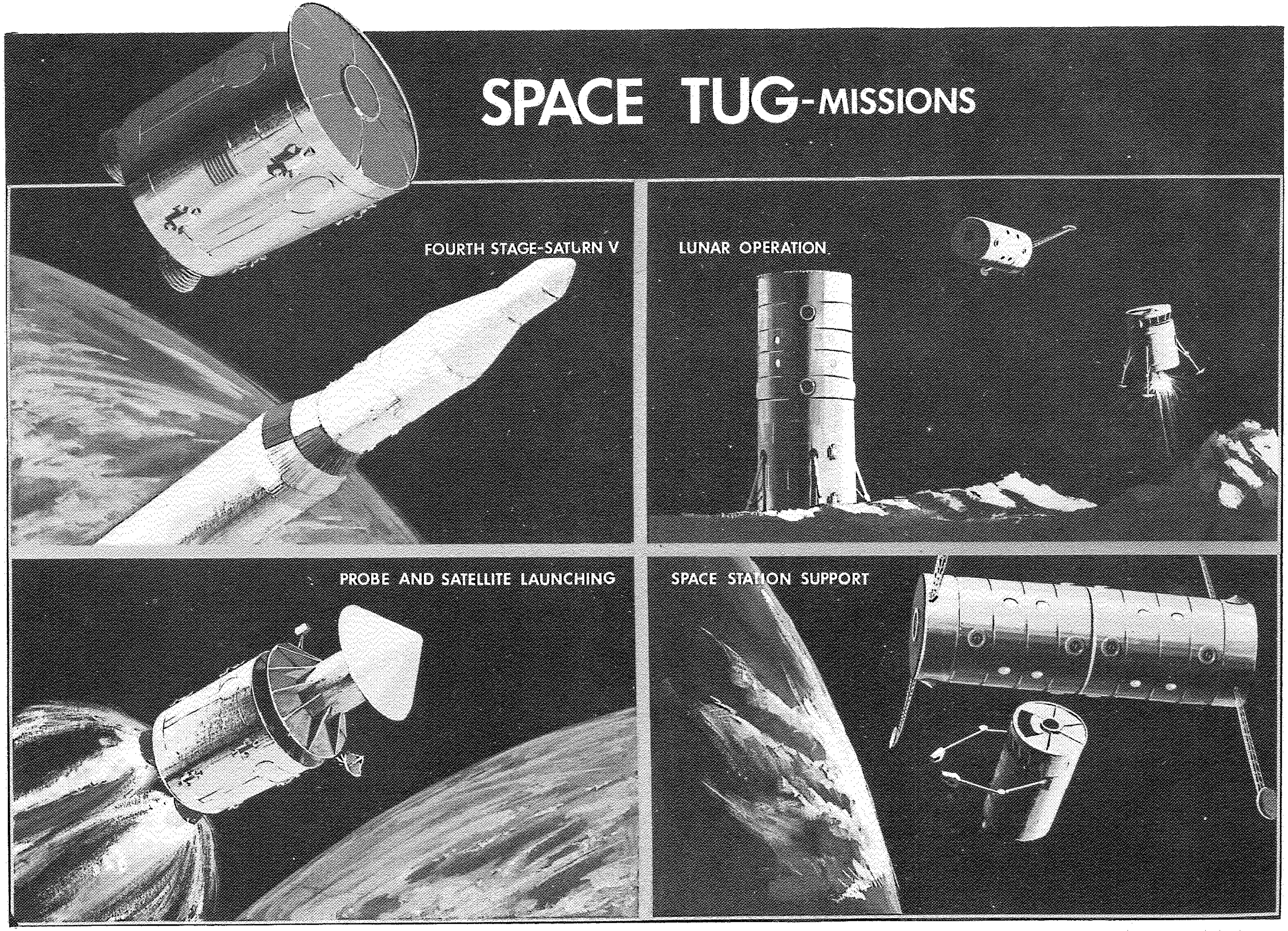

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Figure 20. Space tug missions.

USE OF TUG TO AUGMENT SHUTTLE CAPABILITY

The space tug can form an important link between the space shuttle and a space station or any other orbital mission element by extracting cargo modules from the space shuttle, propelling them toward their destination, and docking them.

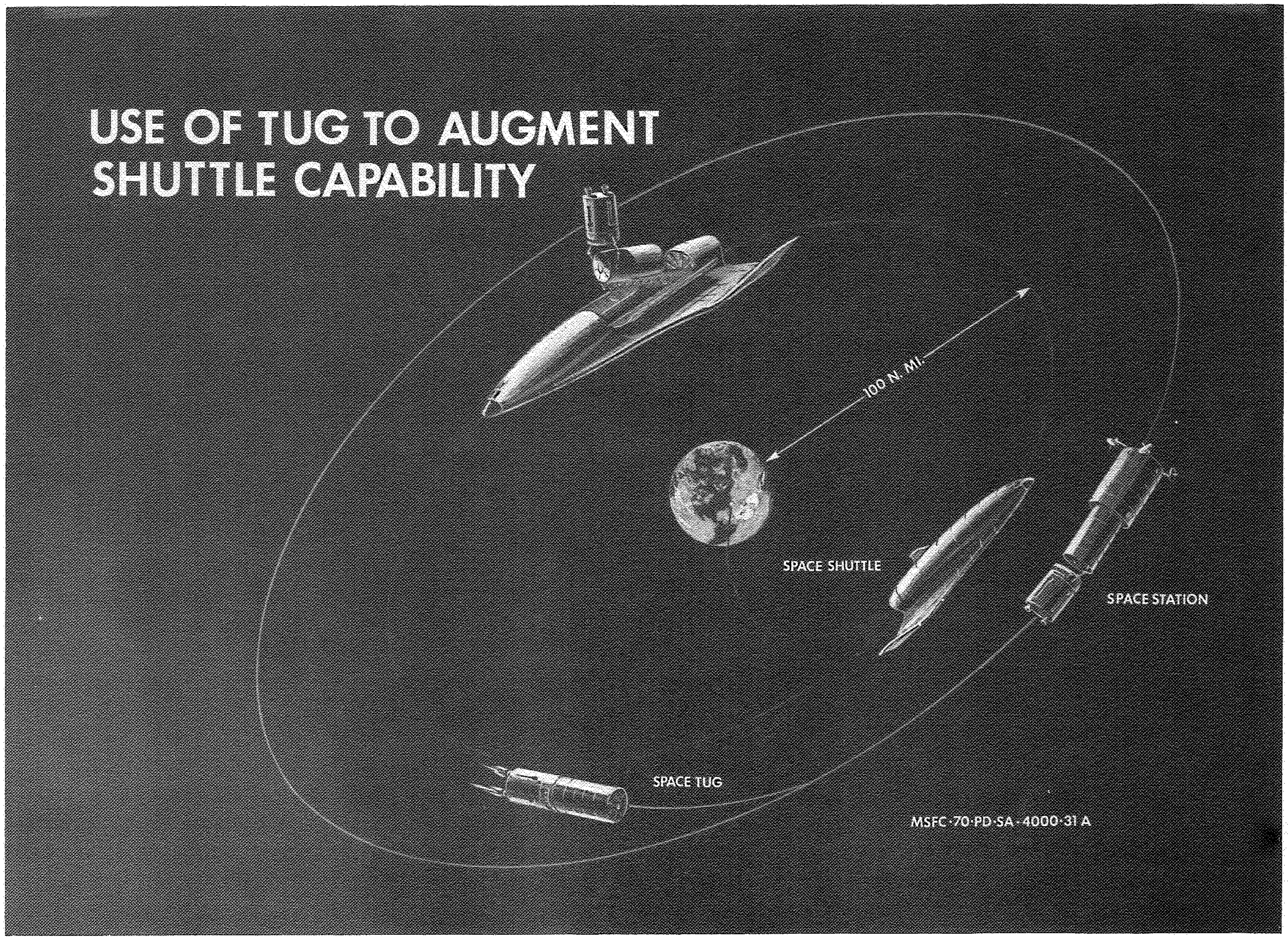

Figure 21. Use of tug to augment shuttle capability.

SPACE TUG/CREW MODULE APPLICATION

The crew module will provide living quarters for three or more men for varied durations, depending on the mission application. Illustrated on this chart are typical missions for (1) the nuclear shuttle trips to synchronous orbit and to the lunar orbit station, (2) landing on the lunar surface, and (3) repairing or retrieving satellites. The crew module is dependent on other systems for propulsion and, therefore, docks readily with either the nuclear shuttle or the propulsion module. Manipulator arms may be provided to assist in assembly and repair operations to reduce EVA.

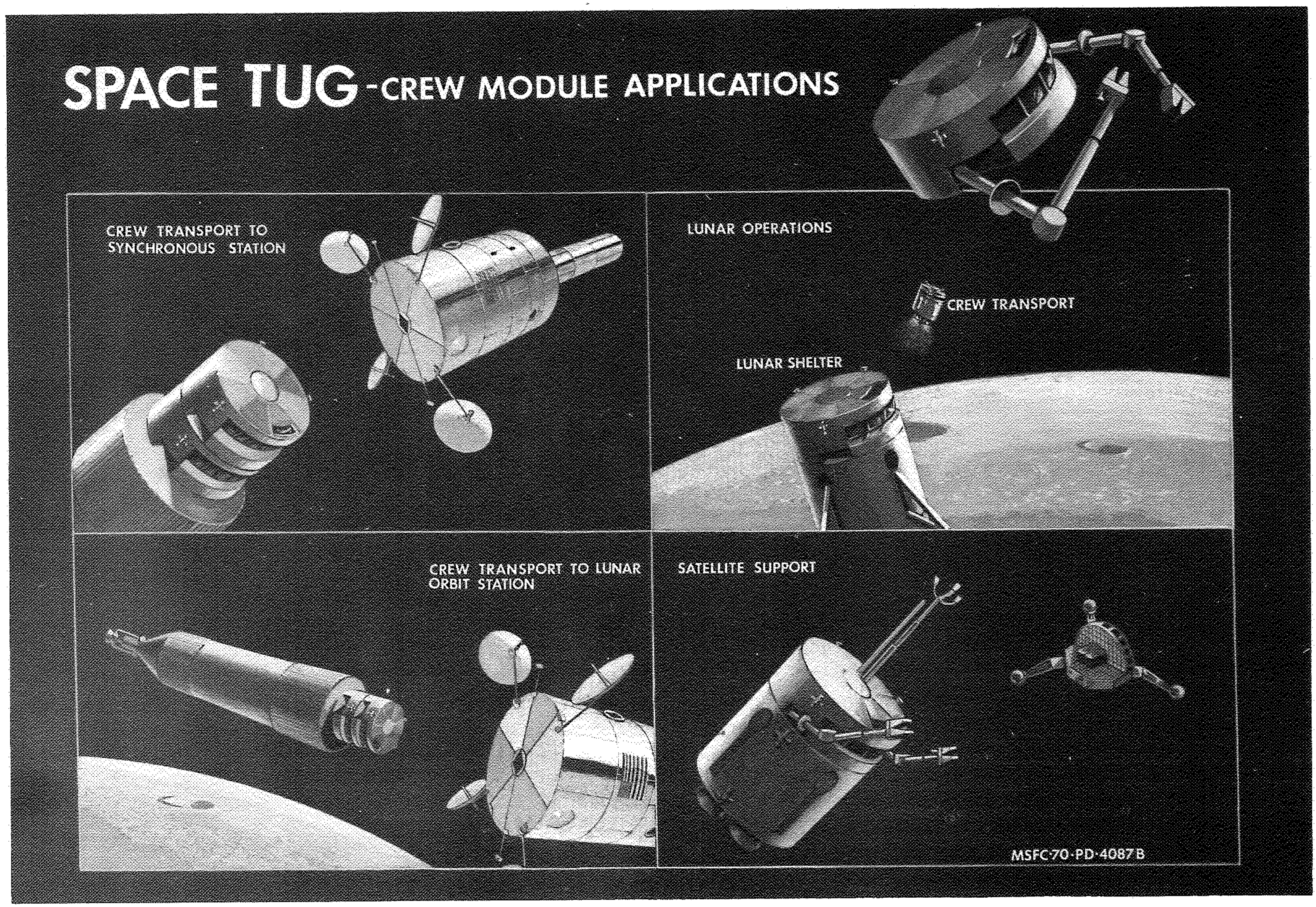

Figure 22. Space tug/crew module application.

EVOLUTION OF ADVANCED SYSTEMS

Introduction of the space station module, space shuttle, and space tug makes possible an expanded manned program in both the earth orbit and lunar environments.

The expansion of manned activities in cislunar space to include a synchronous orbit station and a permanent lunar surface station requires a low cost reusable lunar shuttle. Studies to date indicate an advantage in using a shuttle with nuclear propulsion. It would be used to transport men, supplies, equipment, and tugs from low earth orbit to both the synchronous station and the lunar orbit station. Saturn V flights to the moon will be terminated by introduction of the nuclear shuttle. The space shuttle will transport all payloads and propellants to low earth orbit where they will be transferred to the nuclear shuttle. With the addition of the nuclear shuttle, a permanent station is made economically feasible in synchronous orbit and on the lunar surface. These stations will provide scientific knowledge and operational experience necessary for manned planetary missions of the 1980's. A brief operational description of the nuclear shuttle and lunar surface base follows.

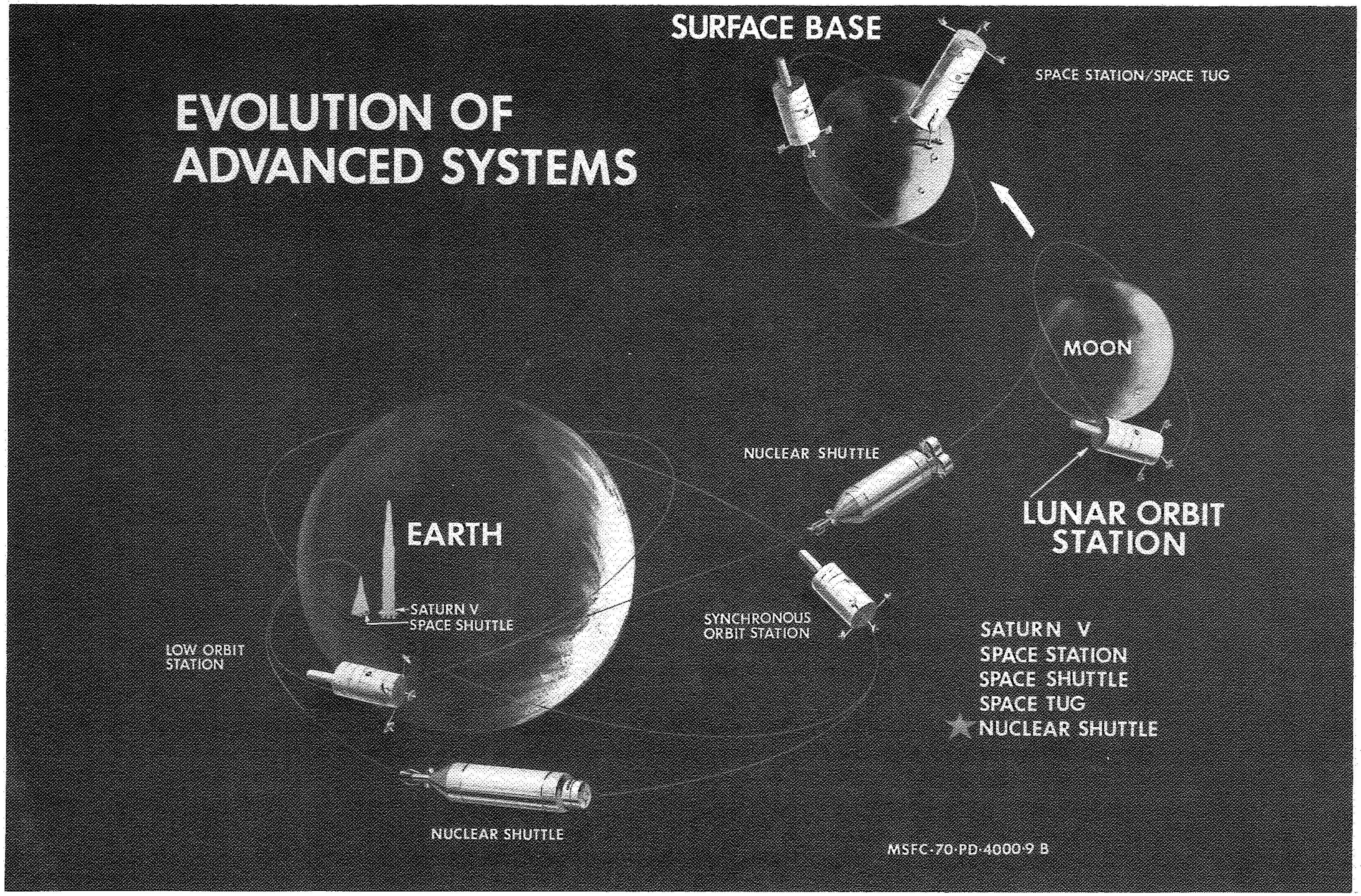

Figure 23. Evolution of advanced systems.

NUCLEAR SHUTTLE

The introduction of a low cost reusable space transportation system is required to support long term high energy missions, such as synchronous and lunar surface bases. At this time, it appears that the nuclear shuttle is the most economical system to fulfill these requirements. In addition to cislunar missions, the nuclear shuttle would serve as an economical propulsion system for manned planetary missions in the later period.

The nuclear shuttle, designed for multiple reuses, will be able to operate in either a manned or unmanned mode. It will possess the capability of long term, cryogenic storage in space and will have the ability to station-keep in orbit between mission applications.

A two-stage configuration of the Saturn V will launch the nuclear shuttle into orbit. The space shuttle will thereafter be used to transport fuel and payload into orbit to support the nuclear shuttle operations. The nuclear shuttle will be refueled and will have necessary maintenance performed between mission applications by personnel of the orbiting space base.

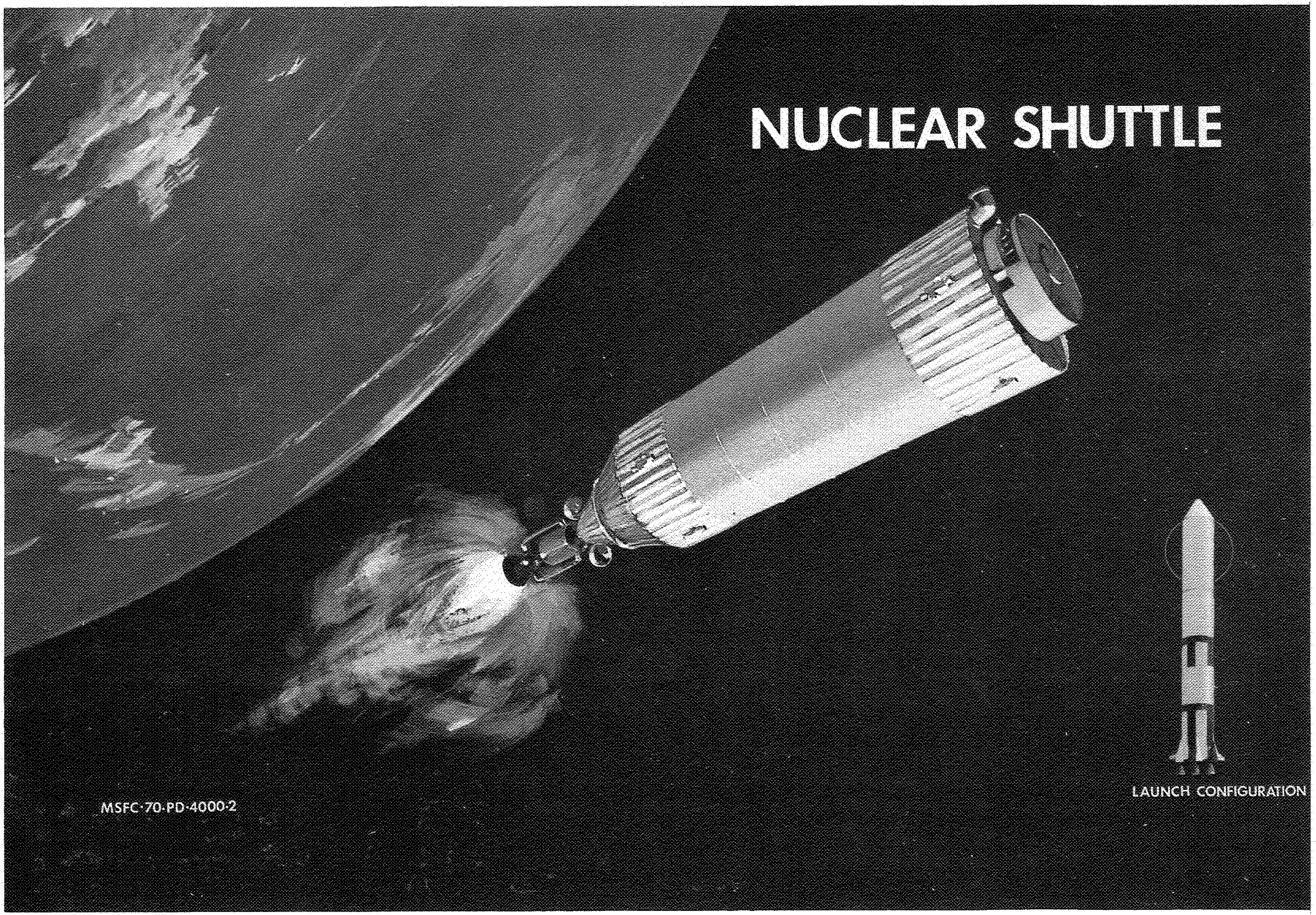

Figure 24. Nuclear shuttle.

NUCLEAR SHUTTLE MISSION

The nuclear shuttle will provide transportation to a synchronous orbit with payloads such as crew modules for satellite service, a manned station module for earth survey and scientific research, and a space tug and expendables for synchronous orbit operations.

It will provide earth-orbit-to-lunar-orbit-and-return transportation in support of lunar orbital and surface missions.

Multiple nuclear shuttle units form the propulsion basis for planetary missions.

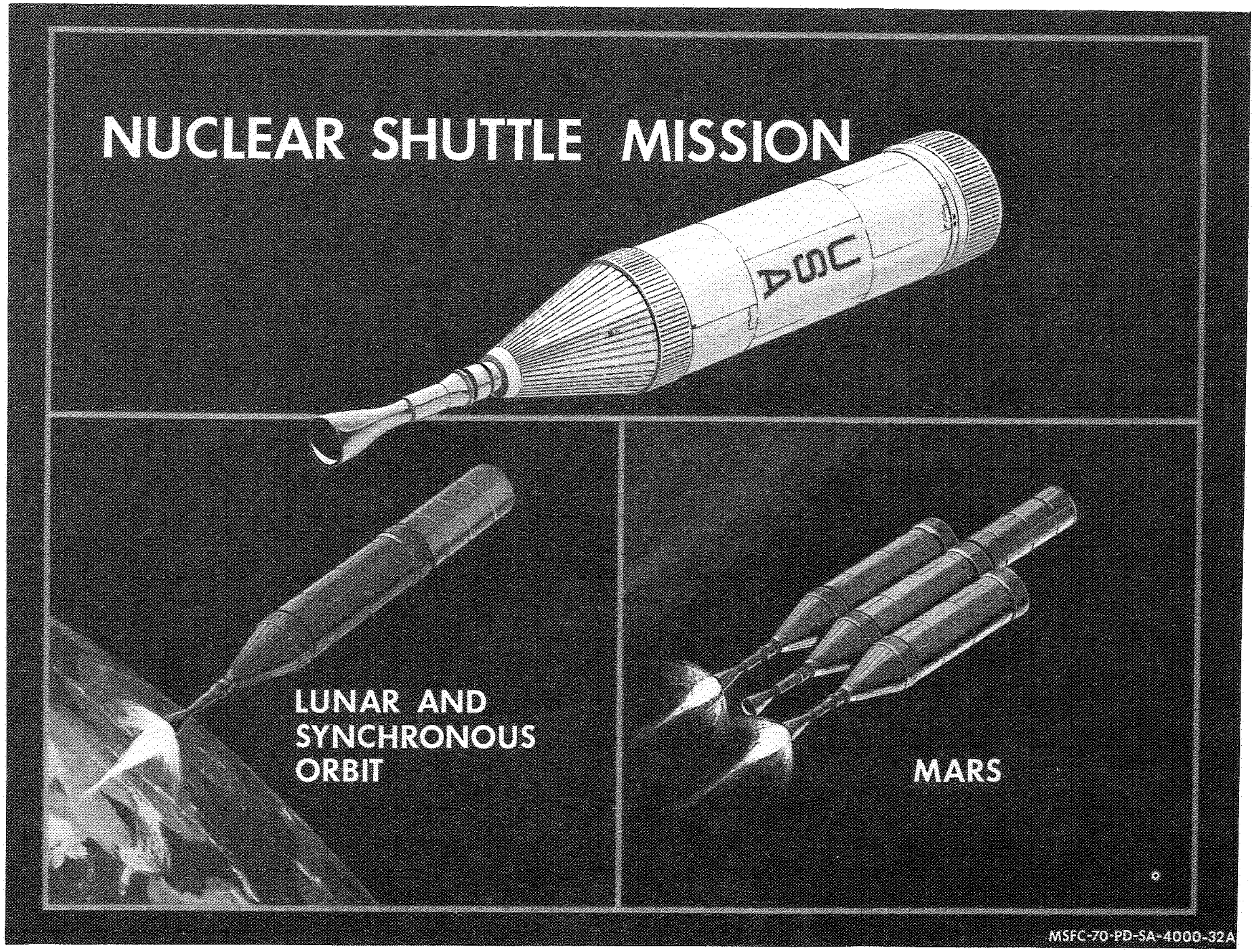

Figure 25. Nuclear shuttle mission.

NUCLEAR SHUTTLE LOGISTICS CONFIGURATION

The nuclear shuttle will initially be used as a logistics vehicle for supporting manned operations in synchronous orbit, in lunar orbit, and on the lunar surface. The nuclear shuttle should, therefore, be adaptable to transporting payloads of varying size, weight, and configuration. The payload weight that the nuclear shuttle will be able to transport to its destination is a function of the weight it is expected to return to earth orbit. For instance, in early phases of the program the space tugs will be returned to earth orbit from both synchronous and lunar orbit stations to be refueled and/or refurbished.

Several representative payload configurations for the shuttle are illustrated on the facing page. Configurations of both cargo modules and fully fueled space tugs will be able to be transported on a single flight. The space station or experiment modules will also be able to be transported to any point of scientific interest in cislunar space. Other applications of the nuclear shuttle would include rotation of crews between synchronous and lunar orbit stations and earth orbit and transportation of specialized equipment required for lunar surface operations.

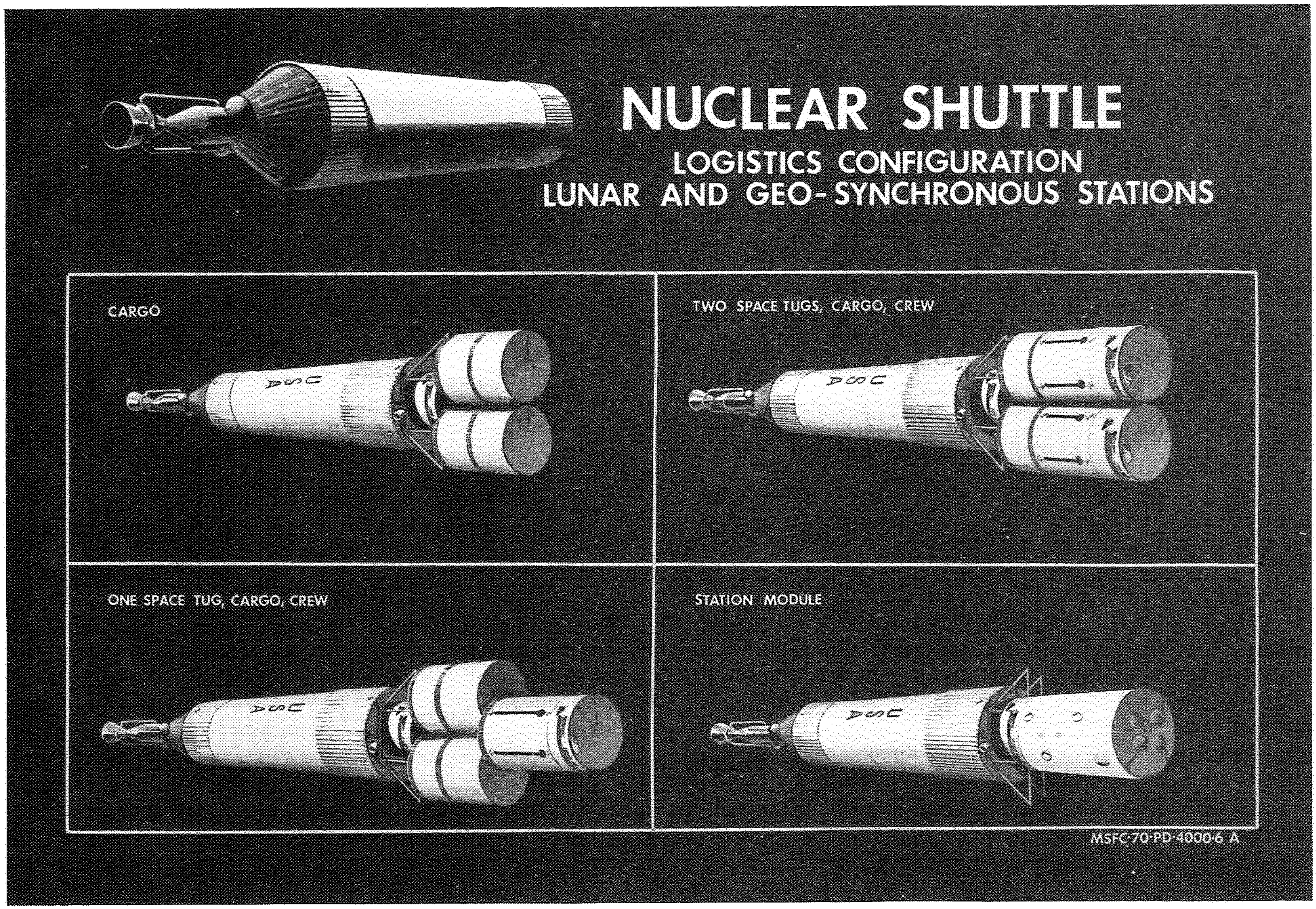

Figure 26. Nuclear shuttle/logistics configuration.

NUCLEAR SHUTTLE REFUELING

On the facing page, the nuclear shuttle is shown during a routine refueling operation utilizing the orbital propellant storage facility (OPSF) in low earth orbit. The refueling is being done to prepare the nuclear shuttle for another round trip from earth orbit to synchronous or lunar orbits.

The OPSF (noted here as the liquid hydrogen depot) uses a rotational mode for settling the liquid hydrogen prior to transfer into the shuttle via large pumps through a counter-rotating docking terminal. The OPSF is resupplied on a replacement tank basis by routine operation of a space shuttle configured in a tanker mode.

Existence of the OPSF in low earth orbit as a detached segment of an overall space base complex is necessary for conduct of the extensive lunar exploration program currently envisioned which, in addition to synchronous missions, requires frequent refueling and reusing of the nuclear shuttle vehicles for delivery of crew, cargo, and experiment modules.

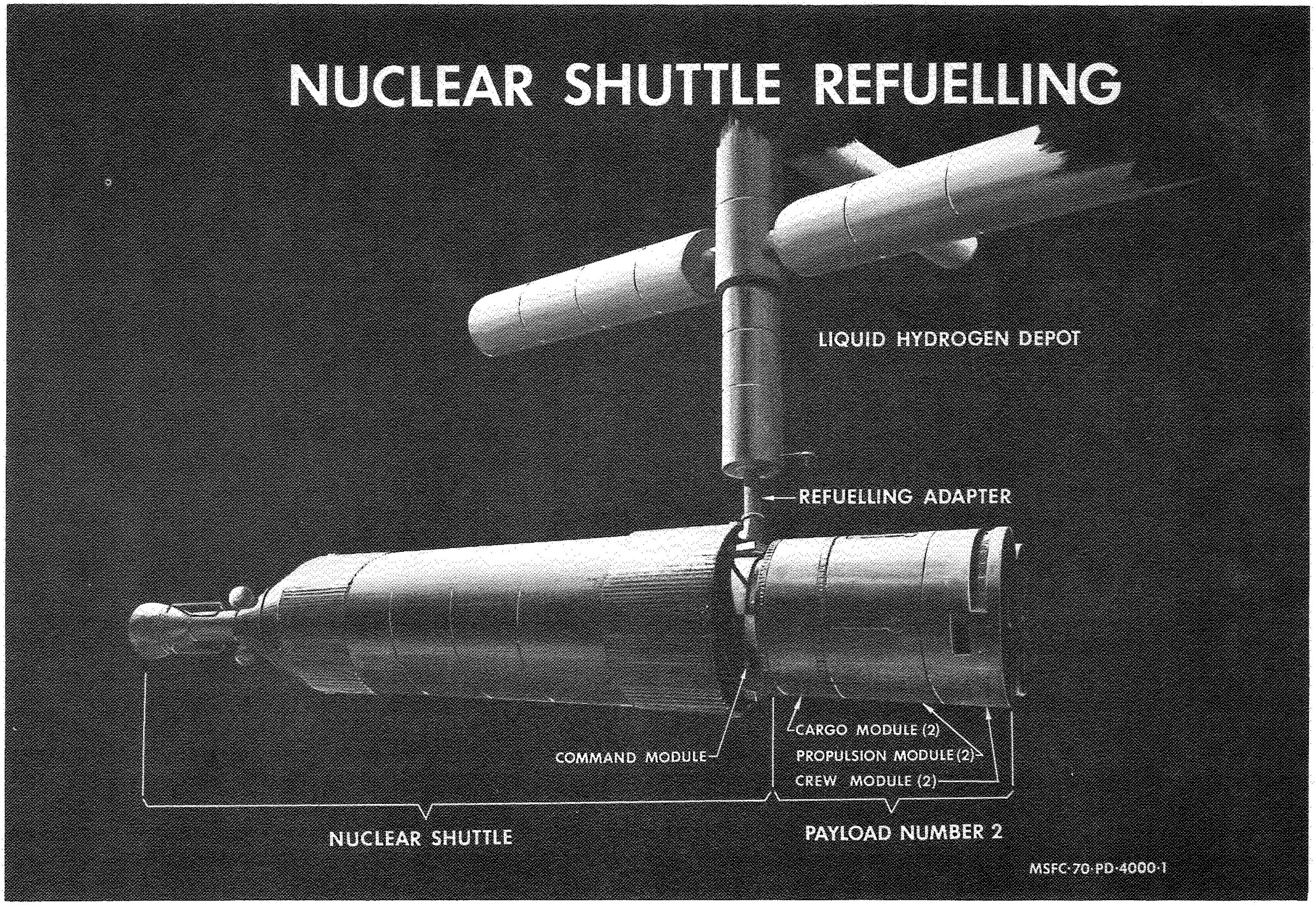

Figure 27. Nuclear shuttle refueling.

EARTH ORBIT CARGO TRANSFER

The facing chart shows one of the primary modes of using three major elements of the Integrated Program. The sequence shown depicts the cargo transfer from a space shuttle to the nuclear shuttle which is to depart from earth orbit to lunar orbit.

The space shuttle cargo bay is hinged open. An interior expulsion device moves the space shuttle cargo upward and out into the open, exposing the individual cargo modules for removal (Phase I).

A space tug with a manipulator equipped crew module extracts the cargo module from the space shuttle palet and docks with it (Phase II).

The space tug then propels itself and the cargo module toward the nuclear shuttle (Phase III), stationed at some distance away, and transfers the cargo module to the nuclear shuttle cargo structure by hard docking (Phase IV).

This operation and other similar cargo transfers will be a standard operation in earth orbit for any cargo destined for the moon.

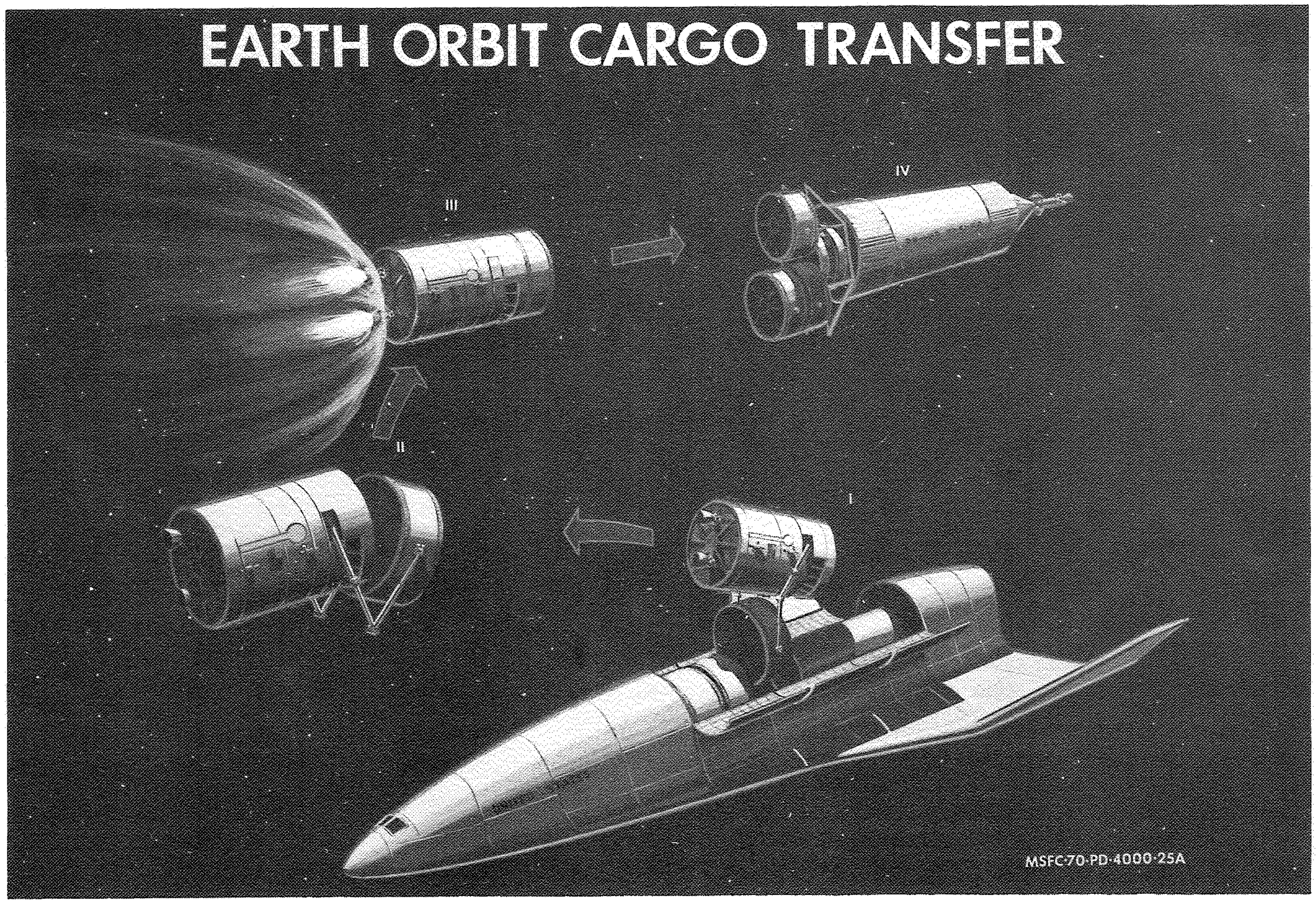

Figure 28. Earth orbit cargo transfer.

LUNAR SURFACE BASE

With the introduction of the nuclear shuttle for logistics support, the development of a permanent base on the lunar surface becomes feasible. The development of a lunar base could be one of the most important steps taken in the next decade to eventually explore the entire solar system. If lunar resources could be developed to sustain a base, the preparation and operation of the base could provide invaluable data on manned planetary operations in the following decade.

The initial buildup of the base requires the space station module to be placed on the lunar surface from lunar orbit with the propulsion module of the space tug. The station is manned and logistically supplied via the operation of the space tug from lunar orbit. At this phase of the lunar program, all equipment, supplies, and crew rotations are supported from earth orbit with the nuclear shuttle. All supplies and equipment for the lunar surface are first brought to the lunar orbit station and then transferred to the lunar base.

In-depth selenological exploration can begin as the base expands and specialized equipment is assembled. Drills of several hundred feet capability can be employed to determine if lunar resources can be exploited. Large optical X-ray and gamma-ray telescopes can be erected, and an extended base operation can be developed.

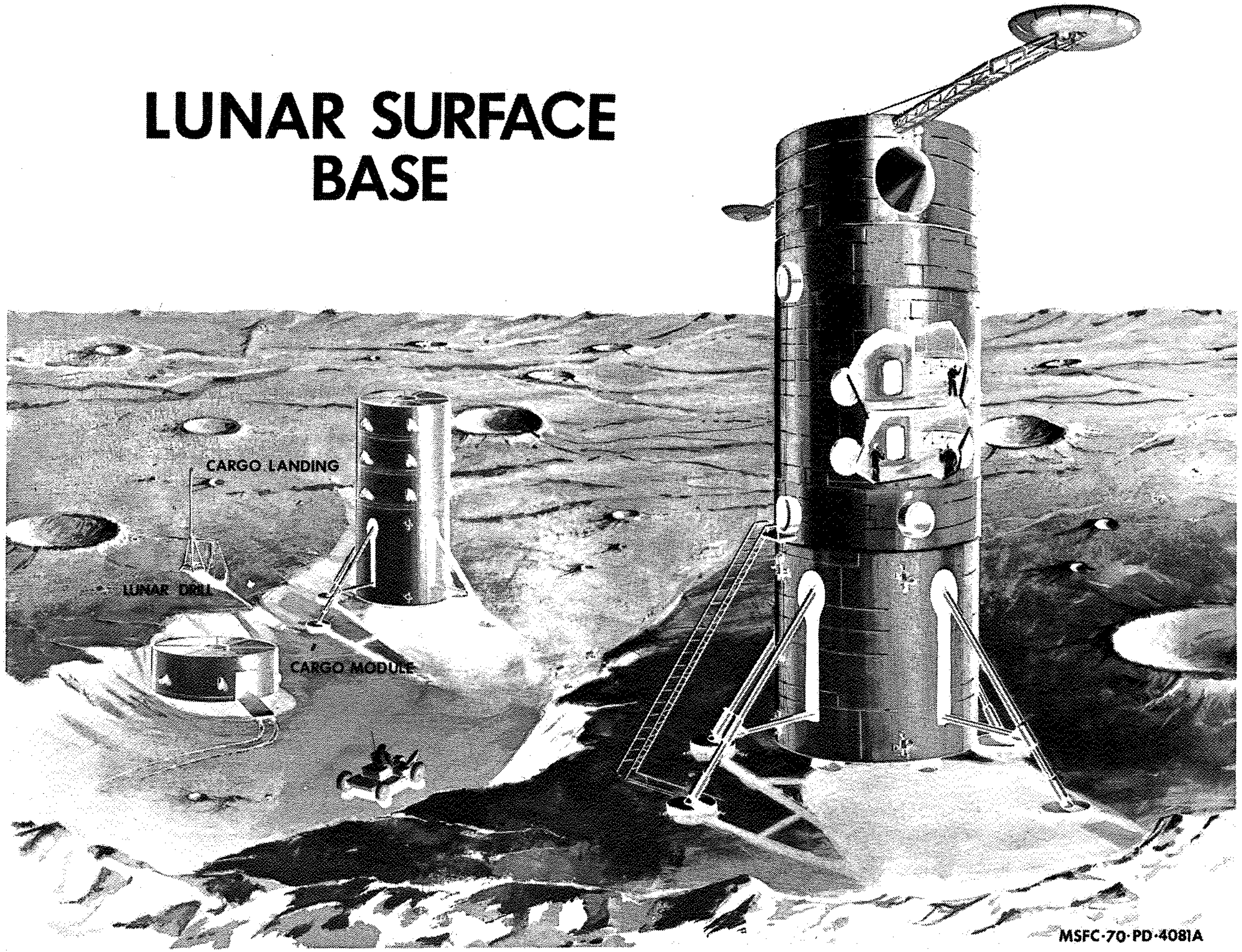

Figure 29. Lunar surface base.

LUNAR ORBIT OPERATIONS

The existence of orbiting and surface bases at the moon will require extensive lunar orbit operations. The operations will be primarily concerned with handling cargo brought by nuclear shuttle vehicles and preparing and launching space tugs to the lunar surface. These various operations are illustrated on the facing page.

The arrival of a nuclear shuttle logistics vehicle at the orbiting station will require orbital operations to transfer propellants to the storage depot, dock space tugs to the station, transfer arriving crewmen to the station, and prepare the nuclear shuttle for the return to earth orbit.

Operations required in utilizing the space tug will include refueling at the propellant depot, maintenance and refurbishment, and checkout and launch for the many surface visits. The space tug would also be involved in shuttling cargo and crew and other orbital maneuvering that might be required.

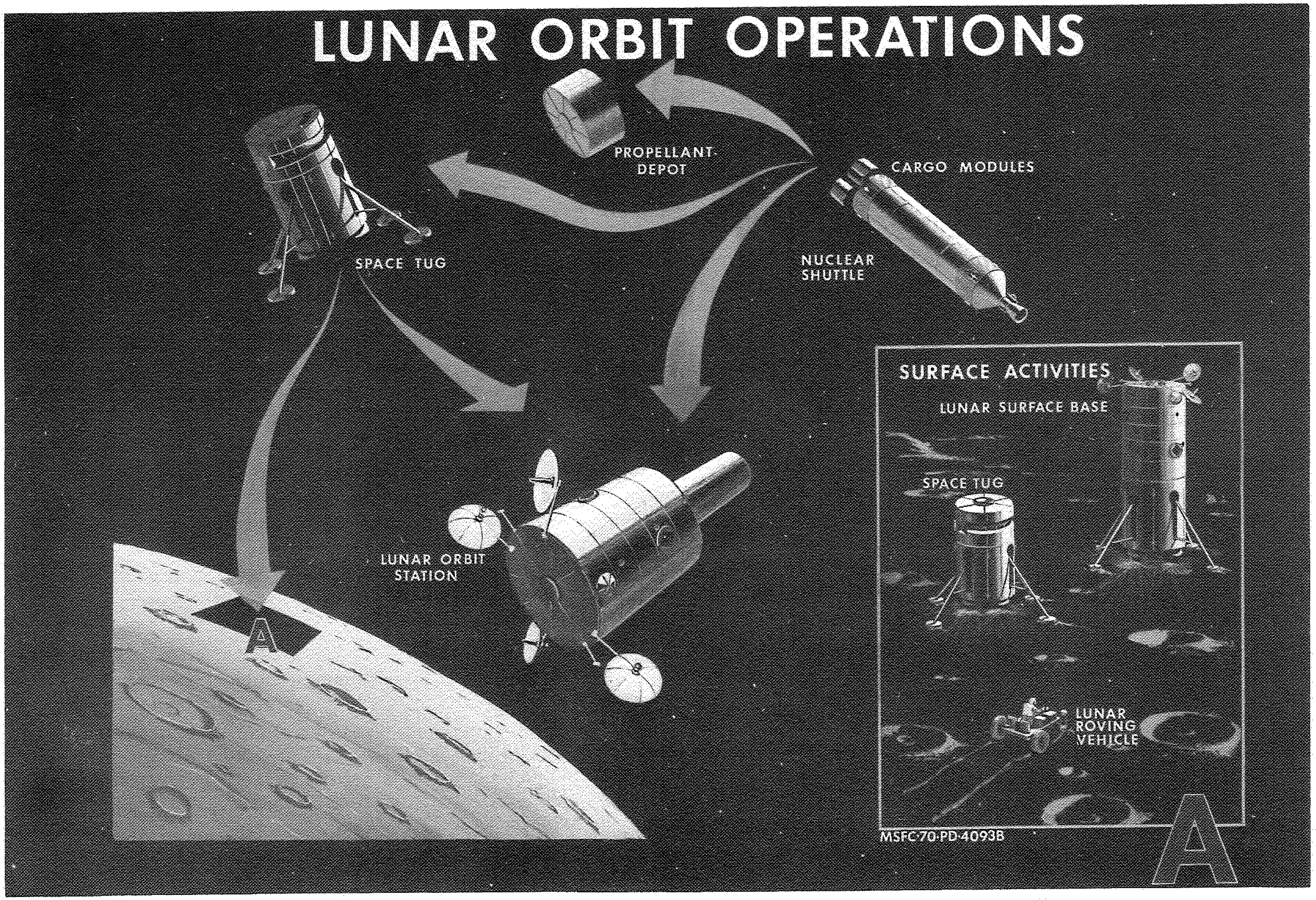

Figure 30. Lunar orbit operations.

SPACE SCIENCE AND TECHNOLOGY – INTERMEDIATE PERIOD

The intermediate period will see an evolution from single purpose space experiments of earlier years to sophisticated research laboratory facilities in space. Exploration of the solar system will continue using advanced systems of greatly enhanced capability with emphasis on the exploration of Mars.

A wide variety of earth sensors will be qualified for later operational application. The space shuttle will be used to deploy certain automated sensor systems into high inclination orbits.

Advanced technology laboratories will be operated in earth orbit to investigate and evaluate systems and techniques required for manned planetary exploration.

A continuing program of biomedical and biological investigations in an earth orbiting life sciences laboratory will be conducted. The effects of long duration space flight on humans, animals, and plants will be investigated.

Large solar and stellar telescopes will be flown in association with the space station. High energy and radio astronomy investigations will also be conducted. The space shuttle will be used to transport, activate, deploy, and retrieve certain telescope packages. A high energy cosmic ray laboratory facility will be included in the space station both for the study of cosmic rays and for the utilization of these ultra high energy particles to initiate nuclear interactions at higher energies than attainable in earth laboratory facilities.

This period will find an extensive lunar exploration capability. The initial elements of a permanent lunar base will be established. A drilling capability (100 to 300 feet) will be provided; this will assist greatly in the search for water and other resources to support future exploration efforts. Regional selenological studies on the lunar surface will be facilitated by a greatly increased roving vehicle capability.

Exploration of the outer planets will be initiated by using automated systems. However, general emphasis will continue to be directed toward Mars – its atmosphere, surface features, and environment. The first sample of the Mars soil will be acquired and returned to earth using a completely automated system. The greatly enhanced knowledge of Mars and its environment and the solar system as a whole, particles and fields, etc., will open the gates to the manned exploration of Mars and other planets which will come in future years.

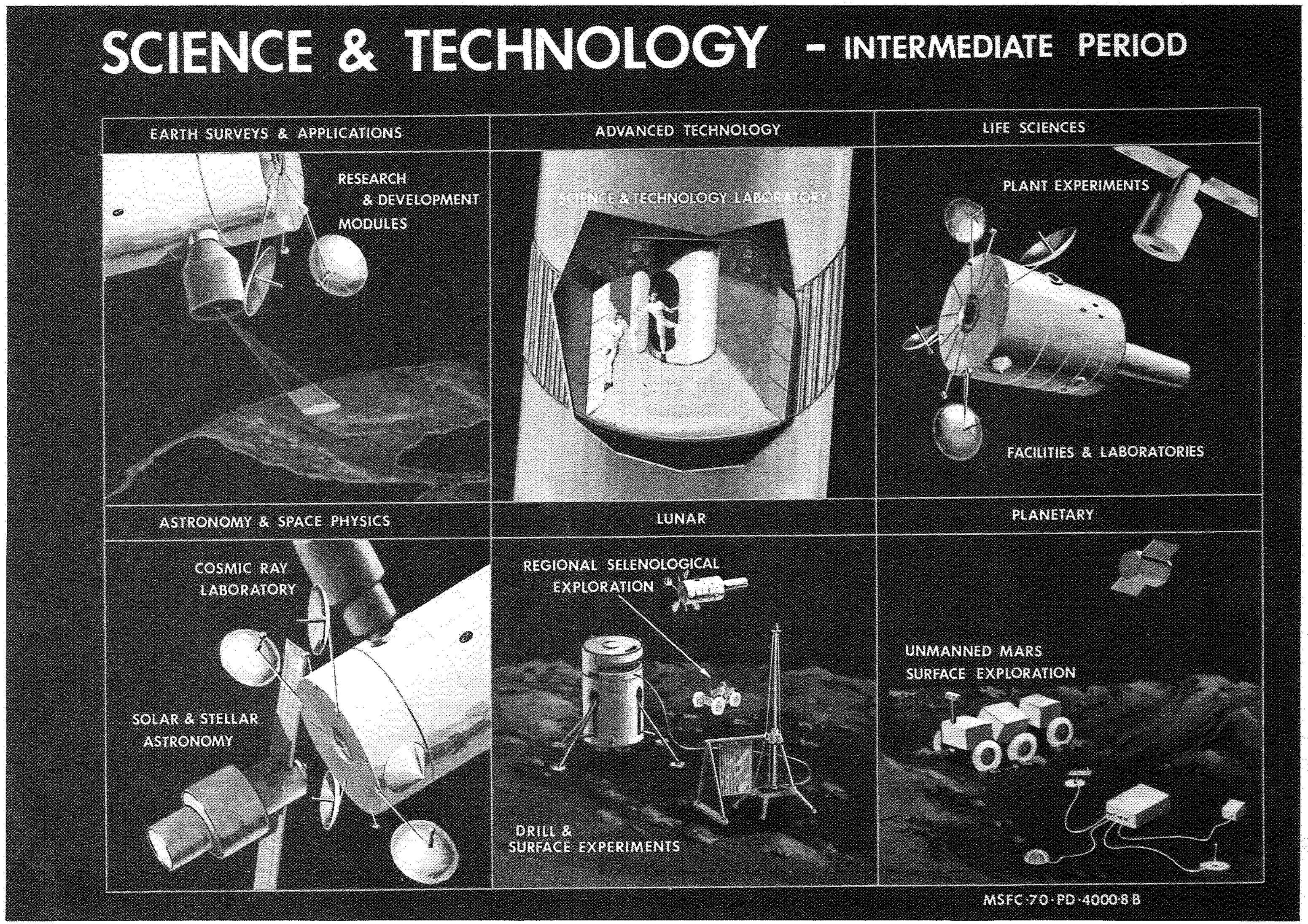

Figure 31. Science and technology – intermediate period.

REUSE AND COMMONALITY

Economy is the key to accomplishing the ambitious NASA missions that have been described previously. If a unique system was developed for each application illustrated, 11 new systems would be required. In addition, if the missions were performed in the Apollo manner, each of these systems would be expendable, and new hardware would have to be purchased for every flight. Obviously, the Apollo way of doing business would not produce the necessary economies for NASA to accomplish the missions of an integrated program.

The concepts of reusability and commonality were applied extensively in planning the Integrated Program to achieve feasible economies in development and operations. Commonality – the multiple application of hardware – makes it possible to reduce the number of new systems from 11 to 4. Substantial savings in development funds will result from the use of common hardware. Commonality is illustrated on the facing chart in the multiple applications of the space station module, the nuclear shuttle, and the space tug.

Economy of operation will be achieved through reuse of flight hardware. The space shuttle is the prime example of reusability. Since all missions require earth-to-orbit transportation, a large volume of traffic will be generated. The application of a reusable low cost space shuttle to this tremendous transportation task will result in substantial savings. Reuse savings will also be significant for the nuclear shuttle and space tug. The space tug will make the extensive space maneuvering required in this program economically feasible. The cost of supporting synchronous and lunar missions would be reduced substantially with a reusable space propulsion system such as the nuclear shuttle.

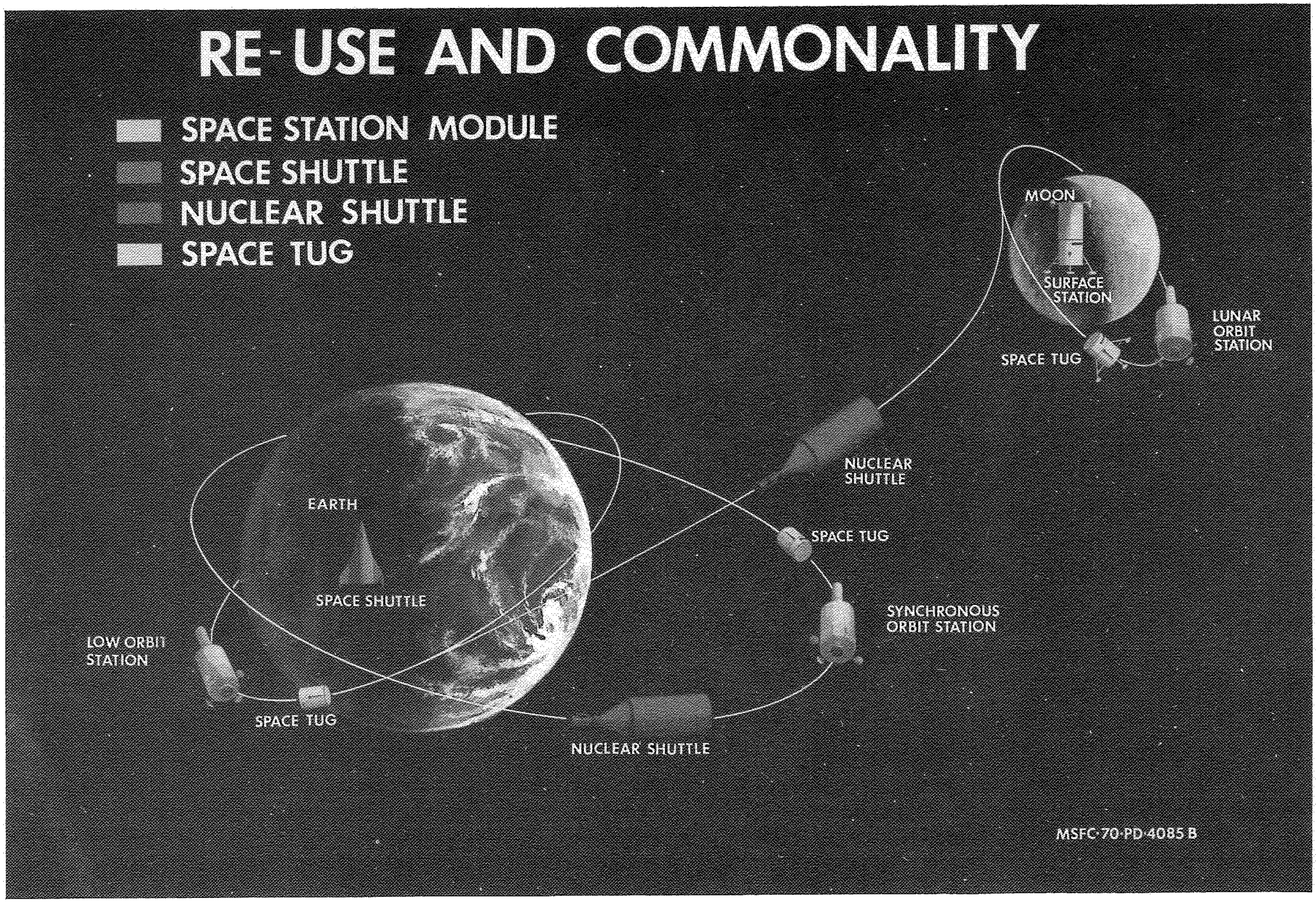

Figure 32. Reuse and commonality.

ADVANCED MISSIONS – SUMMARY

A summary of an Integrated Program as shown so far is given on the facing page. In the earth orbit program, permanent stations will have been established in both synchronous and low altitude orbits with a combined population of 18 personnel (12 men in low orbit station and 6 men in synchronous orbit station). These stations are made possible with the low operational cost of the space shuttle and nuclear shuttle. Addition of the space tug to these two low cost transportation systems will have made it economically feasible to establish stations in lunar orbit as well as on the lunar surface. Each station will support a crew of 6 or more men and will be capable of growing into a lunar colony in the later period if exploitation of lunar resources is feasible.

Automated systems shown in the planetary program are representative of missions that will have been launched earlier to provide valuable scientific data on various planets of our solar system. Emphasis will be placed on Mars since the first manned planetary landings will be made on that planet. The Viking will be the first soft lander in the program and will provide data on surface and atmospheric characteristics required to develop a landing system for man. The high data rate orbiter will provide high resolution maps of potential landing sites for man. Grand Tour missions represent a family of potential missions for flybys of interest. These missions include two-planet, three-planet, and four-planet possibilities with the payload ranging in size from Titan class to uprated Saturn V class. These missions will investigate surface and atmospheric properties of Jupiter, Saturn, Uranus, Neptune, and Pluto.

In summary, an Integrated Program approach will make it possible to realize benefits from earth orbit for mankind, determine if exploitation of lunar resources is desirable, and establish the systems and operations for manned planetary exploration with a minimum of new systems.

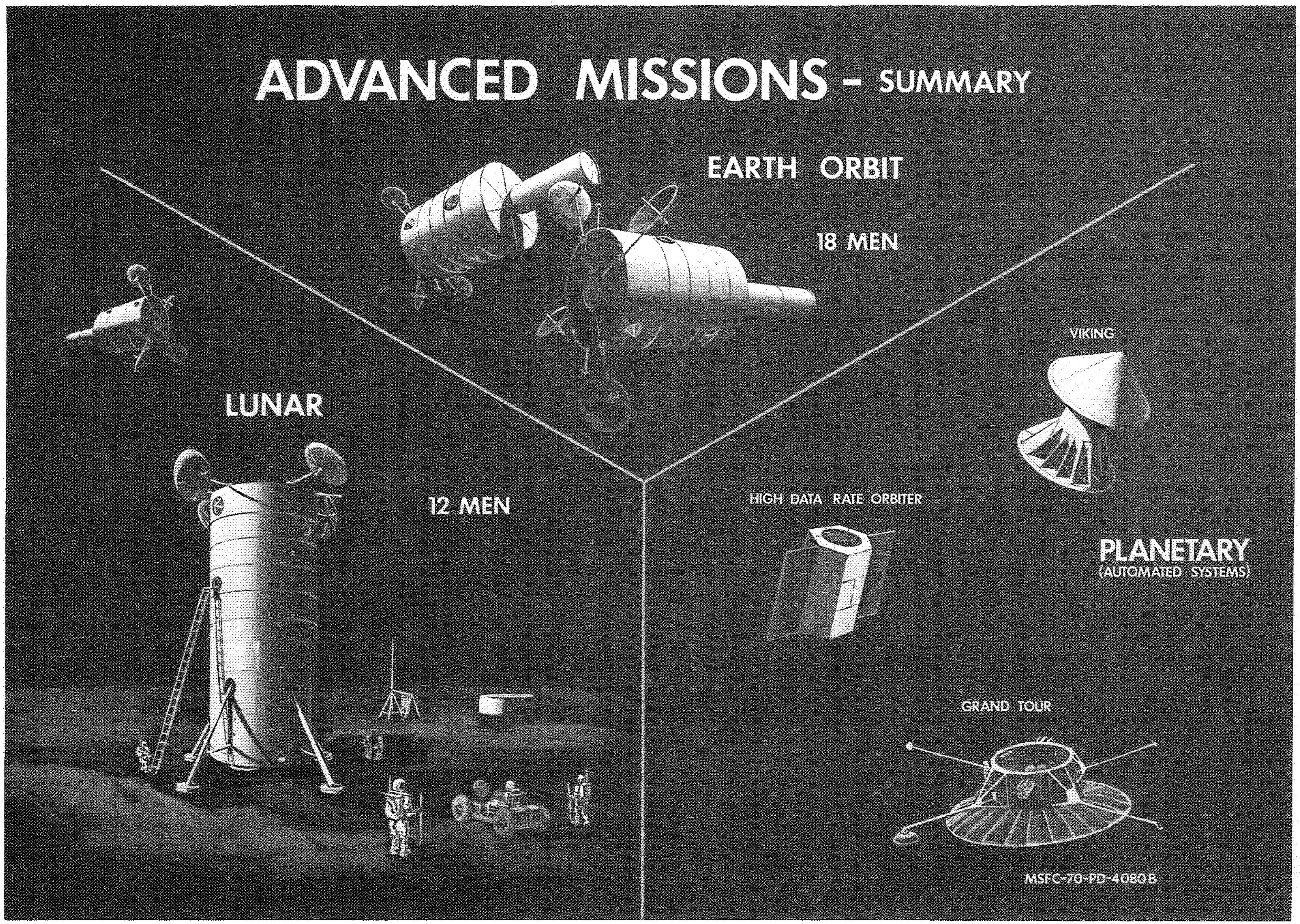

Figure 33. Advanced missions – summary.

ADVANCED MISSIONS – FURTHER EVOLUTION

With the advent of the late period, the nation will find itself in position to capitalize on the new capability and new systems developed before. These systems are the foundation for building major space facilities. The early and intermediate period will also provide the scientific knowledge and operational experience necessary for the major missions of the following decade. The manned Mars missions, for example, require extensive precursor activities, such as studies of the human effects of long duration space flight; unmanned reconnaissance of Mars; and creation of highly reliable life support systems, power supplies, and propulsion capability.

The later period should find the nation with a much enhanced capacity to proceed toward further long range program objectives. The establishment of a large space base, the exploitation and colonization of the moon, the manned exploration of Mars, and the automated missions to the outer planets will provide major scientific advances in the knowledge of our solar system and returns to man that will justify the investment.

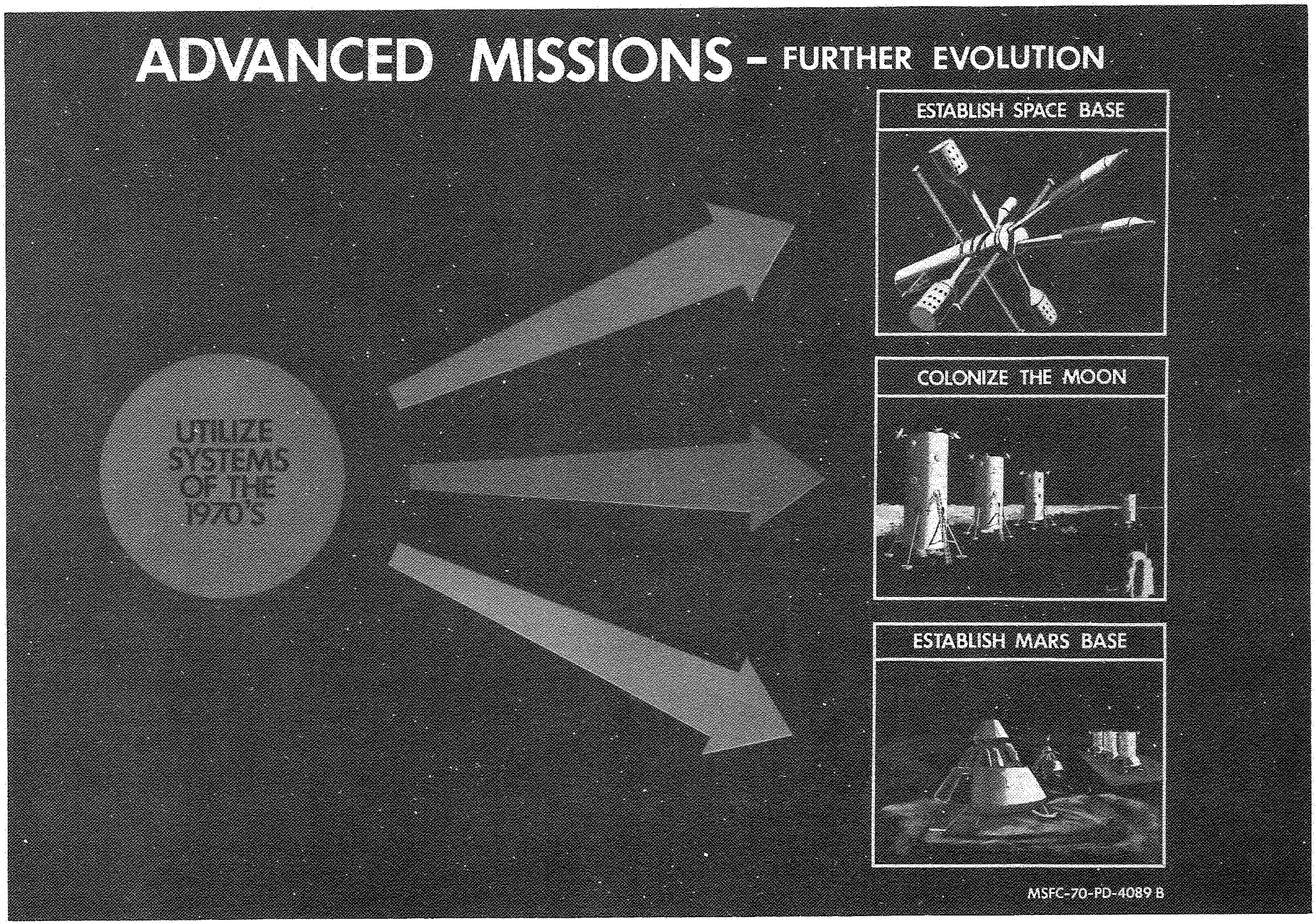

Figure 34. Advanced missions – further evolution.

PLANETARY MISSION EVOLUTION

In the late period, the nation will be in a position to capitalize heavily on the new systems developed by that time. In addition, the advances in knowledge and operational experience necessary for embarking upon major exploitation of space will have been accomplished.

In this time period the space station could be developed into a large space base in low earth orbit, providing it has been proven economically feasible and desirable. This space base would be constructed by clustering space station modules. The base would provide a large space laboratory of common equipment and modules where non-astronaut scientific personnel would be able to conduct a variety of scientific experiments. In lunar orbit a large lunar orbit station could be in operation, supporting extended lunar surface activities and laying the groundwork for future lunar bases. These developments will be made economically feasible by the availability of the low cost space shuttle, the space tug, and the nuclear shuttle.

In the planetary area the precursor activities necessary for manned exploration of the planets will have been accomplished. One additional major new system – the Mars excursion module – will have to be developed for the manned Mars landings. A manned Mars mission will be made feasible by the new systems developed. The space station module will be used as a crew compartment and cargo storage area, and the nuclear shuttle will be used for propulsion. The buildup for the Mars mission comprised of crew, cargo, experiments, and fuel will be accomplished by the low cost space shuttle. The space station modules and nuclear shuttles necessary for the mission will be placed into earth orbit by the two-stage Saturn V.

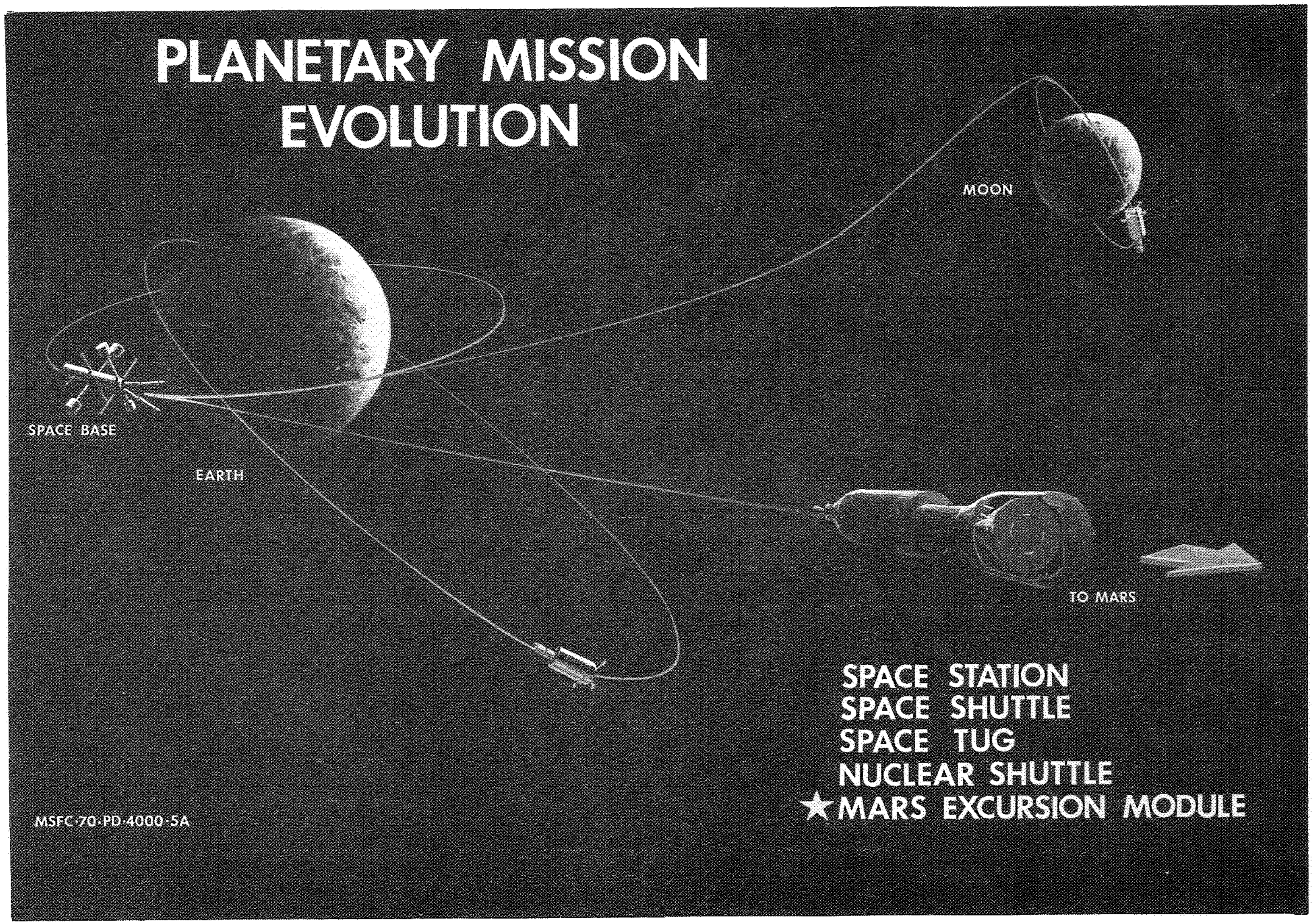

Figure 35. Planetary mission evolution.

SPACE BASE

The space station program will be the first step in an incremental program leading toward a centralized and general purpose earth orbital laboratory in the late period. This centralized facility, or space base, will introduce a new, more mature and routine mode of space operations than past programs. Long term operation with an associated low cost reusable transportation system will enable full exploitation of earth orbital operations. These new systems and operational concepts will involve significant reductions in operating costs and make possible large scale operations. Initially, the base will accommodate approximately 50 persons including a small number to perform command, control, service, and maintenance functions. Growth to a 100-man capacity is anticipated. All persons will be highly trained in specialized disciplines. Since the base will provide an earth-like environment in addition to large zero gravity facilities, little training, in comparison to present astronaut training, will be required to compensate for the environment. The base will be assembled in a 55-degree inclination, 270 nautical mile orbit by the coupling of both common and special purpose modules launched to earth orbit by Saturn V two-stage launch vehicles.

One of the space base options being investigated is shown on the facing page. It is designed for both zero and artificial gravity operations. In its final assembled form, portions of the living quarters are conceived to rotate around a central hub at about 4 rpm at a radius of some 100 feet from the axis of rotation. Large portions of the base will be counter-rotating to facilitate docking and to support scientific investigations taking place in the weightless environment. It is modular in construction to enable reconfiguration or expansion through in-orbit assembly. The base is powered with a large nuclear power supply and contains advanced closed loop life support systems. Command post functions permit highly autonomous mission operations and will reduce mission support ground activities.

The base provides an extensive experiment support capability for space astronomy, space physics, earth surveys, advanced technology, aerospace medicine, materials processing, and engineering operations. Extensive laboratory facilities are provided. Modules which can operate in an attached mode to the base are launched periodically during the lifetime of the base and docked to one of the many experiment support docking ports provided on the base. Included are earth survey and materials processing modules as shown. Others, which require extremely fine pointing or very low gravity levels not provided by the base, will be operated as free-flying, remote modules which return and dock to the base periodically for servicing. Some of the astronomy and space biology experiment modules fall into this category.

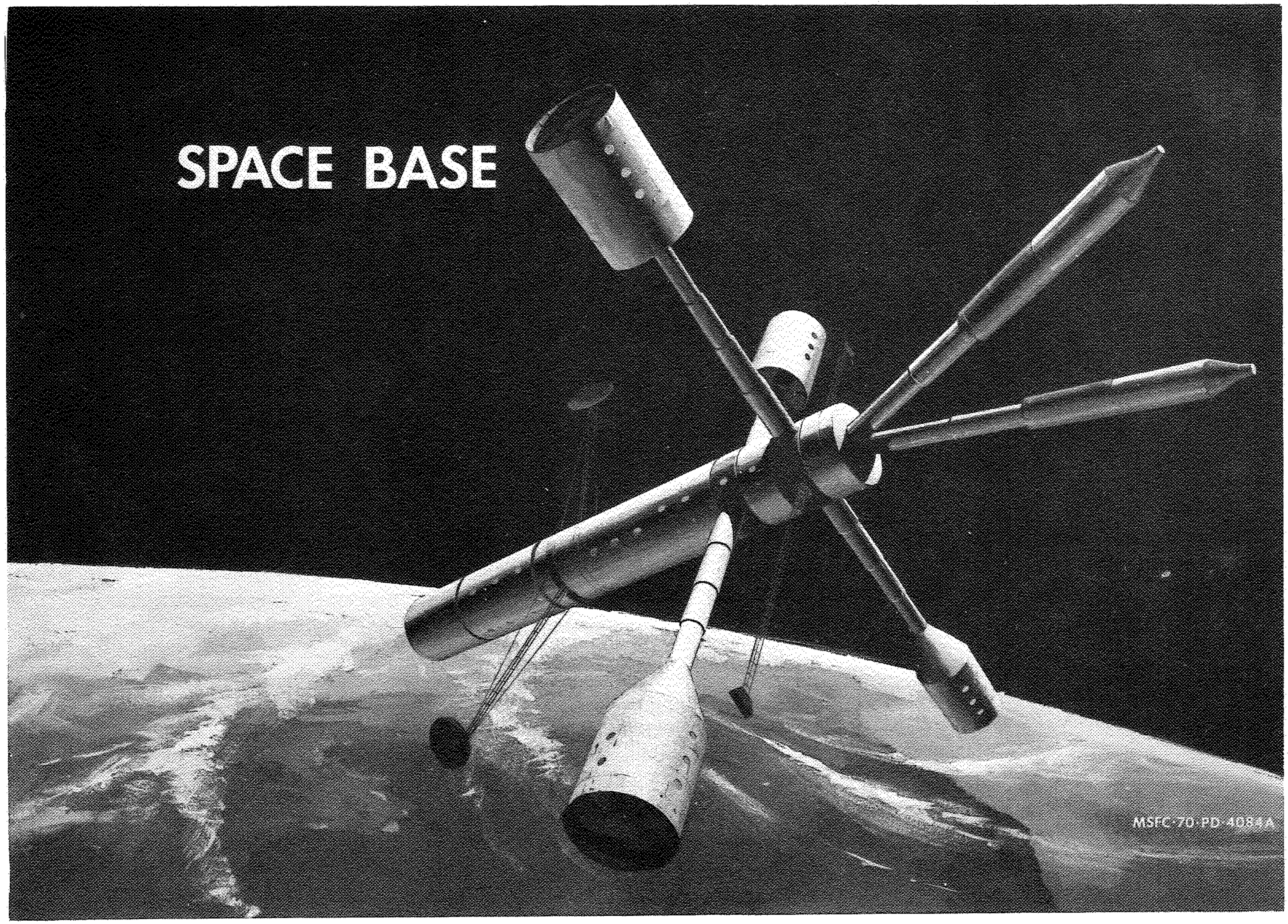

Figure 36. Space base.

SPACE BASE OPERATIONS

The space base will serve as a focal point for a wide variety of orbital activities taking place in low earth orbit. It provides continuous support services for permanently docked experiment modules, control/monitor functions for detached experiment modules, and periodic refurbishment/resupply services for these modules.

Docking, servicing, and recharging functions are also provided to the space tug which was utilized in the initial assembly-buildup of the base and which now provides a variety of support functions as a part of the overall base operations. Included are such tug functions as overall base exterior inspection and repair; service of the nuclear power supply; support in the unloading of upcoming cargo from the space shuttle to the base; service, inspection and retrieval of remote experiment modules or satellites; and transfer of crew and cargo modules from the space shuttle to a nuclear shuttle for missions to lunar and geosynchronous orbits.

Versatile docking facilities are provided for the space shuttle at the base to enable accommodation of frequent crew and cargo deliveries. During use of the space shuttle to resupply the nearby propellant storage depot, the base will monitor, support, and provide shuttle crew accommodations if needed. Monitoring of propellant transfer operations, servicing, and maintenance at the propellant depot will be provided by the space base/space tug system.

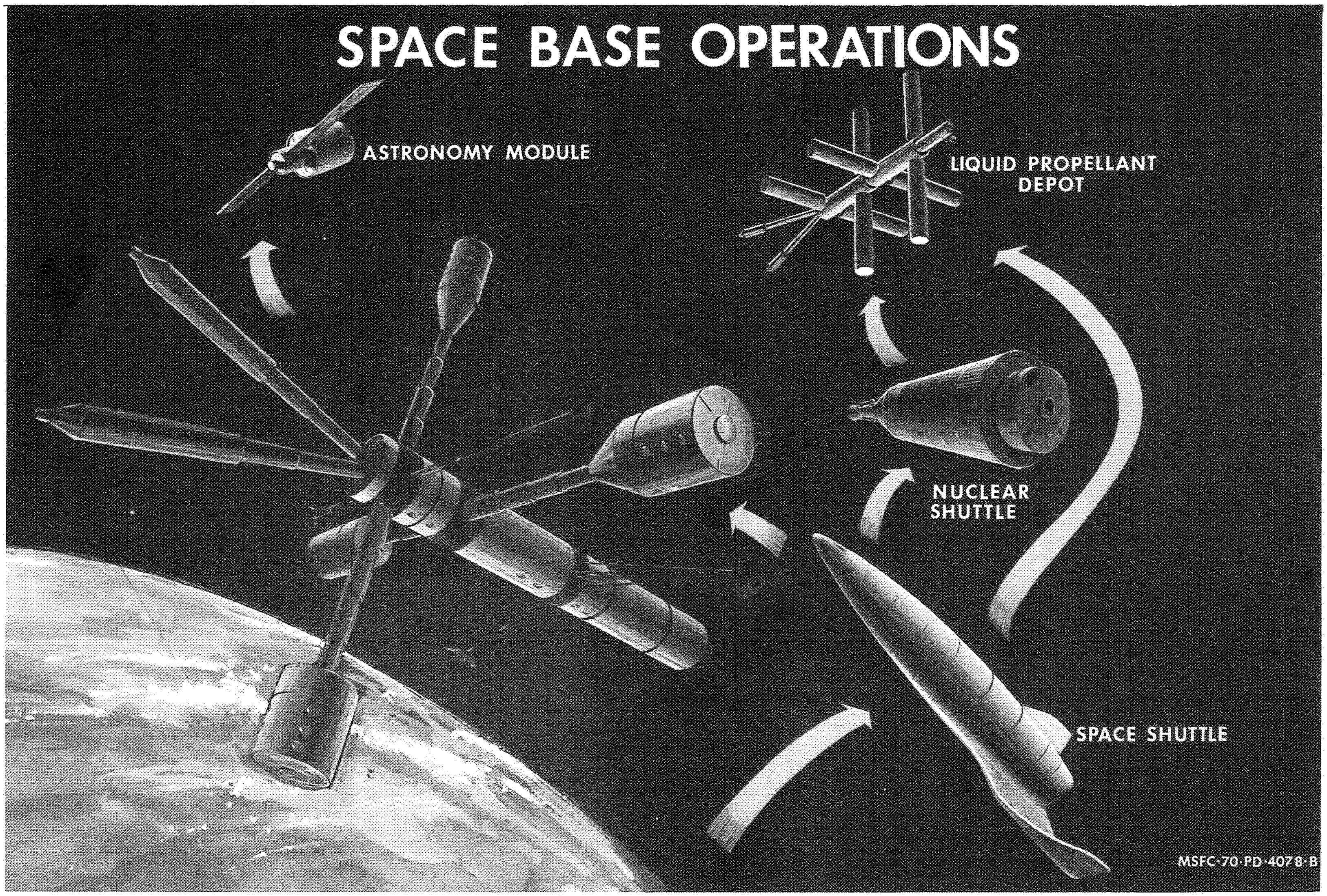

Figure 37. Space base operations.

MARS LANDING MISSION PROFILE

A 1986 opposition-class mission has been selected as typical of those being considered. After a Venus swing-by, the two space vehicles arrive at Mars where, after a brief orbital period, a Mars Excursion Module from each vehcle descends to the surface. After a 40- to 60-day surface stay time the ascent stage of the Mars Excursion Module rendezvouses with the Planetary Mission Module for a direct heliocentric transfer to earth.

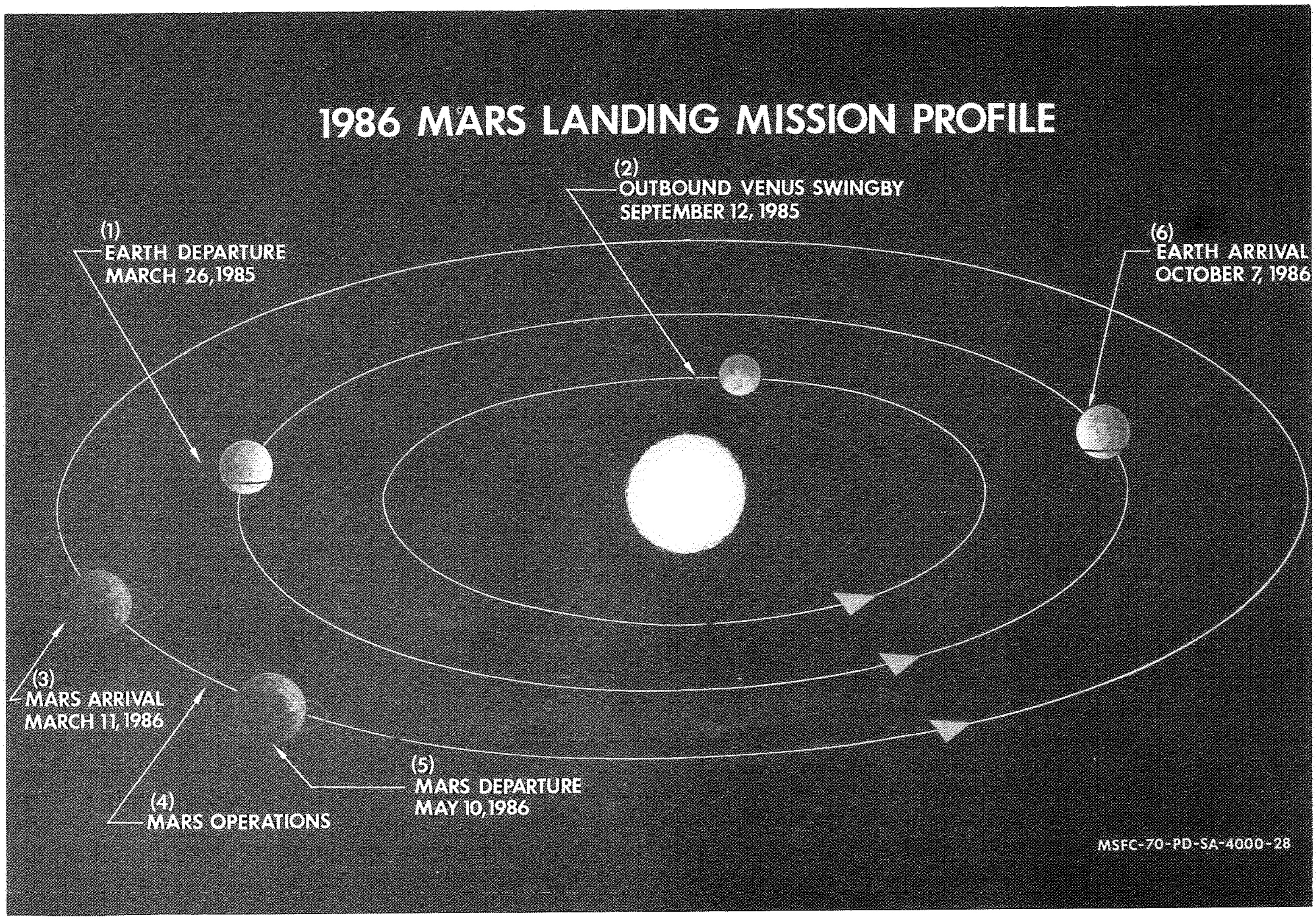

Figure 38. Mars landing mission profile (1986).

EARTH ORBIT DEPARTURE

Two planetary space vehicles, of essentially the same design, depart earth in the spring of 1985 on a heliocentric transfer to Mars. Two of the three propulsion modules inject the vehicles into their desired trajectory and return to earth orbit for reuse.

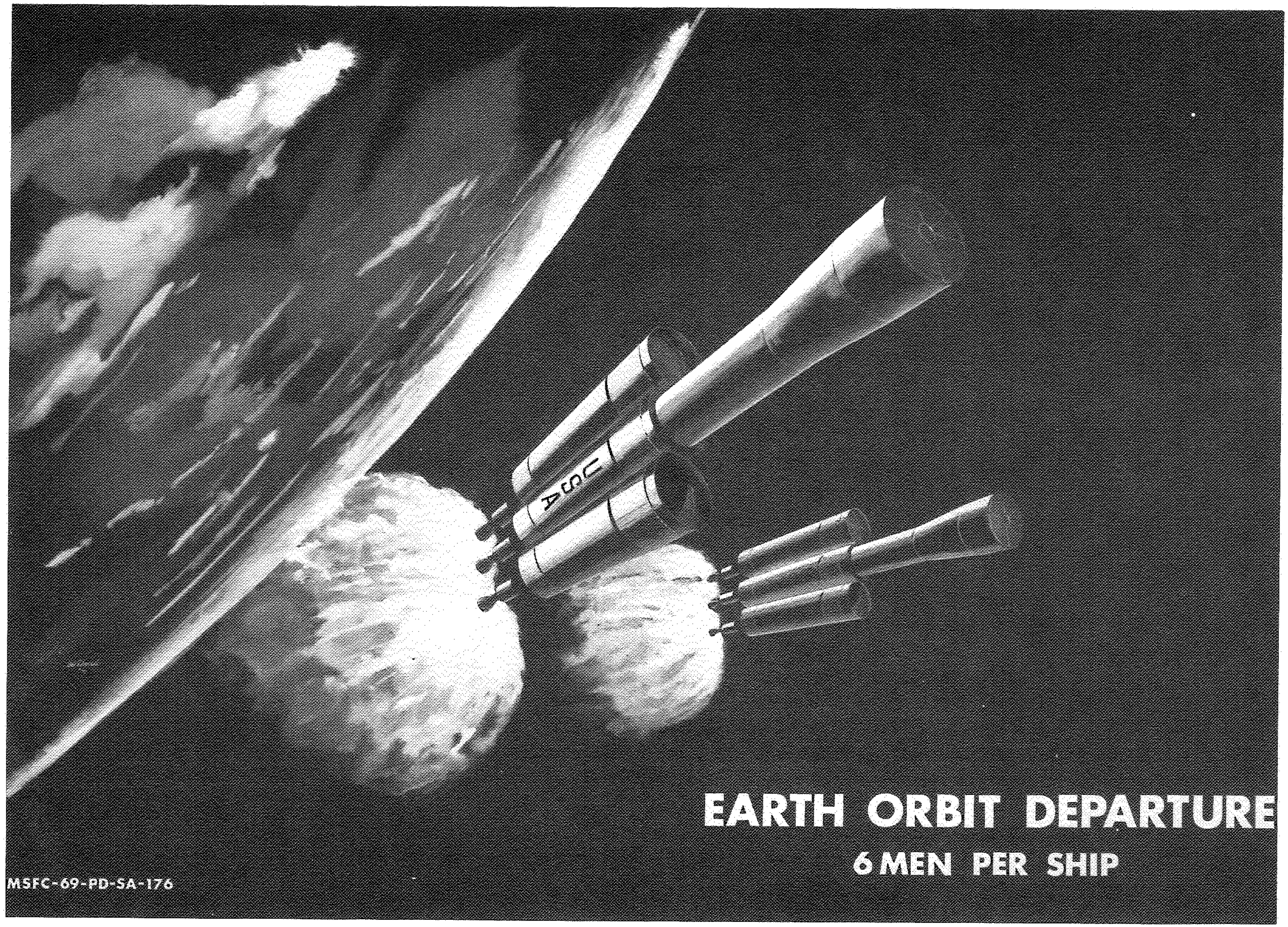

Figure 39. Earth orbit departure.

RELEASE OF VENUS PROBE

During the Venus swing-by, a probe is released which would penetrate the planetary atmosphere to measure atmospheric composition, magnetic field, and visible clouds. A soft lander probe breaks away from the main probe and descends to the Venus surface.

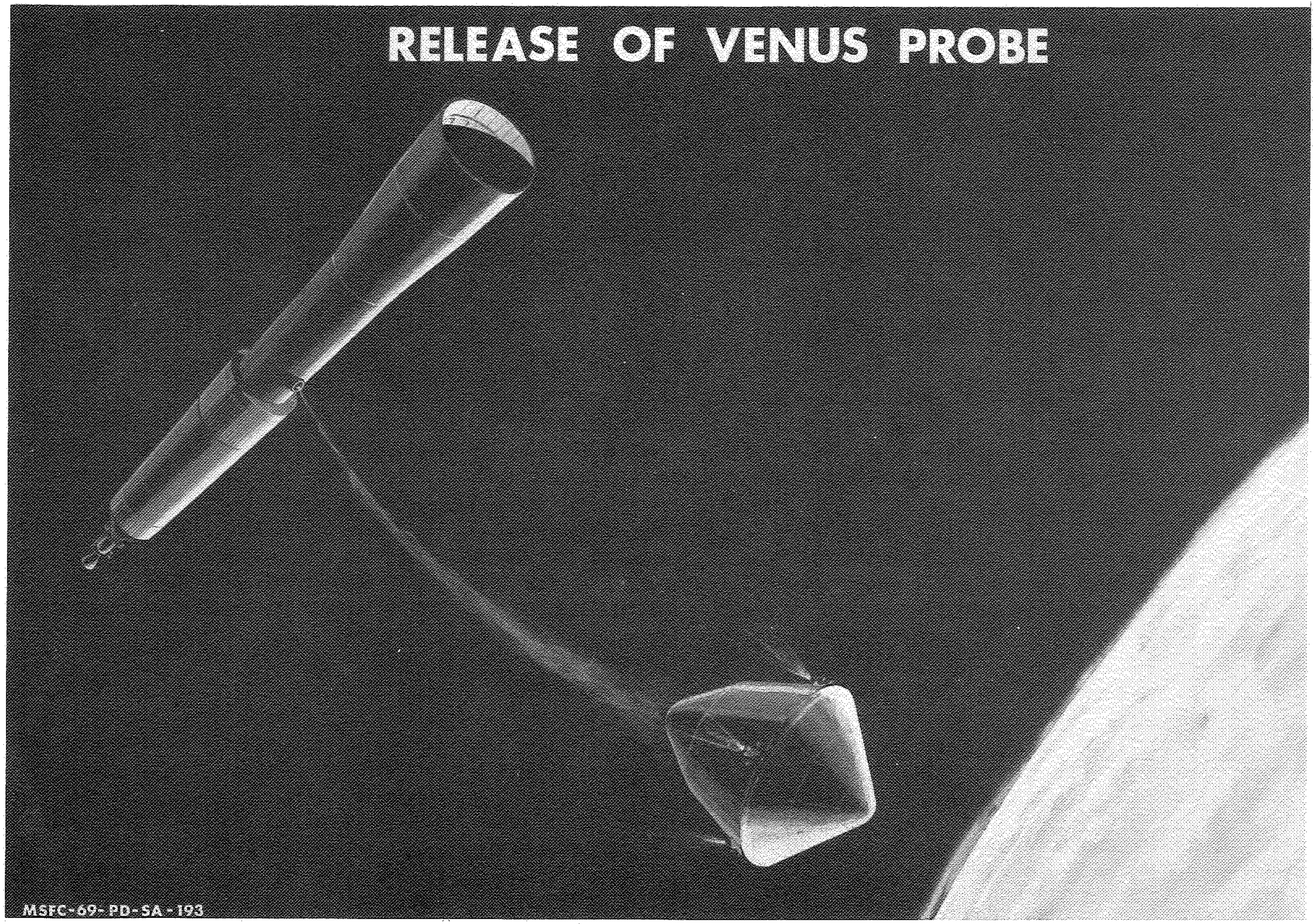

Figure 40. Release of Venus probe.

MARS SURFACE SAMPLE RETURN

Prior to the manned Mars landing from Mars orbit, unmanned probes descend to the surface for surface sample acquisition. The samples are returned to the planetary mission module by a return stage built into the unmanned lander. The returned samples will be analyzed on board before a manned landing is initiated.

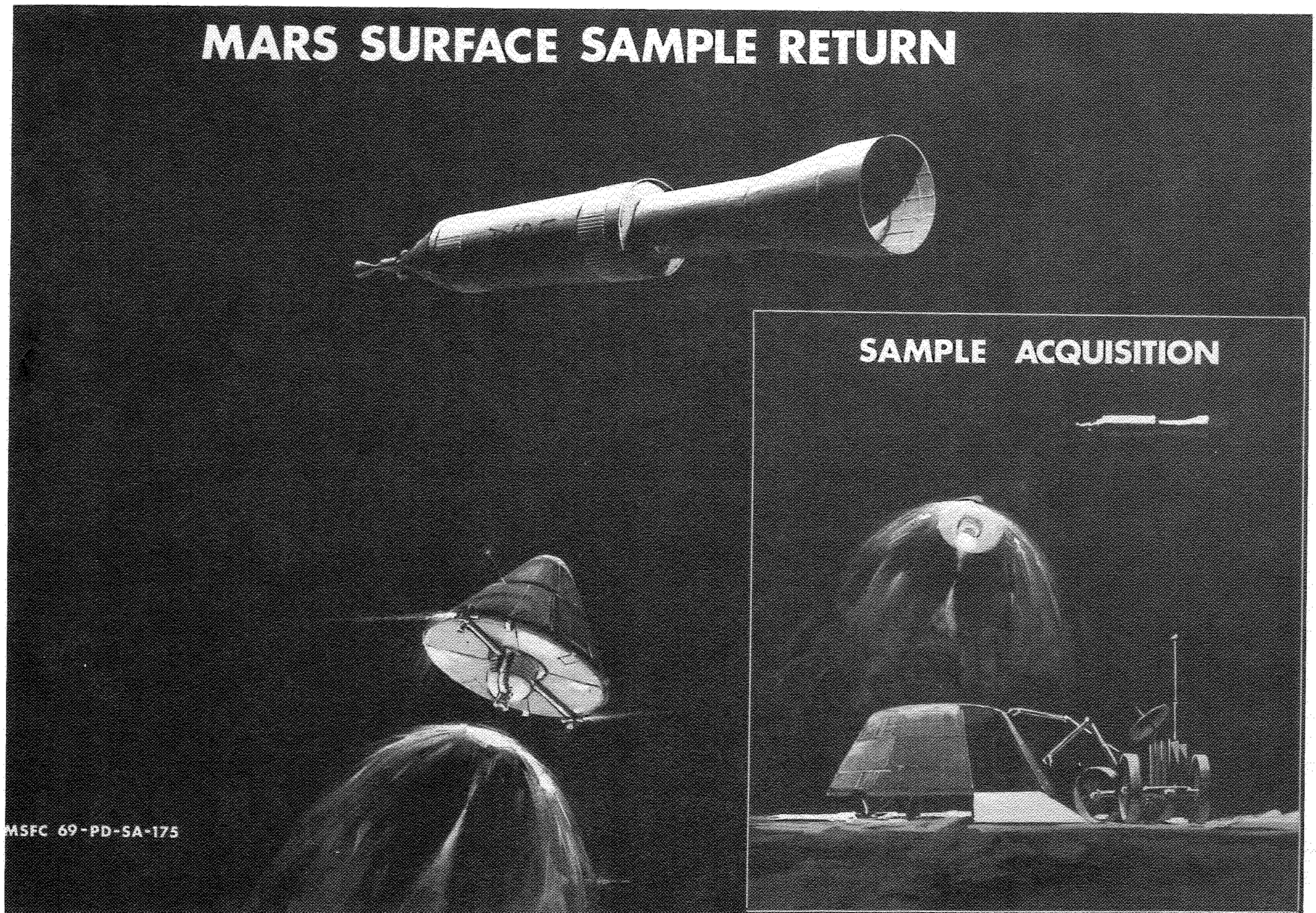

Figure 41. Mars surface sample return.

MARS INITIAL LANDING

One of the prime objectives of space exploration is to obtain a better understanding of the origin and evolution of the universe. With the equipment and techniques developed in the earth orbital and lunar programs previously described, man may expand his horizons to the exploration of the planets and, thus, better attain this understanding.

The extension of man's space exploratory capability to include the surface exploration of Mars would require only one major new development – a Mars excursion module (MEM) – for transporting men and equipment from Mars orbit, to the surface, and back to the orbiting spacecraft which would, in turn, return the men to earth. The nuclear shuttle, station module, and other mission related equipment are common with that of the earth orbital and lunar programs.

The Mars surface activity on the initial mission will be similar in many ways to the early lunar exploration activities. Notable, however, is the much longer stay-time (30 to 60 days per MEM) which permits more extensive observation, experimentation, and execution of scientific objectives. Surface operations include experiments to be performed in the MEM laboratory as well as the external operations on the Mars surface. The small rover vehicle will permit trips to interesting surface features beyond the immediate landing area.

While the landed crew carries out the surface expedition, part of the crew remains in the orbiting mother ship to conduct experiments, monitor the surface operations, and conduct the necessary spacecraft maintenance. During the outbound and inbound legs of the mission, experimental activities will be conducted, such as solar and planetary observations, solar wind measurements, biological monitoring of the crew, test plant and animal observations, and (during the inbound leg only) analyses of the Mars samples.

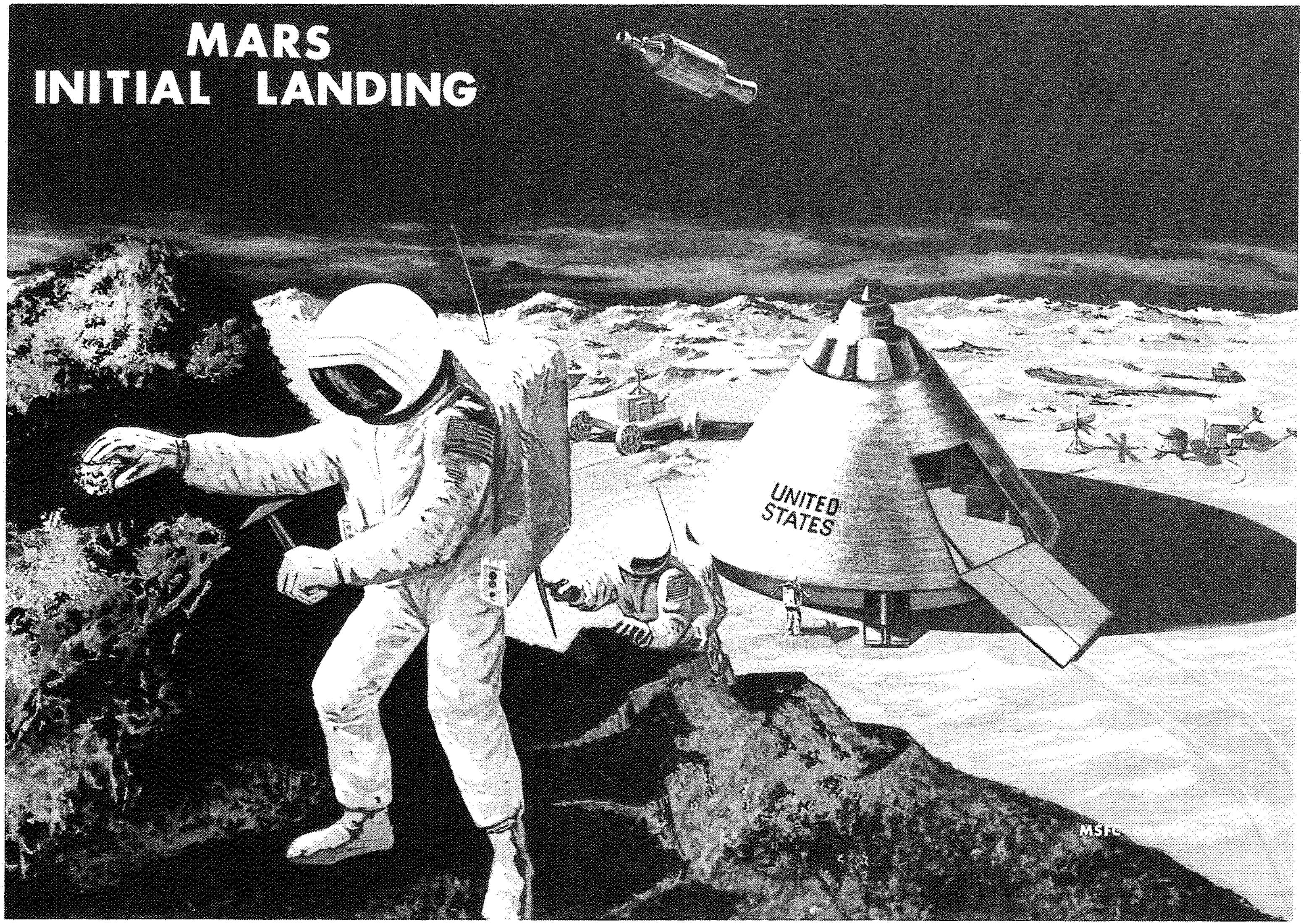

Figure 42. Mars initial landing.

MARS EXCURSION MODULE CONFIGURATION

The Mars excursion module (MEM) is designed to transport the surface exploration crew and their equipment to the Mars surface, provide living accommodations for a 30- to 60-day exploration period, and transport the crew, scientific data, and samples back to the orbiting spacecraft.

The MEM is an Apollo-shaped vehicle which uses aerodynamic braking to remove most of the velocity of the spacecraft during descent and a terminal propulsion system for the final braking and landing maneuvers. The descent stage also contains the crew living quarters, a scientific laboratory for use during the surface exploration, and a hangar for transporting a small rover vehicle to the surface and storing it during periods of non-use. The descent stage also serves as a launch platform for the ascent vehicle.

The crew compartment is located above the MEM ascent stage. This compartment is occupied by all crew members during descent and ascent phases of the mission and serves as a command control center during the surface exploration.

After completion of the surface exploration phase of the mission, the MEM ascent propulsion system launches the men, their equipment, and samples back to Mars orbit where they rendezvous with the orbiting spacecraft.

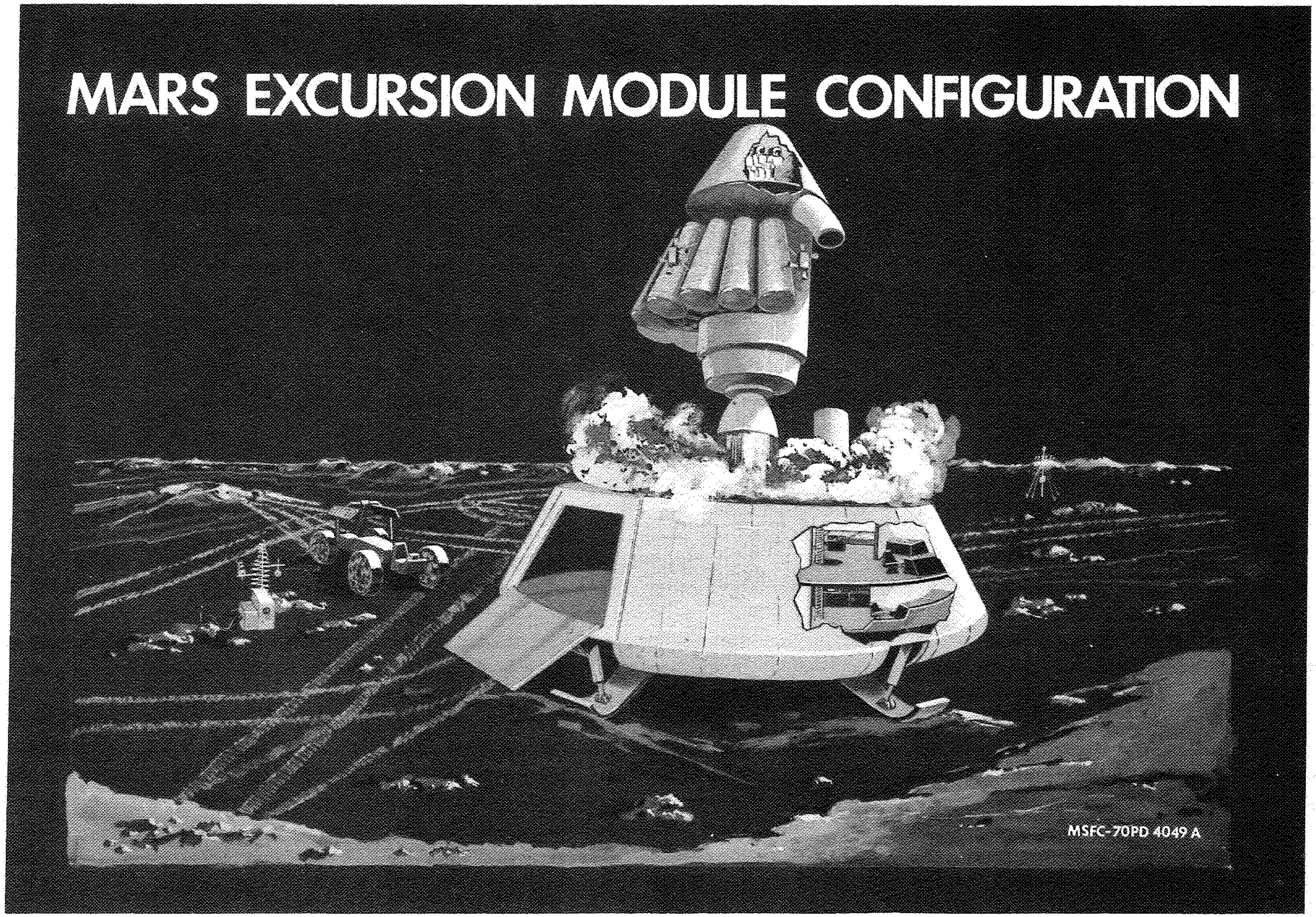

Figure 43. Mars excursion module configuration.

SPACE SCIENCE AND TECHNOLOGY – LATE PERIOD

The late period will emphasize a continuing exploration of the solar system and general application of space capabilities for benefits to mankind.

Research effort and observational programs in earth orbit will have shifted almost exclusively to the application of near earth space facilities to support earth oriented problems, e.g., weather, communication, navigation and traffic control, oceanology, natural resources, medicine, etc. These scientific and observation facilities will have been made possible by using the systems and laboratory facilities developed in the decade of the 1970's – the space base and its research laboratories, the space shuttle, and the space tug.

A diversified program of various technological investigations and tests will be implemented. Materials with unique properties will be manufactured under weightless conditions and returned to earth for specific applications.

A permanent medical and biological facility will be established in earth orbit and will be used in a clinical capacity. It will serve as a quarantine facility for crew members (and samples) returning from Mars surface missions.

A national astronomical space facility will become operational. Continuous observations of the sun will be made and the outer reaches of the universe will be probed in many regions of the electromagnetic spectrum. The observatories of this astronomical complex will be widely separated in space. Observatories will be provided in low earth orbit, in synchronous orbit, and on the moon.

A large, permanent lunar base will be established to permit astronomical studies from the lunar surface and to act as a staging area for continuing intensive and extensive exploration of the lunar surface, exploitation of lunar resources, and various scientific studies.

The decade of the 1980's will be highlighted by initiation of manned exploration of the planets. This exciting and most challenging exploration will utilize information on Mars and its environment obtained by automated scientific probes and landers of the previous decade. Space systems and experiments required for exploration and exploitation of near earth space and the moon will be utilized in the exploration of Mars.

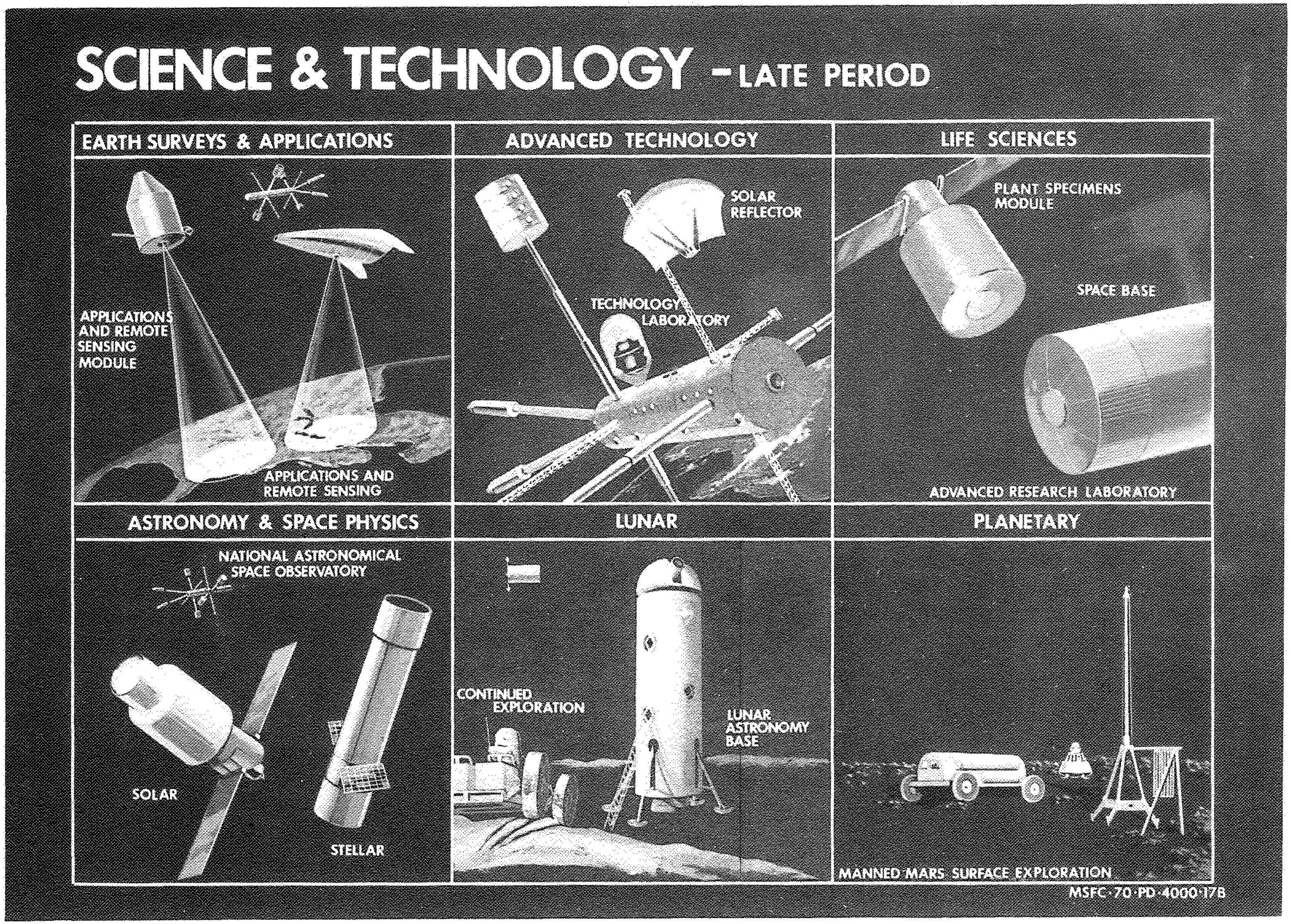

Figure 44. Science and technology – late period.

MISSION EVOLUTION THROUGH HARDWARE COMMONALITY

The commonality chart shown earlier discussed the mission rationale and systems developed during the early and intermediate periods. The chart on the facing page, also concerned with commonality, is intended to show how these systems are utilized in the ambitious base buildup efforts of the late period. For instance, the space station module is an integral building block of the space base and is also utilized in both Mars orbit and on the Mars surface. It should be noted that the Mars excursion module is the only major new system required to implement the missions of the late period. The late period is the time during which the systems of the early and intermediate periods will be exploited, and the returns on the investment of the previous decades will be substantiated.

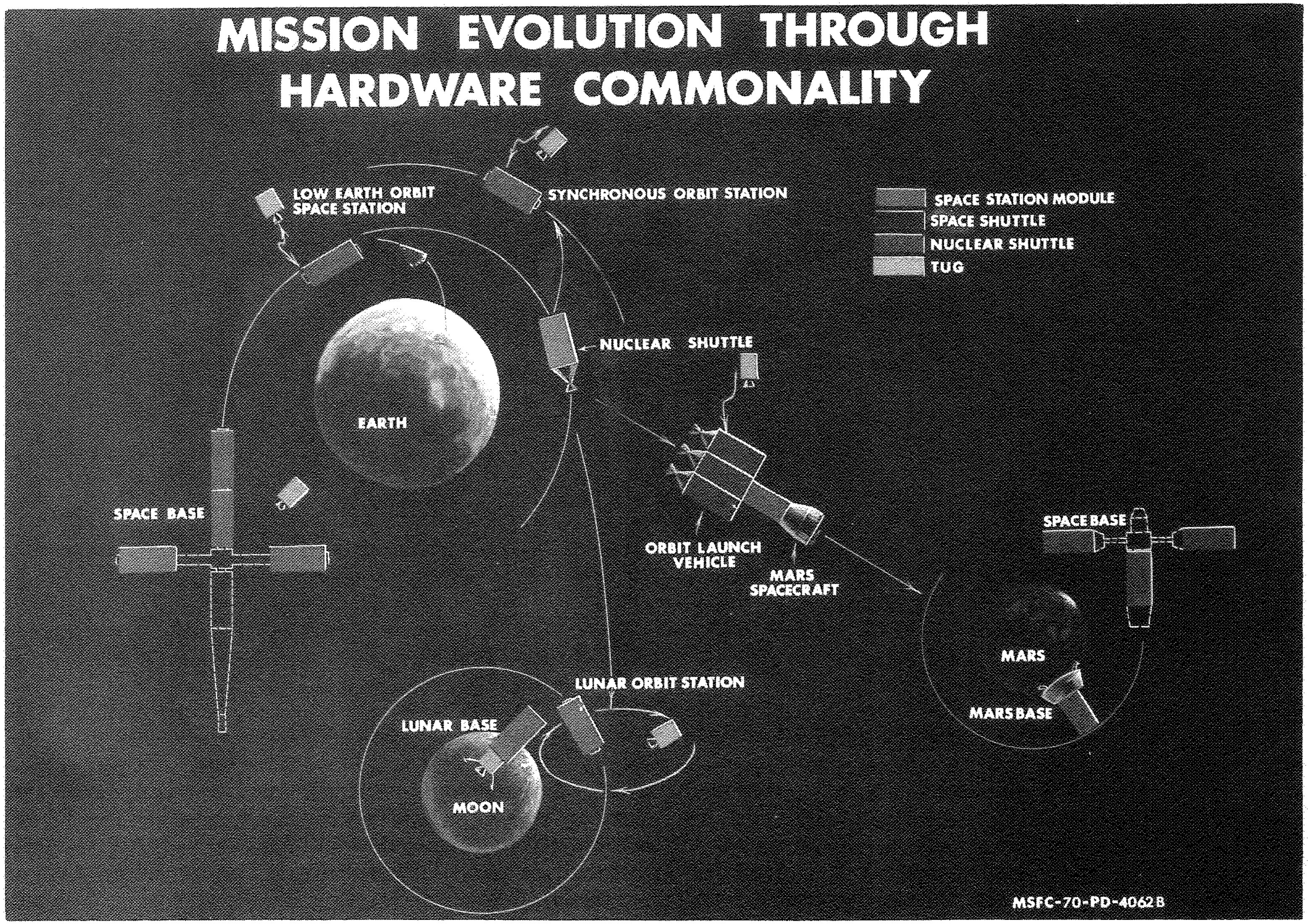

Figure 45. Mission evolution through hardware commonality.

SPACE FLIGHT EVOLUTION

A summary of the missions and systems which have been described previously are shown on the next two charts. These missions, with the indicated sequencing, constitute an Integrated Program. It should be emphasized that development of the key systems will make it possible to execute many program and mission variations without substantial funding increases. The program provides a logical evolution from the utilization of Apollo systems in the early period to the new systems of the intermediate period, subsequently, to the extensive manned activities of the late period.

Maximum utilization of Apollo systems in the early period is demonstrated by the use of two Saturn V launched Skylabs in earth orbit. Additional missions for further lunar exploration would use low cost reusable systems.

During the early period the Apollo systems provide the experience for the design of new systems which will provide the commonality and reusability necessary to economically increase capabilities in the intermediate period. These systems are: a space station module, a space shuttle, and a space tug. Two space station modules are integrated to serve as a space station in earth orbit until the end of the decade. This same basic module is used in lunar orbit and as a lunar surface base. The reusable nuclear shuttle is introduced to reduce the cost of space propulsion. Initially, it is used to provide low cost transportation between low earth orbit and lunar and synchronous orbits.

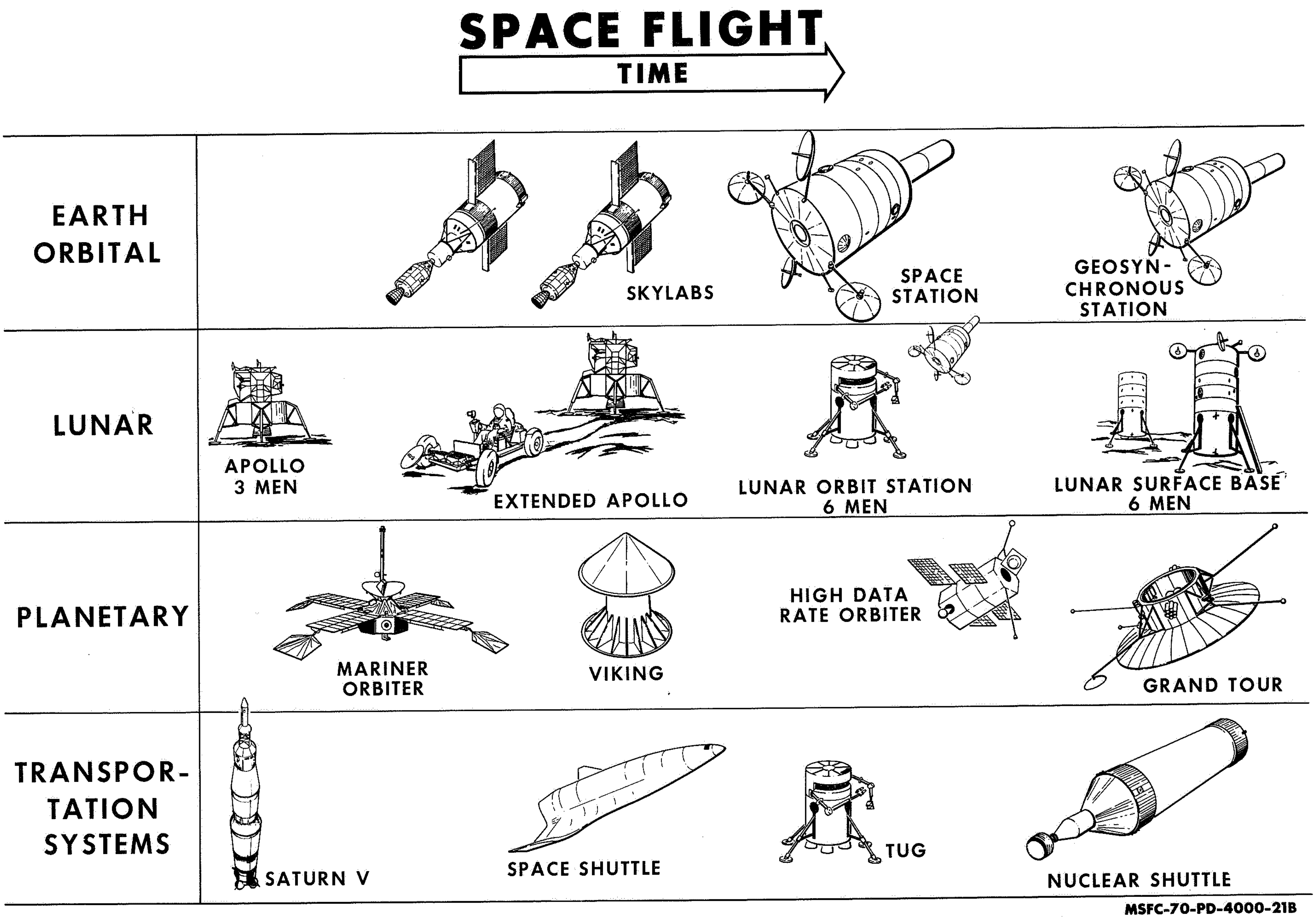

Figure 46. Space flight evolution.

SPACE FLIGHT EVOLUTION (Continued)

The earlier systems and mission activities provide the foundation for the development of major space facilities in the late period. The space station evolves into a space base that can support up to 100 people. This facility allows extensive multi-disciplinary scientific activities as indicated. Similarly, these new systems permit increased lunar operations if lunar exploitation proves to be economically feasible and desirable. The logical culmination of the late period is the manned Mars landing mission. The systems developed and the experience gained earlier make this challenging mission feasible. The level of manned planetary activity in the late period and beyond will depend largely upon the results and findings of earlier missions, including the practicality of recovering resources from the planets.

In summary, the shown space flight evolution represents a total space program which will accomplish the recognized objectives. It offers the nation the opportunity to reap significant returns from its space investment while contributing extensively to the advancement of knowledge. Through applying the concepts of commonality and reusability in the design of new systems and by diligently seeking to economize in space flight operations, the nation in the next two decades will be able to engage in a wide variety of scientific and exploratory space missions in an economical manner.

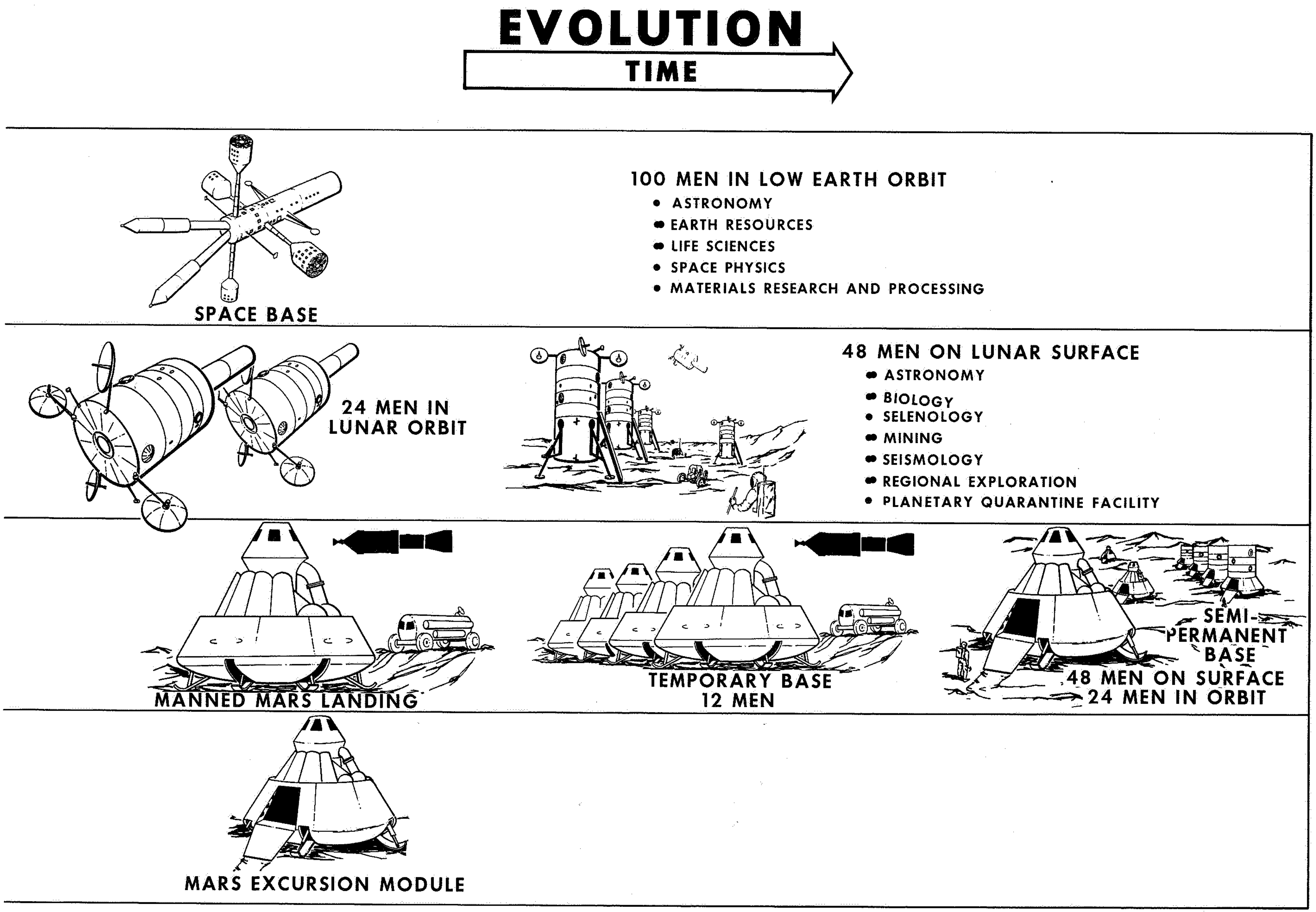

Figure 47. Space flight evolution.

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APPROVAL

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SPACE FLIGHT EVOLUTION

By Georg von Tiesenhausen and Terry H. Sharpe

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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