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SPACE TRANSPORTATION SYSTEM OVERVIEW AND PROGRAM PLANS

by

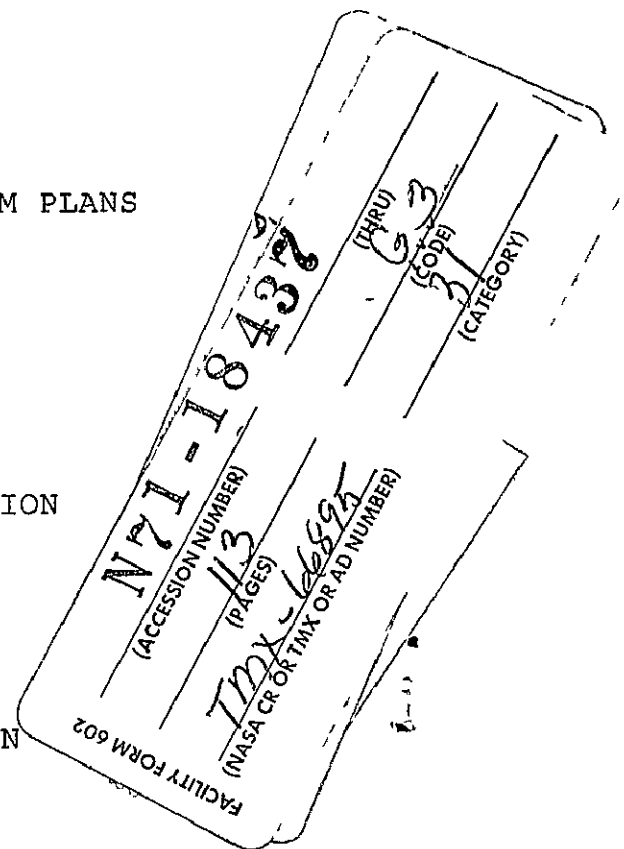
DALE D MYERS
ASSOCIATE ADMINISTRATOR
OFFICE OF MANNED SPACE FLIGHT
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D C

BRIEFING TO

EUROPEAN LAUNCHER DEVELOPMENT ORGANIZATION

JULY 7, 1970

BONN, GERMANY



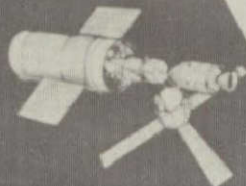
NASA-5-69-4600 V

NASA HQ MR70-5764

6-26-70

INTEGRATED PROGRAM

EARTH ORBITAL



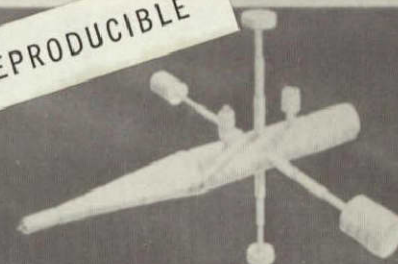
SATURN WORKSHOPS



SPACE STATION



SYN ORB STA



SPACE BASE

NOT REPRODUCIBLE

LUNAR



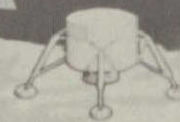
APOLLO 3 MEN



EXTENDED APOLLO



LUNAR ORBIT STATION



LUNAR SURFACE BASE

PLANETARY



MARINER ORBITER



VIKING



HIGH DATA RATE ORBITER

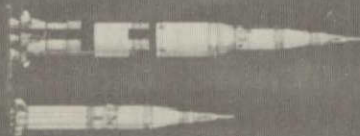


GRAND TOUR



MANNED MARS EXPLORATION

TRANSPORTATION SYSTEMS



SATURN



SPACE SHUTTLE



TUG



NUCLEAR SHUTTLE

INTEGRATED PLAN

An overall plan for space exploration and utilization has been established. The plan is flexible with no specific time schedule placed on the longer term elements. The plan involves the establishment of permanent bases - first in earth orbit then extending out into deeper space with a system of reusable transportation systems for logistic support. Normally, the larger manned systems are preceded by smaller unmanned systems and ultimately the features of both will be incorporated in the future space activities.

THE NEED FOR A SPACE TRANSPORTATION SYSTEM

**CONTINUED PROGRESS IN SPACE RESEARCH AND USE
DEMANDS LOWER COST TO CARRY OUT VARIED
MISSIONS REQUIRED**

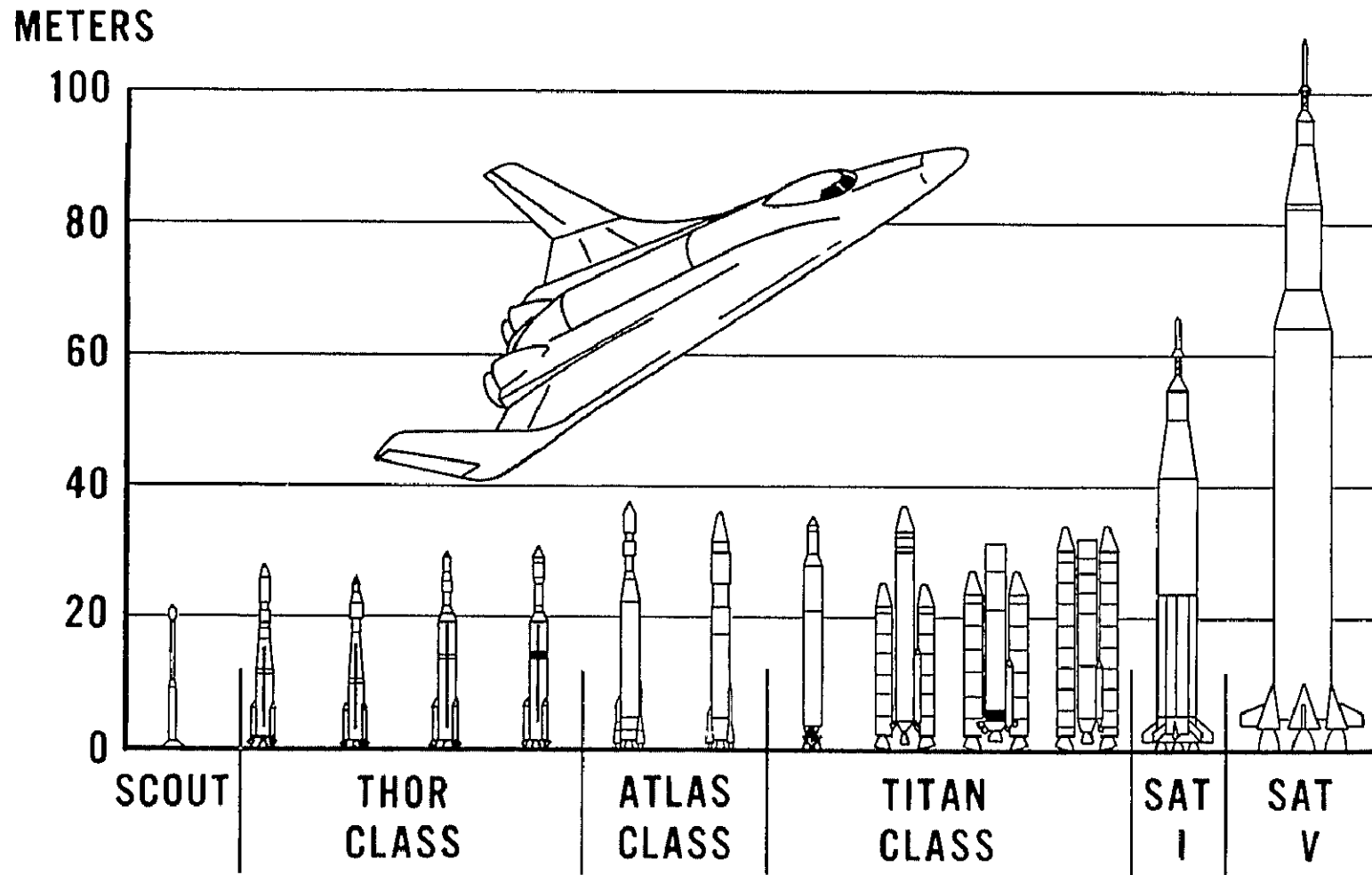
**THE SPACE TRANSPORTATION SYSTEM REPRESENTS A
LOGICAL STEP TOWARD EFFICIENT EXPANSION OF
SPACE ACTIVITY BY**

- **REVOLUTIONARY CHANGE IN TRANSPORTATION**
- **GREAT FLEXIBILITY**
- **ECONOMICAL USE OF MAN**

THE NEED FOR A SPACE TRANSPORTATION SYSTEM

To support future space flight operations, we must greatly reduce the annual costs of space transportation operations, while sustaining the necessary number of space flights. During this first decade of space operations, our technology base has steadily advanced to the point that new systems can be defined now, which can satisfy the (1) basic need of major reductions in the cost of placing satellites, men, equipment and supplies, into orbit, and (2) major advancements in space system versatility. To use space as we use other parts of our environment, it must be readily accessible and economical. The most significant feature of the shuttle concept is maximum reusability from flight to flight.

LAUNCH VEHICLE REPLACEMENT



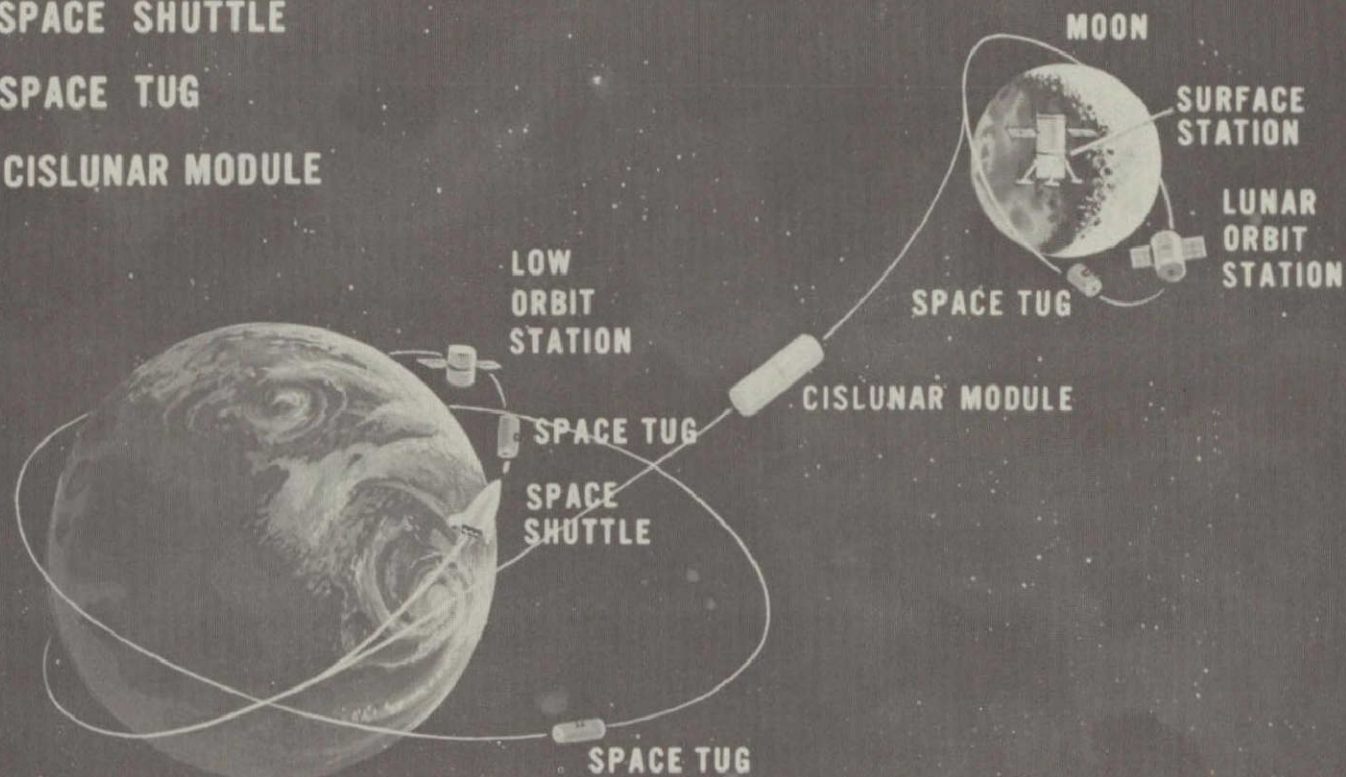
LAUNCH VEHICLE REPLACEMENT

Multiple usage represents one of the essentials for cost reductions in space shuttle operations. The shuttle baseline has been defined to encompass payload transportation from the thousand pound Thor class vehicle through the 35,000 pound Saturn 1B capability, and will eventually replace all these launch vehicles.

The small 100 pound class satellite will still be more efficiently launched by the smaller scout booster from such economically operated bases as Wallops Island, Virginia. The 250,000 pound capability of the Saturn V rocket will still be maintained to orbit very large payloads.

ELEMENTS OF THE SPACE TRANSPORTATION SYSTEM

- SPACE STATION MODULE
- SPACE SHUTTLE
- SPACE TUG
- CISLUNAR MODULE



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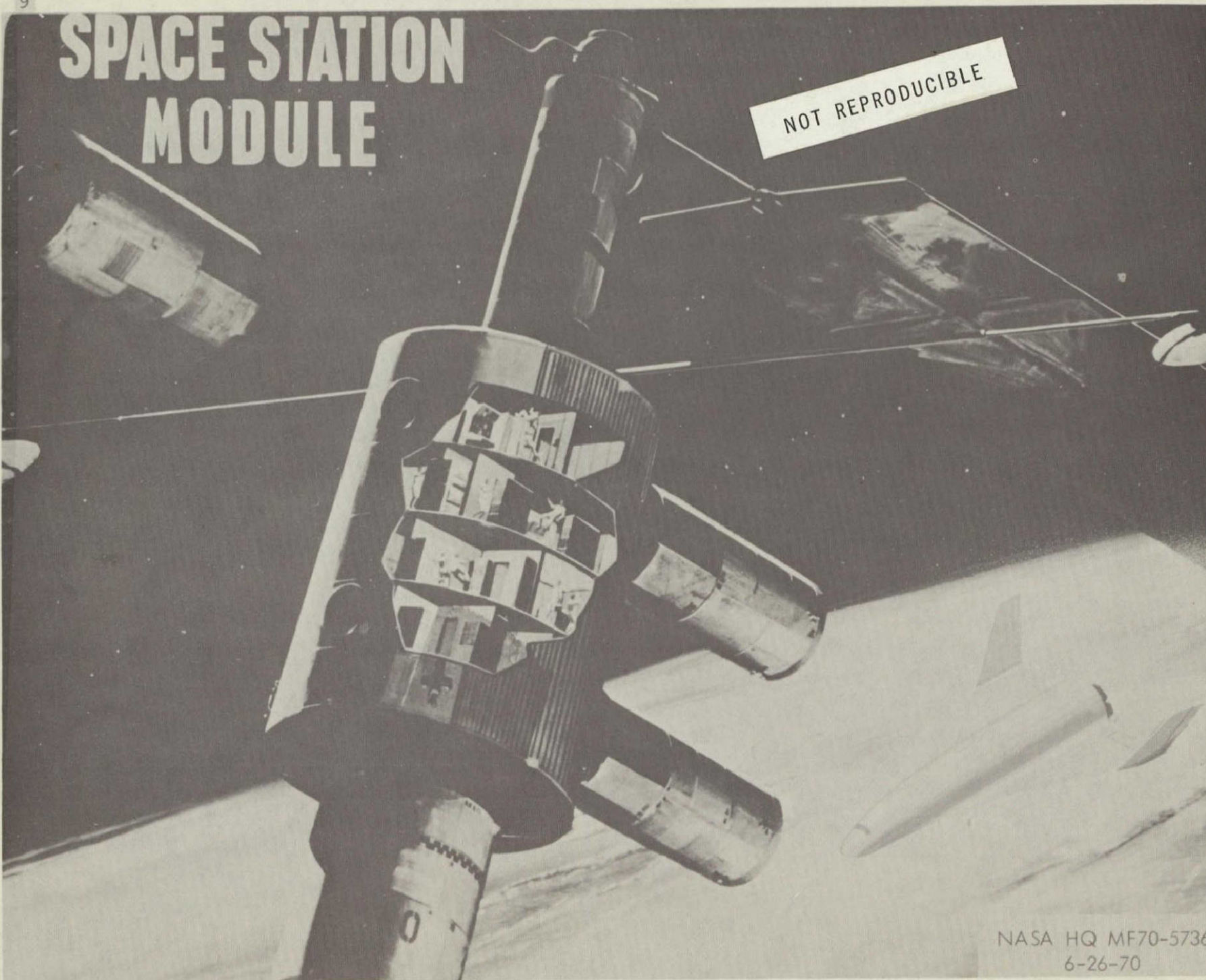
ELEMENTS OF SPACE TRANSPORTATION

This illustration depicts the major elements of the space transportation system as it is now envisioned. A key feature of this system is that all of its elements the Space Shuttle, the Space Tug and the Cislunar Module will be designed for a maximum degree of mutual operational compatibility. For example, the Space Shuttle will be able to deliver the Space Tug to earth orbit and then service it. The Shuttle will also carry liquid hydrogen propellants, payloads, and other operational logistics for the nuclear shuttle. The Space Tug will be able to deliver payloads to high energy orbits and will be a key element of the Space Transportation System.

All of these elements will make it possible to assemble and operate a space station in low or synchronous earth orbit, lunar orbit, or as planetary mission modules. In planning future space exploration the Space Transportation System will be a key to the development of these plans.

SPACE STATION MODULE

NOT REPRODUCIBLE



NASA HQ MF70-5736
6-26-70

SPACE STATION

The Space Station will provide a centralized facility in orbit for international research, applications, and space operations. The facility will have a crew large enough to permit a high degree of specialization. The crew will include experimenter/astronauts qualified in a research discipline but with minimum spacecraft systems training. A general purpose laboratory with commonly used instrumentation, photographic processing and automatic data processing will be available onboard.

The Space Station will be designed for a very long life over which to amortize the substantial investment. Onboard maintenance and economical resupply using the Shuttle will make this possible. As a further means of minimizing operating costs, the Space Station will have capability onboard for fault isolation, and navigation; therefore, it will be unnecessary to man ground stations and control centers to the extent used for Apollo.

The Space Station will be designed like a ground-based laboratory facility for modification and growth. Research and development equipment not available or even conceived at the time the station is launched will be delivered by the Shuttle and installed in one of the integral laboratory areas. Alternatively, the new research equipment may be installed in an additional module which will be docked to the Space Station or may fly near by and be controlled from the station.

The Space Station will provide an efficient, comfortable and safe place for the crew to live and work. Routine functions will be automated so that the crew can use their skills productively.

SPACE STATION

- **INTERNATIONAL GENERAL PURPOSE LABORATORY**
- **FREE OF EARTH'S ATMOSPHERE AND GRAVITY**
- **ECONOMICAL SPACE RESEARCH**
- **MODULAR REPLACEMENT AND GROWTH**
- **LONG USEFUL LIFE WITH MAINTENANCE AND RESUPPLY**
- **SUPPORTS EXPERIMENT MODULES**

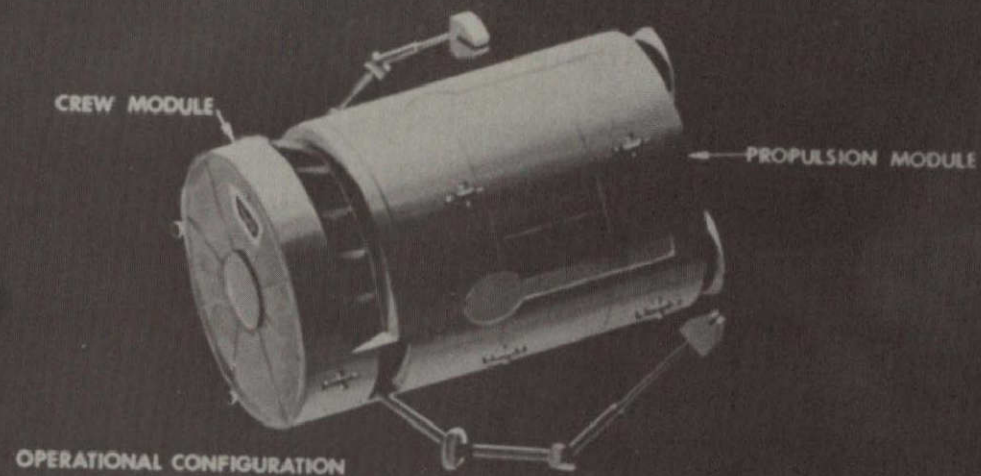
SPACE STATION

The ability to initiate a Space Station concept is largely based on the capabilities and experience obtained from over a decade of space flight. This experience encompasses both manned and unmanned programs and is intended to take advantage of both. The Space Station will blend both together as we move into the next decade.

The current concepts for Space Station provide living quarters for a 12-man crew, supplies for six months, 25 kw of power, a sea level atmosphere, and general purpose laboratory facilities. The core module of Space Station is 10 meters in diameter and approximately 15 meters long. Four full decks are arranged perpendicular to the cylinder axis with unpressurized volume for storage of consumables at both ends. Multiple docking ports for experiment modules and cargo modules will be provided.

SPACE TUG

EARTH ORBIT APPLICATIONS



NASA HQ MR70-5605
REV 6-26-70

NASA HQ MR70-5605
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SPACE TUG CONCEPT

Projections of future United States space activities indicate the need for extensive orbit transfer and maneuvering capability to satisfy the operational requirements of earth oriented, lunar and interplanetary missions. This inter-orbital and on-orbit operational capability can be effectively achieved by a Reusable Space Tug system which could be based and maintained in space.

The Tug must be transportable to earth orbit by the Space Shuttle. It may be transported fully fueled or partially fueled, with or without payload. Refueling and payload delivery, etc., can be accomplished by additional Space Shuttle flights. The Tug will be reusable for both manned and unmanned missions and normally will be space based for NASA missions with return from orbit by the Space Shuttle for major refurbishment and repair. It could, however, be operated as a ground based system. The primary propulsion system and probably the auxiliary propulsion system will be oxygen/hydrogen, in common with the shuttle.

The Space Tug concept is a highly versatile, multi-application, manned or unmanned system comprised of four basic modules (crew, propulsion, intelligence and cargo) each of which may operate independently or with other flight systems. In addition to the basic modules, auxiliary modules or kits are envisioned such as Lunar Landing Legs, Power, Manipulator Systems and Sattelite Repair Kits. Each module and kit would be long lived, reusable and readily maintained to greatly reduce the cost of recurring space operations. Specific modules or kits would be employed for the particular mission applications.

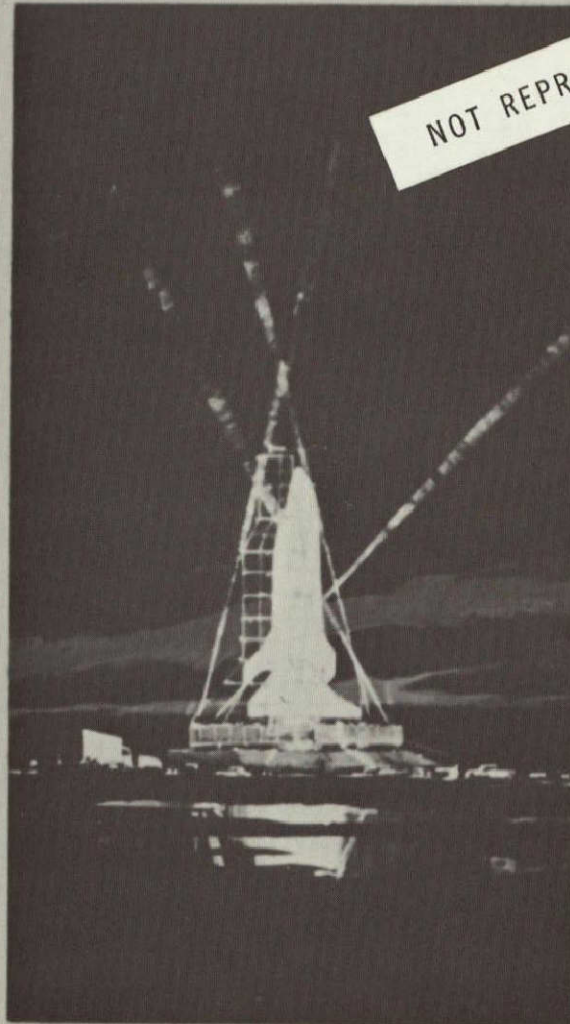
SPACE TUG

- HIGHLY VERSATILE MULTI-APPLICATION SPACECRAFT
- KEY PART OF THE SPACE TRANSPORTATION SYSTEM
- CAPABILITIES WILL INCLUDE-----
 - PLACING OR RECOVERING UNMANNED SPACECRAFT
IN LOW TO HIGH ENERGY ORBITS
 - MOVING CARGO
 - ADJUSTING TO SPACECRAFT ORBITS
 - GENERAL SUPPORT OF SPACE STATION

THE SPACE TUG

The Space Tug is envisioned as a key part of the space transportation system. The concept calls for a highly versatile, multi-application, manned or unmanned spacecraft. It will be made up of four basic modules (crew, propulsion, astrionics, and cargo) each of which may operate independently or with another element of the space transportation system. Essentially space based, the tug will be able to perform a wide variety of missions - placing or recovering unmanned spacecraft, moving cargo, adjusting spacecraft orbits and general support of the space station. The tug will be compatible for transport into deep space. The illustration is for a manned version of the tug. Unmanned operations would be possible by replacing the crew module with a payload or other module.

SPACE SHUTTLE



NOT REPRODUCIBLE

- 2 STAGES - BOOSTER AND ORBITER
- FULLY REUSABLE
- VERTICAL TAKEOFF / HORIZONTAL LANDING
- LARGE CARGO CAPABILITY
- SHIRT SLEEVE ENVIRONMENT FOR CREW AND PASSENGERS
- ACCEPTABLE G LOADS FOR NON - ASTRONAUTS
- 7 DAYS SELF - SUSTAINING
- APPROACH TO AIRLINE - TYPE OPERATIONS

SPACE SHUTTLE

In order to achieve our goal of a low cost space transportation system the following characteristics have been identified.

- a. An operational mode which will reduce costs on order of magnitude below present operating costs.
- b. A flexible capability to support a variety of payloads and missions.
- c. An airline type operation for passengers and cargo transport.
- d. A reusable system with a high launch rate and short turnaround time.

SPACE SHUTTLE PROGRAM

**PROGRAM
OBJECTIVE**

**ACHIEVEMENT OF AN ECONOMICAL
SPACE TRANSPORTATION SYSTEM
THRU MINIMIZING DEVELOPMENT
AND OPERATIONAL COSTS**

PROGRAM OBJECTIVE

The objective of the space shuttle program is to provide a low-cost, economical space transportation system. This requires that the development costs as well as the operational costs be minimized. A recoverable and aircraft type reusable space logistics system will result in a major reduction in the cost of space operations.

We hope to increase reliability and hardware maturity by incremental flight testing until all operational characteristics are fulfilled. This aircraft development approach, augmented by what we have learned in the space program, should considerably reduce development costs of the space shuttle.

SHUTTLE CAPABILITIES

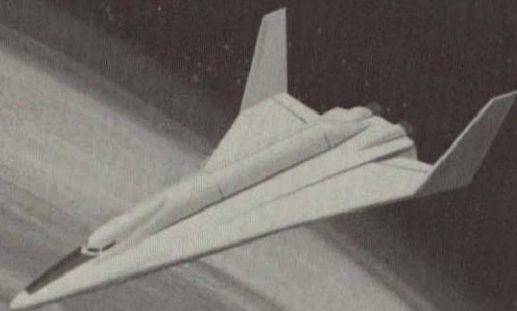
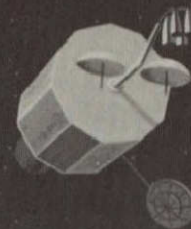
- SATELLITE PLACEMENT AND RETURN
- REPAIR AND SERVICE SATELLITES
- DELIVERY OF PROPULSIVE STAGE TO SYNCHRONOUS ORBIT AND SATELLITE TO LOW EARTH ORBIT
- SPACE STATION SUPPORT
- SHORT DURATION SCIENCE & APPLICATIONS MISSIONS
- RESEARCH LABORATORY
- SPACE RESCUE
- PROPELLANT DELIVERY

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SHUTTLE CAPABILITIES

The Space Shuttle will have the capability to perform a variety of missions ranging from satellite placement and return to carrying out independent short duration science and applications missions. The potential uses of the shuttle are increasing as more detailed studies are made.

SATELLITE PLACEMENT AND RETURN

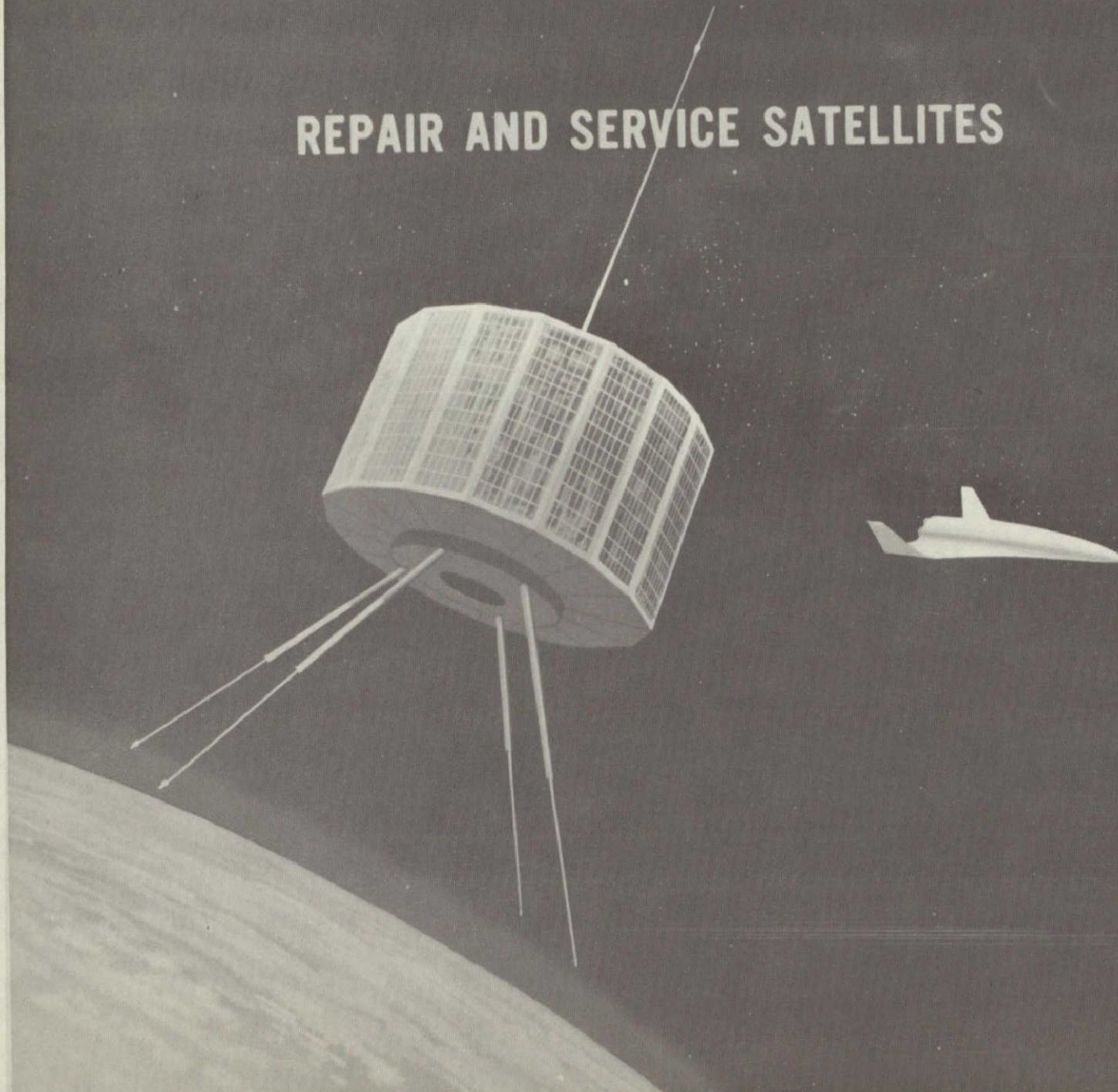


NASA HQ MH70-6288
6-26-70

SATELLITE PLACEMENT AND RETURN

Satellites will be transported to low earth orbits in the internal cargo bay of shuttle, providing them with a more favorable launch environment than present expendable launch vehicles. Having arrived at the desired orbit, satellites can be given a final checkout and then begin their assigned function. Satellites can also be retrieved by the shuttle and returned to earth.

REPAIR AND SERVICE SATELLITES

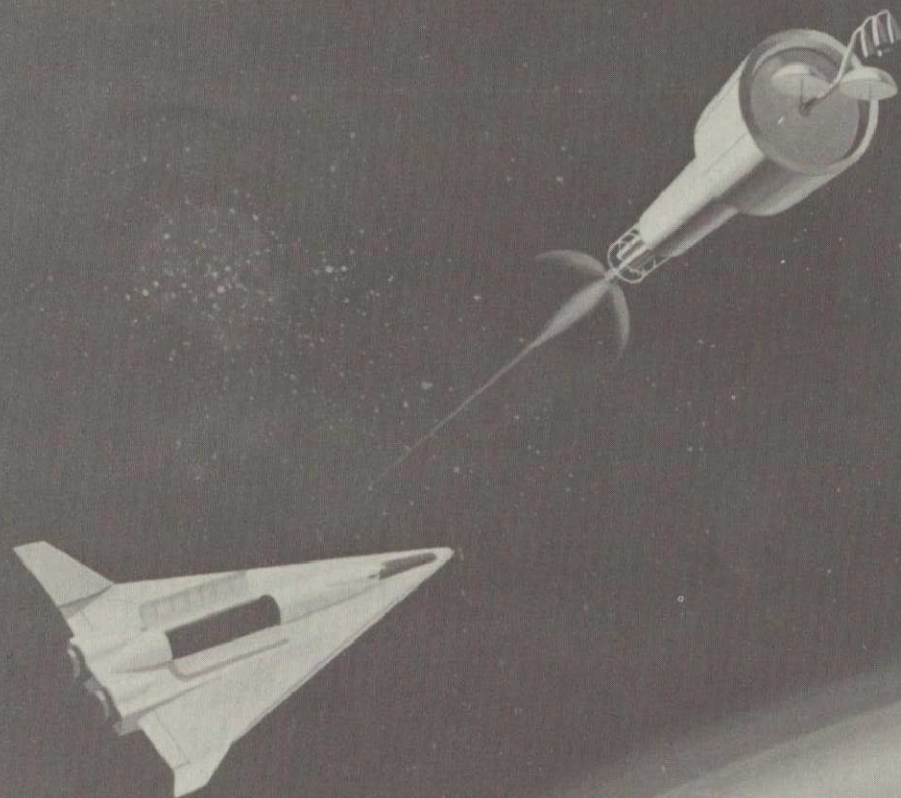


NASA HQ MH70-6287
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REPAIR AND SERVICING SATELLITES

The shuttle will allow future satellites to be designed for varying degrees of maintenance and repair. Satellites can be revisited for periodic servicing for such things as film retrieval, component updating, and replenishment of consumables.

DELIVERY OF PROPULSIVE STAGE AND SATELLITE TO LOW EARTH ORBIT

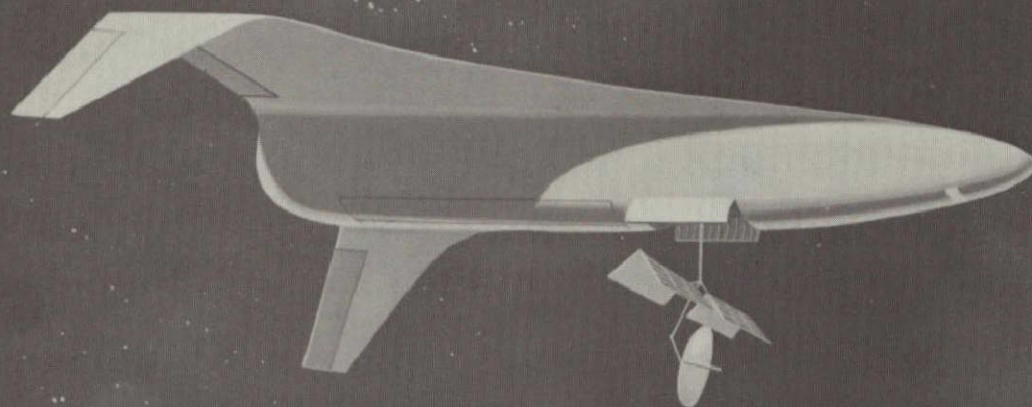


NASA HQ MH69-5683
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DELIVERY OF PROPULSIVE STAGES AND SATELLITES

Propulsive stages and payloads for high energy missions will be delivered by the shuttle to low earth orbits. After a final on-orbit checkout the propulsive stage and its payload is removed from the cargo bay and positioned for launch. The propulsive stage will transport the payload to its final orbit such as a geosynchronous or escape mission.

SHORT DURATION SCIENCE AND APPLICATIONS MISSIONS

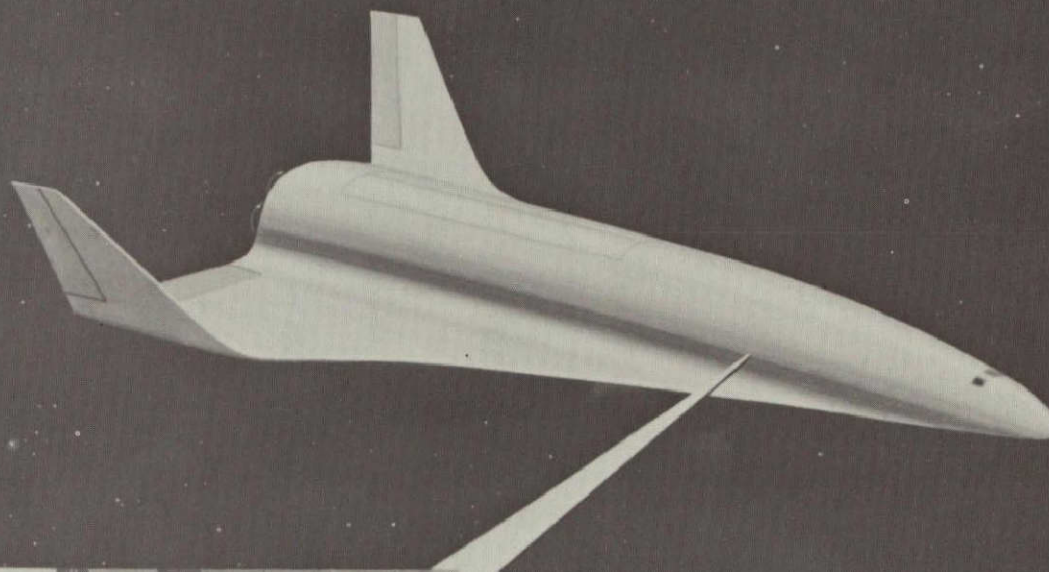


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SHORT DURATION SCIENCE AND APPLICATIONS MISSIONS

The space shuttle can be outfitted to conduct special purpose short duration missions of approximately thirty days. In this manner the shuttle could augment the space station for unique earth or skyviewing mission opportunities.

RESEARCH LABORATORY



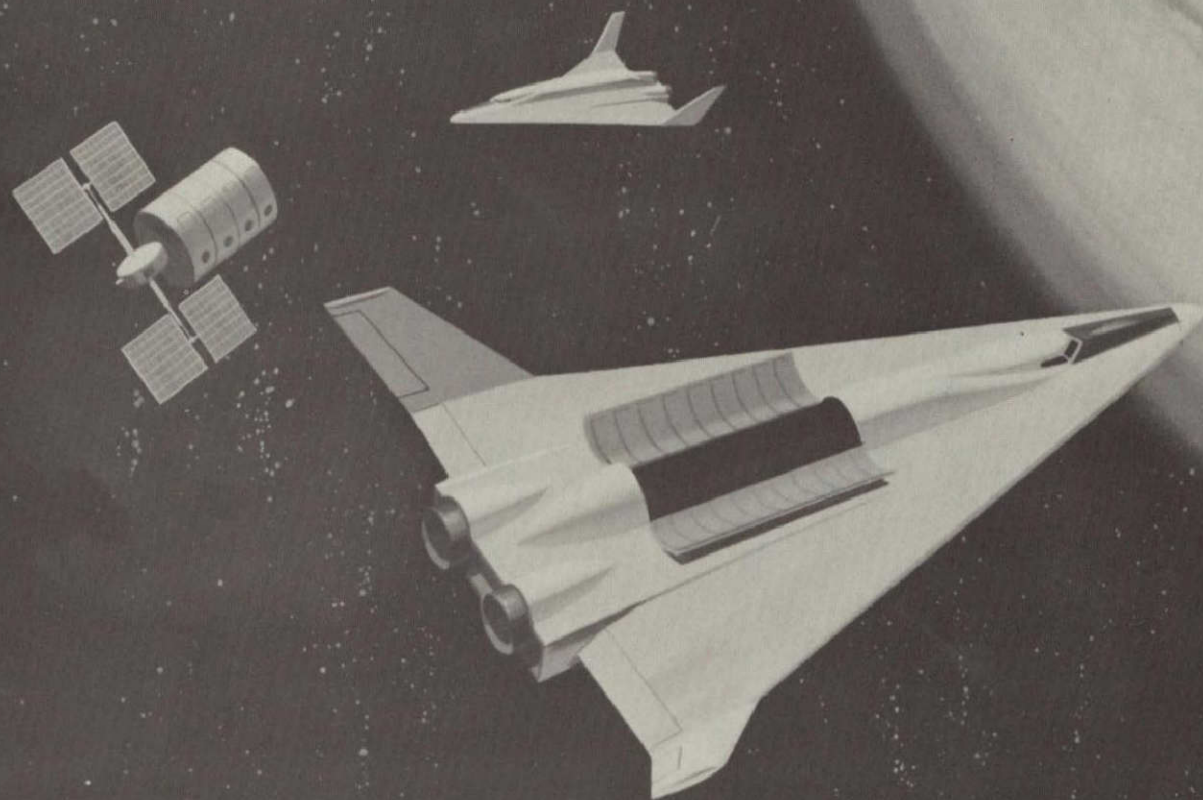
NASA HQ MH70-6351
6-26-70

RESEARCH LABORATORY

The shuttle can also serve as a space research laboratory. The development and testing of new components and space systems can be enhanced by using the shuttle to check them out in the environment of space.

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SPACE RESCUE

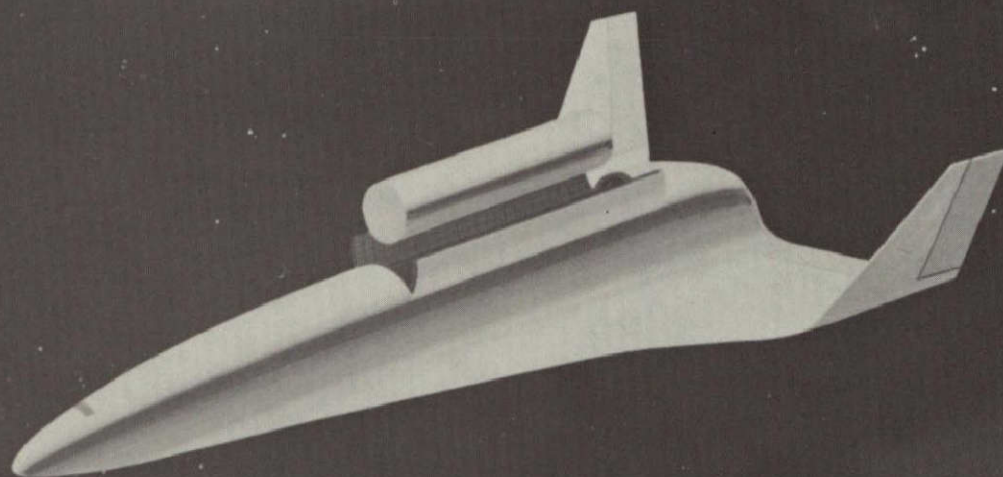


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6-26-70

SPACE RESCUE

The space shuttle will make ground based space rescue possible with its quick response capability and operational flexibility. In some instances the shuttle may eliminate the need for space rescue by the timely delivery of replacement components and equipment.

PROPELLANT DELIVERY

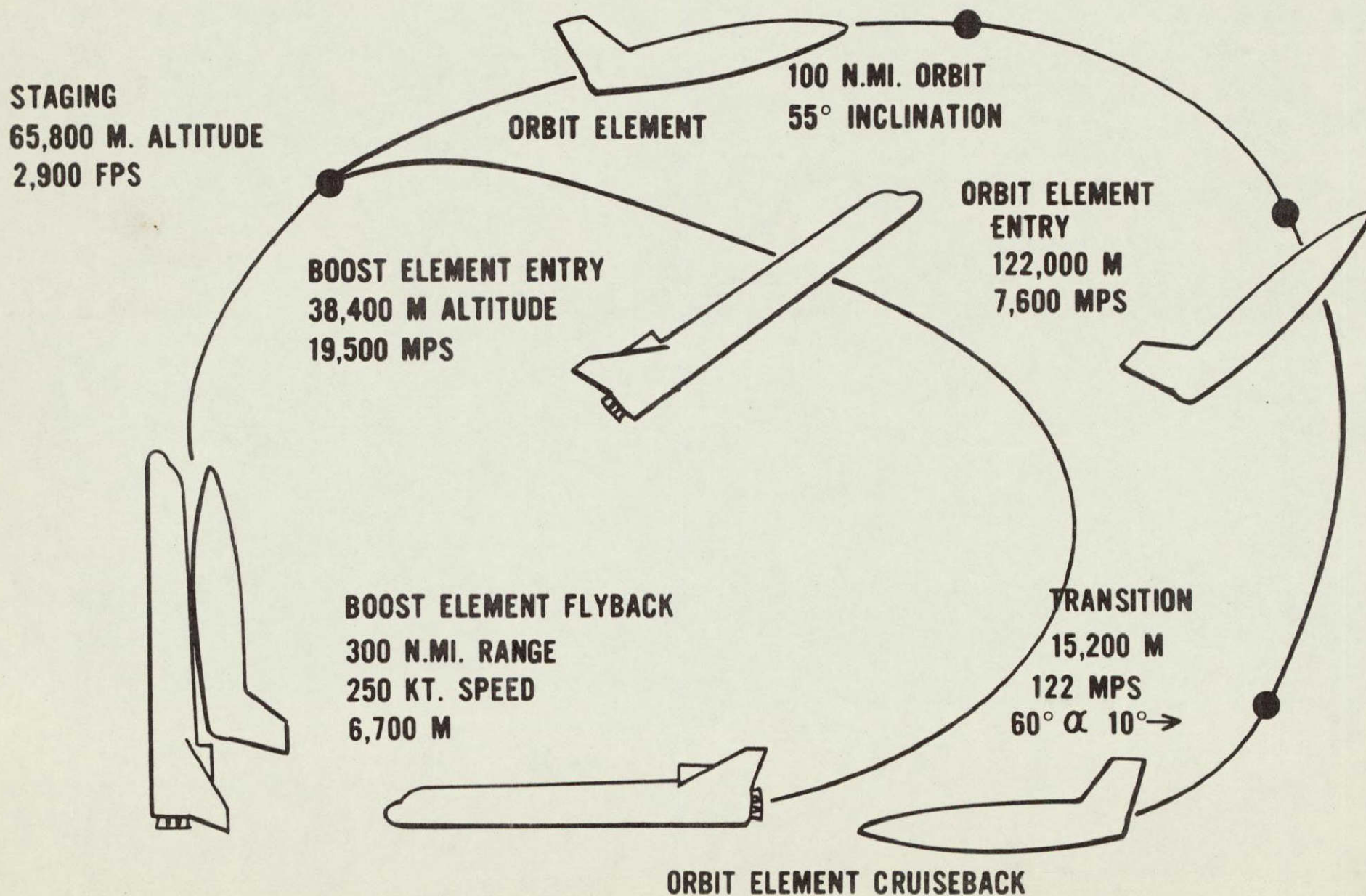


NASA HQ MH70-6291
6-26-70

PROPELLANT DELIVERY

Large scale space operations will require significant amounts of propellants. Making use of its payload weight and volume capability the shuttle can serve as a tanker to provide an effective means of on-orbit refueling for the space tug and other propulsive stages.

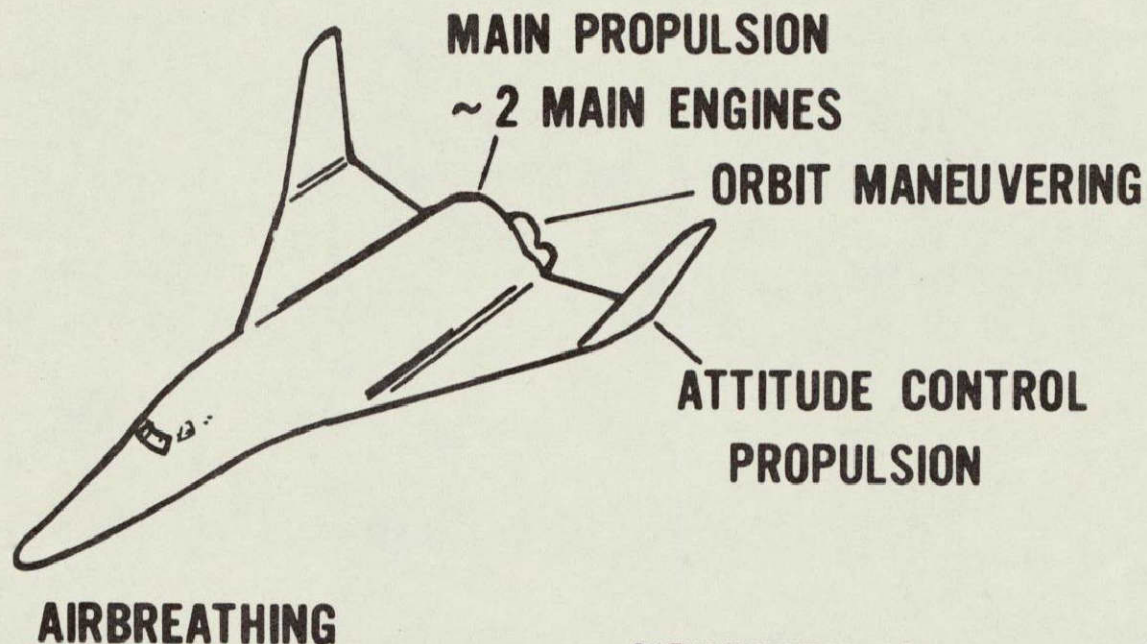
SPACE SHUTTLE MISSION PROFILE



SPACE SHUTTLE MISSION PROFILE

The space shuttle mission profile starts with the orbiter and booster in the vertical launch position. During the launch phase, longitudinal acceleration is limited to 3 g's with staging occurring at 65,800M altitude and velocity of 2,900 meters per second. The boost element then enters the earth's atmosphere at a maximum "g" of 4, and has the capability to cruise or flyback approximately 550KM at a speed of 250 knots. The orbit element continues into orbit by burning its main propulsion engines. For return to earth, the orbiter will impart a Δv to start its entry. Shown on this figure is the low crossrange profile conditions. Transition from an angle of attack of 60° to 10° will occur, after entry velocity is subsonic, in preparation for cruise back. Entry acceleration will be less than 2 "g's" for both the low and high crossrange entries.

SHUTTLE PROPULSION



MAIN ENGINES: 12-14 REQUIRED

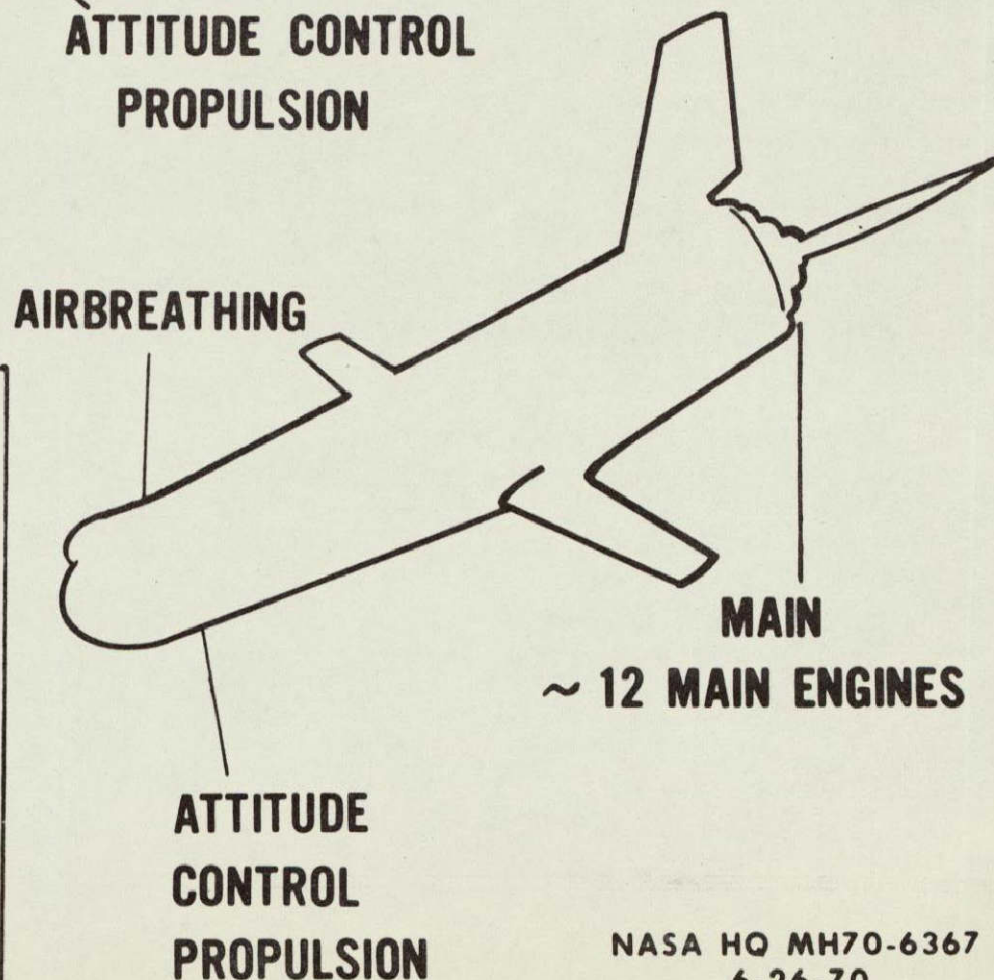
- HIGH PRESSURE
- HYDROGEN/OXYGEN
- 182×10^3 KGS THRUST

AIR BREATHING ENGINES: 18-22 REQUIRED

- PROTECTION REQUIRED
- HYDROGEN CONVERSION BEING EVALUATED
- 8172 TO 18370 KGS THRUST

REACTION CONTROL SYSTEM THRUSTERS: 16-30

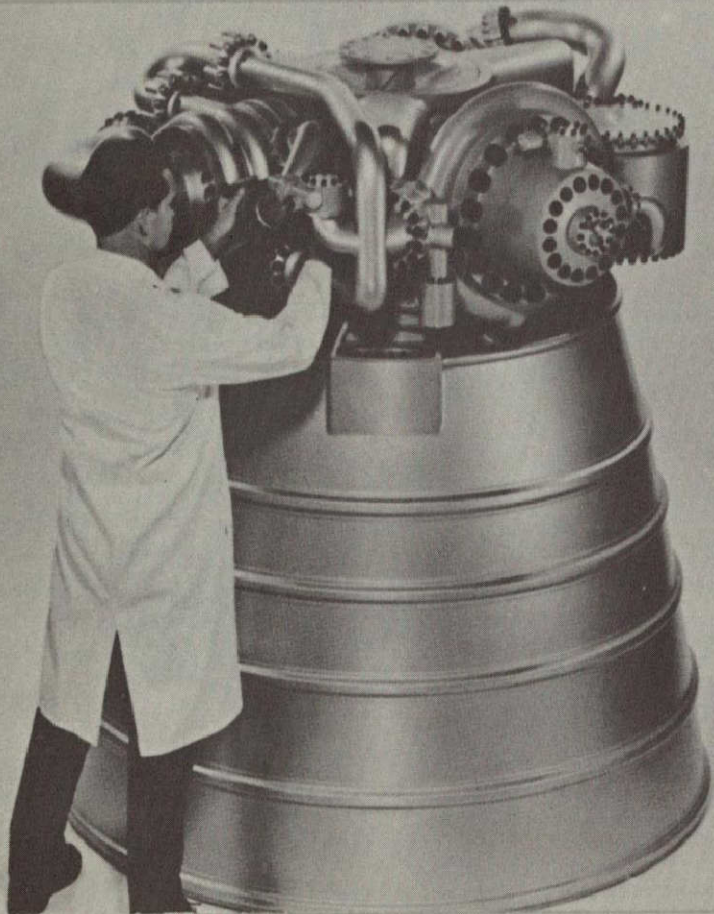
- GASEOUS HYDROGEN/OXYGEN
- 795 TO 1360 KGS THRUST



SHUTTLE PROPULSION

Space Shuttle propulsion encompasses the main engines for boost and orbit insertion, the airbreathing engines for powered landing and ferry of both booster and orbiter, and the reaction control thrusters for attitude control and orbital maneuvering. These systems are baselined to burn hydrogen and oxygen, and will be subjected to separate study and development prior to integration into the shuttle vehicles.

SPACE SHUTTLE MAIN ENGINE



• CHARACTERISTICS

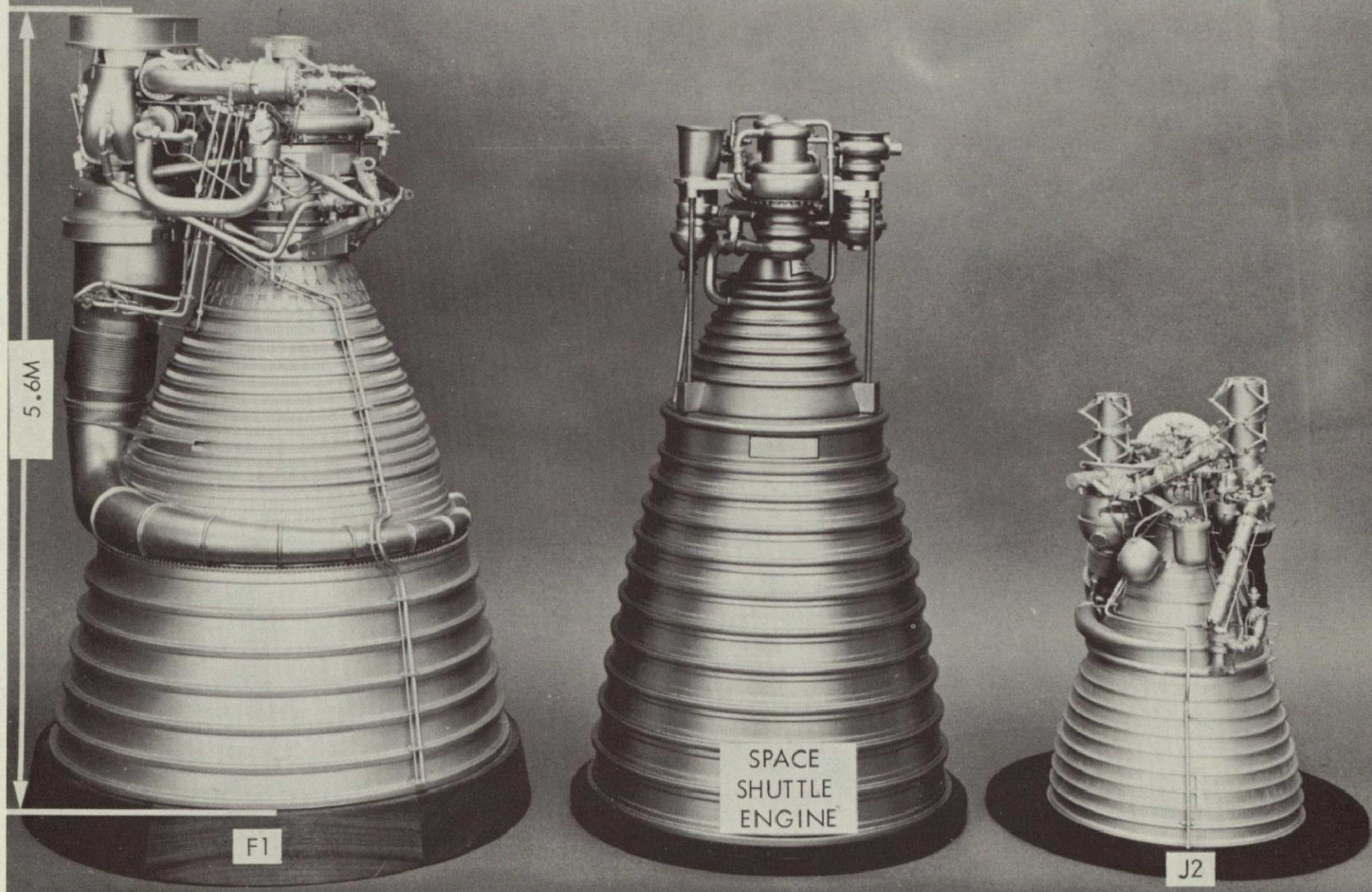
- LIQUID HYDROGEN / LIQUID OXYGEN
- 182×10^3 KGS THRUST LEVEL (BELL NOZZLE)
- HIGH PERFORMANCE
- REUSABILITY
- LOW COST OPERATION
- LONG SERVICE LIFE
- THROTTLEABLE
- MINIMUM MAINTENANCE

NASA HQ MH70-5534
REV. 5-25-70

SPACE SHUTTLE MAIN ENGINE

This list of main engine characteristics represents significant challenge in rocket engine technology. While there are liquid hydrogen - liquid oxygen rocket engines flying today, we are pressing on the limits of performance in the Shuttle application, and this high performance coupled with reusability and the other characteristics of airline-like service adds new dimensions to this engine development.

ENGINE SIZE COMPARISON



NASA HQ MH70-5535
3-10-70

ENGINE SIZE COMPARISON

This chart, which is a photograph of actual scale models, shows the relative size of the space shuttle engine at an expansion ratio of 120, compared to the F-1 engine on the left which is the kerosene/oxygen engine used in the first stage of the Saturn V vehicle, and the J-2 engine on the right, which is used in the 2nd and 3rd stages of the Saturn V.

PROPOSED ENGINE CONCEPTS

	AEROJET	PRATT-WHITNEY	ROCKETDYNE
PREBURNER	DUAL	SINGLE	DUAL
BOOST-PUMPS	VEHICLE MOUNTED	ENGINE MOUNTED	ENGINE MOUNTED
FUEL PUMPS	3 STAGE SHROUDED	2 STAGE UNSHROUDED	2 STAGE SHROUDED
TURBINE DRIVE	COOLED	UNCOOLED	UNCOOLED
INJECTOR	PLATELET/VANES	CONCENTRIC TUBE-SPRAY BAR	CONCENTRIC TUBE
COMBUSTION CHAMBER	FULL REGENERATIVE	TRANSPIRATION (LH ₂)	FULL REGENERATIVE
EXTENDIBLE NOZZLE COOLING	RADIATION /FILM	DUMP	DUMP

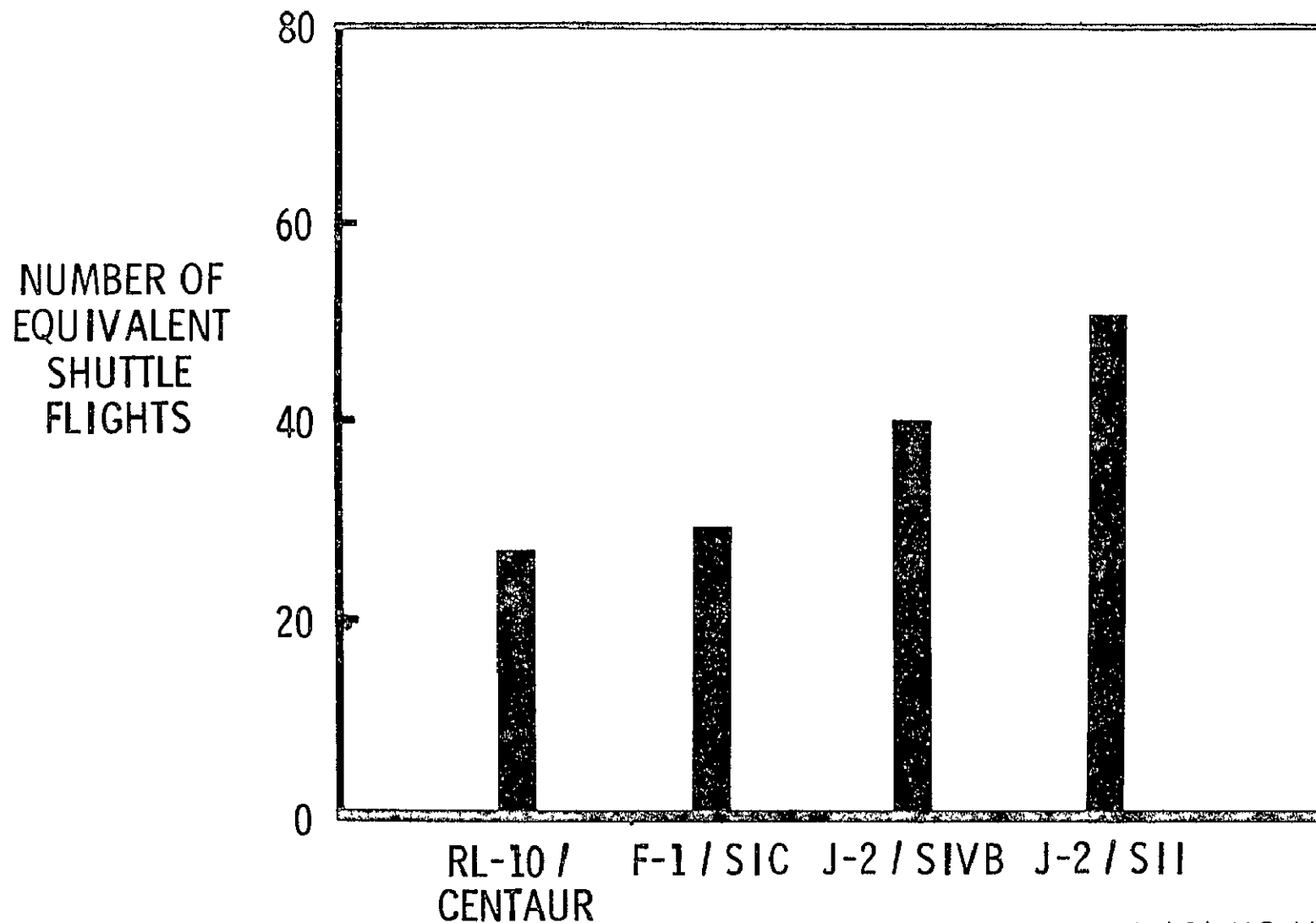
PROPOSED ENGINE CONCEPTS

Each of the engine contractors selected for the design definition phase has proposed an engine concept to achieve the desired characteristics. This chart lists some of the principal concept differences as proposed. These concepts are, of course, subject to change as each contractor goes deeper into the study and as detailed requirements are established.

SPACE SHUTTLE

NUMBER OF PROPULSION SYSTEM REUSES

(BASED ON GROUND TESTS)



NASA HQ MH70-5554
3-11-70

PROPULSION SYSTEM REUSES

While reusability of the rocket engines for the Space Shuttle presents a significant challenge, the current propulsion systems in use in our Space Vehicles have demonstrated lifetimes and reuses in ground testing which lends confidence to our ability to develop engines that will meet the Shuttle goal of 100 flights. This chart indicates the equivalent shuttle flights which are encompassed by the ground test programs on several liquid rocket engines. For example, this chart indicates that a single J-2 engine in the S-II stage of the Saturn V vehicle has been through ground testing which is equivalent to more than 50 shuttle flights.

SPACE SHUTTLE

STATUS OF ENGINE DEFINITION PHASE

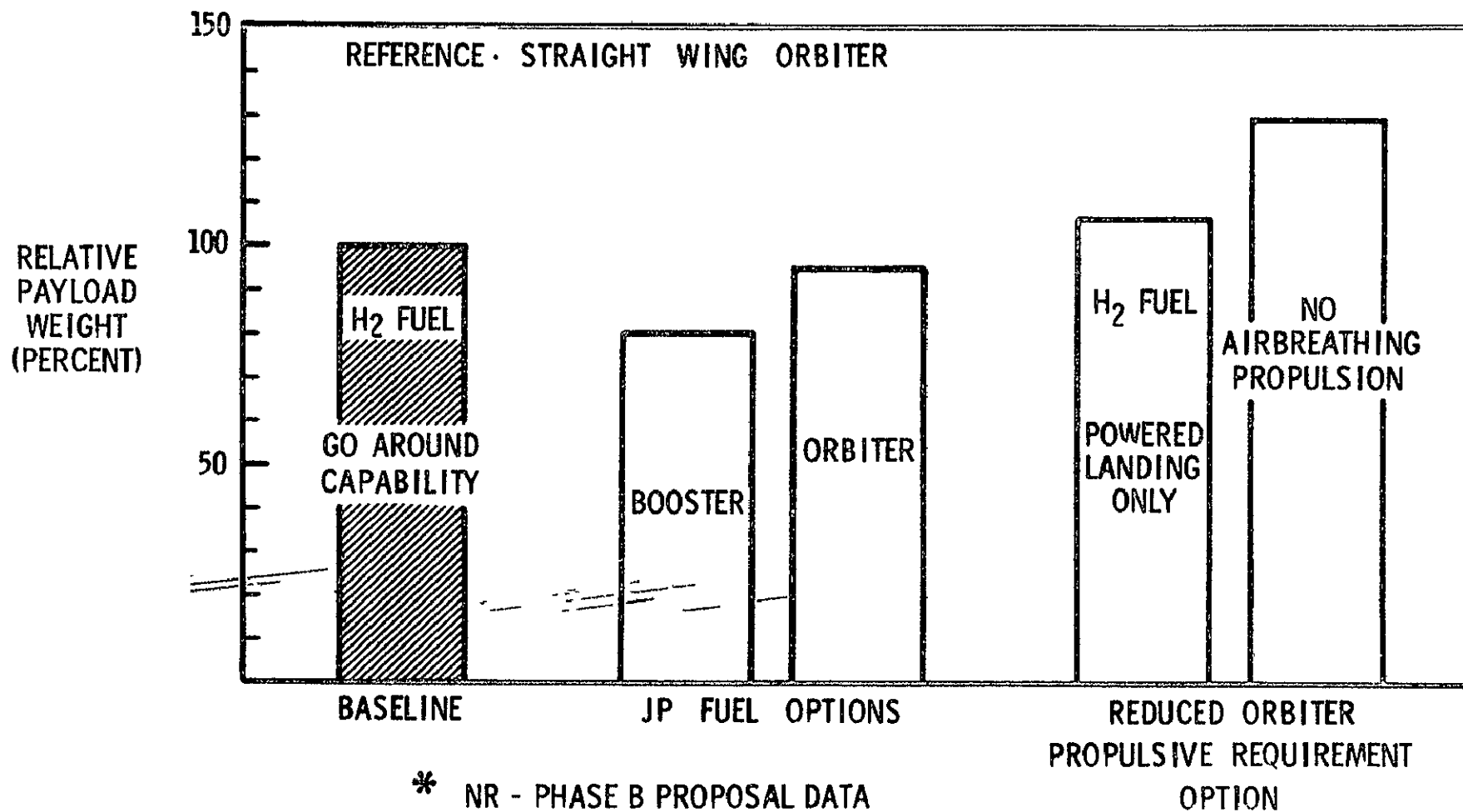
- NASA HAS COMPLETED EVALUATION OF PROPOSALS
- AEROJET, PRATT-WHITNEY, AND ROCKETDYNE HAVE BEEN SELECTED FOR CONDUCTING STUDIES
- PARALLEL CONTRACTS AWARDED IN MID-JUNE FOR 11 MONTHS EFFORT

NASA HQ MH70-6350
6-26-70

STATUS OF ENGINE DEFINITION PHASE

In response to a request for proposal by NASA, proposals were received for definition studies for the Space Shuttle Main Engine. These proposals have been evaluated and contracts have been awarded to three firms for the conduct of these studies. All three contracts are parallel eleven month efforts and were initiated in mid-June of this year.

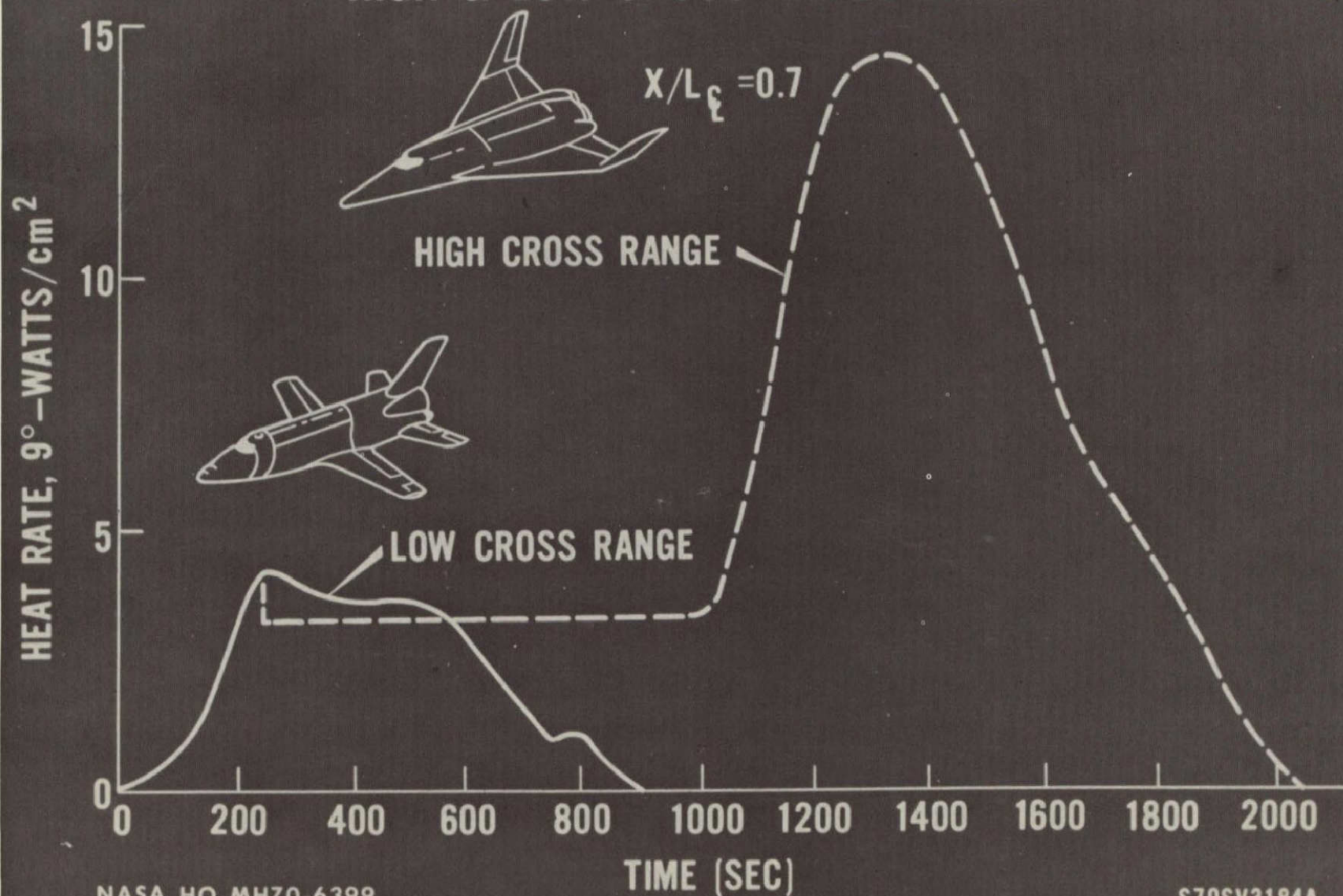
TYPICAL PAYLOAD IMPACT OF AIR BREATHING SYSTEM DESIGN OPTIONS *



TYPICAL PAYLOAD IMPACT OF AIR-BREATHING DESIGN OPTIONS

During the definition studies, major trade-offs will be made to determine the desirability of no power approaches for a returning orbiter and the advantage of using H2 fuel versus JP fuel. As shown, the baseline system uses H2 fuel and go-around capability. Previous studies have shown that if JP fuel is used on the booster and orbiter payload would be reduced 20%. If JP fuel is used only for the orbiter (H2 fuel in the booster) the orbiter payload is reduced 5%. It can be seen from this chart that a payload gain of up to 20% over the baseline configuration is possible utilizing no power approach and landings for the orbiter vehicle. This area will be studied in more detail during the current phase.

COMPARISON OF ORBITER FUSELAGE HEATING HISTORIES HIGH & LOW CROSS RANGE ENTRY



ORBITER HEATING HISTORIES

An approach to minimize the total heat energy a space shuttle is exposed to during re-entry is to re-enter at a very high angle of attack with high lift coefficient and low lift loading. This mode combined with a high plan form area results in a low heating rate and low total heat load, potentially limiting temperatures to about 2000°F.

This re-entry mode limits lateral ranging capability. Greater lateral range will require re-entry at a low angle of attack to increase hypersonic lift to drag ratio. This approach results in increased heating rates and higher surface temperatures for a longer time with increased total heat load.

WIND TUNNEL TESTS



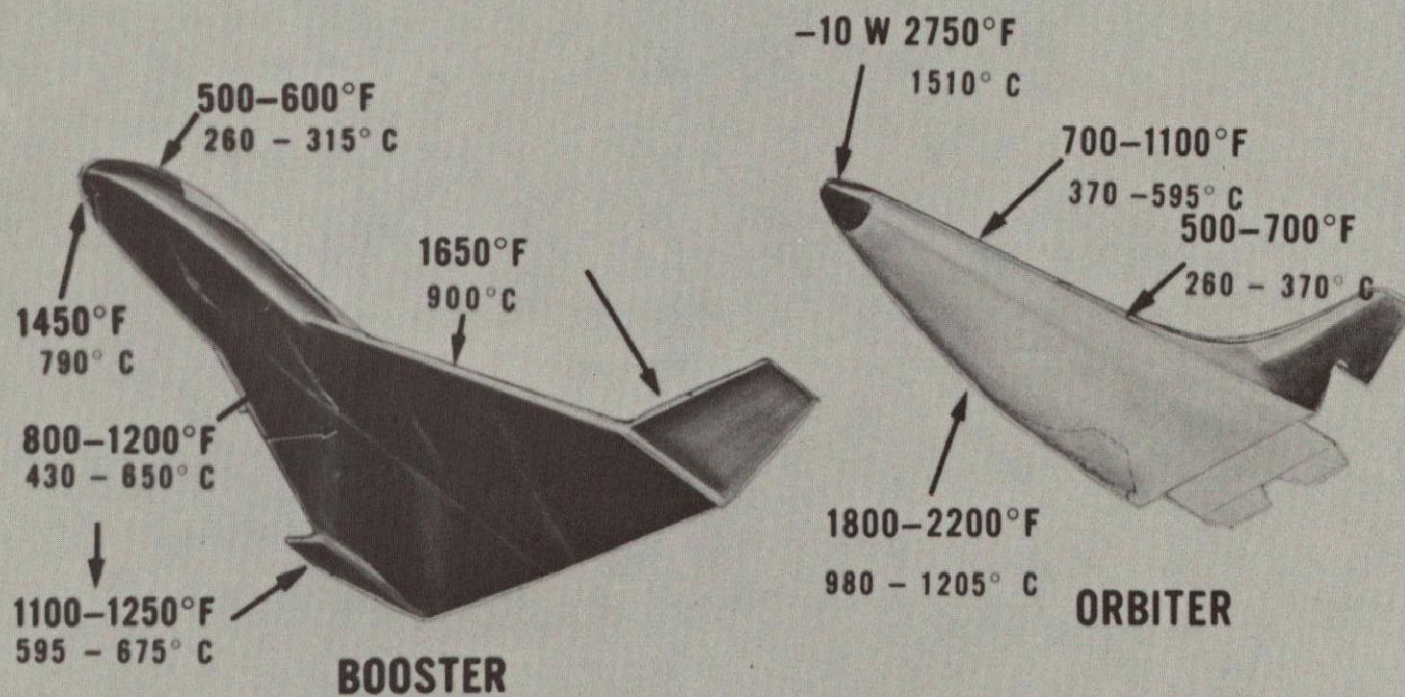
**ORBITER AT MACH 20
HIGH ANGLE OF ATTACK**

NASA HQ MH70-5532
REV. 3-18-70

WIND TUNNEL TESTS

Wind tunnel model of one Space Shuttle orbiter configuration being tested at 20 degrees angle of attack at simulated Mach 20 re-entry speed in a helium tunnel at Langley Research Center. Flow patterns made visible by electron-beam technique allow high speed movies for analysis.

PREDICTED TEMPERATURES

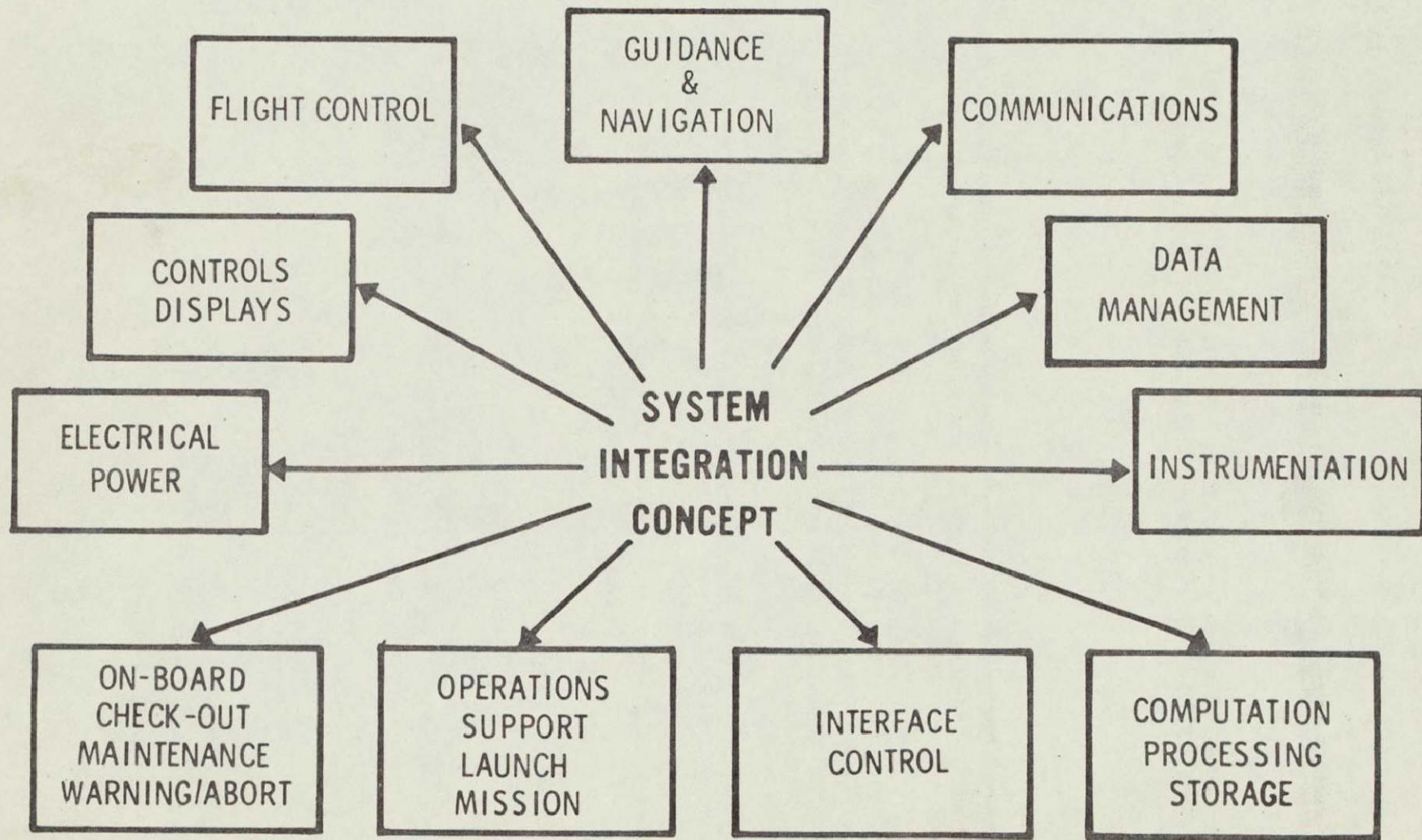


SUMMARY OF PREDICATED TEMPERATURES

Anticipated temperatures on the booster and orbiter illustrate the less severe design problem for the booster. Temperature variations on different sections, in addition to determining the materials to be used and the thermal protection design, also dictate the positioning of radiators, antennas and access panels.

The orbiter design problem is made more difficult if high cross range is a requirement because in addition to the higher temperatures a longer period of exposure will necessitate a heavier thermal protection system.

INTEGRATED AVIONICS



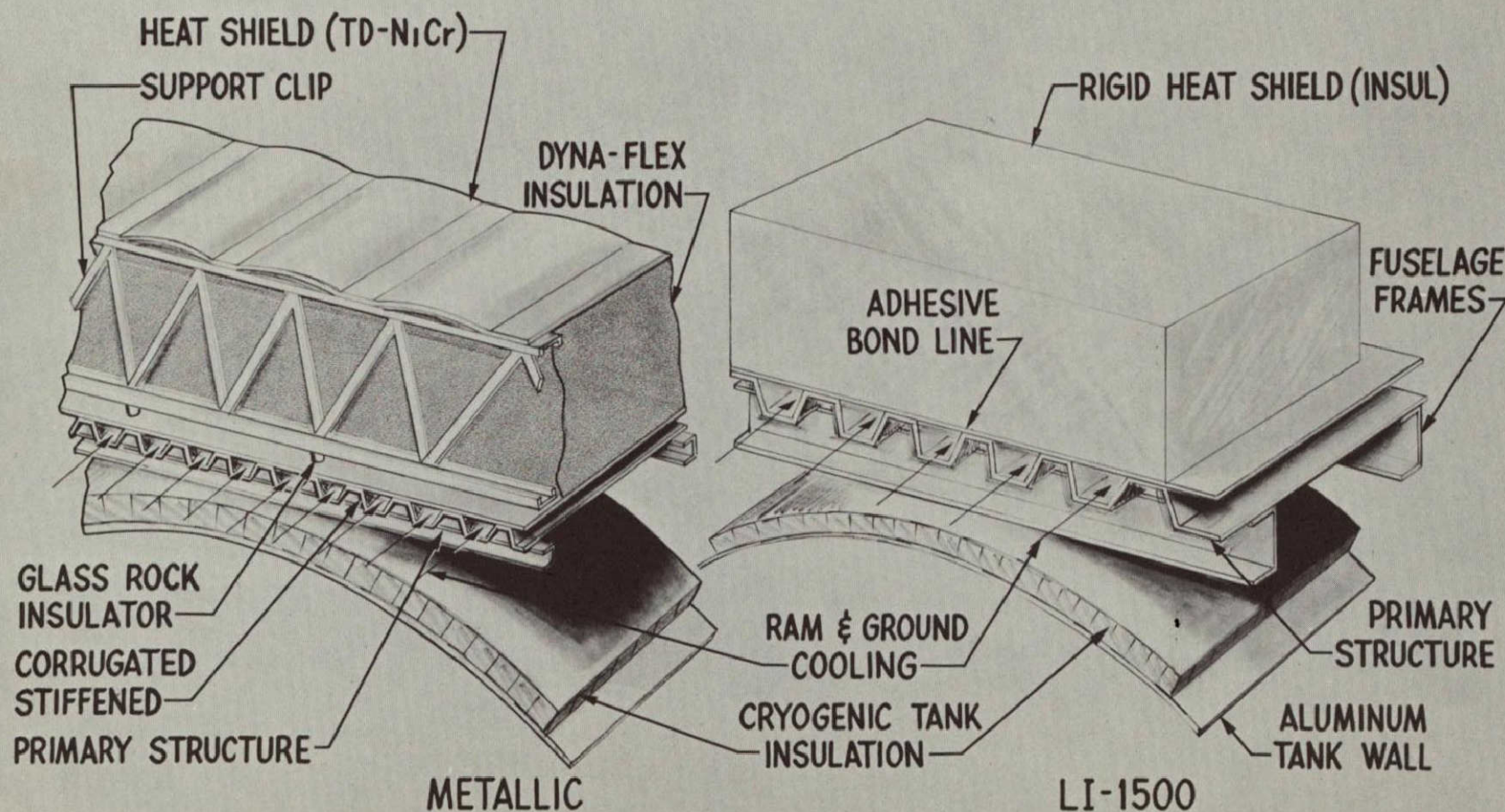
INTEGRATED AVIONICS

The chart portrays the integrated avionics concept in terms of system functions as inputs and operational functions as outputs. The need to achieve full integration is demonstrated by review of the manned spacecraft and recent high performance aircraft program developments in which electronics approximate one-third of the vehicle development costs. In addition, electronics have a significant effect on creating or eliminating operational constraints and large investments in operational support.

The ability to develop any element of the vehicle electronics system such that it will satisfy the desired system operating requirements does not necessarily require a breakthrough in technology. However, advance work is required to successfully integrate all of the requirements into a cohesive high density system which will offer a substantial reduction in system weight, power and cost.

TYPICAL HEAT SHIELD APPROACHES

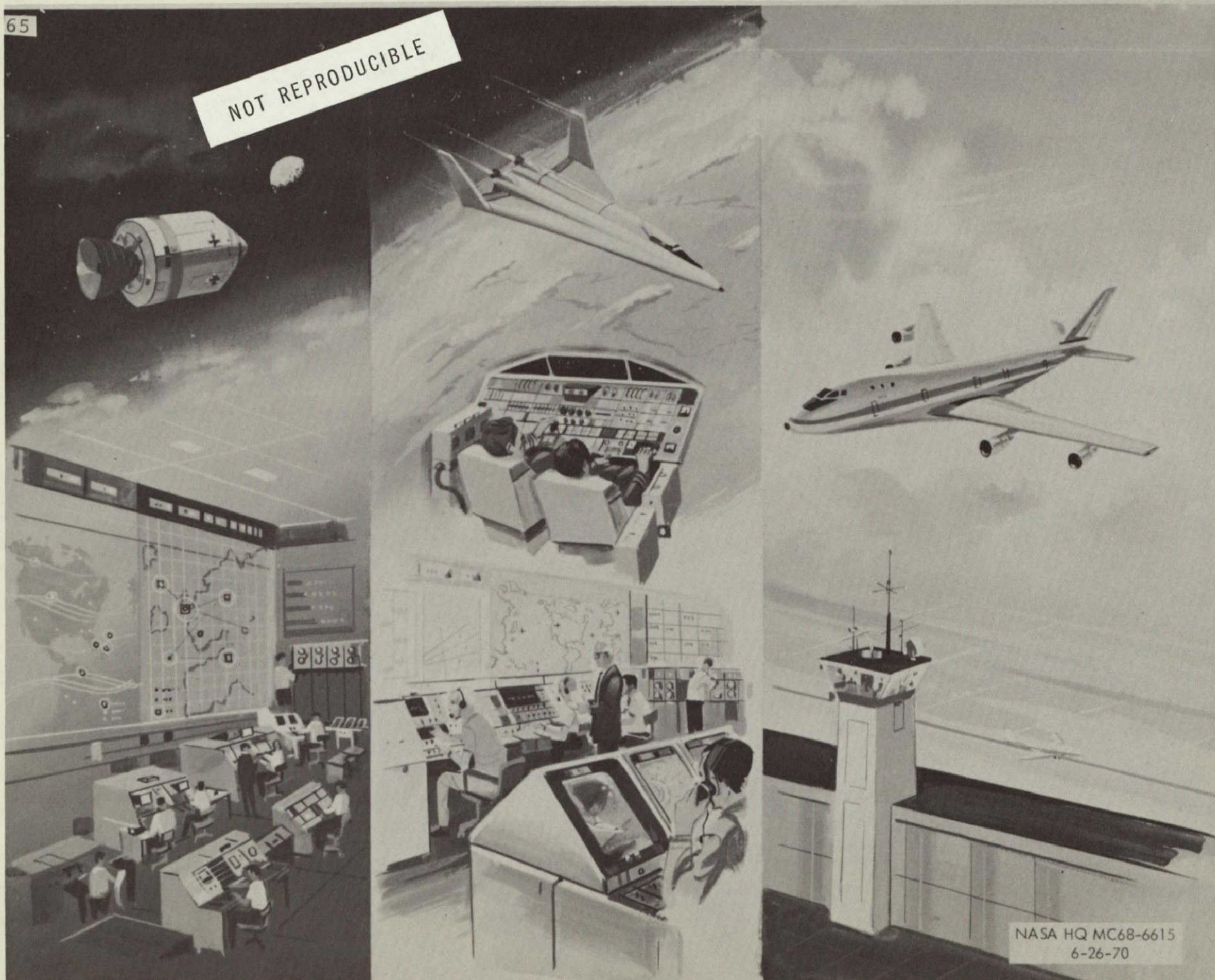
NON-LOAD CARRYING TANKAGE



TYPICAL HEAT SHIELD APPROACHES

A key element in developing an economical space shuttle is a lightweight heat shield which can be inspected and validated for re-use as well as providing easy replacement of defective panels. Corrugated radiative high-temperature thermal protection panels with multiple clip supports appear to offer an efficient candidate concept. The total ΔT from the hydrogen tank to the heat shield approaches 3000°F, necessitating a number of insulation techniques and purges with provisions for compensating pressure buildup during descent and dissipation of residual heat after landing.

NOT REPRODUCIBLE

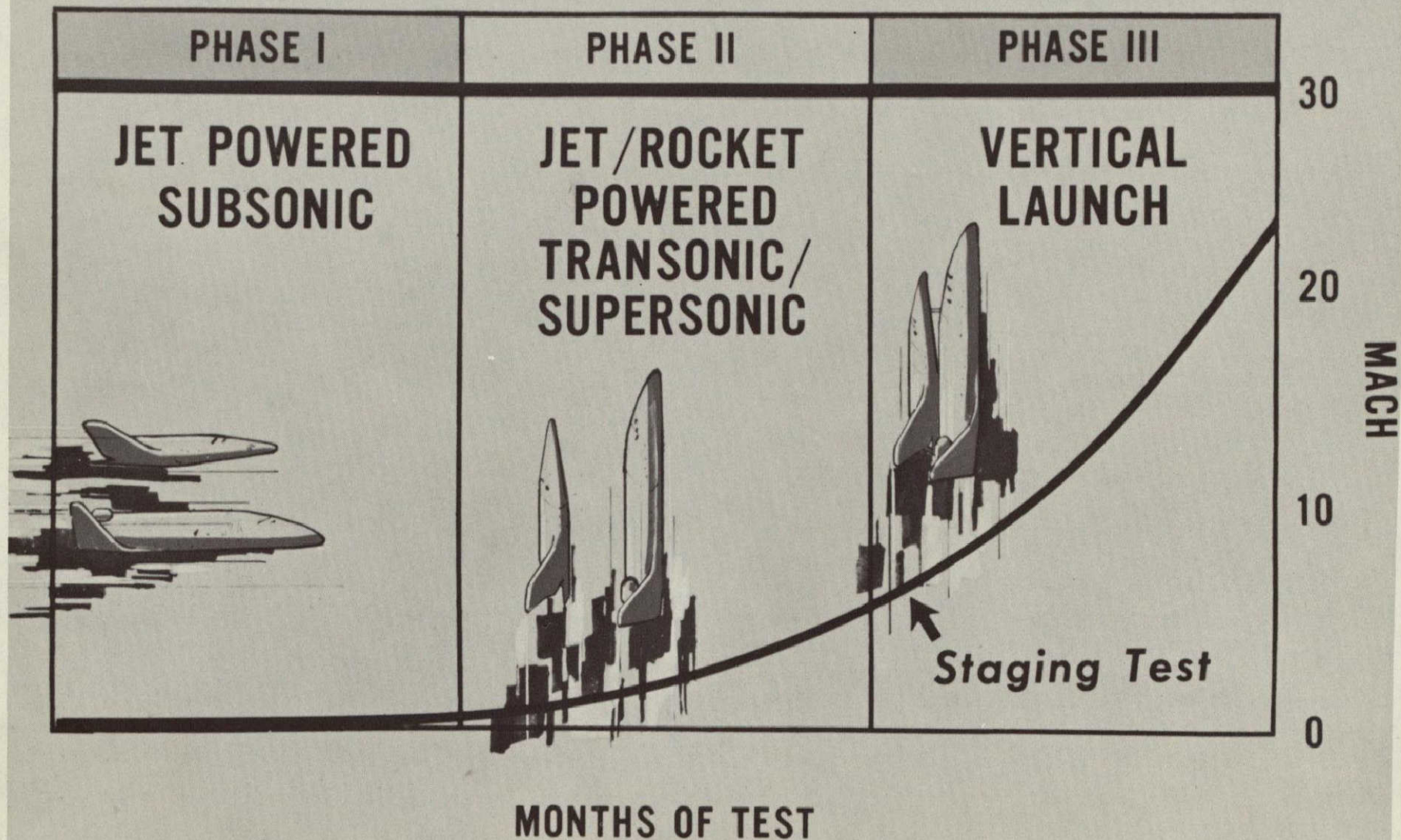


SHUTTLE CHECKOUT

In the manned spacecraft program, checkout and testing have been conducted in detail as a ground function only. The interface to the spacecraft has been complicated by a varying degree of manual intervention. During flight, the monitoring of status has been done by ground controllers with caution and warning information provided onboard to the crew.

The shuttle self test and warning system will be employed at the start of factory testing and will continue throughout the life of the vehicle. This will allow for a minimization of ground support equipment and auxiliary checkout stations and their associated activities during factory build-up, testing and the operational phases of the program. The goal is to achieve operational reliability and flexibility comparable to that of the modern airliner.

FLIGHT TEST CONCEPT



FLIGHT TEST CONCEPT

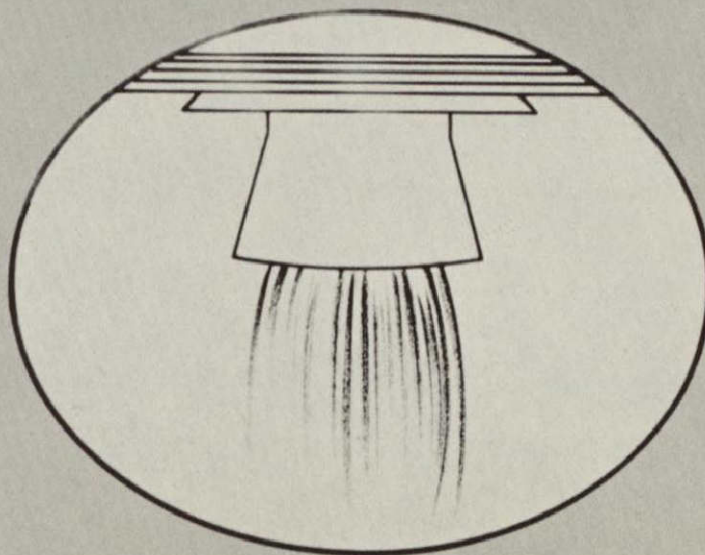
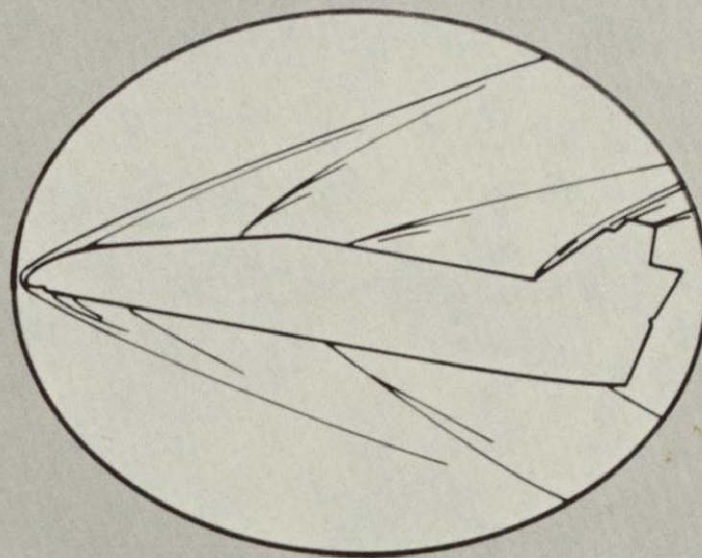
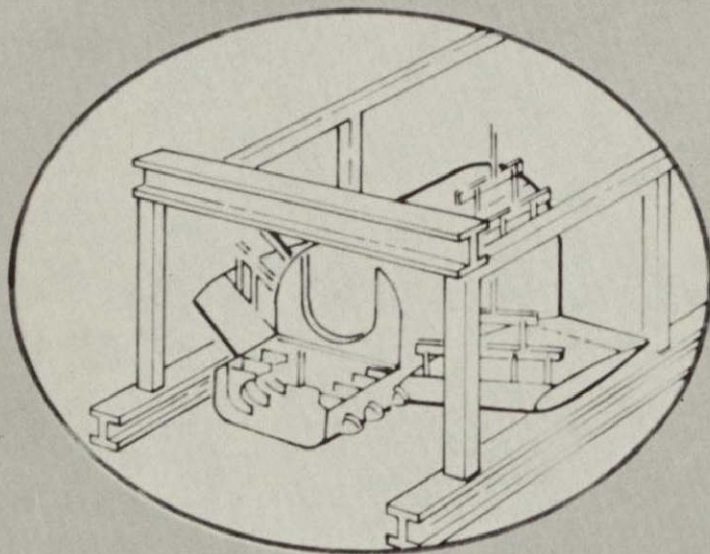
Over the next year the definition phase will produce plans for the flight test program. NASA favors the use of "operational type" vehicles for testing which are refurbished later for full operational use. This would be similar to the approach used for the C5A and the 747. Because the initial number of shuttle vehicles produced will be small, those vehicles allotted to flight test will represent a significant portion of the "fleet" cost therefore, our planning is not to provide prototypes which can have no operational use. Of course, a recognition of the need for changes resulting from the flight test program will mitigate against a strict "production approach" on the first flight test vehicles.

A progressively more difficult flight test program is planned which will parallel to some extent the ground testing. Rather than committing to sub-orbital flight as in the case of past space vehicles, our planning is for an aircraft development approach with modifications and corrections for malfunctions being made following each test phase.

The flight test concept presently envisioned is shown in this Figure. The first phase of testing would involve horizontal subsonic flight of the orbiter and booster separately under jet power. The possibility of extending this phase of testing to higher altitudes and supersonic speeds by employing rocket propulsion will be studied. The second phase as indicated would involve vertical launches of the booster and possibly the orbiter. These vehicles would employ both jet and rocket propulsion. In Phase III, vertical launch of the total vehicle would provide sub-orbital and orbital flight.

In addition to flights involving the basic booster and orbiter, there will be considerable testing of systems in support aircraft.

PROOF OF CONCEPT & DESIGN VERIFICATION



NASA HQ MH70-6365

6-26-70

PROOF OF CONCEPT AND DESIGN VERIFICATION

During the Phase B study approximately 4,600 hours of wind tunnel testing using 25 to 30 wind tunnel models will be conducted. These tests will verify stability characteristics and handling qualities of selected configurations, develop data on aerothermal heating, stage separation and aeroelasticity. Regimes up to Mach 20 will be investigated.

In addition to the structural and thermal protection system analysis being conducted by the Phase B contractors, a test program of major structural sub-assemblies by these contractors is planned. These tests of critical areas will provide the basis for more accurate weight estimates and confirm design and fabrication techniques. Similar tests will be conducted at MSFC in a chamber simulating mission ascent and re-entry heating conditions.

Each of the engine definition phase study contractors will conduct limited testing of components and subsystems, either full scale or sub-scale, to verify his analysis and choice of concept. Testing will include preburners, thrust chambers, valves, seals, bearings and some elements of the turbomachinery.

SPACE SHUTTLE MASTER FACILITIES PLANNING APPROACH

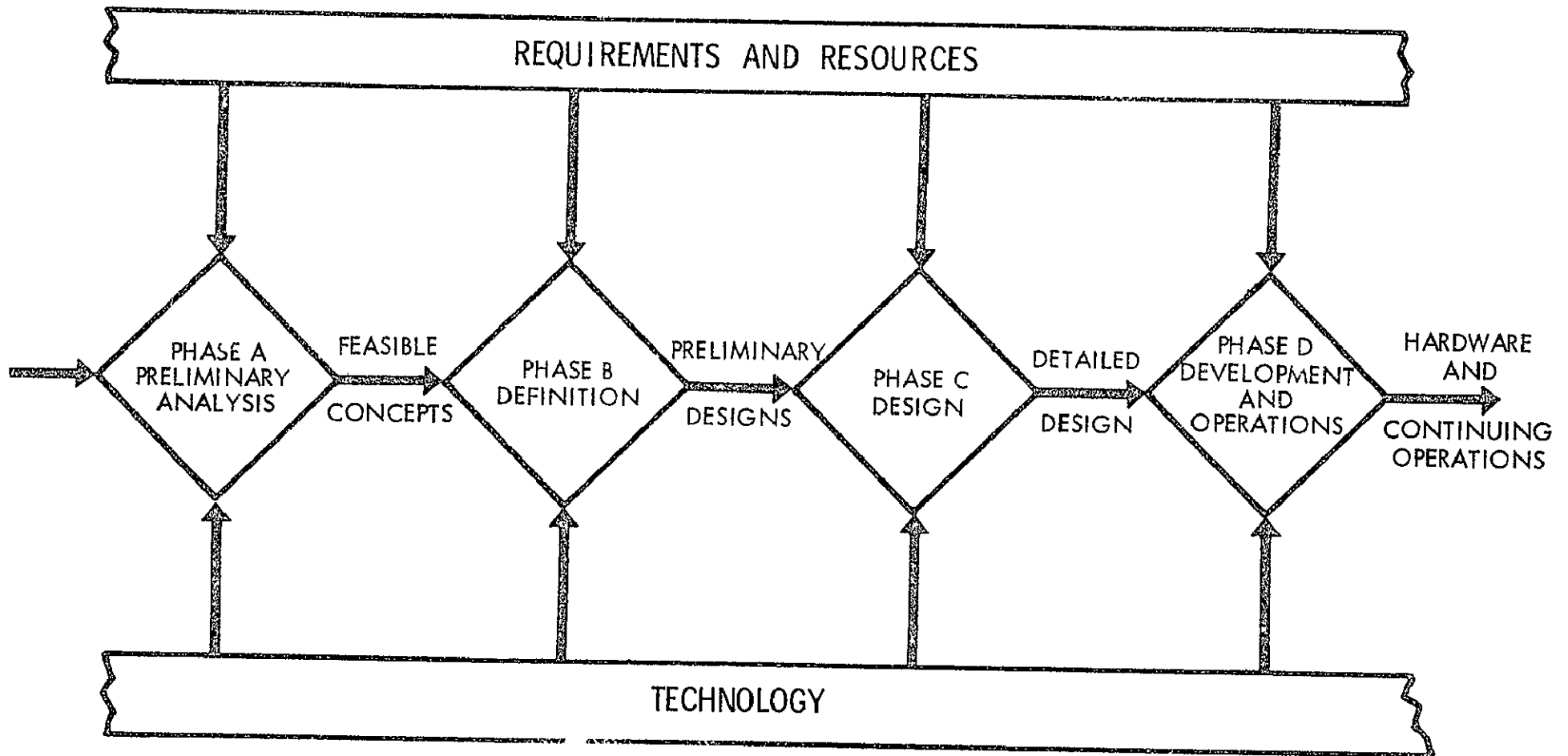
- ACCOUNTS FOR UNIQUE ASPECTS OF SHUTTLE
- CONSIDERS UTILIZATION OF EXISTING FACILITIES
- STRESSES CONSOLIDATION OF DEVELOPMENT,
TEST AND OPERATIONAL FACILITIES

MASTER FACILITIES PLANNING APPROACH

We are developing a master plan for the space shuttle program facilities, such that the major site selections for the facilities required can be established by the end of the Phase B space shuttle studies. The master plan will reflect the following parameters

1. The availability of existing facilities and their required modifications.
- 2 The availability of manpower, propellants and other resources
3. Environmental factors such as noise and weather
- 4 The desire to locate many or all of the facilities in one location, so that we can maintain a steady work force through the development, test and flight phase, and so that multiple use of these facilities can be made for several phases of the project

PHASED PROJECT PLANNING



PHASE PROJECT PLANNING

Phase Project Planning is a phased approach to the planning, approval and conduct of major research and development activity

Its purpose is to provide, through defined phases, an adequate basis for management decisions on the extent to which new project activities can be properly undertaken and commitments made. Four major management decisions points within the evolution of a project are of special significance - these have been designated Phases A, B, C, and D

Phase A consists of feasibility analyses and studies to determine whether the proposed objective or mission is valid. Phase B comprises detailed studies and definition, comparative analyses and preliminary design directed toward a single approach from among the alternate approaches selected in the first phase. Phase B involves the preparation of detailed design specifications, manufacturing, test and operations plans, and comprehensive program schedules and cost estimates. Phase D covers development, manufacturing, testing, checkout, operations and evaluation.

This general flow of planning will be followed in the execution out of the Space Shuttle Program.

SPACE SHUTTLE

DEFINITION PHASE OBJECTIVES - VEHICLES

- DEFINE THE SPACE SHUTTLE SYSTEM
- ACCOMPLISH PRELIMINARY DESIGN
 - TWO POINT DESIGNS, HIGH & LOW CROSS RANGE
 - CONFIGURATION VERIFICATION
- PREDICT SCOPE, TIMING AND COST OF PROGRAM
- IDENTIFY TECHNOLOGY REQUIREMENTS

VEHICLE DEFINITION PHASE OBJECTIVES

The fundamental objectives of the definition studies are

- a To define the Space Shuttle System
- b To accomplish preliminary designs of the space shuttle with the orbiter optimized for
 - High aerodynamic crossrange, 1,500 nautical miles
 - Low aerodynamic crossrange, 200 nautical miles
- c. To obtain an understanding of the scope, schedule and cost of the space shuttle system
- d. To identify and obtain an understanding of the supporting research and technology which must be accomplished

To accomplish these objectives the contractors will perform system analyses, design analyses, subsystem definition and preliminary design, identify supporting research and technology, and prepare program plans for follow-on phases

MAJOR SPACE SHUTTLE DEFINITION PHASE TECHNICAL TRADEOFFS

- PAYLOAD CAPABILITY (WEIGHT AND VOLUME)
- CROSS RANGE
- UNMANNED VS. MANNED BOOSTER
- LIQUID HYDROGEN VS. JP FUEL FOR AIR BREATHING ENGINES
- POWERED VS. UNPOWERED LANDING
- INTERACTION WITH OTHER SPACE TRANSPORTATION SYSTEM ELEMENTS, i.e. SPACE TUG, ORBIT TO ORBIT SHUTTLE, NUCLEAR SHUTTLE

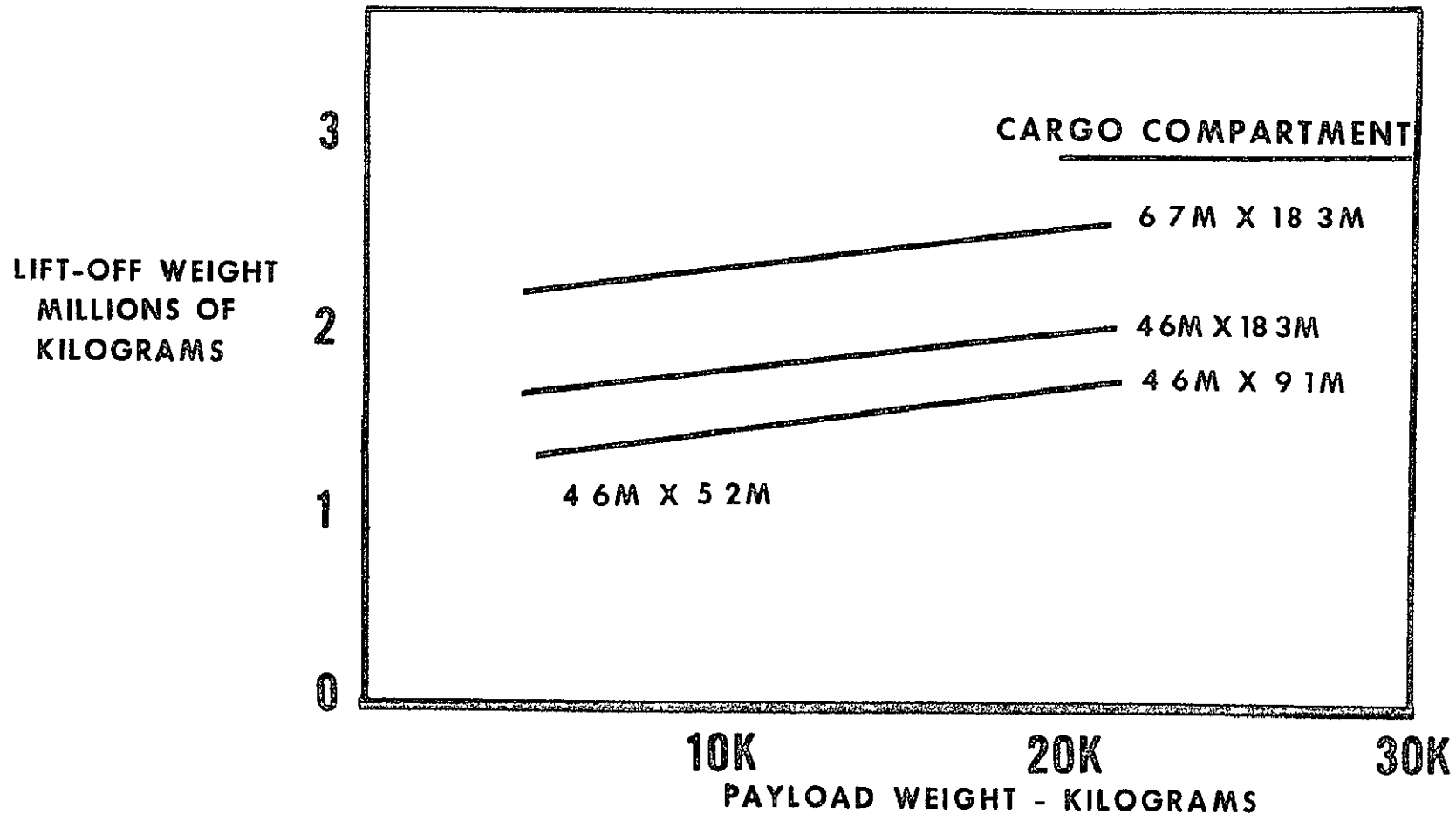
DEFINITION PHASE TECHNICAL TRADEOFFS

The Space Shuttle definition phase activity will involve many tradeoffs, the purpose of which is to provide assurance that the design selected is the best vehicle to meet the objectives and requirements of the program. Tradeoffs vary from determining the effects of cross range (which would affect configuration selection) to determining whether liquid hydrogen or JP fuel should be used for air breathing engines (which would affect system trades).

It is planned that most of the trade studies that affect configuration will be completed by the end of the third month of the studies. System trade studies will continue until the six month point in the definition activities.

SYSTEM PERFORMANCE SENSITIVITY

SIZE EFFECTS-BASE LINE CONCEPT (PHASE A DATA)



NASA HQ MH70-6371
6-26-70

SYSTEM PERFORMANCE SENSITIVITY

There are many tradeoff studies being performed in the early stages of the definition studies. One of these studies is to determine the sensitivity of the shuttle system to cargo compartment size. Baseline, for now, is a cargo compartment that is 4.6M by 18.3M. The sensitivity of the configuration to other cargo compartment sizes has been performed in earlier studies and will be examined in more detail during the definition studies. Of special interest in these studies, is the effect on lift-off weight and payload weight.

SPACE SHUTTLE DESIGN REFERENCE CHARACTERISTICS ESTABLISHED FOR DEFINITION PHASE

- TWO STAGE FULLY REUSABLE
- VERTICAL TAKE OFF/HORIZONTAL LANDING
- 1.5 MILLION KGS GROSS LIFT-OFF WEIGHT
- 4.6M DIAMETER X 18.3M LENGTH CARGO BAY SIZE
- TWO MAN CREW
- ORBITER SELF SUSTAINING FOR 7 DAYS
- NOMINAL 270 N. MI. ORBIT AT 55° INCLINATION
- SHIRTSLEEVE ENVIRONMENT FOR CREW AND PASSENGERS
- FLIGHT CREW CONTROLLED ABORTS
- "G" MAXIMUM ASCENT AND RE-ENTRY ACCELERATION
- BENIGN PAYLOAD ENVIRONMENT

DESIGN REFERENCE CHARACTERISTICS ESTABLISHED FOR DEFINITION PHASE

These Phase B study characteristics provide a point of departure for defining a reusable shuttle system. They encompass a range of configurations and design approaches. Technical risks and costs implicit in any of these design alternatives will be prime considerations of the study. Some of these baseline characteristics we are presently pursuing are

Vertical take-off, horizontal landing

Self sustaining 7 day orbit operations capability

Take-off weight approximately 3.5 million pounds with payload and fully fueled

Two-man crew

Payload volume of about 10,000 cubic feet for cargo, supplies, fuel or passengers

An approach to airline-type operations

Minimum refurbishment and quick turnaround time prior to next flight

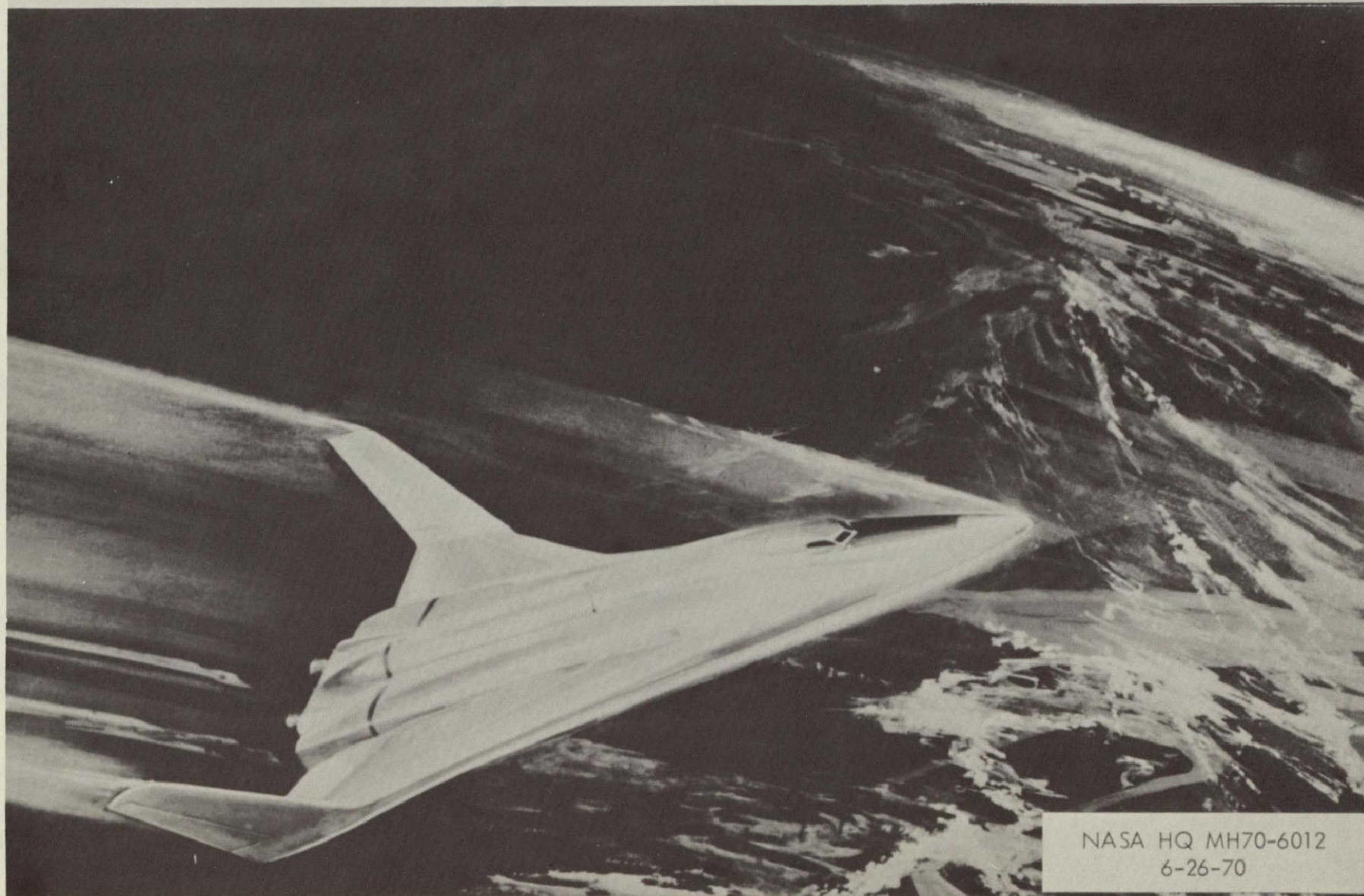
SPACE SHUTTLE STATUS OF DEFINITION PHASE

- NASA HAS COMPLETED EVALUATIONS OF PROPOSALS
- NORTH AMERICAN ROCKWELL AND MC DONNELL DOUGLAS HAVE BEEN SELECTED TO CONDUCT DEFINITION STUDIES
- BOTH STUDIES INITIATED LAST WEEK IN JUNE FOR A PERIOD OF 11 MONTHS

STATUS OF VEHICLE DEFINITION PHASE

From proposals received in response to a request for proposals issued by NASA, two aerospace companies have been selected to conduct the Space Shuttle Vehicle Definition Studies. Contracts were signed in late June of this year for the eleven month parallel efforts

NORTH AMERICAN ROCKWELL
HIGH CROSSRANGE CONCEPT



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6-26-70

North American Rockwell high crossrange orbiter configuration proposed for the definition studies.

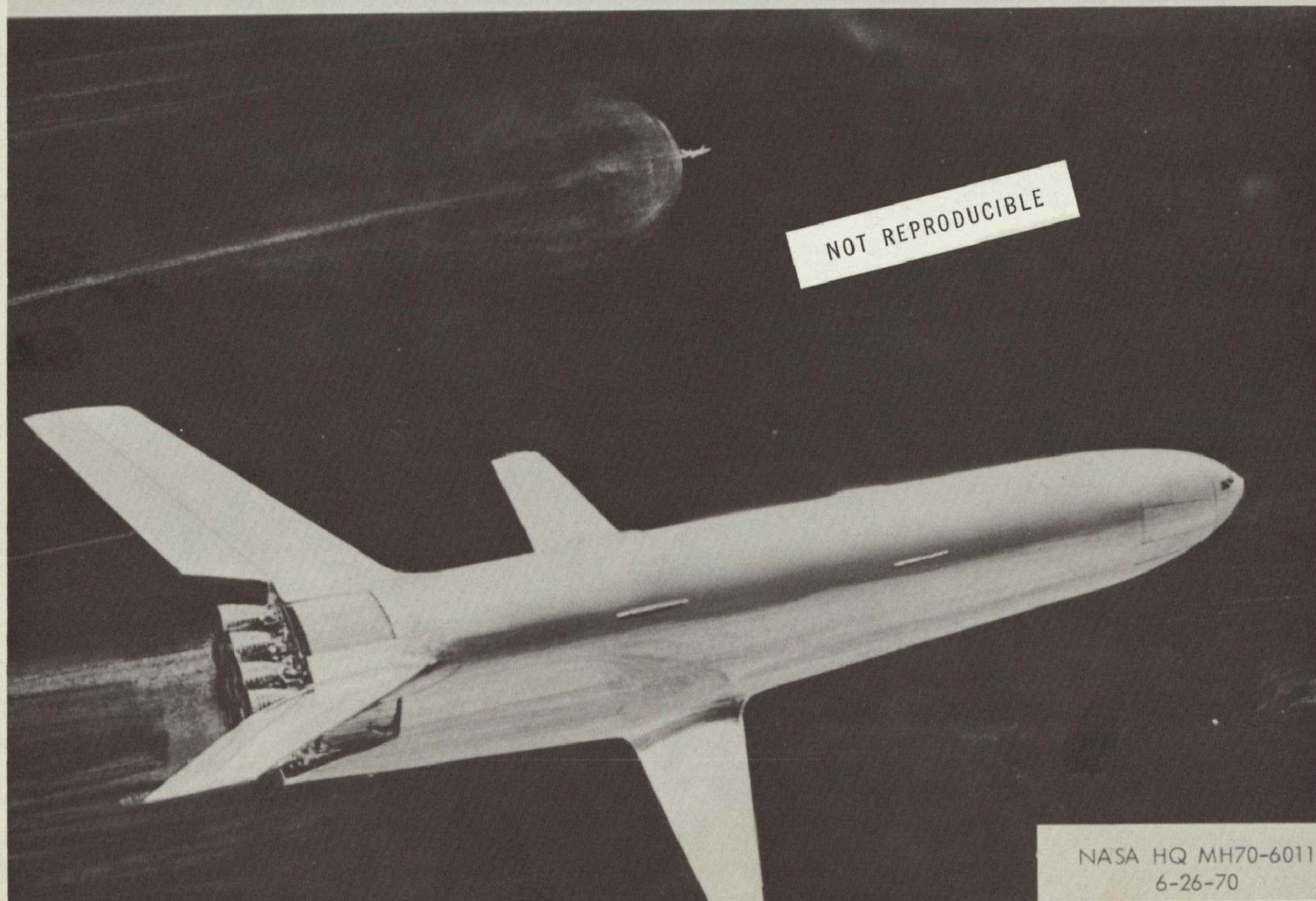
NORTH AMERICAN ROCKWELL
LOW CROSSRANGE CONCEPT



NASA HQ MH70-6013
6-26-70

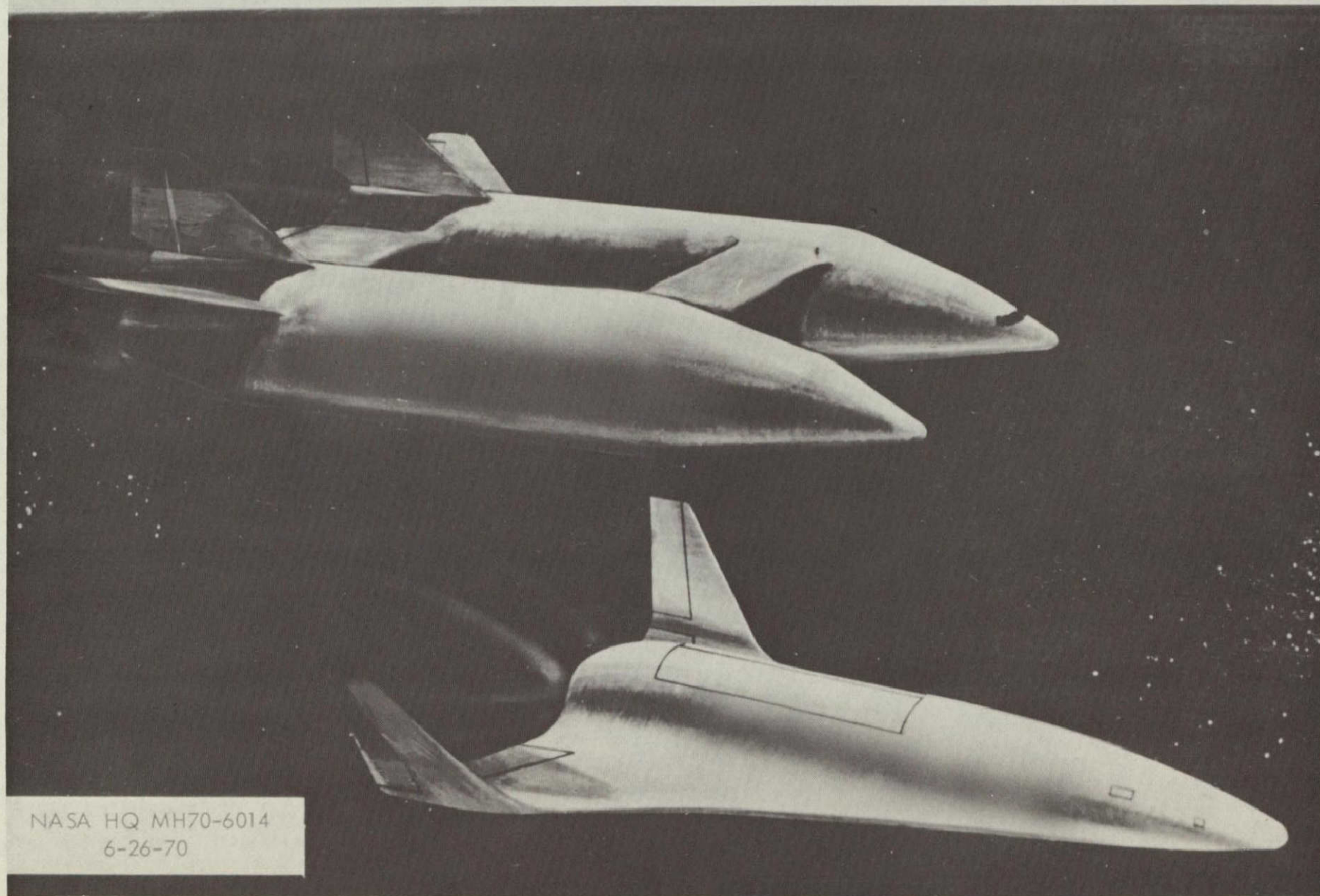
North American Rockwell low crossrange orbiter configuration proposed for the definition studies.

NORTH AMERICAN ROCKWELL/CONVAIR
FIXED WING BOOSTER



North American Rockwell/Convair common booster configuration proposed for the definition studies.

MCDONNELL DOUGLAS
HIGH CROSSRANGE SHUTTLE

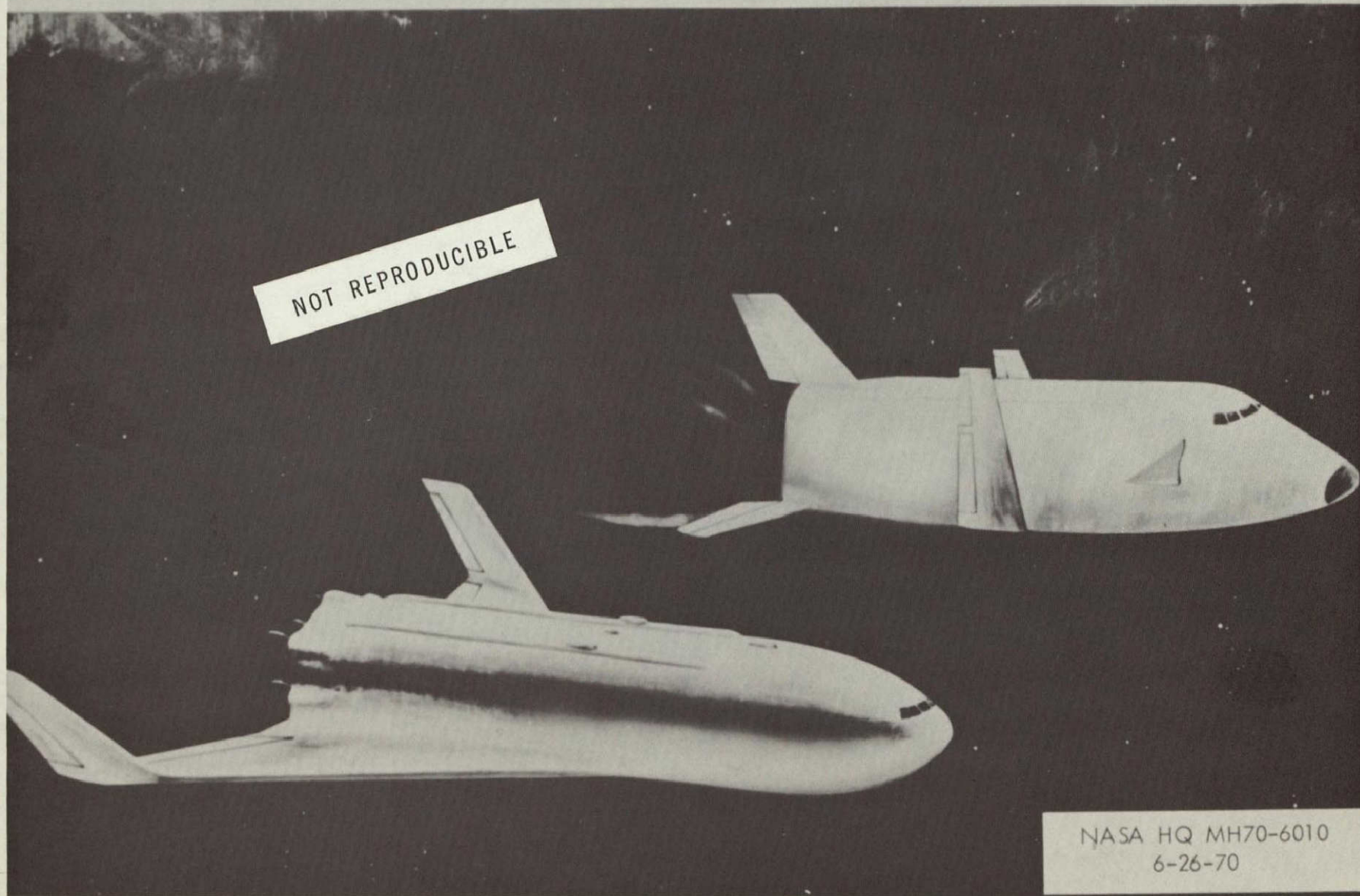


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The McDonnell Douglas high crossrange shuttle configuration proposed for the definition studies.

MCDONNELL DOUGLAS LOW CROSSRANGE SHUTTLE

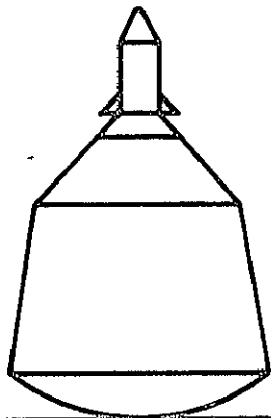
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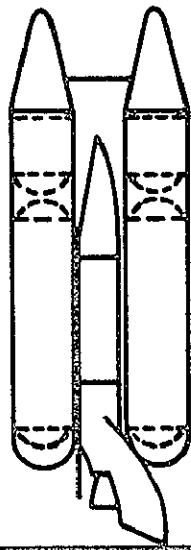
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McDonnell Douglas low crossrange shuttle configuration proposed for the
definition studies

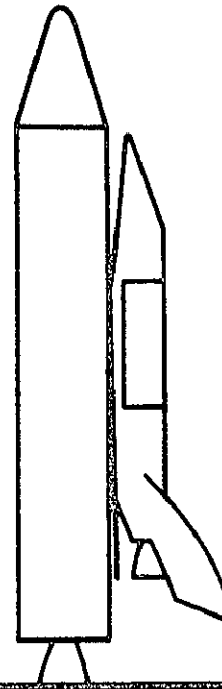
OTHER CANDIDATE CONCEPTS



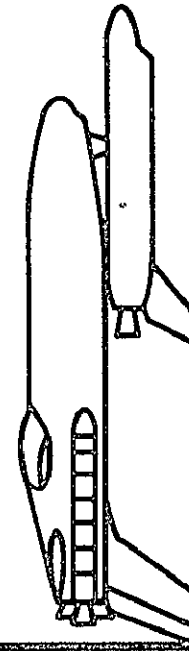
SINGLE
STAGE
TO ORBIT



ONE &
ONEHALF
STAGE



EXPENDABLE
FIRST
STAGE



J2-S WITH
STRAP-ON
SOLIDS

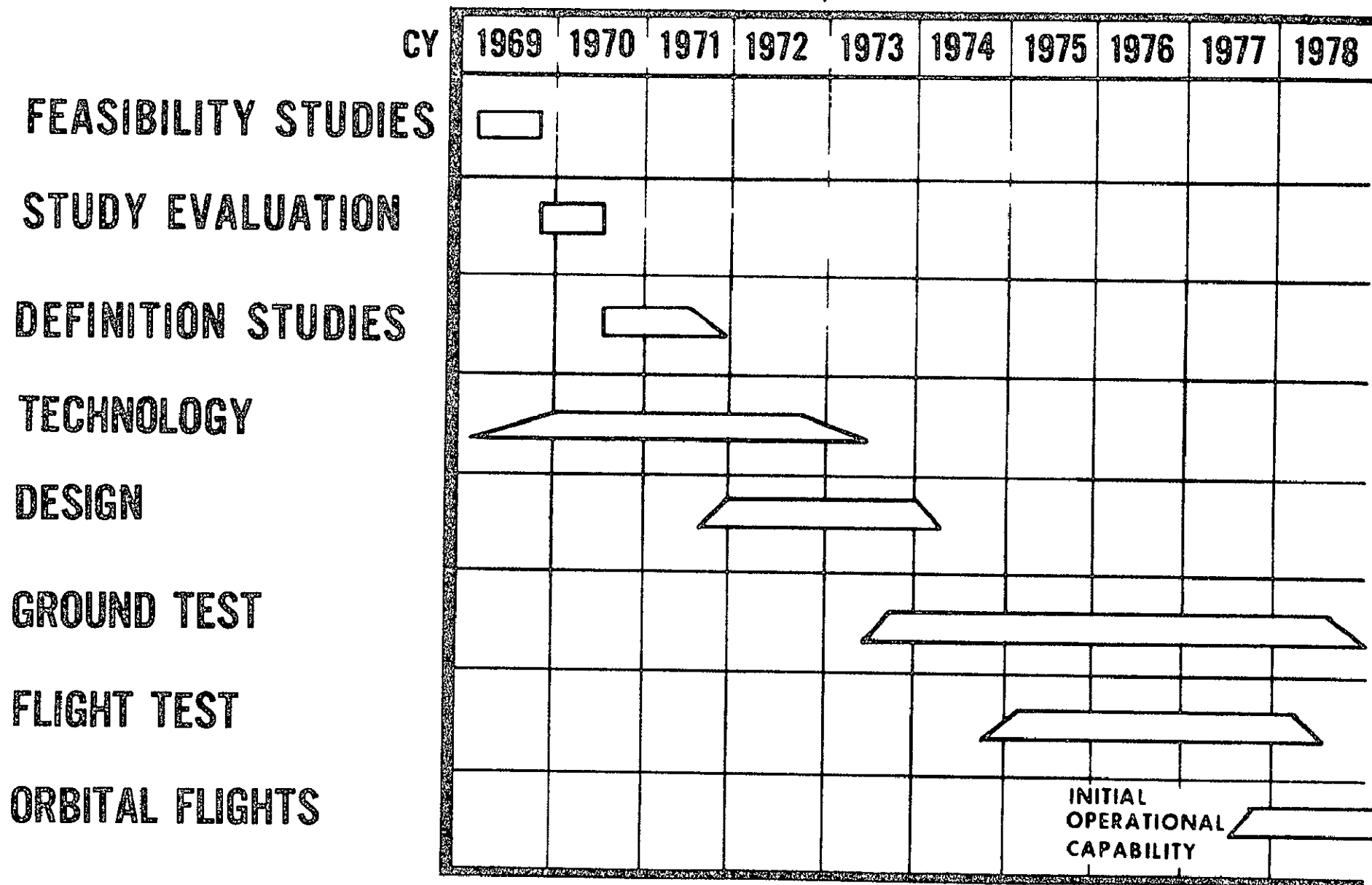
ALTERNATE CONCEPTS

The Phase B studies are based on a fully reusable, two stage shuttle vehicle. The importance of the shuttle to the future of space exploration is so fundamental that concurrent investigations of alternate systems concepts have been established to assure the thoroughness of NASA's approach

The four concepts illustrated are the subject of studies recently placed under contract with Chrysler, Lockheed and a team comprised of Grumman and Boeing.

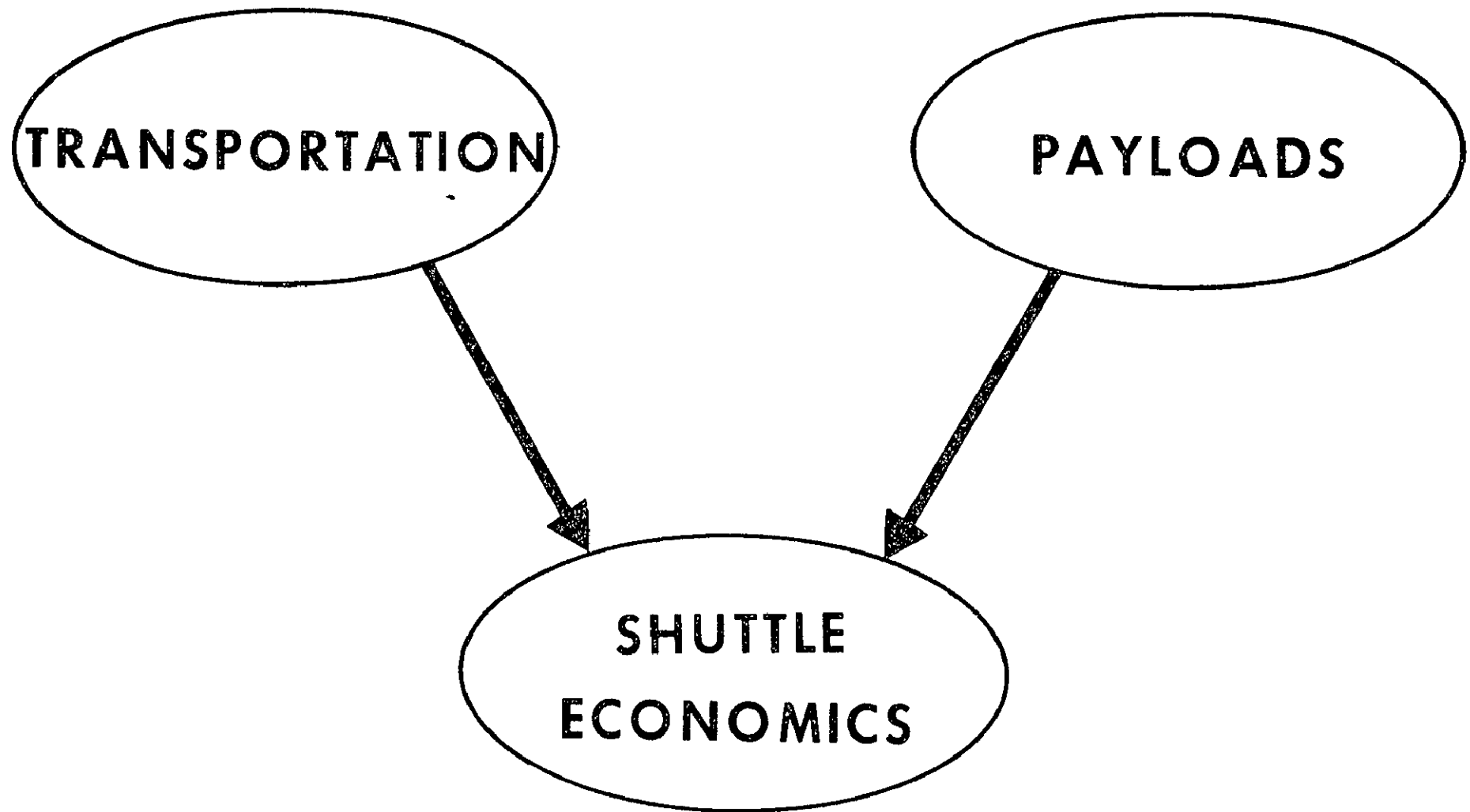
SHUTTLE PLANNING SCHEDULE

(PRELIMINARY)



SHUTTLE PLANNING SCHEDULE

The Space Shuttle Planning Schedule is included to present a preliminary overview of NASA's plan to design, develop, test and manufacture a reusable space vehicle with an initial operational capability in the third quarter of calendar year 1977. This plan is in consonance with the Phased Project Planning concept which is provided for the orderly planning and definition of new major R&D undertakings.



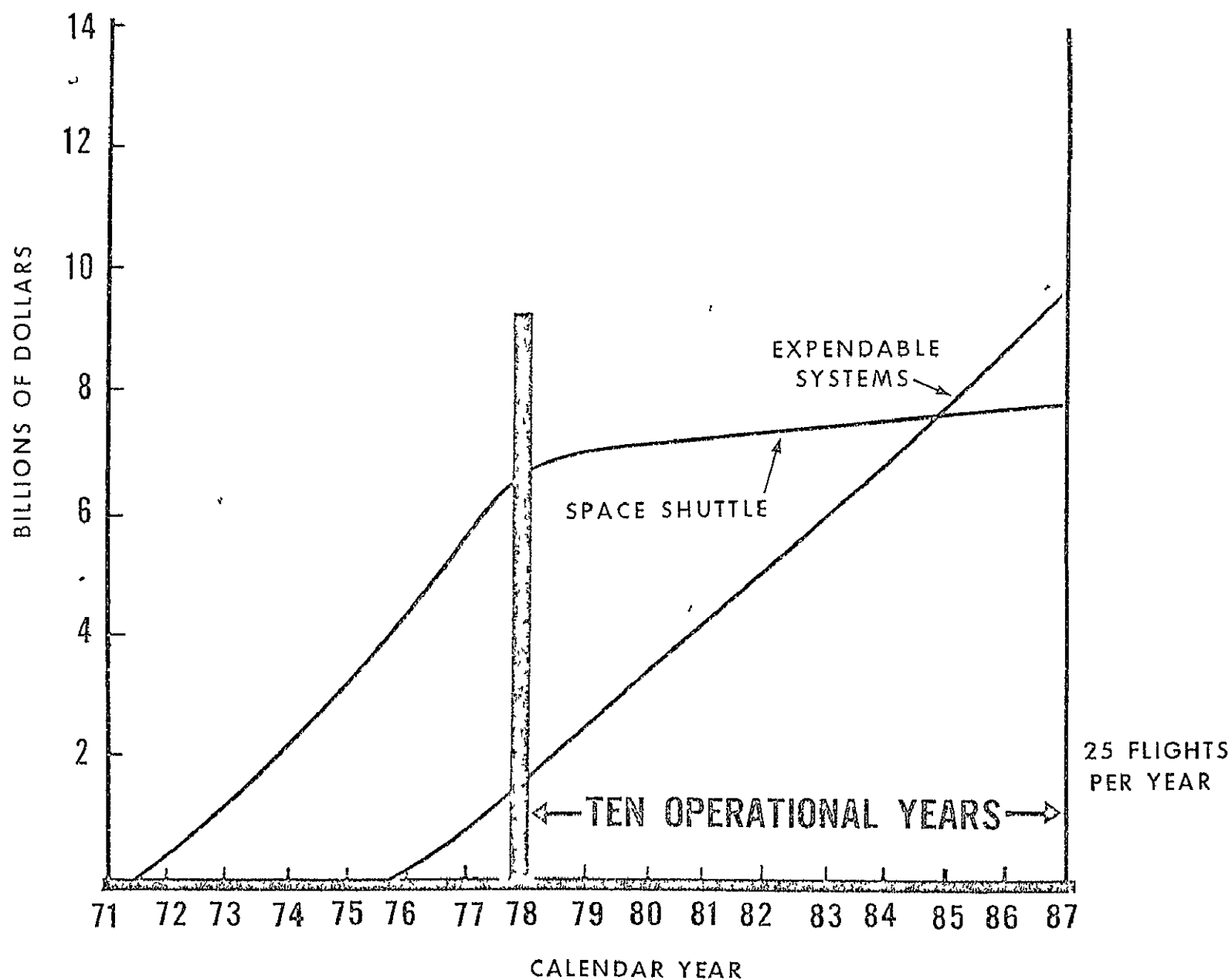
SHUTTLE ECONOMICS

The reusable Space Shuttle concept was generated in response to the recognized need that expanded space progress required a significant reduction in the costs associated with expendable launch vehicles.

As the subject of shuttle economics was further examined, it became evident that additional and even more promising savings will accrue from the shuttle's effect on payload design and logistics

The reduction in transportation costs along with a reduction in payload costs will make the shuttle an economically feasible system

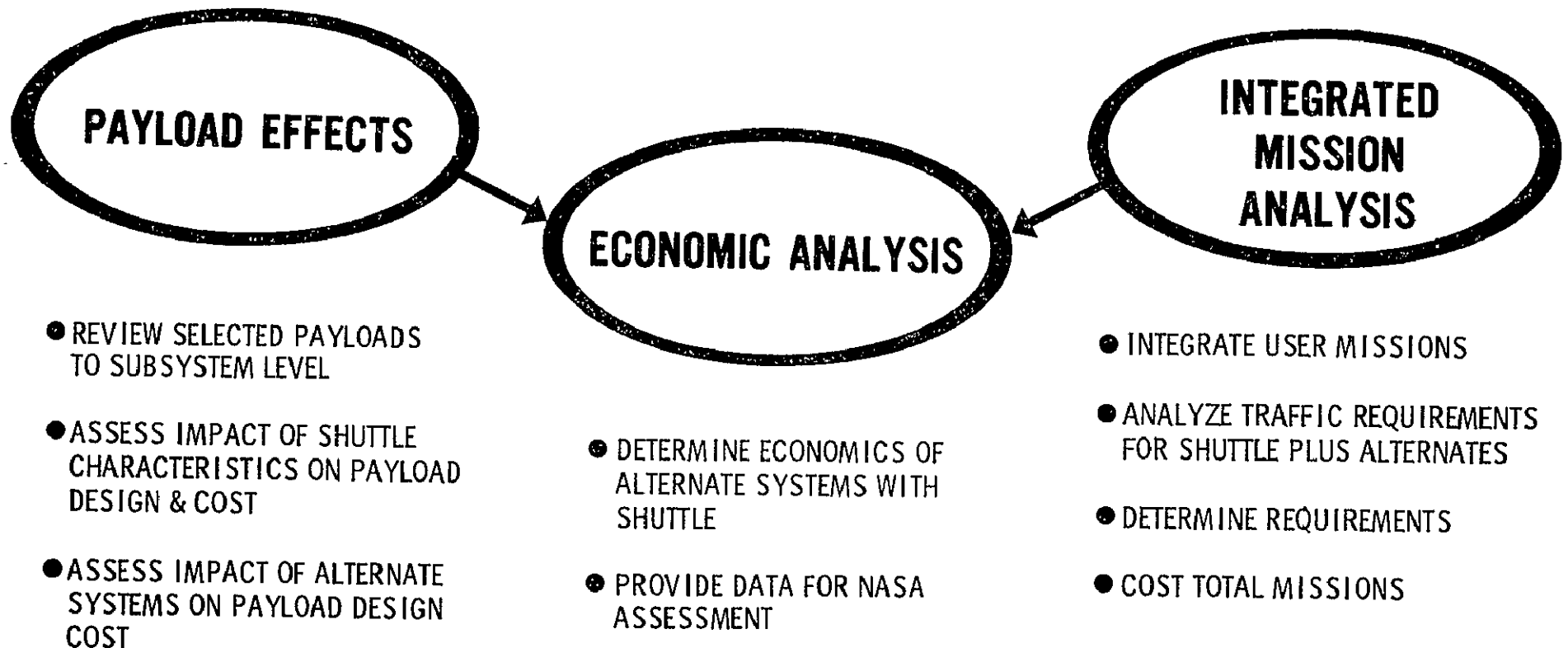
SHUTTLE REDUCES COST OF SPACE FLIGHT OVER EXPENDABLE SYSTEMS



THE SHUTTLE REDUCES THE COST OF SPACEFLIGHT OVER EXPENDABLE SYSTEMS

A graphic plot of Space Shuttle Research, Development and Operations costs, based on a conservative mission model, indicates a break-even point on investment (at intersections with cost plot for expendable systems) of approximately seven years after initiation of shuttle operations.

ECONOMIC STUDIES



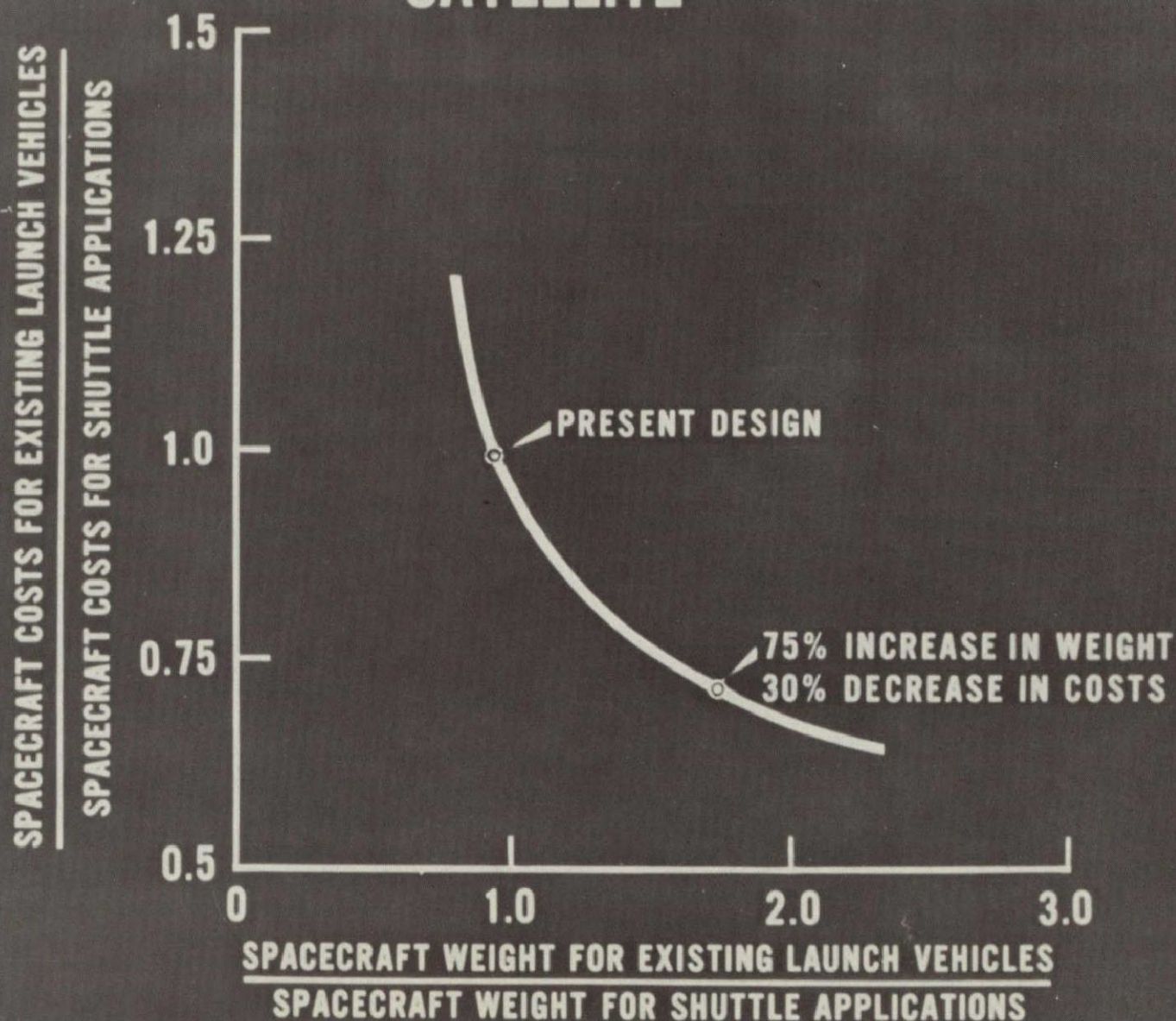
ECONOMIC STUDIES

In recognition of the fact that the potential economies of the shuttle are not only operational, NASA has prepared a study to further examine effects of the shuttle on payload, finally in terms of design and cost.

A second study has been established to provide an integrated mission analysis, including total mission cost, based on an analysis of traffic requirements.

The results of both of the above are to be used as a basis for an overall economic analysis of the shuttle vs comparison with alternate systems.

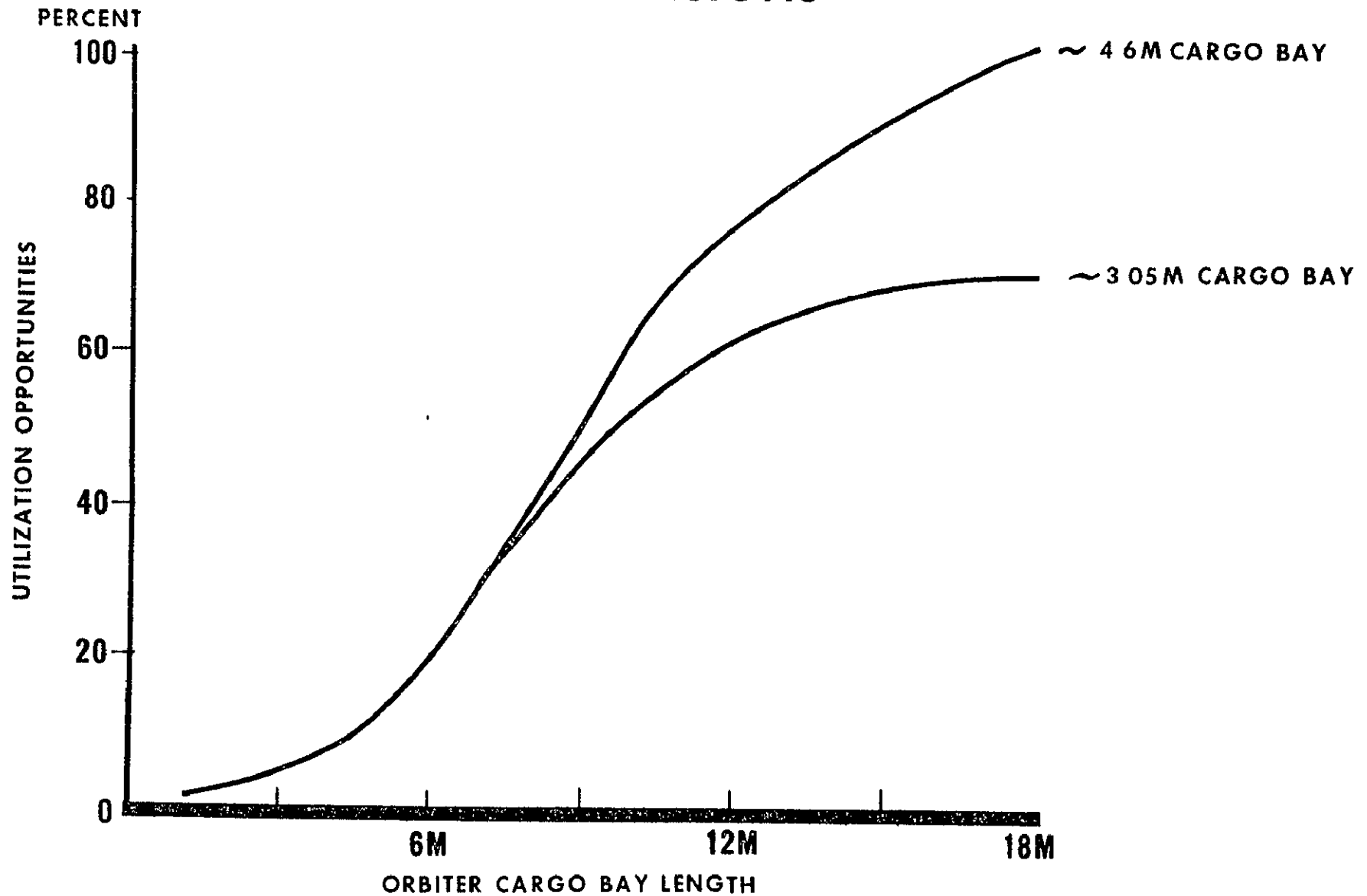
SHUTTLE EFFECTS ON ADVANCED COMMUNICATIONS SATELLITE



SHUTTLE EFFECTS ON ADVANCED COMMUNICATIONS SATELLITE

Based on an advanced class of communications satellites, this is a graphical representation as to how applications of the shuttle can reduce spacecraft costs. Plotting costs for existing launch vehicles versus the shuttle, against spacecraft weights for existing launch vehicles versus the shuttle - with the present design normalized to unity - it can be shown that a 75% increase in weight is equivalent to a 30% decrease in costs is possible.

MISSION UTILIZATION AS A FUNCTION OF CARGO BAY DIMENSIONS



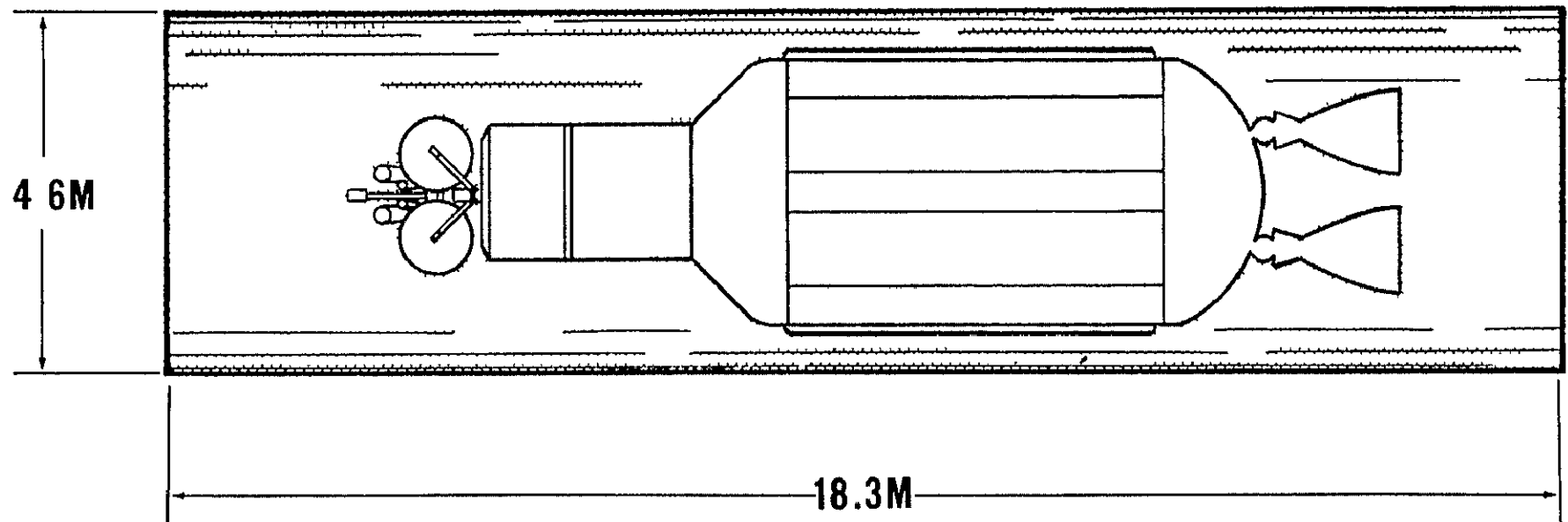
NASA HQ MH70-6396

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MISSION UTILIZATION AS A FUNCTION OF CARGO BAY DIMENSIONS

This curve is based upon a national mission model which averages approximately 50 flights per year over a 10 year period. A shuttle with a 15 foot diameter (4.6 meters) X 60 feet length (18.3 meters) can accommodate nearly all the payloads making up the model.

COMMUNICATIONS SATELLITE IN SHUTTLE PAYLOAD COMPARTMENT



NASA HQ MH70-6354
6-23-70

COMMUNICATIONS SATELLITE IN SHUTTLE PAYLOAD COMPARTMENT

The space shuttle payload compartment dimensions represent a capability as illustrated. This particular potential payload consists of communications satellite mated to an existing Centaur propulsion stage. Recognizing that this particular satellite was designed to be enclosed in the Centaur shroud, when the capability of the shuttle becomes available, the satellite designers will have the opportunity to provide larger antennas.

IMPLICATIONS OF SPACE SHUTTLE

LOW COST, FLEXIBLE, FAST RESPONSE

CAPABILITY, FAVORABLE ENVIRONMENT

WILL OPEN NEW HORIZONS FOR SCIENCE

AND APPLICATIONS IN SPACE

OPPORTUNITIES FOR PARTICIPATION

PROGRAM DEFINITION -- PHASE B

- PARTICIPATION IN DEFINITION PHASE STUDIES
- PARTICIPATION IN TECHNOLOGY PANELS
- CONDUCT OF SELECTED TECHNOLOGY INVESTIGATIONS
- DEFINITION OF USER REQUIREMENTS
- CONDUCT OF SYSTEMS STUDIES

DESIGN AND DEVELOPMENT -- PHASE C/D

- PARTICIPATION AS SUBCONTRACTOR IN SHUTTLE DEVELOPMENT
- DEVELOPMENT OF MAJOR SYSTEMS
- DEFINITION OF MISSIONS
- DEVELOPMENT OF PAYLOADS

OPERATIONS

- PLANNING OF MISSIONS
- PROVISION OF PAYLOADS, EXPERIMENT AND ASTRONAUTS
- UTILIZATION FOR DESIRED MISSIONS
- SUPPLY OF MAJOR SYSTEMS

NASA HQ MH70-6409
Revised 7-1-70