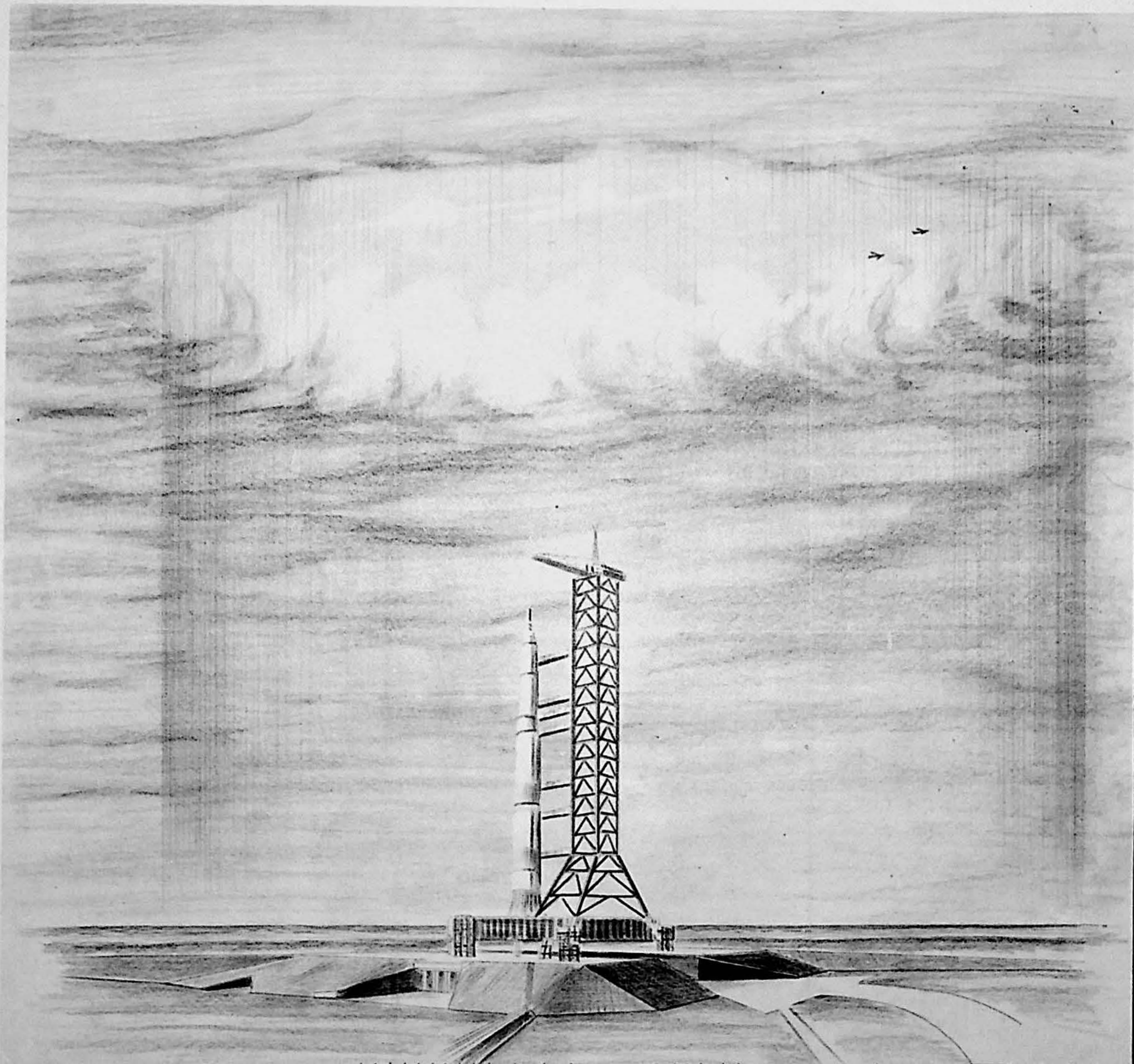

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Georg von Tiesenhausen.

LAUNCH OPERATIONS CENTER

NASA

ANNUAL ACTIVITY REPORT - FY 62

PAST, PRESENT, AND FUTURE PROJECTS

FUTURE STUDIES BRANCH, LAUNCH OPERATIONS CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SEPTEMBER 1962

LOC-FORM 16B-1

LAUNCH OPERATIONS CENTER

ANNUAL ACTIVITY REPORT - FY 62
PAST, PRESENT, AND FUTURE PROJECTS
FUTURE STUDIES BRANCH, LAUNCH OPERATIONS CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SEPTEMBER 1962

ABSTRACT

The purpose of this brochure is to acquaint the individuals associated with this country's space program with the past, present, and planned future efforts of the Future Studies Branch, Launch Operations Center, National Aeronautics and Space Administration. Thus, it is intended for interested persons both within and outside of U. S. Government agencies. Such an approach should provide industry with a more precise awareness of the Government's needs in the various space programs, and should promote cooperation and eliminate duplication of effort in concurrent programs being conducted by the various agencies. Descriptive materials on all programs have been held to a minimum inasmuch as complete details on all referenced material are available upon request from the Future Studies Branch.

As of July 1, 1962, Launch Operations officially became a Center on a level comparable to MSFC. Under this new organization, the Future Launch Systems Study Office is now known as the Future Studies Branch, and is essentially performing similar functions.

This report will give the reader a brief summary of past study efforts, work presently in progress, and planned programs for the future. Because of the scope of work involved, no attempt was made to indicate the detailed technical findings of the studies performed by this organization. Those persons interested in more detailed information on any specific topic discussed in this publication may obtain it from the Future Studies Branch. As current and future study programs of this Branch develop and progress in their level of accomplishment or achievement, follow-on reports of a similar nature to this one will be released.

LAUNCH OPERATIONS CENTER

ANNUAL ACTIVITY REPORT - FY 62
PAST, PRESENT, AND FUTURE PROJECTS
FUTURE STUDIES BRANCH, LAUNCH OPERATIONS CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SEPTEMBER 1962

LAUNCH SUPPORT EQUIPMENT OFFICE
LAUNCH OPERATIONS CENTER

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SEPTEMBER 1962

I. INTRODUCTION

Two years have passed since Dr. Wernher von Braun and his associates joined the National Aeronautics and Space Administration as the George C. Marshall Space Flight Center. At this time, the Future Launch Systems Study Office was established to perform long range planning and preliminary design of launch facilities and GSE as required to support the SATURN vehicle launch program and follow-on vehicles of the future. As the manned lunar landing program evolved, these responsibilities carried over into space activities supporting orbital launch operations, which included orbital storage of cryogenics, orbital rendezvous, and orbital launch facilities with life-support systems. (Ref. Figure 1).

This office is supported by line organizations within Launch Operations and by contractors performing study contracts funded and directed through the office.

Major efforts of this office are directed toward new and unique approaches to the problems of launch facilities, GSE, orbital facilities design, and orbital operations. This is generally carried to the level of preliminary design only, with actual hardware development and design being carried out by the line organizations as required. Continuous coordination and liaison is maintained on such projects with personnel from MSFC (Huntsville) and among Launch Operations personnel (Huntsville and Cape Canaveral). (Ref. Table II).

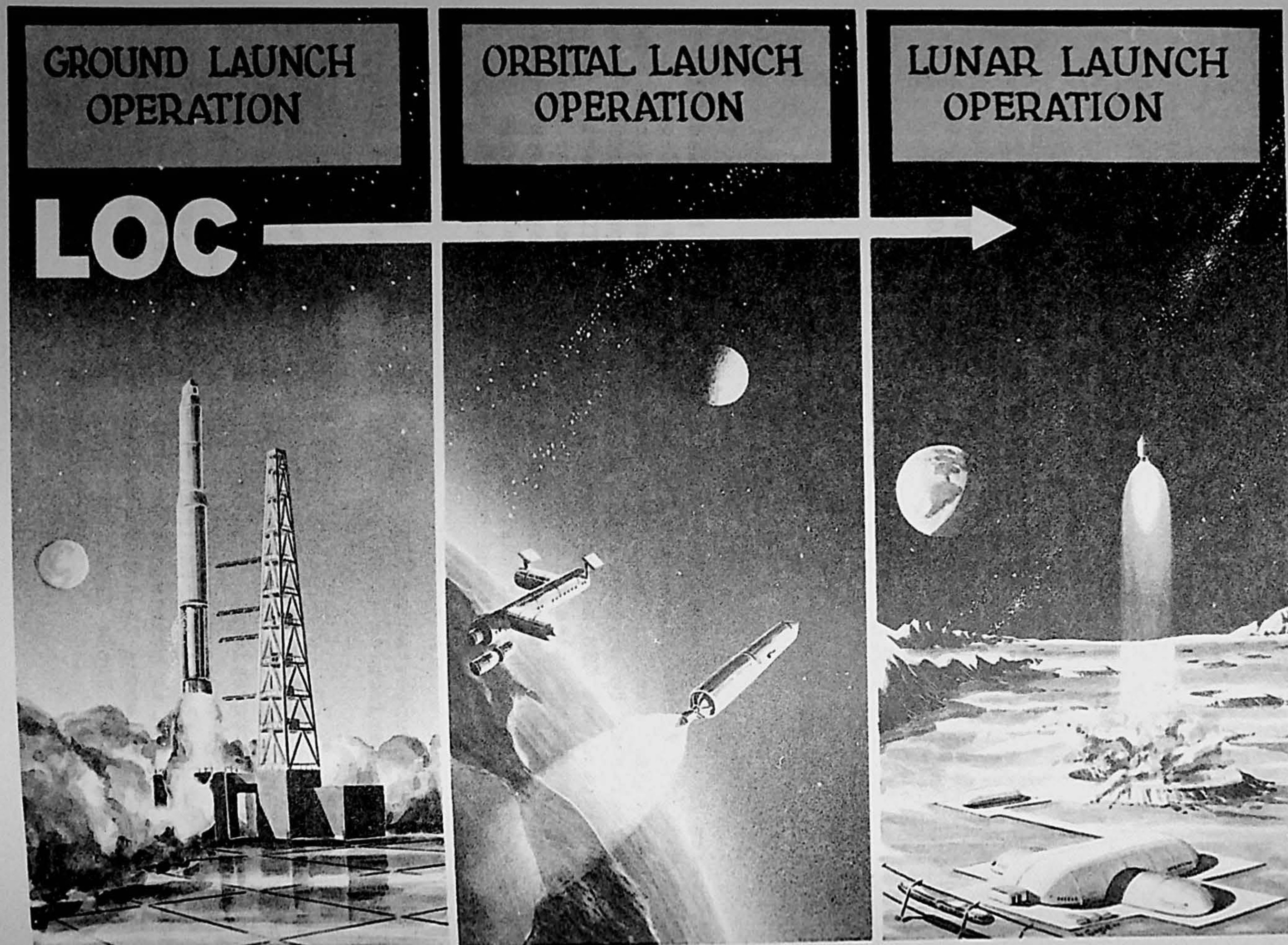


Figure 1. LOC MISSIONS

II. FUTURE STUDIES BRANCH PRIMARY FUNCTIONS AND RESPONSIBILITIES

As discussed previously, the Future Studies Branch is now organized under the general direction of Launch Operations Center, Dr. K. Debus, and specifically by the Launch Support Equipment Office, Mr. T. A. Poppel, (Ref. Figure 2). Directed by Mr. Georg von Tiesenhausen, the Branch is divided into two sections: a Space Launch Section and a Ground Launch Section, (Ref. Figure 3). The mission of this Branch is to perform preliminary design, long range planning, conceptual evaluation, research and development, and coordination of all Launch Operations Center efforts in the study, development, and evaluation of new launch facility and support equipment concepts as applicable to both ground and space launch operations. Distribution of effort is shown in Figure 4. Functions of individual personnel are shown in Table I.

A. The general functions of the Ground Launch Section may be listed as follows:

1. Perform feasibility and design studies, and analytical investigations in the preparation of technical proposals and design criteria for launch facilities and supporting GSE. (Ref. Figure 5).

2. Directs, monitors, and evaluates contractor proposals and study effort related to launch facilities and support equipment.

3. Investigates, analyzes, evaluates, and determines optimum facilities and facility layouts for future space vehicle launch systems.

4. Investigates new and unique approaches to launch facility concepts for possible application to future launch systems, keeping in mind optimum performance, reliability, simplicity, cost and scheduling.

5. Establishes a system's engineering approach for launch facility operational modes.

6. Performs operational, logistic, and cost investigations for feasibility studies on all types of space vehicle launch systems.

7. Serves as a launch facilities representative or advisory member on steering committees, contract management boards, and working groups directing MSFC and LOX study or design contracts.

8. Maintains close contact with industry and other Government agencies performing related study and design efforts.

B. The Space Launch Section performs functions similar to those dis-cussed above as related to orbital launch facilities, orbital support facilities, and orbital operational modes. The following might be conside as being representative of typical activities:

1. Evaluates requirements and determines optimum vehicle and launch systems for extra-terrestrial explorations.

2. Performs research and development studies on specific techn cal problem areas associated with orbital or space launch operations; i.e long term cryogenic storage, propellant transfer under zero-g conditions, insulating techniques, meteoroid protection, leak detection, cosmic and solar flare hazards, etc.

C. Major areas with which the entire Future Studies Branch is active associated are outlined in Table II.

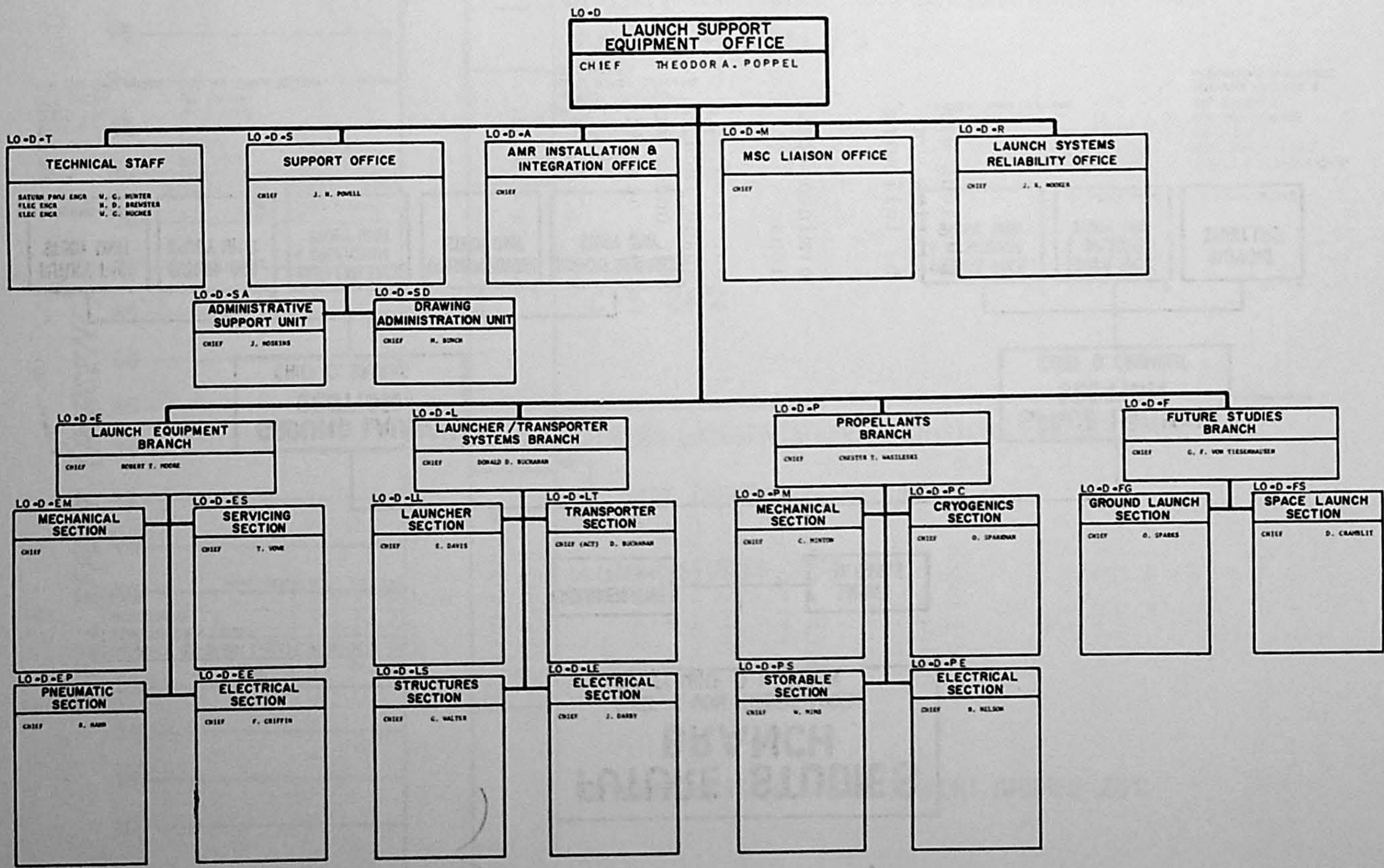
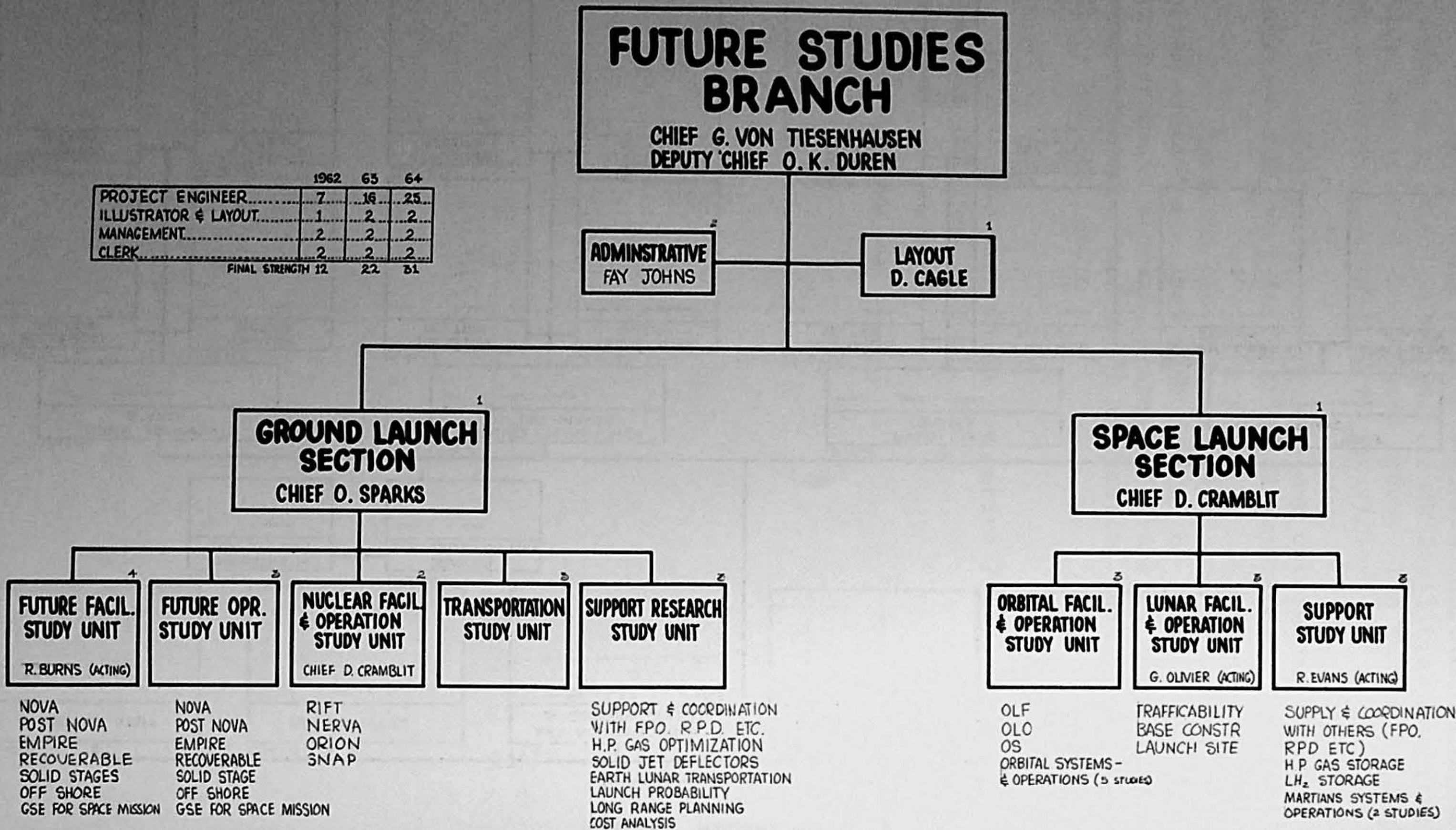


Figure 2. ORGANIZATIONAL CHART - LAUNCH SUPPORT EQUIPMENT OFFICE



	1962	63	64
PROJECT ENGINEER	7	16	25
ILLUSTRATOR & LAYOUT	1	2	2
MANAGEMENT	2	2	2
CLERK	2	2	2
FINAL STRENGTH	12	22	31

Figure 3. ORGANIZATIONAL CHART - FUTURE STUDIES BRANCH

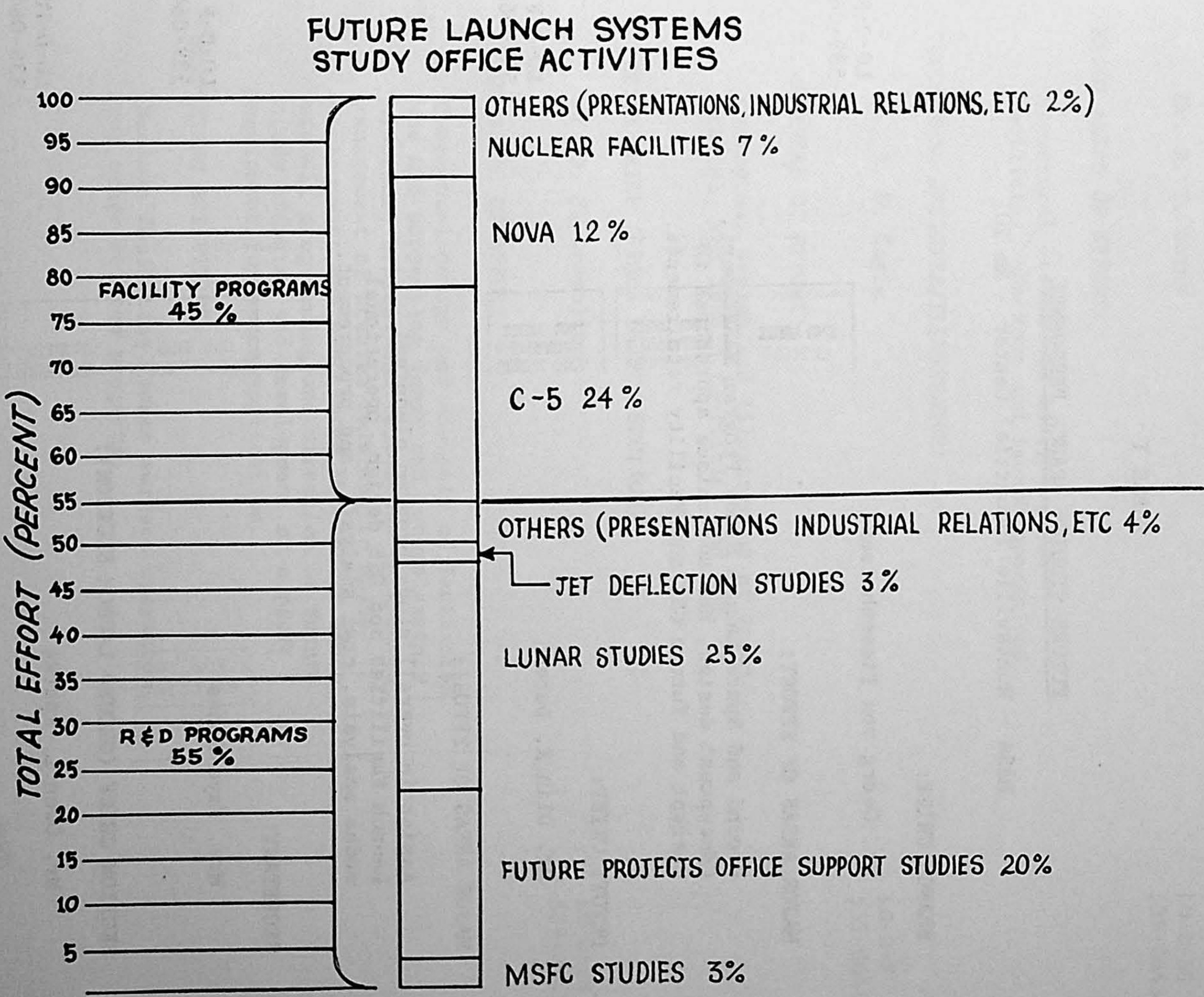


Figure 4. FUTURE LAUNCH SYSTEMS STUDY OFFICE ACTIVITIES

TABLE I

FUTURE STUDIES BRANCH PERSONNEL

NASA - Huntsville Industrial Center - Rm 201

1. BRANCH CHIEF:

Mr. Georg von Tiesenhausen LO-D-F 539-0641

MAJOR AREAS OF EFFORT:

Ground and Space Launch Study Program Management, Conceptual design, new and unique approaches to current and future GSE and Facility requirements.

2. DEPUTY CHIEF:

Mr. Olin K. Duren LO-D-F 539-0641

MAJOR AREAS OF EFFORT:

Assist in overall study program planning, Launch Facilities and GSE design, operational modes analysis, cost analysis, and procurement.

3. SECRETARY:

Mrs. Faye Johns LO-D-F 539-0641

4. SECTION CHIEF (GROUND LAUNCH SECTION):

Mr. Owen L. Sparks LO-D-FG 539-0642

MAJOR AREAS OF EFFORT:

Launch Facilities development, study program definition and management, overall programming and scheduling, solid propellant vehicles and launch facilities, acoustics, and future facility developments (NOVA and Post-NOVA).

5. PROJECT ENGINEER (CIVIL):

Mr. R. T. Burns — LO-D-FG 539-0643

MAJOR AREAS OF EFFORT:

Structural design and analysis, lunar facilities, checkout and launch operations.

6. CONCEPTUAL DESIGNER/ILLUSTRATOR:

Mr. E. D. Cagle — LO-D-F 539-0644

MAJOR AREAS OF EFFORT:

Conceptual design and illustration of ground, orbital, and launch facilities and GSE.

7. SECTION CHIEF (SPACE LAUNCH SECTION):

Mr. D. C. Cramblit — LO-D-FS 539-0641

MAJOR AREAS OF EFFORT:

Conceptual design and analysis of facilities and GSE supporting lunar and interplanetary missions, orbital and rendezvous techniques, management of studies relating to space environment and associated hazards to space travel, programming and direction of future study efforts, and development of support equipment for space application.

SUPPORTING ACTIVITIES:

Nuclear facilities, lunar surface operation, and other related projects.

8. PROJECT ENGINEER (MECHANICAL)

Mr. R. L. Evans LO-D-FS 539-0643

MAJOR AREAS OF EFFORT:

Lunar and space storage of cryogenics, jet stream and flame deflection analysis, insulation techniques, and other space-related projects in the fields of heat transfer, thermodynamics, analytical mathematics and fluid mechanics.

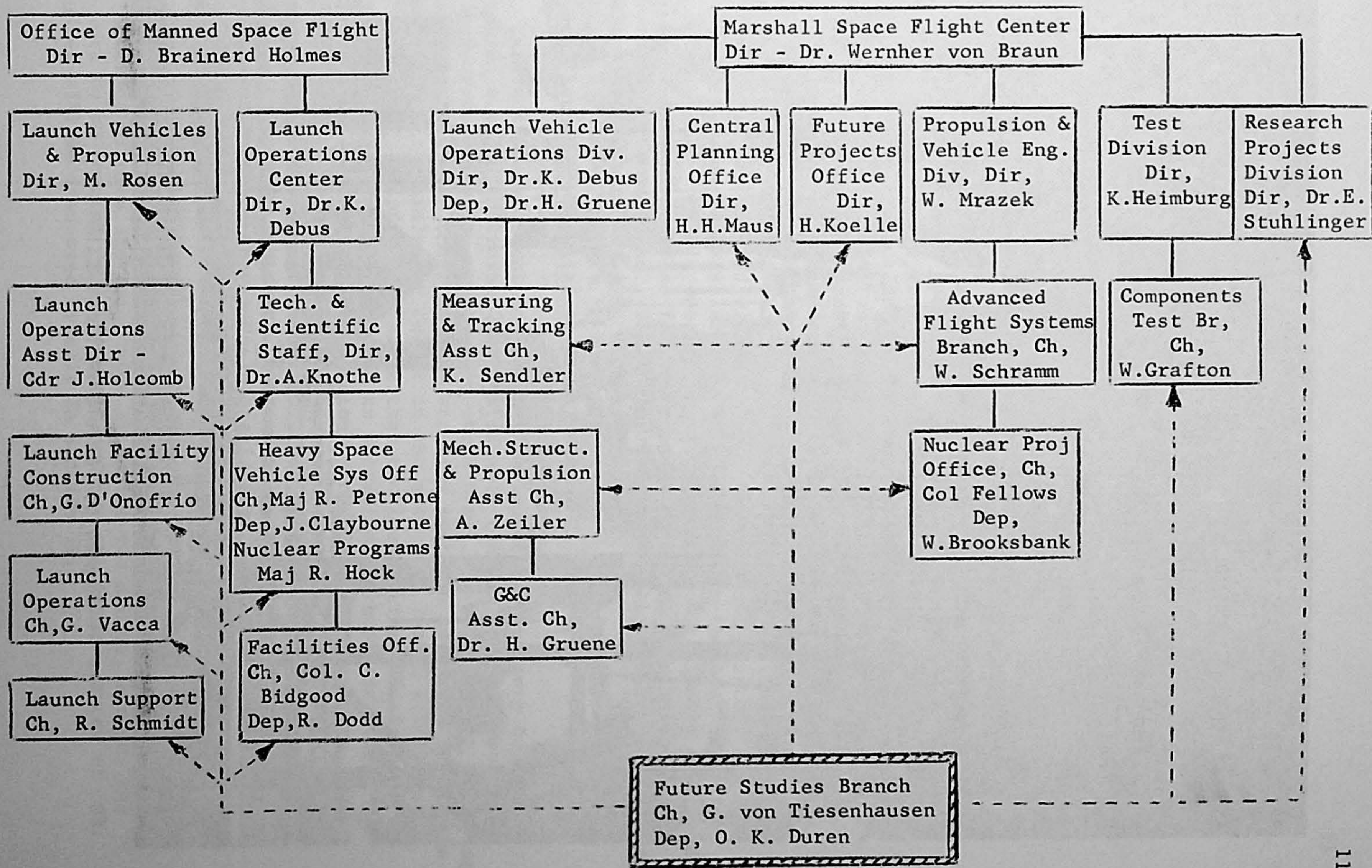
9. PROJECT ENGINEER (MECHANICAL)

Mr. J. R. Olivier LO-D-FS 539-0642

MAJOR AREAS OF EFFORT:

Conceptual design of orbital launch facilities, cryogenic storage tankers, orbital and rendezvous operational techniques, and theoretical analysis of problems associated with the development of GSE and facilities for space application (i.e., zero-gravity venting, cryogenic transfer techniques under zero-gravity conditions, long duration cryogenic orbital storage considerations, and other topics related to heat transfer, thermodynamics, and propulsion).

Table No. II . Future Studies Branch Major Areas of Contact



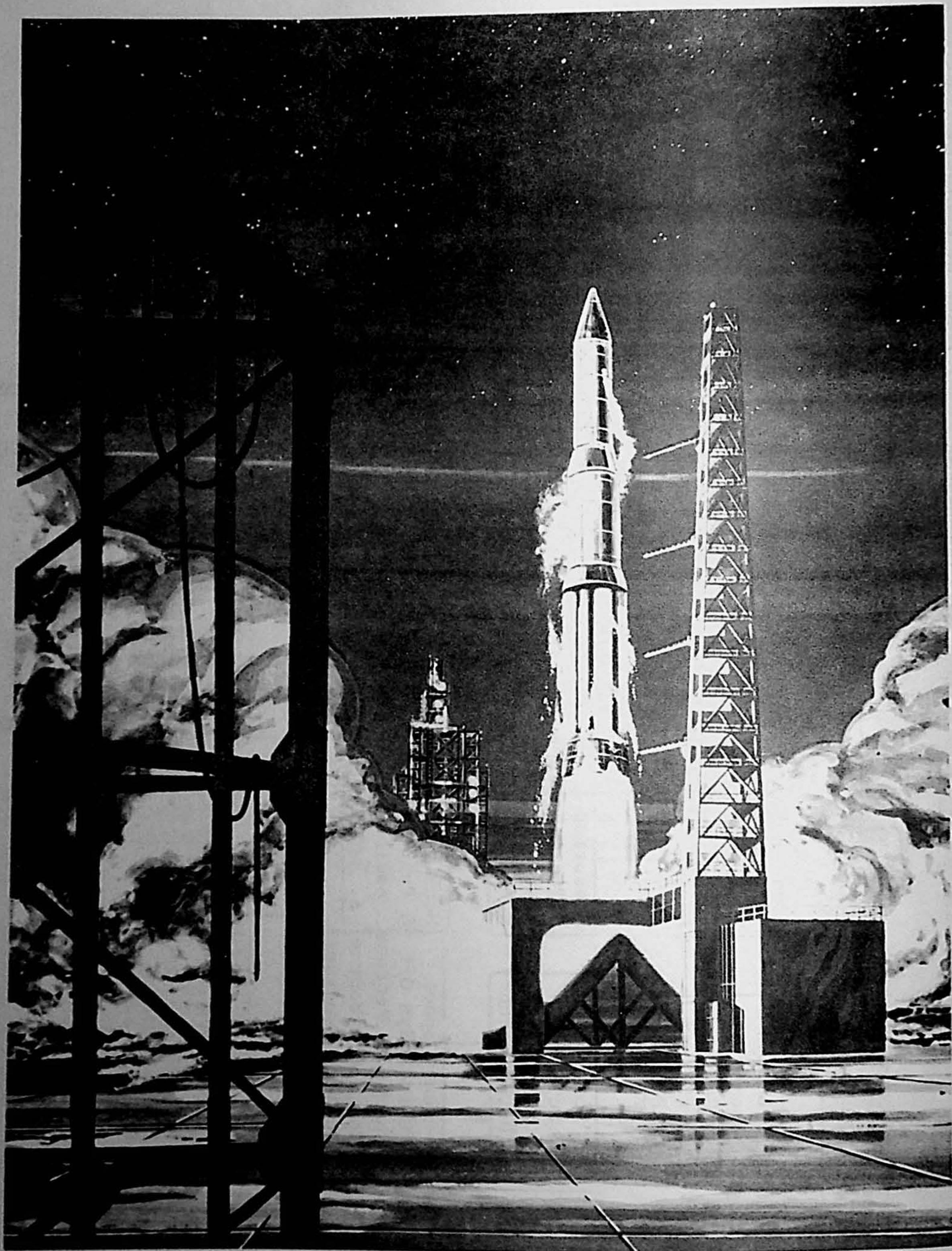


Figure 5. SATURN LAUNCH FACILITY

III. CURRENT EFFORTS

A. In-House Projects (Ground Launch Section)

1. Investigation of Checkout Procedures in Quality Assurance Division and Launch Operations Center.

As the complexity of space vehicles increase, the problems associated with ground launch operational scheduling, timing, checkout, and sequencing become continuously more stringent. The Future Studies Branch of LOC plans to direct considerable study effort toward the development of techniques enabling the prediction of pre-launch checkout and launch contingencies to increase the probability of success in future space missions. To assist in the studies being made concerning launch vehicle preparation and checkout requirements, component reliability, and checkout difficulties is required. Current planning is shrouded by the lack of detailed familiarity with contingencies dictated within these problem areas. Current efforts are being made to overcome this lack of familiarity by on-the-spot investigation and evaluation of vehicle operational checkout procedures being performed during Quality Assurance. Areas for potential engineering development and improvement are being analyzed. This period of investigation will be followed by a similar study program at AMR, Cape Canaveral.

2. C-5 Launch Probabilities

Future space missions impose many stringent requirements on the space vehicle, e.g., maintaining launch timetable (launch window) associated with the rendezvous of space vehicles in earth orbit. Presently, the launching of such vehicles has come under careful scrutiny inasmuch as a hold during the final countdown of a vehicle may result in the miss of a launch window and scrub of a mission. In order to insure that the launch timetable is kept, a preliminary investigation was conducted to determine the built-in hold times required to meet a launch window for various probabilities of success. This investigation, which utilized the past histories of some 225 vehicles for extrapolation to the larger space vehicles, had shortcomings in establishing a relationship(s) between vehicles. Subsequently, this investigation is being continued utilizing a Monte Carlo statistical analysis approach in an attempt to establish a relationship between these various launch vehicles.

3. Work Statements for Future Studies

Current efforts are being made to define the nature, extent, and scope of work to be covered in studies planned for the first quarter of '63. These studies will be discussed briefly in Section IV.

4. RIFT Program

Continuous effort is directed toward coordination of the Reactor-In-Flight Test (RIFT) Program for LOC, Huntsville. This includes participation in safety and hazards analysis working groups, engine review committees and other working groups responsible for monitoring and directing contractor study and design efforts. This function involves daily support and coordination with the Nuclear Vehicle Project Office of MSFC regarding RIFT Program operations pertaining to launch facilities and GSE. This type of in-house effort will ultimately result in the development and specification of detailed design criteria for nuclear facilities and GSE at AMR.

5. Complex 39 Launch Facilities

Continuous effort is directed toward development, design, and evaluation of Complex 39 facilities, ground support equipment, and operational procedures. Current support effort is being directed toward the development, design, and layout of a proposed Complex 39 launch pad area with associated support facilities. (Ref. Figure 6)

B. In-House Projects (Space Launch Section)

1. Lunar Tanker (C-5)

Effort has been initiated toward development of criteria and conceptual design of a cryogenic storage tanker to support the Lunar Orbital Rendezvous (LOR) Program. The C-5 Program, in addition to manned payloads, will involve a number of cargo payloads in support of the overall mission. Cryogenics will be one of the major cargo payloads and may be used for both lunar orbital operations or for resupply of lunar surface storage facilities. This work is being performed to support MSFC efforts in the development of such a tanker. Solution of problems associated with heat transfer, propellant transfer techniques, insulations, storage pressures, and meteoroid protection will be given major consideration.

2. High Pressure Gas Storage

A detailed optimization study has been initiated to investigate the inter-relationships between the various parameters affecting gaseous storage tank design. Such things as wall thickness, tank configuration, tank materials, heat transfer considerations, optimized storage pressure versus volume considerations, and gaseous composition will be thoroughly investigated.

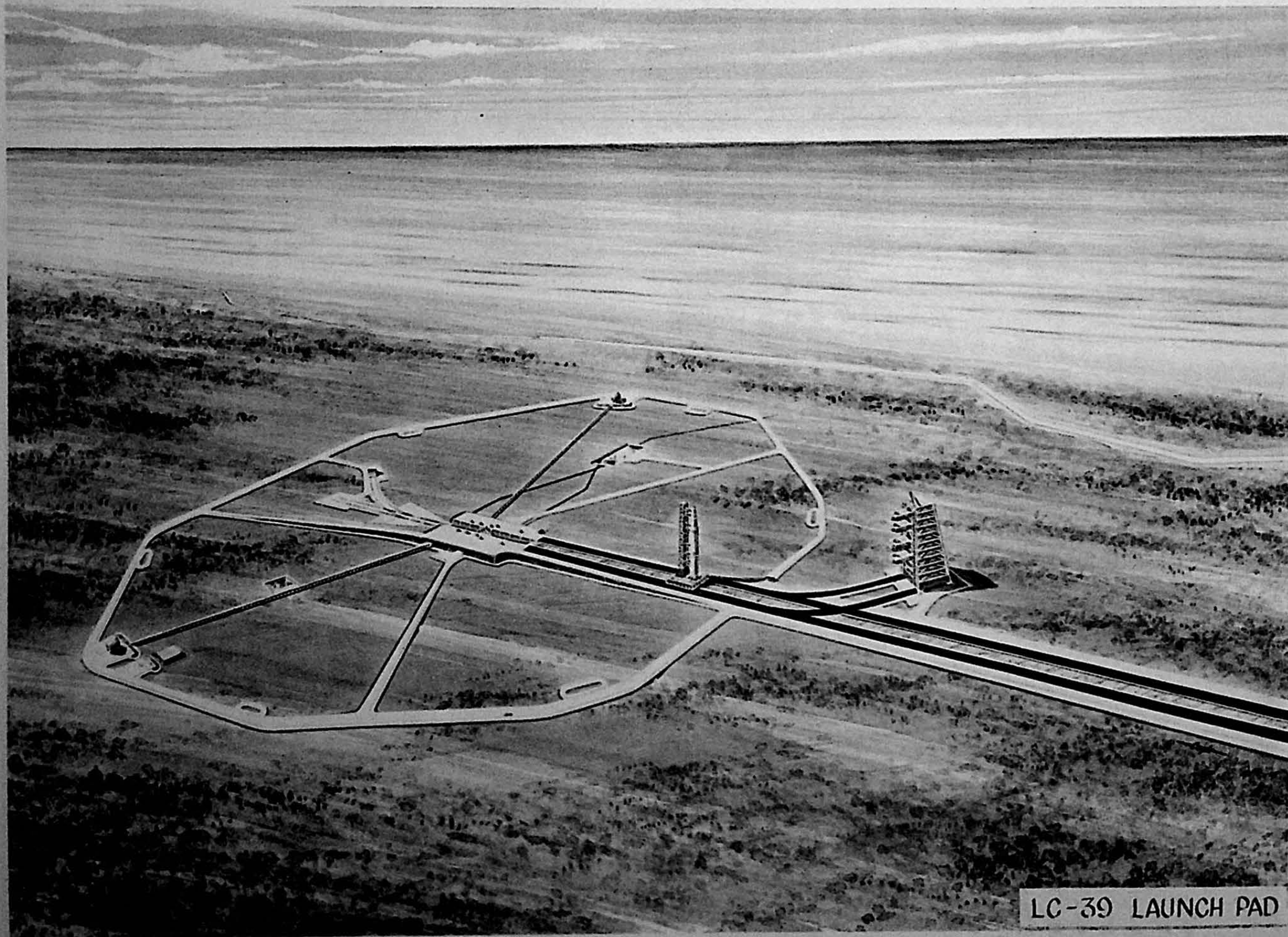


Figure 6. PROPOSED LC-39 LAUNCH PAD

3. Orbital Launch Facilities

In anticipation of future requirements, considerable effort has been directed toward development of a proposed orbital launch facility capable of performing repair, checkout, and launch operations for space vehicles. These efforts have resulted in proposal of an evolutionary orbiting facility composed of two major portions: a scientific laboratory and an orbital launch facility; each of which is a SATURN C-5 payload. Investigation of checkout and repair concepts, major engineering problems (such as meteoroid protection systems weight distribution, crew psychological effects, and the compatibility of such a payload with currently planned vehicles and launch facilities are some of the major problem areas under consideration. (Ref. Figure 7, Scientific Laboratory)

4. Lunar Logistics

Effort has been initiated on a mobility analysis study for various modes of lunar transportation. Fundamental modes of locomotion and maneuverability will be investigated for various assumed lunar surface models. Final study results will include preliminary design data and operational criteria for optimum transportation, construction, and utility vehicle as selected through a detailed analysis of all major parameters such as mobility, maintainability, reliability, minimized weight, simplicity, and controlability.

C. Current Out-of-House Studies

This office is actively participating in a number of study contracts being directed both by MSFC and by LOC. Participation is either in the area of direct supervision of the technical contract or as a member of the contractual management team. The following studies are being actively pursued at this time: (Ref. Table III).

1. NOVA Launch Facilities

Effort is currently underway to initiate a study contract related to the development of NOVA Launch Facilities. This study will be supervised by this office and will consist of two major parts: the purpose of the initi[illegible] phase will be to develop major launch complex facilities requirements and con[illegible] cepts for the most promising candidate vehicle concepts developed by the vehi[illegible] system study contractors. These requirements and concepts will be developed [illegible] the extent necessary to identify any critical facility requirements which co[illegible] influence the final selection of a NOVA Vehicle Configuration. Operational requirements, cost, availability, and reliability factors will be considered in identifying these critical areas. The second phase of this study will be an extension of Phase 1 in sufficient detail to clearly establish and define the optimum concept for the selected NOVA vehicle configuration. This phase of study effort will provide sufficient additional data and preliminary desi[illegible] details for the selected concept from which final design criteria for all ma[illegible]

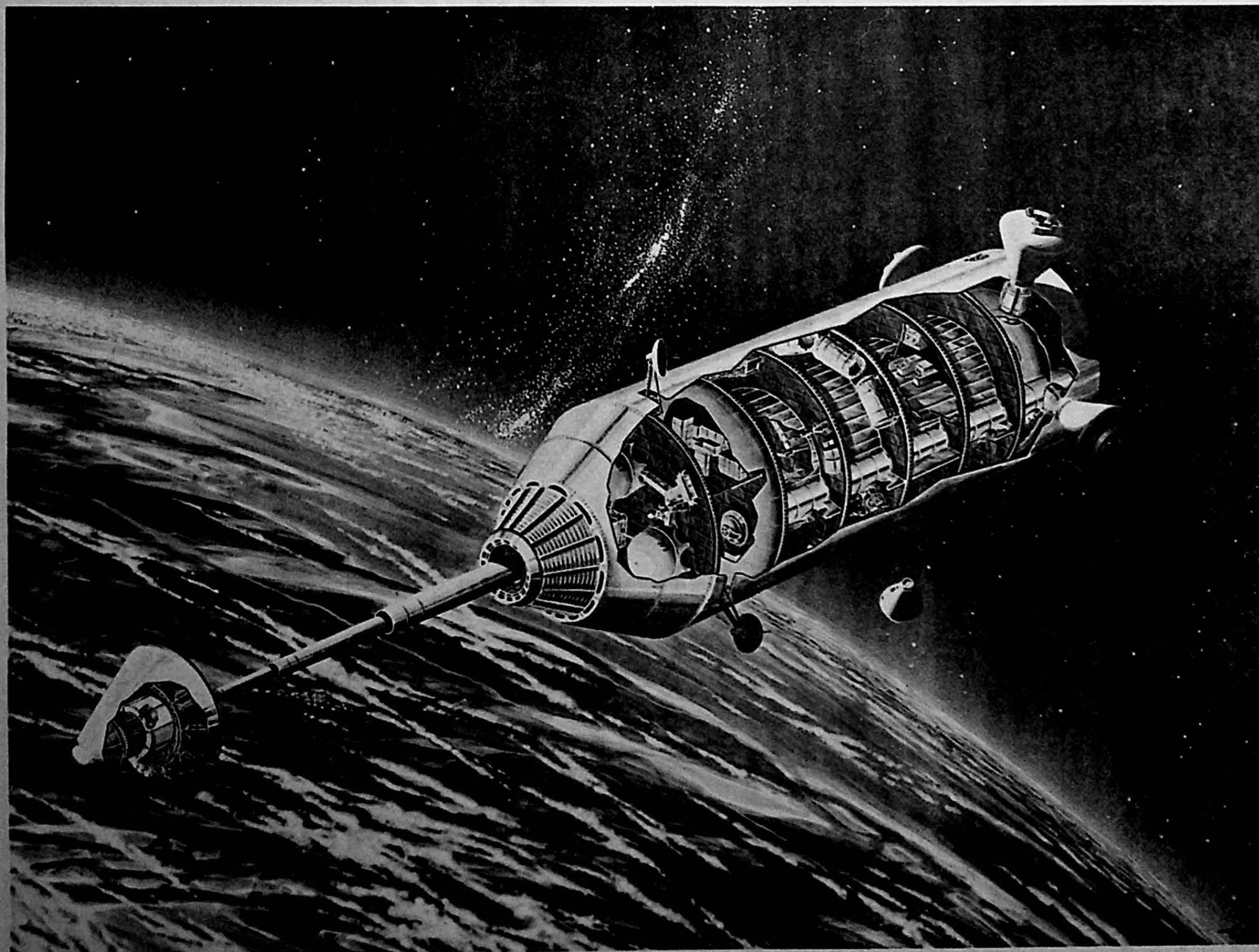


Figure 7. CONCEPTUAL DESIGN SCIENTIFIC LABORATORY

facilities and GSE may be developed. Results will include a general layout of the system complex, conceptual layout of the major facilities and required transportation media, definition of preliminary criteria, and complete analysis of such elements as construction procedures and schedules, special logistical support requirements and overall logistics plan, safety provisions, environmental control, construction costs, and operating costs.

2. Equatorial Launch Sites

This study is being performed by Chrysler Space Division and funded and supervised by the Future Studies Branch of LOC. The purpose of this investigation is to systematically search out all available data on possible equatorial launch sites, to correlate and evaluate this data in relation to present and anticipated requirements in the space program, and to develop a system that will permit ready determination of cross-over points in making trade-offs between operational, economical and mission requirements for both medium and high thrust space vehicles. The results of this study will be placed in a reference manual and will provide answers to the following questions:

a. What launch base concepts offer the most advantages?

b. Which equatorial launch site is most economical?

c. What are the economical and operations trade-offs for an equatorial site?

d. For what type missions does an equatorial launch site become a critical factor?

e. Under what conditions (mission requirements, economics, operational requirements, etc.) is an equatorial site justified?

3. NOVA Class Solid Vehicles

A member of this office is on the team managing the above study being performed by the Boeing Company. Efforts are being directed toward preliminary design of a NOVA class vehicle with emphasis on design analysis of thrust vector control systems, staging concepts, motor clustering, and facility requirements. Detailed layouts of the selected structural concept, layouts of the selected thrust vector control system, reliability analysis, development plans, funding plans, and operations analysis of manufacturing method, fabrication method, ground support equipment, checkout, transportation and launch operational requirements will be included in the final study report.

4. C-1 Class Solid Vehicles (Utilizing C-1 Launch Facilities)

This office provides a member to the management team directing the above contract being performed by Lockheed. Advancement in the state-of-the-art of solid propellant motors is rapidly developing, in view of recent successes with 100-inch diameter motors. Thus, NASA feels that it is necessary to investigate the potentials in clustering motors of this size range in development of a solid propellant booster which could replace the present booster of the C-1 vehicle. This study was initiated to evaluate such a booster to determine if substantial gains can be attained in C-1 performance, cost reduction, reliability, and operational considerations.

5. NOVA Vehicle Systems Studies

Martin and GD/A are currently performing studies on a NOVA class vehicle system capable of placing 500,000# payloads into low orbit or 200,000# to escape with the best attainable reliability utilizing "state-of-the-art" hardware for the timeframe around 1968-70. Both solid and liquid propellant systems are to be considered. The current study may be called a pre-development phase required to more clearly define the desired NOVA vehicle configuration prior to initiating a development program. Major objectives of this study will be to optimize launch vehicle system design and sizing, optimize fabrication techniques, and to determine best methods to achieve "man-rating" with reasonable cost and within a reasonable length of time.

6. Post-NOVA Launch Vehicle Study

This study was initiated to review the anticipated state-of-the-art for very large launch vehicles of the 1974-75 time period. This vehicle is to be considered in the one million pound payload class, although two million pounds payload will not be ruled out. Of primary importance in this study is development of a vehicle concept that will result in specific operating transportation costs of \$25 - \$50 per pound of payload (not including cost of launch facility operations, etc.). This may be compared with current SATURN C-1 costs of \$150/#. Since \$100/# seems to be the lower limit for expendable vehicles, the Post-NOVA must be developed for recovery. Liquid, solid and nuclear propulsion (and combinations thereof) will be considered in these conceptual studies now being performed by RAND, General Dynamics, and Douglas.

7. Advanced Lunar Transportation

In addition to the manned lunar landing program, emphasis must now be placed on transportation of large cargos to the lunar surface. Present systems cannot be economically utilized for this application; therefore, more economically attractive systems are being investigated by Lockheed, Chance-Vought, and Martin utilizing technology from SATURN, RIFT, APOLLO, and other systems. This study is being performed to investigate and compare two possible approaches for a more attractive follow-on lunar transportation system. One approach utilizes a SATURN C-5 with an expendable RIFT-type nuclear third stage used to boost a payload to a lunar orbit. From this lunar orbit, the payload is soft-landed on the lunar surface with a fourth stage, which has the capability for return launching of a manned payload when required. The second approach utilizes an orbit-launched nuclear vehicle and orbital operations techniques. This reuseable nuclear vehicle is used as a ferry vehicle between earth and lunar orbits.

8. Early Manned Planetary Mission

(EMPIRE)

This study being performed by Ford, Lockheed, and General Dynamics involves analysis of a 1970-72 manned mission to Mars or Venus. Launch from earth to earth orbit will be accomplished by a high thrust nuclear stage for a Crocco-type round trip of approximately one year (minimum). The non-stop fly-by appears very attractive for this mission. This study should provide a complete, detailed mission analysis and information in the following typical problem areas: Orbital operational requirements, nuclear propulsion requirements, manning requirements, major sub-system requirements, earth-return modes, trajectory and guidance considerations, life support systems, funding and program plans, vehicle ecologic systems, and environmental protection systems.

9. Reuseable Ground Launch Vehicle in the Fifty to One-Hundred Ton Orbital Payload Class

Considering the SATURN C-5 is established as the major support vehicle for orbital launchings in the 1965-70 time period, this study being performed by Boeing and North American Aviation is intended to establish the conditions under which a reuseable configuration would be advantageous, the configurations best suited to succeed the SATURN C-5, and a plan for the orderly development of the technology and techniques necessary for vehicle reuse.

D. Miscellaneous Activities

Members of this branch actively participate with others on miscellaneous advisory boards, committees, and working groups. A few of the more important are:

1. Space Maintenance and Repair Committee

This committee was established to monitor, control and direct both in-house and contractual studies related to orbital operations techniques, evaluation of man's capabilities in space for performance of maintenance and repair tasks, and development of tooling and vehicle configurations compatible with man's predicted capabilities in space. Current studies will establish concepts for maintenance techniques, space station and orbital launch facility assembly techniques, repair techniques for systems components, tool design criteria, remote manipulator requirements and criteria, and future hardware development requirements.

2. NERVA Engine Review Committee

This committee, comprised of representatives from MSFC and LOC, was established to review, monitor, and evaluate all aspects of the NERVA engine development program, with special emphasis being placed on design problem areas and engine/stage interface development. This committee will keep abreast of all developments in the engine program, and serve as a central planning and coordinating office for MSFC and LOC on all aspects of the engine/stage integration program of combined interest to MSFC, LOC, SNPO, Aero-Jet General, and Westinghouse.

3. Nuclear Safety and Hazards Working Group

By a joint agreement between the AEC and NASA, the AEC will retain review responsibility on the operational safety of nuclear flight systems. To help insure that the RIFT flight test systems will meet all of the AEC imposed requirements, the above group was established and has been acting as a focal point within MSFC and LOC to identify potential nuclear hazards, to propose methods of hazard and safety analysis, and to propose possible design or operational counter-measures.

TABLE III

CURRENT OUT-OF-HOUSE STUDIES

SHORT TITLE	LO-D-F FUNCTION	ORIGINATING OFFICE	CONTRACTORS
1. NOVA LAUNCH FACILITIES	TECH. SUPERVISION	LO-D-F (ACTION PENDING)	
2. EQUATORIAL LAUNCH SITES	TECH. SUPERVISION	LO-D-F	CHRYSLER
3. NOVA CLASS SOLID VEHICLES	MGT. TEAM MEMBER	FPO	BOEING
4. C-1 CLASS SOLID VEHICLES (UTILIZING C-1 LAUNCH FACILITIES)	MGT. TEAM MEMBER	SSO	LOCKHEED
5. NOVA VEHICLE SYSTEM	MGT. TEAM MEMBER	FPO	MARTIN GD/A
6. POST-NOVA VEHICLE	MGT TEAM MEMBER	FPO	RAND GEN. DYNAMICS DOUGLAS
7. ADVANCED LUNAR TRANSPORTATION	MGT. TEAM MEMBER	FPO	LOCKHEED CHANCE-VOUGHT MARTIN
8. EARLY MANNED PLANETARY MISSION (EMPIRE)	MGT. TEAM MEMBER	FPO	FORD LOCKHEED GEN. DYNAMICS
9. REUSEABLE GROUND LAUNCH VEHICLE IN THE FIFTY TO ONE-HUNDRED TON ORBITAL PAYLOAD CLASS	MGT. TEAM MEMBER	FPO	BOEING N.A.A.

IV. FY 63-64 STUDY AND RESEARCH PROJECTS

A. Projects Originating in Future Studies Branch

A preliminary listing of studies planned by this branch for FY 63-64 is summarized on the following pages. This work will be performed through in-house research and study efforts, out-of-house contractors selected through competitive bidding, or combinations of both in-house and contractor efforts.

1. Solid C-1 Launch Facilities and Operations

As discussed earlier, NASA is currently directing a study considering the potential application of solid propellant motors in the 120-inch class to a solid propellant booster which could replace the present S-I liquid stage for future missions of 1966 and beyond. Such a replacement can only be justified if substantial gains can be attained in C-1 performance, cost reduction, reliability, and operational considerations. Since this current study is directed primarily toward vehicle considerations, future study efforts will be directed toward a survey of the impact such a change would have on existing launch facilities and GSE. Complete design criteria, operational requirements, and all necessary redesign will be established for an optimum facility and operational concept. Cost and construction schedules will be provided in detail.

2. Launch Facility Limitations at AMR for Post-NOVA Vehicles

This study will be performed to establish a practical upper limit to the thrust level of Post-NOVA vehicles to be launched from launch sites located within presently available land at Cape Canaveral. Limitations of thrust level will be based primarily on a detailed investigation of the acoustical and blast hazards to launch facilities, personnel, and communities adjacent to,or in the vicinity of,the selected launch pad and assembly areas.

3. Launch Facility Requirements for Nuclear Stages

To assist in the initial planning and site layout of Complex 39 for the provision of nuclear upper stages, and the development of basic facility criteria for the nuclear assembly building as required for reactor/engine assembly and checkout and stage/engine integration and checkout; preliminary study efforts are required in the areas of failure effects analysis for all conceivable launch operational modes, nuclear stage/engine assembly, handling and checkout requirements, operational safety requirements, and remedial procedures for postulated accidents. Some study efforts are being directed along these lines by the RIFT stage contractor as specified in their current NASA contract. The exact scope of work to be covered by this study contract will be governed by the level of effort and caliber of data generated by these initial stage contractor studies, and will be more thoroughly defi at a later date. The ultimate goal of this study is to provide detailed design and safety criteria required for the development and planning of nucle launch facilities, GSE, and associated operational procedures.

4. <u>C-5 Launch Probability Analysis</u>

One of the requirements for mission success in the forthcoming lu program will be the ability to launch a C-5 space vehicle within a specifie time period or launch window. In the past, we have seen that vehicle launch ings have been plagued with various countdown interruptions due to vehicle launch facility malfunction and weather changes.

Due to the increased importance of "launch windows" and a simultaneous increase in vehicle complexity, we feel that an attempt must be mac to predict the characteristics of a C-5 countdown.

Past missile launchings will be statistically analyzed in an effo to predict C-5 malfunctions and hold times. Results of the study may also used to predict overall launch probability and backup vehicle requirements.

5. <u>Control Measures for Orbital Fallout</u>

The purpose of this study is to devise measures and procedures aimed at preventing random impact of vehicles or stages onto inhabited earth land masses after having been injected into a partial or temporary earth orbit. Actually, the ranges or temporary orbits attained by second and subsequent stages of multi-staged vehicles after separation are such that they become a potential hazard to inhabited land masses because their mass is sufficient to preclude complete burnup upon re-entry. Thus, measures and procedures for preventing such an occurrence must be devised for two specific conditions: (1) the case where the stage has attained a temporary orbit, and (2) the case where the stage is separated prior to leaving the atmosphere and will not attain an orbit. Two most obvious approaches to case #1 are orbital destruct or controlled re-entry with possible recovery for reuse. For case #2, where tremendous re-entry temperatures are not attained, a first-hand comparison seems to indicate that controlled impact into water is the better solution. This study should determine the optimized system and procedures necessary to handle both of the cases postulated above. An analysis of destruct systems should indicate the degree of destruction required to insure sufficient burnup upon re-entry. Complete design criteria should be supplied for all proposed destruct, re-entry control or alternate systems. Special attention should be given to ground facility requirements in the areas of telemetry, tracking, and RF transmission and interference problems.

6. High Pressure Gas Storage

Earth orbital space stations and space vehicles require gases to activate various mechanical devices, to control environment, to provide life support, etc. Seemingly, the logical method of storing these gases would be at high pressure and relatively low volume. However, there are a number of parameters to be considered in arriving at an optimized solution. This study will be initiated to investigate the parameters associated with the storage of high pressure gas in an extra-terrestrial environment and optimize these parameters with respect to weight, stress, heat transfer and economical factions.

7. Launch Facilities for Large Solid Propellant Boosters

The object of this study is to develop launch facility concepts required for launching solid propellant vehicles; analyze all aspects of the concepts developed; select an optimum facility and operational concept; and to define a detail including cost and construction schedules.

A definitive description of this study must await the results of current studies being conducted by MSFC to define the solid propellant vehicle configuration and development program. Known areas that will require special facilities (compared to liquid propellant facilities) are: storage, transport, handling, assembly, checkout, ordnance installation, exhaust flame attenuation, safety, erosion protection for exposed equipment, and abort hazard considerations.

This study and the related test program are expected to require approximately 6 months, from January 1, 1963, to June 30, 1963. The in-house effort indicated will be devoted to preliminary investigations to better define specific study requirements, and to supervision, support and guidance of the contractor efforts.

8. Launch Pad Power Connections for the Transporter/Launcher

The mobile launcher/transporter planned for Launch Complex 39 provides that all connections from L/T terminal area to the vehicle be made in the Vertical Assembly Building, after which the L/T is moved to the launch area where all basic power connections (electrical, pneumatic, hydraulic, air conditioning, cryogenics, etc.) must be made with the Pad Terminal Control Room (PTCR).

The purpose of this study is to investigate the prior uses of disconnect panels for making such couplings and determining their suitability for use in this concept, and to develop additional concepts that may be applicable. Perhaps one of the major uses of disconnect panels of this type has been in nuclear fields, e.g., Aircraft Nuclear Propulsion and Nuclear Rocket Test programs, where their application is a necessity to prevent operational personnel from being unduly exposed to the harmful effects of nuclear radiation and to reduce the preparation time between subsequent tests.

9. Lightning Protection Systems for Future Space Vehicles, Launch Facilities and GSE

This study will provide the detailed design criteria required for the development of a system capable of protecting future space vehicles and their associated umbilical towers, service structures, launcher/transporters and supporting electronics systems from the deleterious effects of an atmospheric lightning discharge.

The C-5 SATURN launch vehicle, associated umbilical tower and crawler launcher/transporter combination for Complex 39 will be the tallest structure in the state of Florida. As such, it will be highly susceptible to the receipt of a lightning discharge brought on by an electrical storm or other atmospheric disturbances. To eliminate the potential hazards associated with a high current flow through delicate electronic systems and pyrotechnics systems, the entire vehicle, umbilical tower, transporter/launcher and associated service structures must be adequately grounded at all times while on the launch pad and during transit from the Vertical Assembly Building (VAB) to the pad. Transit time from the pad back to the VAB will encompass some 2 - 3 hours of time. This time requirement eliminates consideration of returning to the VAB for protection in the event of an impending storm because of the frequency and sometimes spontaneous nature of storms in the Canaveral area.

This would also conflict with one of the basic principles upon which the SATURN C-5 mobile concept was founded; namely, the vehicle would be capable of "free-standing" without external support in 3 sigma wind conditions at the Cape. Thus the vehicle will be developed with the capability for remaining on pad during a majority of storms that occur in the Cape area. Detailed preliminary studies will be performed to investigate the physical nature and basic characteristics of atmospheric lightning discharges, and conceptual approaches to an adequate grounding system capable of protecting the vehicle and associated GSE from stray voltages and/or high current discharges at all times. With the material and background generated by this preliminary study, a follow-on study will provide detailed design criteria and preliminary design of a lightning protection system. The adequacy of such a system will be thoroughly verified through complete theoretical analysis and actual model testing where required.

10. NOVA Launch Facilities Study

The NOVA vehicle program is conceived to provide a single-launch capability for placing minimum net payloads of 500,000 pounds into low earth orbit and 200,000 pounds to escape with the best attainable reliability, cost and availability. Contracts have been awarded by MSFC to better define the vehicle configuration and the development program before hardware development is initiated.

The purpose of this study is to conduct early parametric studies in the critical vehicle-launch facilities interface areas to identify degree and trend of vehicle configurations vs. complexity and cost of launch facilities. These results will be made available during the vehicle configuration selection period. When a vehicle configuration has been selected, the effort of this study will be directed to definition and preliminary design of the optimum launch facilities and GSE required for the NOVA vehicle selected. The study results will also detail the cost estimates, construction schedules and operational requirements for all major elements of the launch complex.

This study is planned to parallel the vehicle study for a period of approximately $7\frac{1}{2}$ months, from October 1, 1962, to May 16, 1963.

11. Post-NOVA Launch Facilities

The purpose of this study is to develop advanced concepts of launch facilities required for the very large vehicle configuration concepts now being developed by MSFC study contracts. A definitive description of the study must await completion of these vehicle concepts. However, it is anticipated that new engine concepts may require relocation of launch facilities (remote locations) with attendant logistics and construction problems in addition to major changes in the launch operations and facilities concepts.

It is expected that this study will require approximately 6 months (January 1, 1963 - June 30, 1963).

12. The Prediction of Object Motion in a Vacuum When Subjected to Rocket Engine Exhaust Gases

With the advent of lunar landings planned for the near future, it is essential that considerable thought be given to the behavior of jet exhaust in a vacuum under low gravity conditions, especially in relation to the most probable lunar surface conditions. Of primary concern is the motion of lunar surface particles resulting from the impingement of exhaust gases from a lunar landing or takeoff space vehicle and the resulting hazards to the vehicle itself and to both local and distant manned lunar bases or facilities. The combined parameters of low gravity, high vacuum, and high energy exhaust gases result in the displacement of large masses over considerable distances, so that the problem is not merely a localized one. In-house studies have covered the basic ballistics on the lunar surface and also the partial orbits and escape trajectories that may be attained by such particles. A comparison of the lunar surface escape velocity with the considerably larger exhaust gas velocities alone serves to indicate that the problem is very real, especially when considering that many of our early lunar base facilities may be constructed of inflatable, relatively easily puncturable materials.

In-house studies have indicated the velocity ranges and ballistics to be encountered on blast accelerated lunar particles. The problem now remains to determine the masses of particles that will most probably be accelerated to these velocities. The problem of establishing the momentum energy transferred to these particles is fraught with many uncertainties a inseparable variables. With knowledge of exhaust gas densities, mass flow rates, stand-off shock wave theory, and gas velocity, one can determine the maximum over-pressure and resulting forces that could conceivably be initi applied to an object in the jet stream. Through knowledge of the initial t perature and flow rate of gases, the energy loss at impact, and the probab angles of deflection as a result of surface erosion, one can use a molecul approach to calculate the momentum energy within the gases per unit area of dispersion for a given distance or time and thus calculate the force that would be applied to a stationary object at that point. However, since the particle is in motion, the force, and of course, the velocity and acceleration curves of the particle will be an integral function of time. In typic dimensional analysis, blast wave variables are determined as a function of time by four major parameters: (1) Shock overpressure, (2) Ambient pressure, (3) Time duration of the positive winds, and (4) The speed of sound in the undisturbed air. Of course, items (2) and (4) become zero under lun conditions. Furthermore, it is soon realized that even for conditions such as that on earth, a completely pure mathematical solution is not possible because the variable particle velocity factor cannot be separated in an equa tion from the other time-dependent variables. For this reason, most blast effect equations here on earth are based on empirical relations determined by fitting curves to computed blast data.

It is hoped that through a detailed analytical study program, coupled with supporting model testing, we will be able to arrive at some reasonable empirical relationships that will enable the writing of parametric equations defining particle motion with time up to the time when maximum velocity is attained. Lewis Research Center has performed some preliminary model test work with highly under expanded jet nozzles in a vacuum that is of some qualitative value. However, much more definitive testing appears in order for the solution of this proposed study. The equations developed should not be based on any specific thrust level or nozzle configuration, but rather should include, if at all possible, data relating surface pressure distribution to the parameters of nozzle area ration, nozzle chamber pressure, nozzle contour, and height of the nozzle above the surface (in terms of throat diameters). Model testing by Lewis Research Center in a vacuum has indicated that such relationships may be established.

Through performance of the detailed analytical studies and model tests proposed above, the following specific information should be obtained:

a. Parametric equations and curves defining the velocity-acceleration time history of particle motion resulting from jet impingement in a vacuum.

b. Determination of the velocity and size distribution of particles displaced during a lunar landing or takeoff operation based on the equations developed above and assumed lunar surface conditions.

13. Special Launch Facility Requirements Due to Erosive Effects of Solid Propellant Rocket Exhaust Jets

Launching of large solid propellant boosters introduces new launch facility requirements due to the high erosive effects of the solid particle content of the exhaust. This study shall be conducted in conjunction with a suitable test program to optimize flame deflector design concepts for attenuating the rocket exhaust gases and to develop an economical method for protection of those components of the launch facilities exposed to the exhaust stream as the vehicle ascends.

This study and the related test program are expected to require approximately 9 months, from September 1, 1962, to June 30, 1963.

B. Projects Originated by Other Organizations

This study branch will provide technical support and management team members for a number of studies proposed or being actively pursued by other MSFC and LOC organizations. These studies will fall under the following general categories: launch vehicles, orbital systems and operations, lunar transportation systems and operations, lunar base construction, and Martian Systems and Operations. Although specific work descriptions are not available at this time, the following general study topics will be of prime interest to this study branch:

1. Launch Vehicles

   a. Launch Vehicle Operational Analysis

   b. Very Large Launch Vehicles
   (Post-NOVA class with more than 200 tons of payload to escape).

   c. Super Launch Vehicles
   (Escape payloads exceeding 1,000 tons).

   d. Operational Advanced Nuclear Third Stage
   (Phoebus power density in the 4,000 to 8,000 MW Class).

2. Orbital Systems and Operations

   a. Orbital Systems Integration

b. Hydrogen Tanker Vehicle

c. Mark II Space Laboratory
(Non-rotating Space Laboratory and Orbital Launch Support Facility Compatible with SATURN C-5)

d. Mark III Space Station
(Rotating Space Station for 30 - 50 personnel, compatibile with NOVA Vehicles and SNAP 8 Power Systems).

e. Orbital Facility Complex
(Provides support for multiple satellite systems, lunar bases, and planetary expeditions).

3. <u>Lunar Transportation Systems and Operations</u>

Advanced Lunar Transportation Systems

4. <u>Lunar Base Construction</u>

a. Systems Requirements and Integration

b. Mark I, Lunar Shelter
(For first APOLLO Crew).

c. Lunar Power Facilities

d. Communication Facilities

e. Lunar Workshop and Storage Facilities

f. Lunar Surface Personnel Carrier

g. Lunar Base Construction and Utility Vehicles

h. Propellant Storage Facilities

i. Lunar Launch Facilities

5. <u>Martian Systems and Operations</u>

a. Systems Requirements and Integration

b. Manned Surface Roving Vehicle for Mars

V. MAJOR STUDY EFFORTS - FY 62

Because of the variety and complexity of studies undertaken by this branch in FY 62, (Ref. Figure 1) only the major efforts will be discussed at this time. The level of effort expended in these major areas of Facilities and Research and Development is shown in Figure 4. No details are provided in the following summaries inasmuch as the study reports on these topics are available upon request (Ref. Availability List - Table IV).

A. C-3 and NOVA Facility Concepts - Fixed vs. Mobile

Considerable effort was expended toward providing the technical direction and guidance required for the development of C-3 and NOVA launch facility concepts, cost estimates, and schedule requirements. This effort came in response to a letter from the Associate Administrator, NASA, which requested the Director, Launch Operations Directorate and the Commander, AFMFC, to analyze launch requirements for an early manned lunar landing program. Launch facility concepts for both liquid and solid propellant booster vehicles of the SATURN C-3 and NOVA configurations were established. Different launch facility requirements to meet different launch rates were considered (Fixed vs. Mobile) as well as off-shore on-shore concepts for the NOVA class vehicles (Ref. Figures 8 and 9).

Basically, the C-3 facility consists of a vertical assembly building, three launch pads, and a connecting track system (Ref. Figure 10). The vehicle is assembled on a mobile launcher/transporter in the off-pad vertical assembly building, and is then moved in a vertical position to the above grade launch pad by means of the connecting rail system. The umbilical tower is an integral part of the launcher/transporter which permits this movement to be accomplished without breaking the umbilical connections. Final checkout, pre-launch operations, and launch are controlled through a digital link between a computer on the launcher/transporter and one in the Launch Control Center at the vertical assembly building. Each pad has an independent propellant storage and transfer system.

The NOVA on-shore facility concept consists of three fixed vertical assembly and launch buildings and a Launch Control Center area. The vehicle booster is transported through a canal system to the building on a launcher/barge, which is then secured to the building structure to serve as a launcher. The upper stages of the vehicle are assembled and checked out in the Vertical Assembly and Launch Building. Final checkout, prelaunch operations, and launch are controlled through a digital link between a computer in the Launch Building and one in the Launch Control Center. The vehicle is then launched from within the fixed structure through the open roof (Ref. Figure 8).

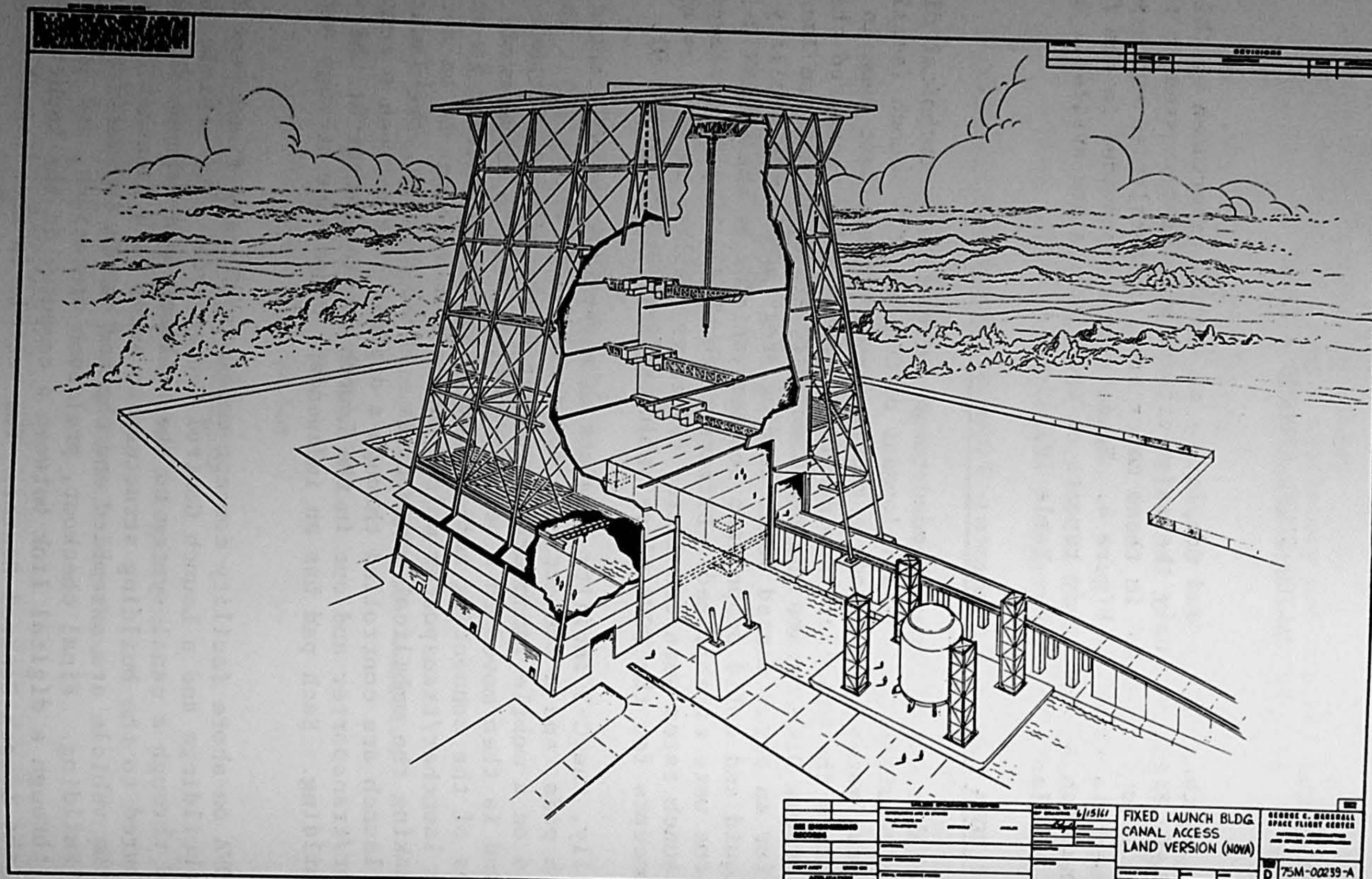


Figure 8. FIXED LAUNCH BLDG. LAND VERSION (NOVA)

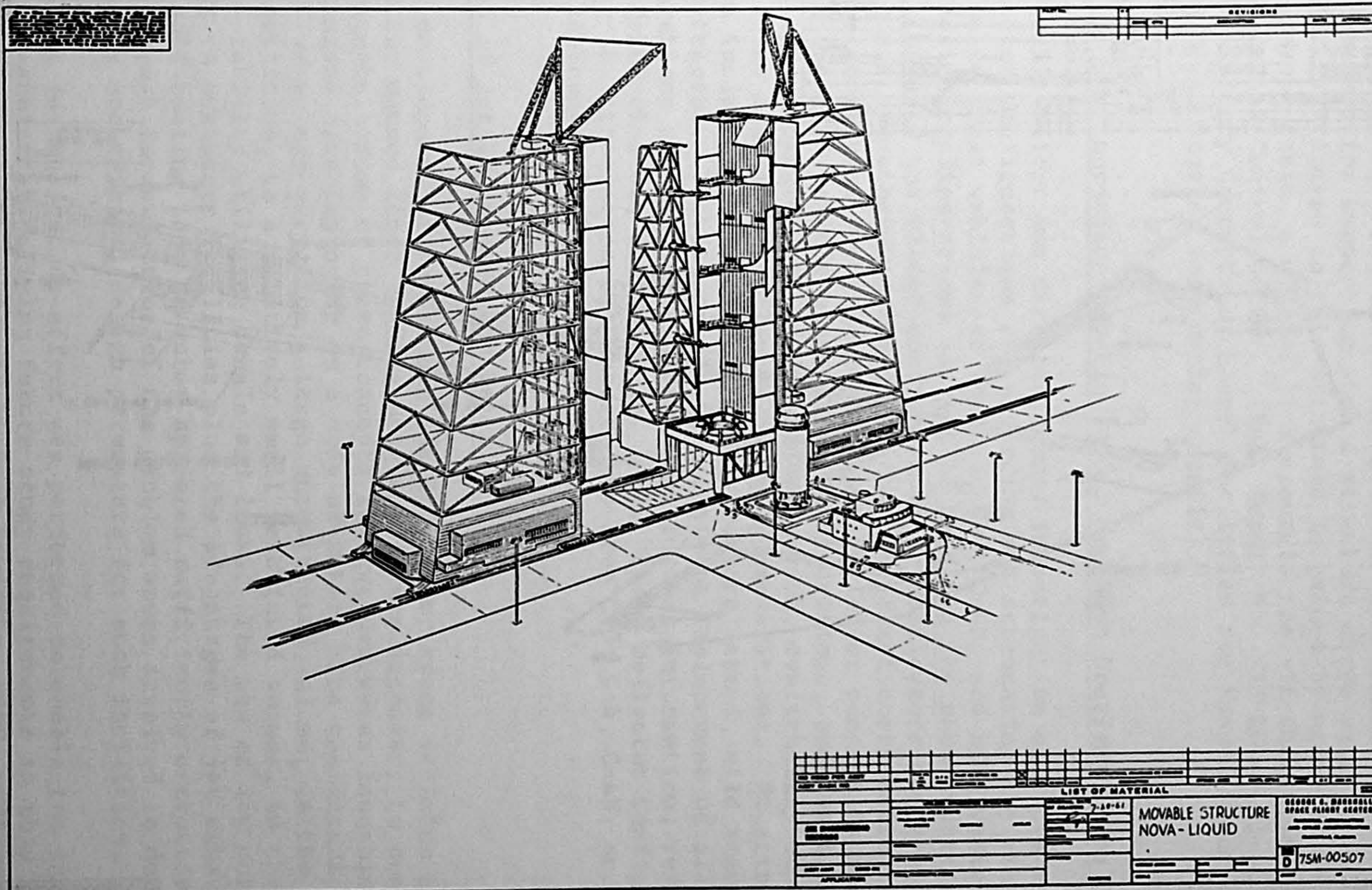


Figure 9. MOVABLE STRUCTURE NOVA

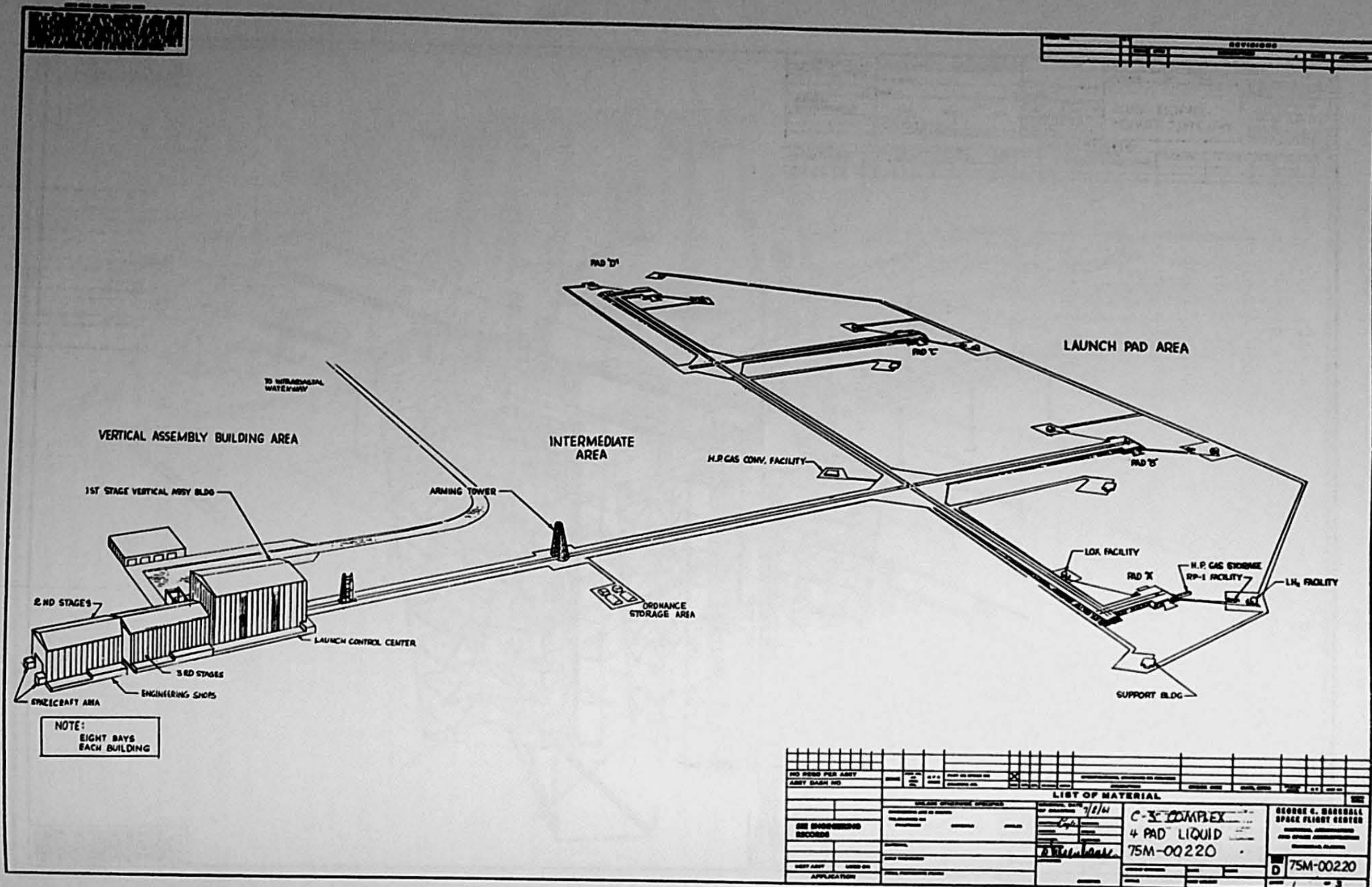


Figure 10. C-3 LAUNCH COMPLEX - 4 PAD

Off-shore launch facilities developed for NOVA are quite similar to the on-shore facilities with the obvious exception of the foundation structure. One proposed method for supporting such a structure above water would be on clustered pilings. Access to this structure is gained by water-borne vessels and by causeways. Again, a digital link connects the off-shore facility with the on-shore Launch Control Center. (Ref. Report No. MIN-LOD-DL-3-61, August 1, 1962, "Preliminary Concepts of Launch Facilities for Manned Lunar Landing Program", by O. L. Sparks, for further details).

B. Deflector Configurations for Liquid C-3 and NOVA Configurations

Considerable effort was directed toward investigation of above and below ground deflector configurations for diverting and attenuating the exhaust jets of liquid fueled boost vehicles of the C-3, C-4, C-4N, and NOVA vehicles. A variety of design configurations capable of handling the above vehicles were developed. Emphasis was placed on the use of dry deflectors since maintenance and repair costs are substantially lower than the fixed costs associated with wet deflector configurations. However, a wet deflector concept is presented for use with the NOVA vehicle since other considerations, such as acoustical attenuation, pad location, extended holddown period, availability of coolant, etc., may impose additional deflector design considerations. Materials of construction include reinforced concrete, structural steel, mild steel, or a combination thereof. Provisions for the repair or replacement of all deflector configurations are also considered. For further information, reference Report No. M-LOD-DL-5-61, September 18, 1961, "Flame Deflector Configurations Required for the Attenuation of Exhaust Jets From C-3, C-4, C-4N, and NOVA Space Vehicle Boosters", by R. L. Evans.

C. Effects of Jet Impingement on Water

In the development of new launch facilities for space vehicles to be employed in the manned lunar landing program, it was necessary to consider many new concepts. Some of these concepts involve overwater launching with the rocket engine jets impinging on a body of water. The characteristics of this body of water may vary from a large unrestricted volume, in the case of off-shore facilities, to a relatively small restricted volume, in the case of a land-based facility utilizing canals and locks. The use of low cost water-barge access to overwater facilities plus the advantages of jet exhaust attenuation in a self-healing body of water appeared sufficiently attractive to justify a thorough investigation of the problem areas involved to determine the feasibility and critical design parameters for such facilities.

Sufficient in-house study effort was performed to enable the establishment of a work statement defining future study requirements in this area. This detailed study, to be performed by Test Division, MSFC, will provide the following:

1. Through analytical calculations and model test evaluations, determine the total effects of rocket jet impingement on water of varying depths and volumes as represented by the extremes of a relatively small restricted body of water and a large body of water such as the ocean.

2. Determine the relation of these effects to overwater launch facilit design parameters to include the use of a rigid underwater flame deflector placed at various depths beneath the water surface as required for "bottom" protection.

3. Establish reliable scaling laws related to all critical overwater launch facility design parameters associated with the attenuation of these effects.

D. Structural Members and Variable Gravity

Study effort has been directed toward the basic areas of concern that would confront the designers of structures to satisfy environments other than those to which we are accustomed on earth. The unusual conditions to be considered are the effects of temperature differential, chemical stability of materials, and gravity variation. Of these items, the variation of weight with gravity presents some interesting conditions. Designers are familiar with the considerations given dead weight in the design of a structure. The question then arises as to what magnitude would reduced or increased dead wei affect the design of a structural member in a reduced gravity, i.e., a lunar or orbital structure, and what method could be utilized to approach an optimu design. Initial study results illustrate the effect of dead load in the design of basic structural members, and point out how this might affect the mechanics and analysis of structures in gravities varying upward from a zero value. For further information, reference Report No. MIN-LOD-DL-4-62, "Structural Members and Variable Gravity", by R. T. Burns.

E. Lunar Storage of Liquid Propellants

As described in Reports MIN-LOD-DL-1-62 and NASA TN-D-1117, Lunar Storag of Liquid Propellants", a considerable amount of detailed study effort has been directed by this office in all major technical aspects of this problem area. The following abstract of the above report describes work accomplished in FY 62:

> "Unlike the earth with its attendant atmosphere, the moon is situated in a near vacuum (10^{-13} earth atmospheres) which produces a thermal environment quite different from that on earth. Thus, the temperature of the lunar surface and objects located thereon depends primarily on the laws and mechanisms of radiation heat transfer. The temperature of the lunar subsurface and foreign bodies contained therein are also influenced by this form of energy transfer, but are primarily affected by conduction heat transfer.

Radiation equations are set down which show that the temperature of the lunar surface during the daylight period is proportional to the cosine of the angle formed by the sun's rays and a normal to the lunar surface. A geometric relationship is established between this angle and the lunar latitude and lunar time angles. Basically, it shows that the lunar surface temperature decreases with increasing latitude angles; also, the lunar surface temperature is at its maximum at any given latitude at a time angle corresponding to noon.

The surface temperature of a well-insulated liquid propellant storage tank is then examined in light of this hypothesis. Several parameters were examined to determine their influence in controlling or limiting the tank surface temperature. Parameters investigated include tank surface properties, tank geometry, and locally altering the lunar surface in the vicinity of the tank. (Ref. Figure 11).

The heat flux with respect to two classes of propellants (low boiling point and high boiling point) stored above-ground is discussed. Due to the equilibrium temperature of high boiling point propellants, it is pointed out that the storage period may be indefinite under proper thermal conditions. Low boiling point fuels, on the other hand, may be stored for a finite period only. The most desirable methods for maintaining these propellant classes are presented with respect to latitude location, tank geometry, tank surface properties, and alteration of lunar surface properties.

The thermal environment of a tank situated beneath the lunar surface is described. Due to the complexities of the problem, the tank surface temperature is assumed to be equal to the lunar subsurface temperature. Subsequently, the heat flux with respect to the stored propellant is discussed.

In conclusion, a comparison of the storage times attainable for LH_2 storage above-ground and below-ground shows that they can be made almost equal. On this basis, it is seen that factors other than heat transfer decide whether the storage tank should be buried under or placed on the lunar surface."

F. Acoustics Study

Considerable in-house effort was directed toward determining the overall sound power levels, transmission characteristics under inversion conditions, and accompanying acoustical hazards associated with the launching of large space vehicles. Following these initial study efforts, a detailed theoretical and actual measurements program was conducted by Bolt, Beranek, and Newman working under a contract directed by this office. This study was conducted in three principle parts. Part I involved estimation of the noise and vibration

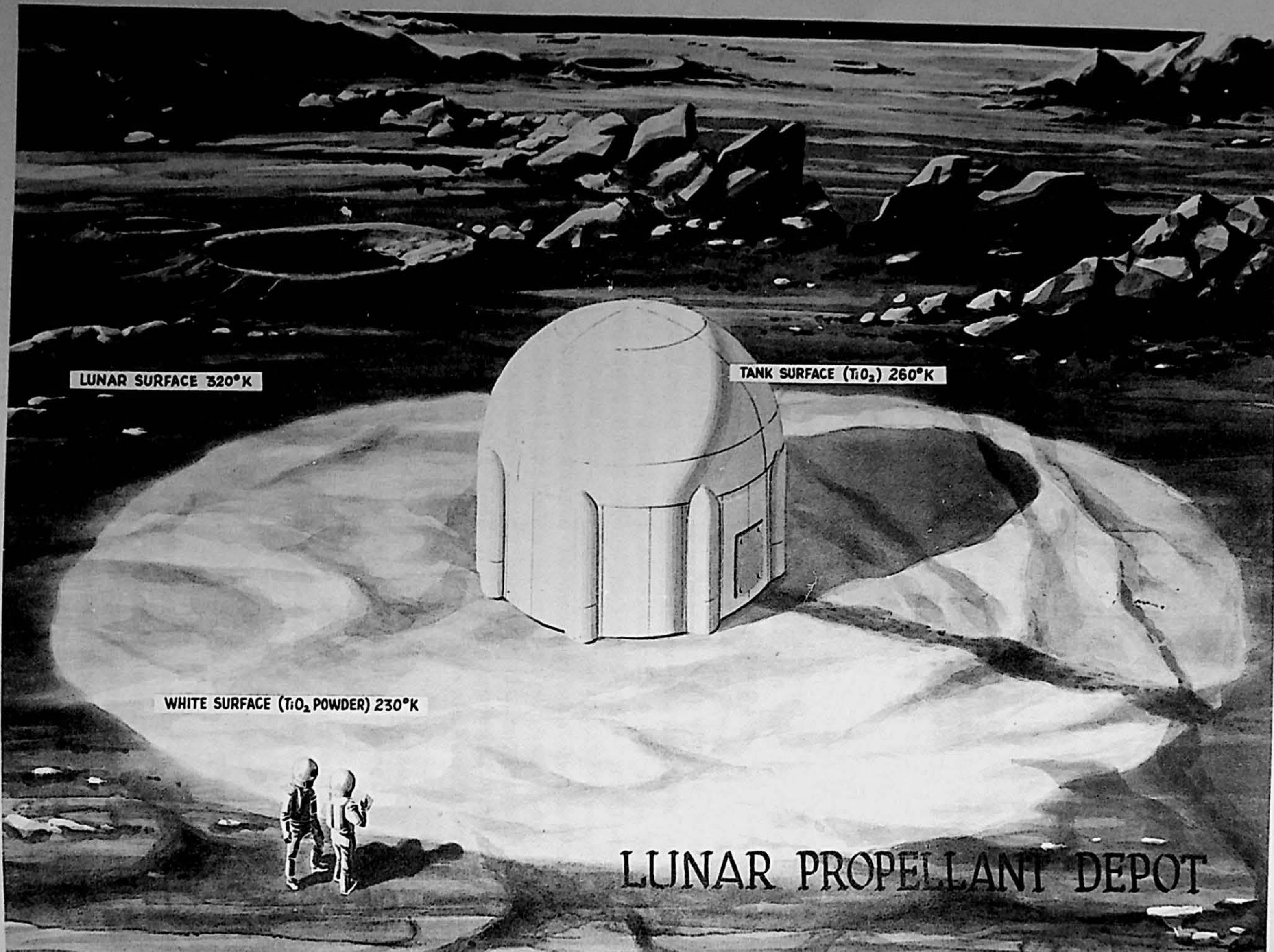


Figure 11. LUNAR PROPELLANT DEPOT

field of future large boosters based on available data, analysis of typical long-range sound propagation and meteorological conditions for coastal, over-water, and inland launch sites, and formulation of appropriate acoustical design criteria applicable to personnel, critical launching equipment, building structures, and residential communities. Part II was initiated to verify the estimates of Part I above with the aid of measurements on the F-1 engine test firings and during SATURN launch. Part III involved further analysis of the mechanical and vibration fields of large boosters based on available meteorological data for the Cape Canaveral area.

G. Leak Detection in Manned Spacecraft

All manned spacecraft must carry an air supply sufficient to provide all human needs and to maintain full cabin pressure for the entire duration of an orbital or interplanetary flight. Since weight must always be kept to a minimum, great excesses of supply air and heavy leak detection equipment cannot be carried on board. Therefore, the loss of air through internal leaks or through an exterior skin of the vehicle, and the detection of such leaks must be considered a most serious problem. Meteoroids in space increase the probability of skin puncture and the high external vacuum greatly increases the leakage flow rate through a puncture. Thus, a cabin leak must be quickly detected, located, and eliminated.

In addition to the manned capsule, special attention must also be given to the entire orbital launch vehicle and its associated propellant tankers. Past experience has shown that between pre- and post-static firings, a large number of leaks may develop in the pneumatic system of a booster or space vehicle. Thus, once in orbit, an orbital launch vehicle system will require extensive leak checkout prior to launch into outer space. Items requiring leak check would include (but not be limited to) such things as propellant tanks, high-pressure storage spheres, pressurization lines, pneumatic couplings, tees, joints, etc.

It can be envisioned that two approaches to the leak detection problem are necessary: (1) a portable system may be required by the astronaut for external leak checkout of the manned space capsule and orbital launch vehicle systems in orbit or at an orbital checkout station prior to launch into deep space. (2) An onboard fixed or semi-portable system may be required during flight phases for detection of leaks in the manned capsule or in the orbital launch vehicle. Continuous monitoring and readouts from leak detection systems in both the manned capsule and orbital launch vehicle would then assist the astronaut within in making a decision at any time regarding the nature of a leak, in determination of the degree to which a leak will jeopardize his mission, and in establishing a criterion upon which to base a decision regarding the possible need to abort the mission and return to orbit for repair.

After coordination of these considerations with Quality Division, which has similar problems involving automated ground checkout requirements for future SATURN vehicles, a joint scope of work was submitted to the University of Michigan and the University of Ohio for the purpose of investigating automatic leak detection techniques. The University of Michigan's study was specifically oriented to the potential use of radio isotope tracers and solid state devices for leak detection, whereas the University of Ohio studied all other physical phenomena. The Future Studies Branch of LOC has monitored these studies and will review the final data obtained for potential application to future space vehicles, space stations, etc.

H. Orientation on the Lunar Surface

Upon landing of a manned vehicle on the surface of the moon, it then becomes necessary to establish a reference system, such that an instantaneous bicordinate "fix" can be established at any desired time. Because of the lack of atmosphere, surface winds, temperature extremes, and exposure to various types of corpuscular radiations, detailed physical mapping or survey does not readily lend itself to such conditions.

Very precise and reliable methods and equipment will be required, both for lunar surface navigation and for establishing precise launch timetables and takeoff trajectories for a return flight to earth.

Although considerable work has been directed toward determination of lunar trajectories and establishment of space referenced guidance systems during midcourse and terminal flight phases, very little effort has gone into determining the optimum procedures and equipment required for precision navigation and orientation of a vehicle once landed on the lunar surface. Thus, it becomes necessary to establish a precise and reliable space reference system, along with definition of the basic "hardware" operational requirements and preliminary design criteria for use in conjunction with the established reference system. Selection of optimized automated tracking concepts and instrumentation requirements must be established after primary consideration is given to reliability, minimized weight, and operational capabili in the extremes of lunar environment.

This study office performed considerable research into these problem areas to assist in clearly defining areas requiring future study and development.

I. Launch Facility Requirements for the C-4 Space Vehicle

Following the study efforts described in "A" above, the entire vehicle program was re-oriented to the C-4 vehicle configuration, and included consideration of solid and nuclear stages. A complete re-evaluation of launch facility requirements including cost estimates and scheduling was made in the light of this vehicle change (Ref. Figure 12). Fixed vs. mobile launch facili concepts were thoroughly evaluated from a reliability, safety, availability, and growth potential standpoint. Operational modes of transfer for the mobile concept were thoroughly evaluated for both the rail concept (Ref. Figure 13) and the canal versions (Figure 14). For further information on these study results, Reference Report No. MIN-LOD-DL-6-61, October 27, 1962, entitled "A Preliminary Study of Launch Facility Requirements for the C-4 Space Vehicle".

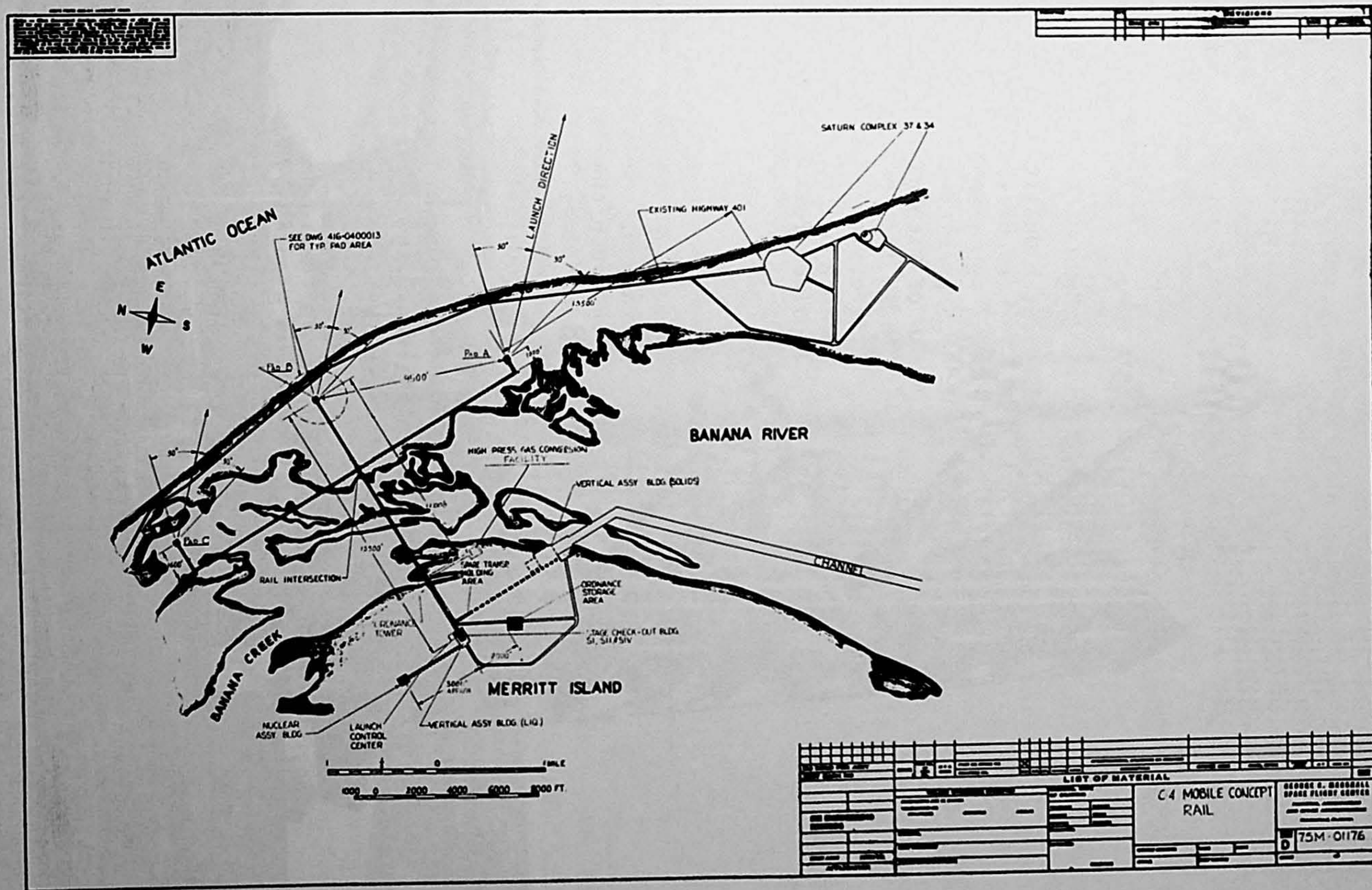


Figure 12. C-4 MOBILE CONCEPT - RAIL

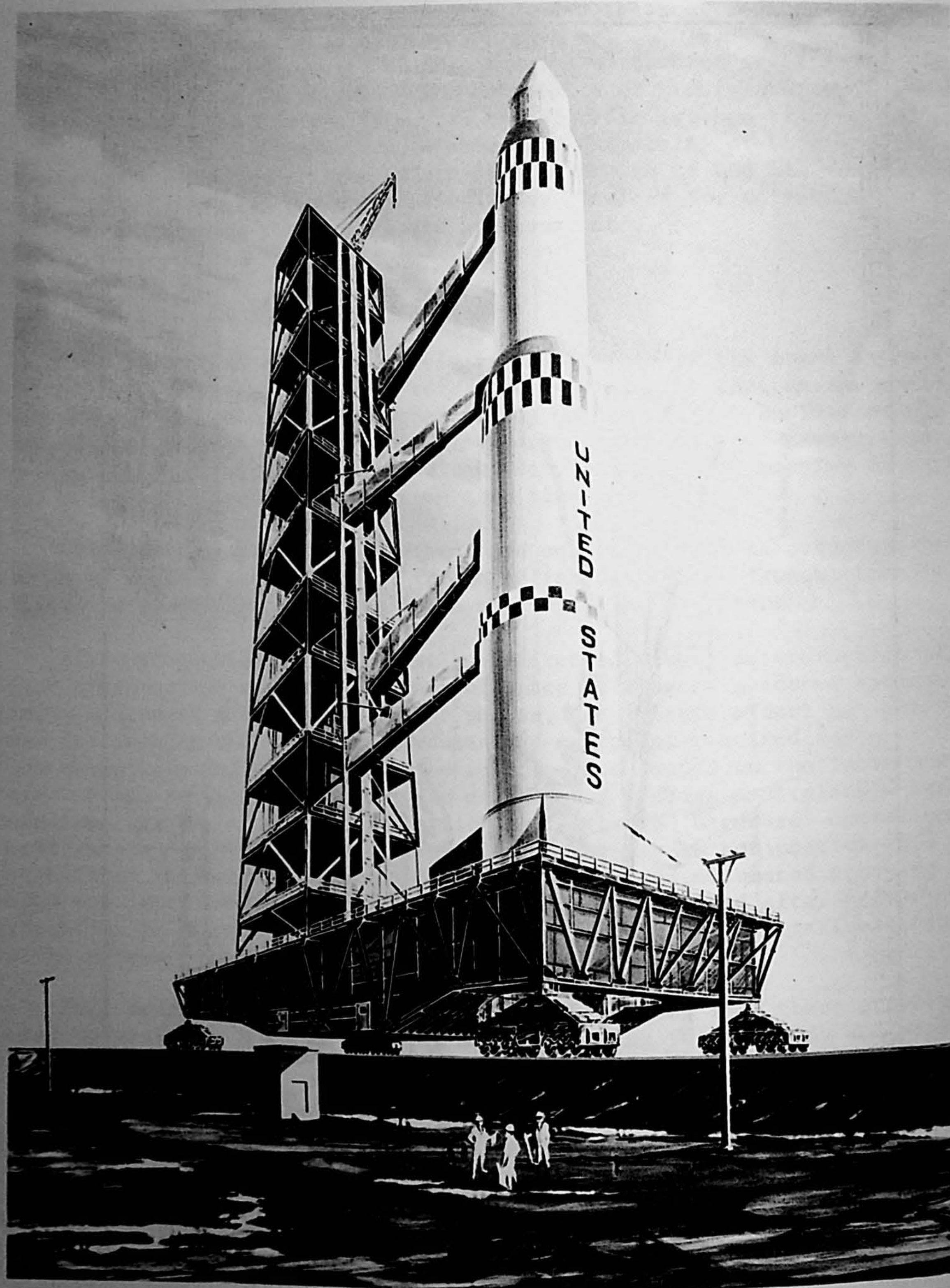


Figure 13. MOBILE LAUNCHER/TRANSPORTER - RAIL CONCEPT

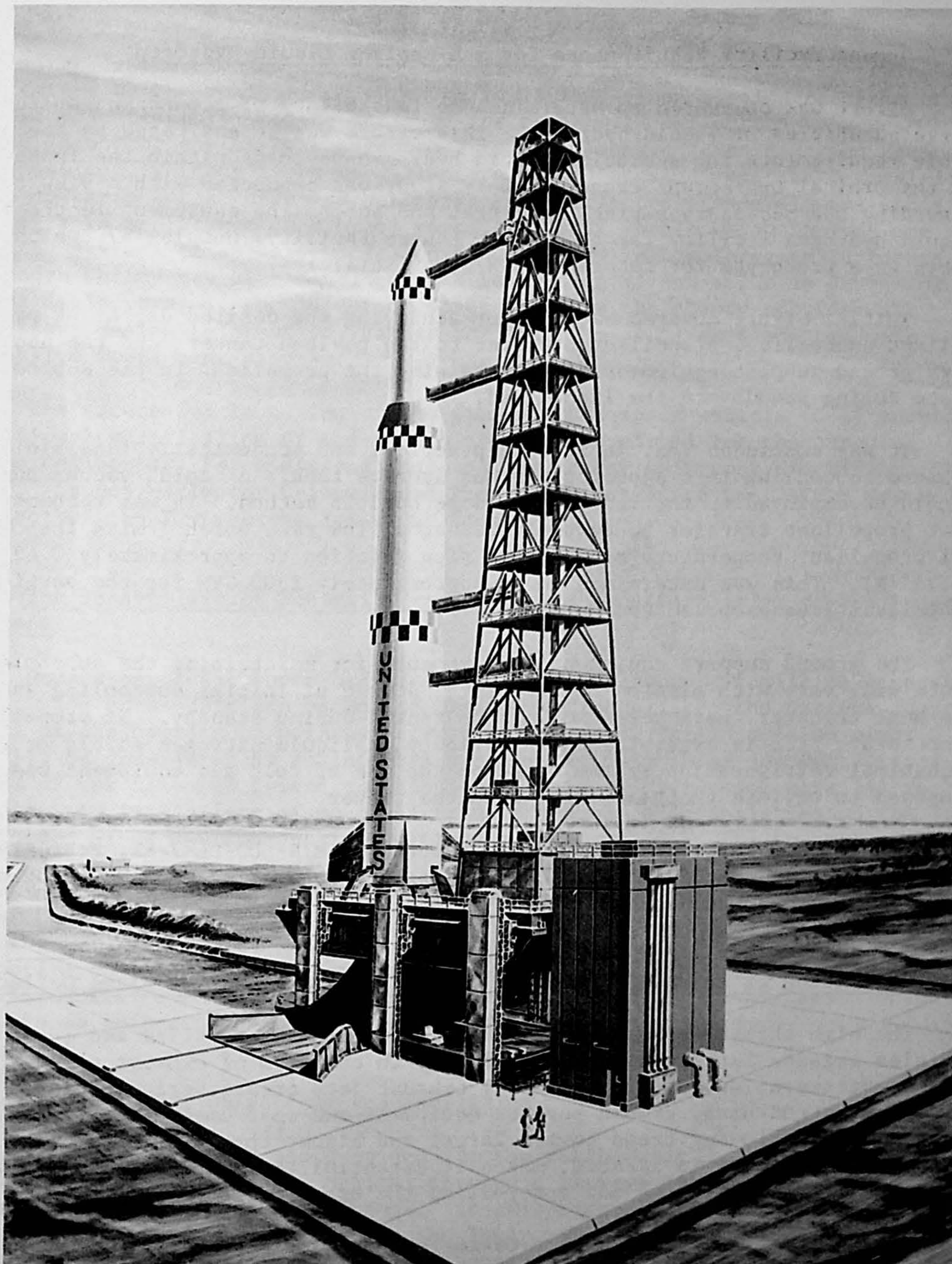


Figure 14. MOBILE LAUNCHER/TRANSPORTER - BARGE CONCEPT (IN LAUNCH POSITION)

J. Ground Facility Requirements for Sub-Cooling Liquid Hydrogen

Effort was conducted to determine the feasibility of ground subcooling large quantities of liquid hydrogen. This effort was necessitated by the pos sible requirements for subcooled liquid hydrogen payloads within the framewor of the Orbital Operations Program. This study was conducted with a view towa providing the necessary piping, fittings, and subcooling equipment in the pla liquid hydrogen facility for the SATURN Launch Facility, Complex 37, which wi serve as a prototype for future SATURN/NOVA facilities.

Initial effort covered methods for achieving the desired degree of propellant subcooling, propellant transfer to the payload tanker, and the necessary ground support equipment for maintaining the propellant in the subcooled state during standby on the launch pad.

It was concluded that it is both practical and economically feasible to achieve subcooling in a spherical ground storage tank. A "cold" vacuum pump should be employed in the reduced pressure boiloff method. It was recommendec that propellant transfer be accomplished at a flow rate which limits the overall propellant temperature rise due to pipe friction to approximately 0.43°R (0.25° K). This was determined to be approximately 2500 GPM for the particula propellant line proposed for Complex 37.

The ground support equipment requirements for maintaining the subcooled state will vary with mission requirements, degree of initial subcooling and the heat transfer characteristics of the tanker during standby. If propellant temperature rise is excessive during standby, a liquid nitrogen shield or a mechanical refrigeration system based on the use of cold gas equipment was proposed to obviate the heat input into the tanker.

For further information, refer to Report No. MIN-LOD-DL-7-61, February 6, 1962, entitled "Ground Facility Requirements for Subcooling Liquid Hydrogen", by W. E. Dempster and J. R. Olivier.

K. Evaluation of Parameters Related to the Design of the C-1 Flame Deflector

The high thrust rocket engines used in present-day missiles and space vehicles release large quantities of energy in the form of exhaust gases. The high-temperature, supersonic, velocity exhaust jets create serious hazards to personnel, structures, ground support equipment and instrumentation at the lau sites. The continuing trend toward larger and higher thrust engines, with the concomitant increase in hazards, makes it essential that accurate methods be established for predicting and controlling the exhaust jet effects.

The quantity and distribution of the exhaust jet energy depends on severa variable factors. The total energy available is determined by the type and amount of propellant used; the form and rate of energy release is controlled b the rocket engine design and the number of engines; and distribution of the energy in the area surrounding the launcher is controlled by the exhaust flame deflector design. Since the magnitude of the first two of these variables is determined by the vehicle design criteria to meet given mission requirements, the flame deflectors must be designed for controlled deflection of a predetermined amount of energy at the launch site. In study efforts directed toward this subject, various types of deflectors were discussed, and the general design criteria for an uncooled heat-sink type deflector was developed. This criteria is applicable to a broad range of thrust levels which include the booster systems of space vehicles to be developed in the foreseeable future. Although theory has been developed and is of significant value in designing flame deflectors, it should not be construed that the theory provides all necessary design information, rather the theory must be supplemented with an extensive model test program.

The successful launching of the first SATURN space vehicle (C-1) provided additional verification of the design criteria developed for the uncooled flame deflector. For additional information, refer to Report No. MIN-LOD-DL-5-62, "Launch Deflector Criteria and Their Application to the SATURN C-1 Deflector", by R. L. Evans and O. L. Sparks.

L. The Feasibility of Monorail Transit Methods and Facilities on the Lunar Surface

Once a permanent lunar basing system is established, it will be necessary to provide some efficient method of transportation between the various components of the complex or perhaps between lunar bases. This provision might readily be considered as an integral part of the lunar base concept. Effort in FY 62 was directed toward compilation of data and reference material regarding the feasibility of monorail transit methods and facilities on the lunar surface. Since environmental conditions present an adversity to both mechanical and human mechanisms during lunar surface operations, such a transit system appears to be a simple, stable, and valuable component of future, more complex lunar basing systems. Available literature obviously gives little data that might govern mechanical and structural specifications for fabrication and construction on the moon and immediately reveals that a great deal of effort is still required even for development of earth based monorail systems. Detailed efforts on this project will be re-initiated at a later date.

M. Earth Orbital Operations and Facilities

Continuous support was provided for the earth orbital operations program in the conceptual design of orbital cryogenic storage tankers and rendezvous techniques for refueling operations. At this time, the C-2 and C-3 SATURN vehicles were being considered for the lunar missions program. A proposed tanker for the rendezvous and transfer operations is shown in Figure 15. The actual docking and transfer operation is shown pictorially in Figure 16. Rendezvous techniques for the mating of one tank with another or with a receiving vehicle are shown on Figures 17 and 18, respectively. The use of proposed LOX

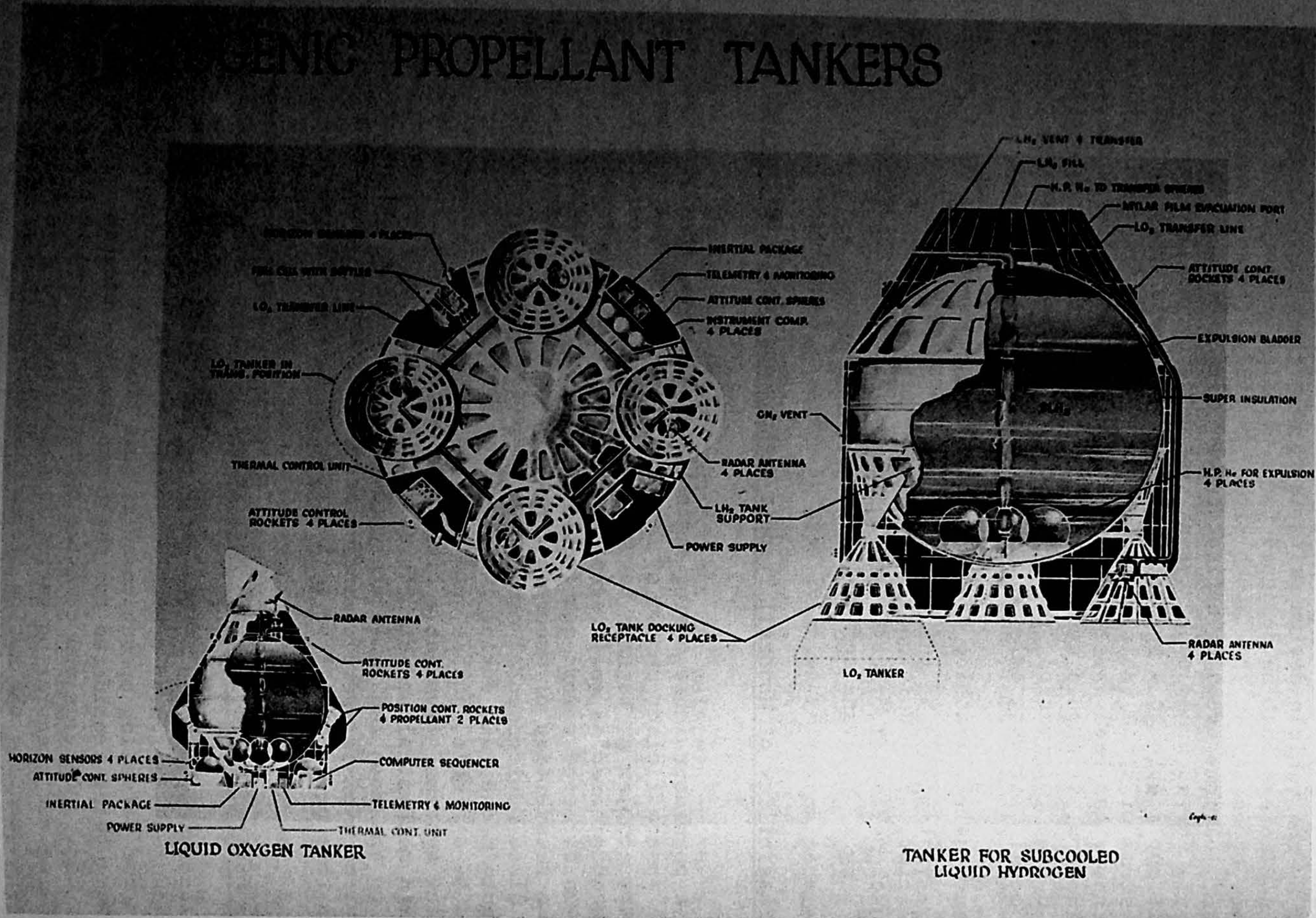


Figure 15. CRYOGENIC PROPELLANT TANKERS

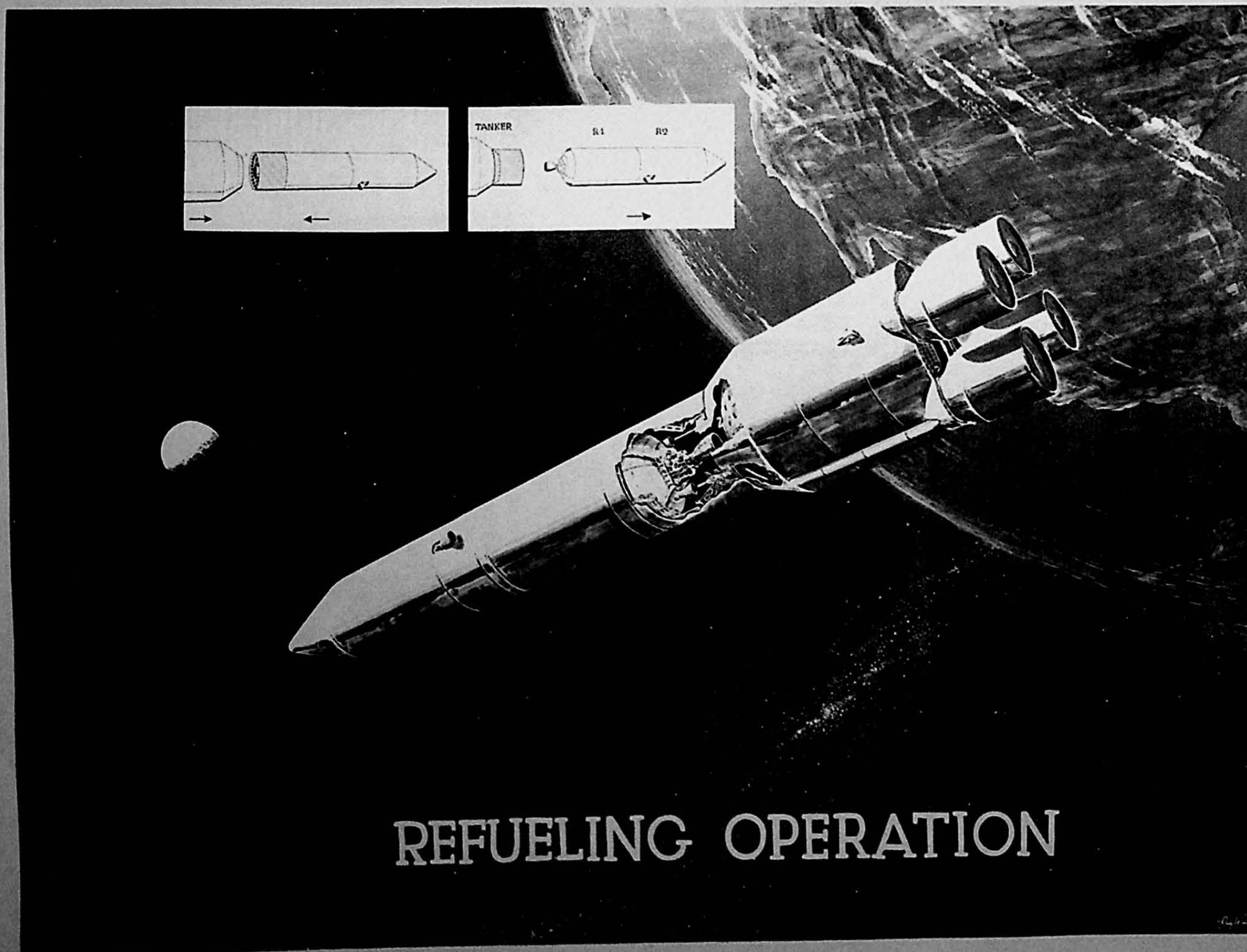


Figure 16. REFUELING OPERATION

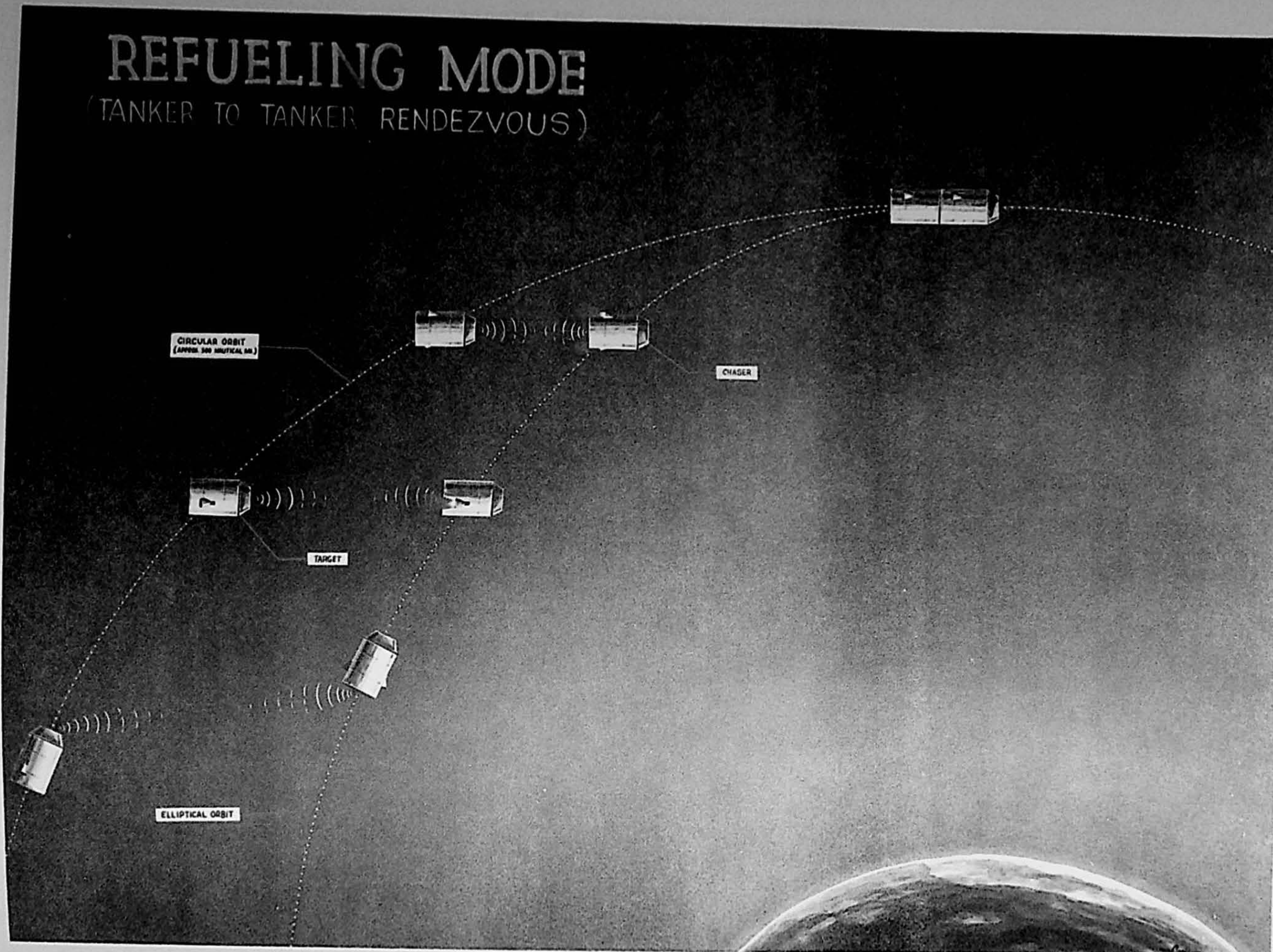


Figure 17. REFUELING MODE - TANKER TO TANKER

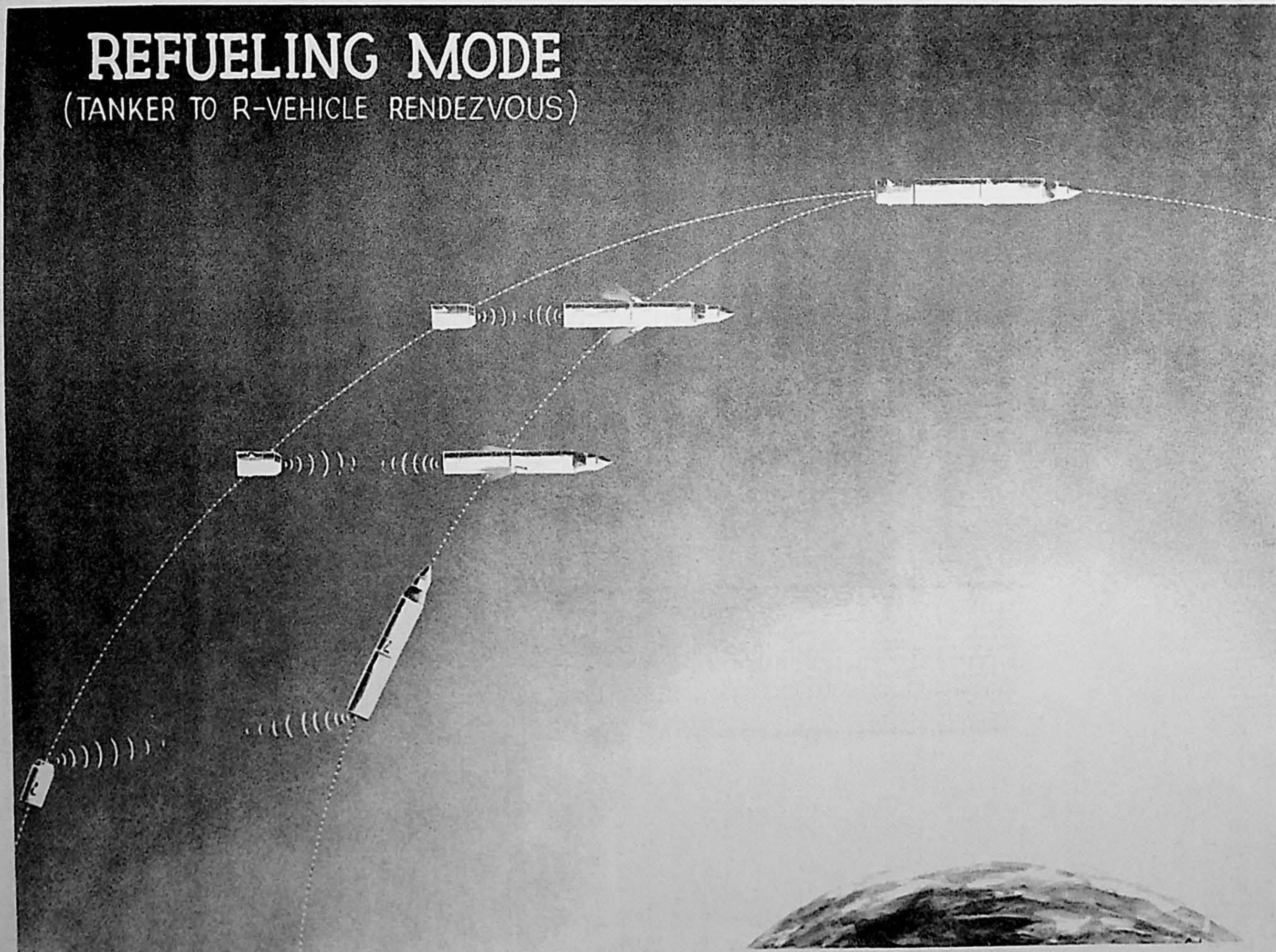


Figure 18. REFUELING MODE - TANKER TO VEHICLE

and LH_2 tankers for an orbital propellant depot is illustrated on Figure 19. Preliminary design details and supporting calculations for these studies are available in this office. Continued efforts will be directed toward these and similar concepts for support of future earth orbital operations programs and for the currently planned lunar orbital operations.

N. Cryogenic Tankers

Detailed design and analysis studies were performed relative to the orbital storage and transfer of liquid oxygen. (Ref. Figure 20). Tanker design was established after giving primary consideration to venting vs. non-vented concepts, tank materials and equilibrium skin temperatures, tank insulations, plumbing requirements, tank support structures, and tank shape factors. Transfer systems were proposed based on a thorough evaluation of expulsion techniques

O. Cosmic and Solar Flare Radiation

Investigation of cosmic and solar flare radiation has been conducted in an effort to establish shielding requirements and design criteria for manned space operations. Occurrence probability of high and low energy flares, location of the orbit with respect to the earth's geo-magnetic equator, anticipated flight duration, and relative biological effectiveness (RBE) of solar protons, and maximum integrated whole body radiation doses to be allowed for space operation were some of the parameters investigated in this preliminary study.

P. Hazards Associated with Lunar Landing or Return Operations

With the advent of lunar landings planned for the near future, it is essential that considerable thought be given to the behavior of jet exhaust in a vacuum under low gravity conditions, especially in relation to the most probable lunar surface conditions. Of primary concern is the motion of lunar surface particles resulting from the impingement of exhaust gases from a lunar landing or takeoff space vehicle and the resulting hazards to the vehicle itself and to both local and distant manned lunar bases or facilities. The combined parameters of low gravity, high vacuum, and high energy exhaust gases result in the displacement of large masses over considerable distances, so that the problem is not merely a localized one. Preliminary studies have been directed specifically toward determination of the trajectories or flight paths of lunar surface particles accelerated by the jet blast from a lunar landing or return vehicle. A range of particle velocities was assumed based on an anticipated effective exhaust gas velocity of 13,250 ft./sec. for a LOX-Hydrogen engine. Thus, velocities both above and below those required for escape or orbit from the lunar surface were considered. Follow-on work to be accomplished will involve analysis aimed at predicting the mass and distribution of particles most likely to be associated with the velocity distribution ranges previously assumed. Determination of the momentum energy coupling relationships between exhaust gases and lunar surface particles of assumed sizes and density will provide a better feel for the degree of hazard involved.

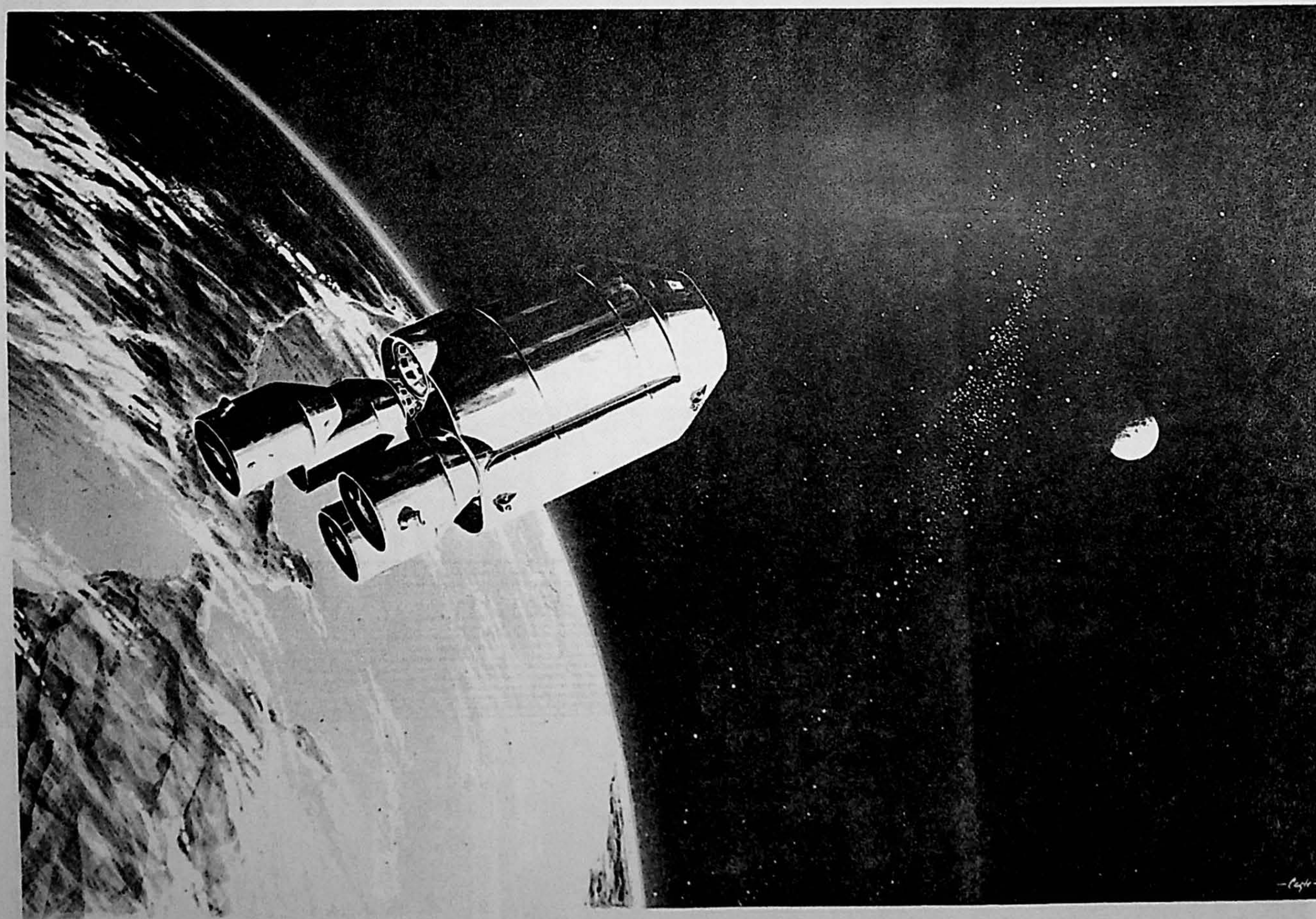


Figure 19. ORBITAL PROPELLANT DEPOT

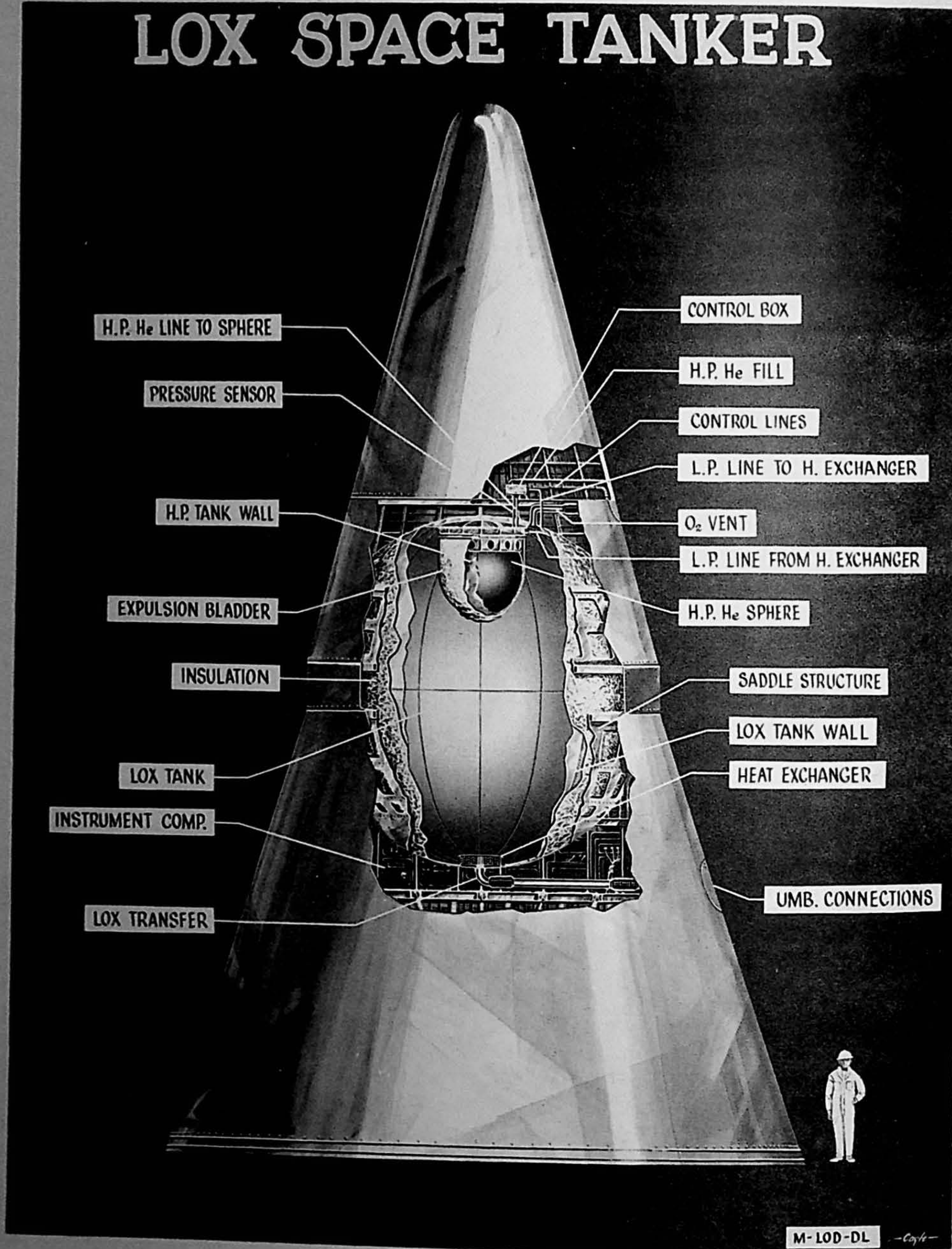


Figure 20. LOX SPACE TANKER

Initial study indicates that cratering, large dust clouds, and the ballistics of relatively large lunar surface particles resulting from a lunar landing or return launching may present serious problems in relation to the landing operation itself and most definitely can produce hazardous conditions for both distant and surrounding lunar base facilities, equipment, and personnel. For further information, refer to Report No. MIN-LOD-DL-8-62, April 30, 1962, "A Consideration of Lunar Surface Ballistics and the Hazards Associated with Spacecraft Landing or Return Operations", by D. C. Cramblit.

Q. Hazards Associated with the Static Testing and Launch of Nuclear Vehicle

In conjunction with the efforts to develop a nuclear powered upper stage for SATURN C-5 comes the need for the development of test, handling, and launch facilities. Since the field of nuclear technology is a highly specialized one, the major facility development programs will ultimately be accomplished through the efforts of a large number of personnel who are relatively unfamiliar with the requirements of such a program. Although a detailed education will not be required in many cases, it behooves these people to become familiar with the basic terminology and design requirements to be considered in their respective areas of responsibility. For this reason, considerable research and study was performed for the purpose of preparing a comprehensive report to familiarize responsible personnel with the general effects of nuclear radiation, presently accepted terminology and definitions, and specifically, with major problem areas to be considered in design of a nuclear launch facility. Radiation effects on general organic and inorganic materials, electronic components, and man were also covered, along with a detailed discussion of these hazards as they specifically apply to launch facilities, components, and operational concepts. For further information, refer to Report No. MTP-LOD-D-61-1, November 17, 1962, "Radiation Hazards Associated with the Testing and Launch of a Nuclear Space Vehicle" by D. C. Cramblit.

R. Propellant Mass Measurement in Zero Gravity Environment

In any manned space flight mission, it should be possible to determine the quantity of individual propellants on board at any time. Thus, a requirement exists for an on-board propellant mass measurement system which is operable in a zero gravity environment. A system has been proposed for application to the orbital tanking mode. This system is then generalized and made applicable to any stage propellant tank.

The proposed concept for determining the mass of propellant within an orbiting space vehicle assumes a non-vented system. The mass of propellant within a vehicle propellant tank can be determined by knowing the total volume and physical properties of the liquid propellant contained therein. By monitoring the pressure and temperature of a known mass of helium gas within the propellant tank and the pressure and temperature of the propellant, the gas laws may be utilized to determine the propellant mass within the tank. For further information, refer to Report No. MIN-LOD-DL-6-62, "Proposal for Determining the Mass of Liquid Propellant Within a Space Vehicle Propellant Tank Subjected to Zero Gravity Environment" by R. L. Evans and J. R. Olivier.

S. Barge Launcher/Transporter Concepts

Considerable effort was expended toward detailed evaluation of the barge approach to the mobile launcher/transporter concept, (Ref. Figure 14). Assistance was received in stability and propulsion analysis from a Naval Architect Consultant. Additional effort was expended by the David Taylor Model Basin in a model test program funded through this office. Results of these studies may be made available upon request.

T. Orbital Storage or Liquid Hydrogen

Effort has been completed on an extensive research study involving the long term storage of liquid hydrogen in space. A NASA technical note, number D-559, entitled "Orbital Storage of Liquid Hydrogen" by J. R. Olivier and W. E. Dempster was published in August 1961.

This report presents the influence of various design parameters on the storage time of liquid hydrogen in space. Emphasis was placed on non-vented storage of subcooled liquid hydrogen in a low geocentric orbit (300 n. mi.).

The non-vented storage concept has economical and technological advantages over the vented tank concept. However, for extended non-vented storage periods, the liquid hydrogen must be subcooled prior to launch.

A spherical tank was considered the optimum shape from a heat transfer standpoint. However, this report was based on an 18 ft. diameter cylindrical tank with hemispherical bulkheads. This coincides with diameter of the S-IV stage of the SATURN vehicle.

The calculations to determine storage times were based on the assumption of having stagnant fluid conditions in the orbiting tank in order to obtain conservative results. The calculations further considered the fundamental differences in thermal environment of a vehicle tank, which is an integrated structural element, and an orbital storage tank, which is an individual structure except for the duration of powered flight.

U. Crawler Concepts

After review and study of barge, rail, and crawler transporter/launcher concepts, it was concluded that the crawler concept was the most desirable from a monetary, availability, and operational standpoint. The feasibility of this concept was further verified through a detailed study contract awarded to the Bucyrus - Erie Company. This company was selected to prepare this study because of their past experience in designing and manufacturing crawlers as well as other means of moving heavy mining and excavating equipment. The weights supported by commercially available crawlers developed for large excavating machinery is greater than the estimated weight of the SATURN C-5 transporter.

They have the advantage of low bearing pressures, resulting in economical road construction; and automatic hydraulic leveling and hydraulic steering systems which insure proper handling of the space vehicle. In addition, electrical systems have been developed to give accurate and reliable control of the extremely high torques and accelerations encountered in other motions in large excavator service. These systems can be readily adapted to the problem of controlling acceleration and deceleration of the launcher under a wide variety of conditions resulting from wind and grade. This detailed study considers the feasibility of utilizing available crawlers and determines what modifications would be required. The parameters for roadways under the various conditions which may be encountered are established, along with cost estimates for the structural portions of the transporter and crawler. As the study progressed, modifications were suggested indicating that an independent crawler transporter carrying a detachable launching pad might be practical. These results were further investigated by this office resulting in the conceptual drawings as shown in Figures 21 and 22. Figure 21 shows the system moving into launch position, whereas Figure 22 shows the concept of an independent crawler transporter after it has lowered the launch pad/vehicle combination onto the launch table and is moving away. Results of these detailed studies are available upon request.

Table IV is a summary of other available study reports generated by contractors supporting the NASA contracts previously discussed.

V. Advanced Complex 39 Concepts

Preliminary investigations were conducted toward development of a mobile arming tower concept for servicing and prelaunch pad operations required by the SATURN C-5 vehicle. Such functions as installation and arming of solid propellant destruct and/or igniter systems, and last minute servicing of the manned payloads might be considered possible applications for such a system. Such a mobile tower could also be moved by crawler systems, as shown in Figure 23.

W. Technical Publications

Table V provides a summary of major publications by this office during FY 62. Other miscellaneous efforts of importance will be discussed in Section VI. The Appendix includes a summary of other publications primarily produced during the FY 61 period.

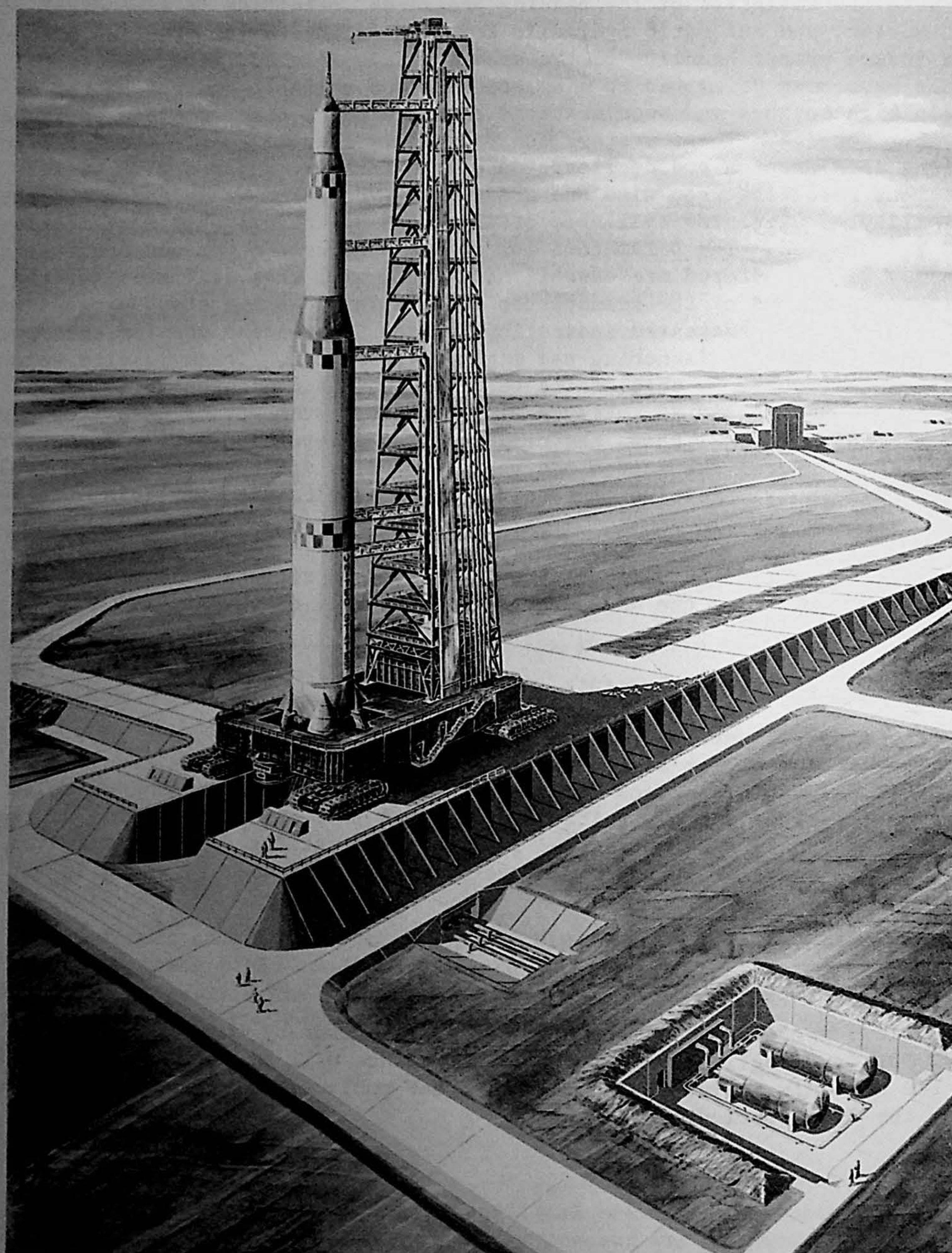


Figure 21. CRAWLER CONCEPT - UNITIZED/CONSTRUCTION

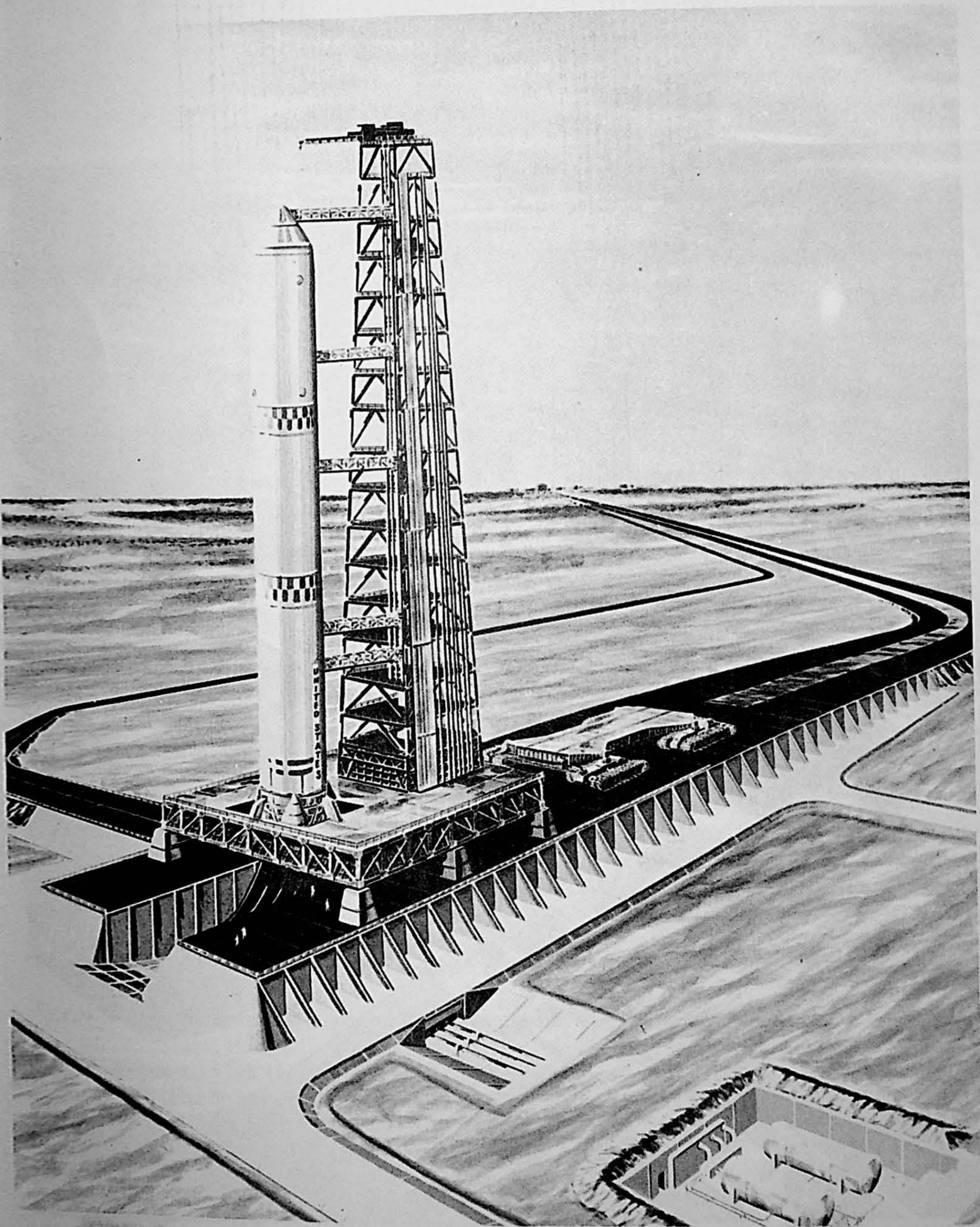


Figure 22. CRAWLER CONCEPT - INDEPENDENT TRANSPORTER

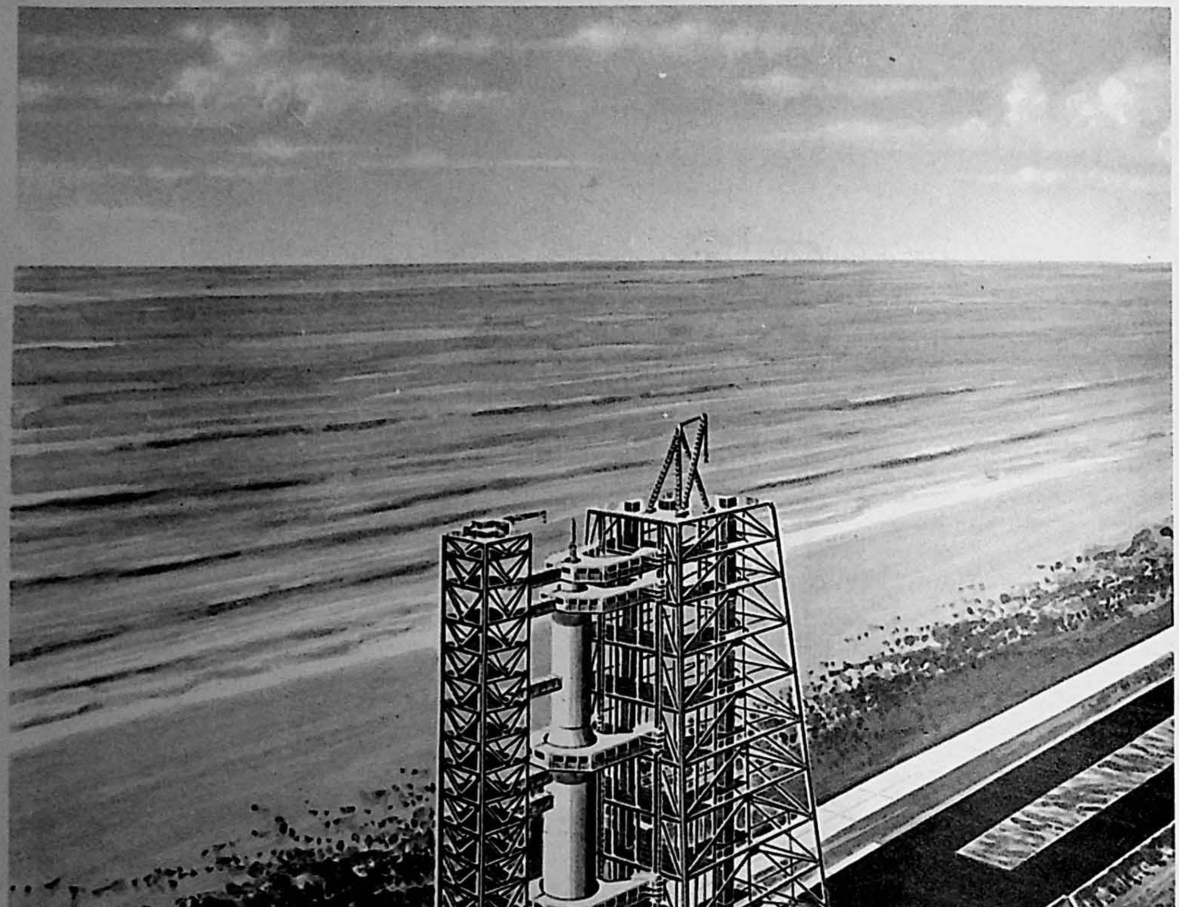


Figure 23. CONCEPTUAL DESIGN - MOBILE ARMING TOWER - COMPLEX 39

TABLE IV

MAJOR STUDY REPORTS AVAILABLE

1. "Acoustical Considerations in Launching and Static Testing of Large Space Vehicle Boosters", by Bolt, Beranek, and Newman.

2. "6 to 12 Million Pound Thrust Launch Vehicles", by Lockheed, General Dynamics, and North American.

3. "Orbital Launch Operations", by Douglas and Vought Astronautics.

4. "RIFT" Program Final Study Results, Lockheed, Martin, General Dynamics, and Douglas.

5. "Analysis of Medium Class Vehicles", by STL.

6. "SATURN C-3 Launch Facilities", by Martin Company.

7. "2 to 3 Million Pound Thrust Launch Vehicle Systems", General Dynamics/ Astronautics, North American.

8. "SATURN C-2 Operational Modes Study", Martin Company and Douglas.

9. "Equatorial Launch Sites", a study by CCMD.

10. "Effects of Liquid Propellant Explosions on Nuclear Rocket Engines", (S-RD) Final Report, A. D. Little Company.

11. "A Study of Large Launch Vehicle System for a Manned Lunar Landing Program", General Dynamics/Astronautics.

12. "Earth Lunar Transportation System Study", Final Report, Martin Company.

13. Final Report, "NERVA Engine Development Program and Associated Tasks", July 1961 through January 1962, Aero-Jet General Corporation.

TABLE V

FY 62 PUBLICATIONS BY M-LOD-DL

1. M-LOD-DL-5-61, September 18, 1961, "Flame Deflector Configurations Required for the Attenuation of Exhaust Jets from C-3, C-4, C-4N, and NOVA Space Vehicle Boosters", by R. L. Evans.

2. MIN-LOD-DL-6-61, October 27, 1961, "A Preliminary Study of Launch Facility Requirements for the C-4 Space Vehicle".

3. MIN-LOD-DL-3-61, August 1, 1961, "Preliminary Concepts of Launch Facilities for Manned Lunar Landing Program", by Owen L. Sparks.

4. MIN-LOD-DL-1-62, "Lunar Storage of Liquid Propellants", by W. E. Dempster, R. L. Evans, and J. R. Olivier. Published also as NASA Technical Report (TN-D-1117).

5. MIN-LOD-DL-7-61, February 6, 1962, "Ground Facility Requirements for Sub-Cooling Liquid Hydrogen",by W. E. Dempster and J. R. Olivier

6. MIN-LOD-DL-8-62, April 30, 1962, "A Consideration of Lunar Surface Ballistics and the Hazards Associated with Spacecraft Landing or Return Operations", by D. C. Cramblit.

7. MIN-LOD-DL-4-62, "Structural Members and Variable Gravity", by R. T. Burns.

8. MIN-LOD-DL-5-62, "Launch Deflector Criteria and Their Application to the SATURN C-1 Deflector", by R. L. Evans and O. L. Sparks.

9. MIN-LOD-DL-6-62, "Proposal for Determining the Mass of Liquid Propellant Within a Space Vehicle Propellant Tank Subjected to Zero Gravity Environment", by R. L. Evans and J. R. Olivier.

10. "The Launch Probability of Space Vehicles Within a Given Launch Window", by Georg von Tiesenhausen and R. L. Evans.

11. MTP-LOD-D-61-1, November 17, 1961, "Radiation Hazards Associated with the Testing and Launch of a Nuclear Space Vehicle," by D. C. Cramblit.

VI. MISCELLANEOUS ACTIVITIES - FY 62

In addition to the major programs conducted by this Office, a number of miscellaneous activities and study efforts are conducted on a day-by-day basis. The following items might be considered as typical examples of these activities:

A. A comprehensive article entitled "Launch Facilities and Ground Support Equipment for Launch Complex 34" was prepared by Mr. von Tiesenhausen for publication in "Astronautics" magazine.

B. A brochure, complete with illustrations and photographs was prepared to describe LOD's field of endeavor in the Manned Lunar Landing Program. Included was a breakdown of the various tasks assigned to LOD in the Orbital and Lunar Launch Operations project, a discussion of current tasks in progress, a listing of major hardware requirements for orbital operations, and orbital operations tasks requiring immediate action. The tasks included space maintenance and repair, orbital operations, preliminary LH_2 and LO_2 Tanker Design, investigation of GSE associated with OLO, orbital propellant storage and transfer investigations, lunar propellant storage, and lunar launch hazards.

C. Orbital Operations Plans

Periodic inputs are provided to the Orbital Operations Program in the form of preliminary design drawings and design analysis of such topics as orbital cryogenic storage tankers, propellant expulsion systems, super-insulation techniques, docking and coupling modes, couplings, and overall operational modes.

D. RIFT Program

Continuous support and coordination of the RIFT Program requires the performance of such functions as definition of facility and GSE requirements, program scheduling and cost estimation, development of contractual statements of work and specifications for performance, proposal and contract review and evaluation, and monitoring of actual contract performance.

E. Presentations

Periodic presentations are made to discuss new concepts and current developments in the Future Studies Branch, and to familiar responsible personnel with the various programs of the future. Such topics, as launch probability studies, orbital operations techniques, orbital facilities, launch facility concepts and operational modes, and nuclear program requirements have been discussed.

APPENDIX

PAST STUDY EFFORTS

A. FY 61

1. The following programs have been selected as being representative of the type of work engaged in by the Future Studies Branch during fiscal year 1961.

Off-Shore Facilities Studies

The advent of crowded conditions at the various launch facilities, large propellant storage requirements for multi-staged vehicles, higher firing rates, nuclear propelled stages and safety considerations introduced the concepts of off-shore and semi-off-shore launch facilities. Considerable in-house efforts were made in this area and prospective bidders for studies were oriented on study requirements. The results of the in-house efforts are pictorially illustrated in Figure 24 and discussed in Report IN-LOD-DL-6-61, "Off-Shore Facility Study".

Modifications Required on VLF 34 for SATURN C-2 Vehicles

The more exacting mission requirements of the SATURN C-1 space vehicle introduced the need for a larger thrust SATURN vehicle called the SATURN C-2. To utilize existing facilities at Complex 34, a feasibility study was made to determine the necessary modifications to Complex 34 and cost requirements which would permit the launching of C-2 vehicles. Results of this study were published in Confidential Report No. IN-LOD-DL-2-60.

Orbital Storage of Liquid Hydrogen

This effort, which required approximately two man years is a comprehensive technical study or orbital storage techniques for LH_2 (vented vs. non-vented) parameters affecting storage time (insulation properties, stagnant vs. agitated fluid conditions, orbital characteristics, tank configurations, etc.) zero-g venting, insulation pre-cooling and the uses of shadow shields. (Ref. Figures 25 and 26). Results of this study are published in Report No. MTP-M-LOD-DL-3-61.

Liquid Hydrogen Sub-Cooling Requirements

A preliminary study on this subject was necessitated by the recommendations and conclusions arrived at in the report previously discussed on orbital storage which cited a requirement for sub-cooling of liquid hydrogen payloads for orbital operations.

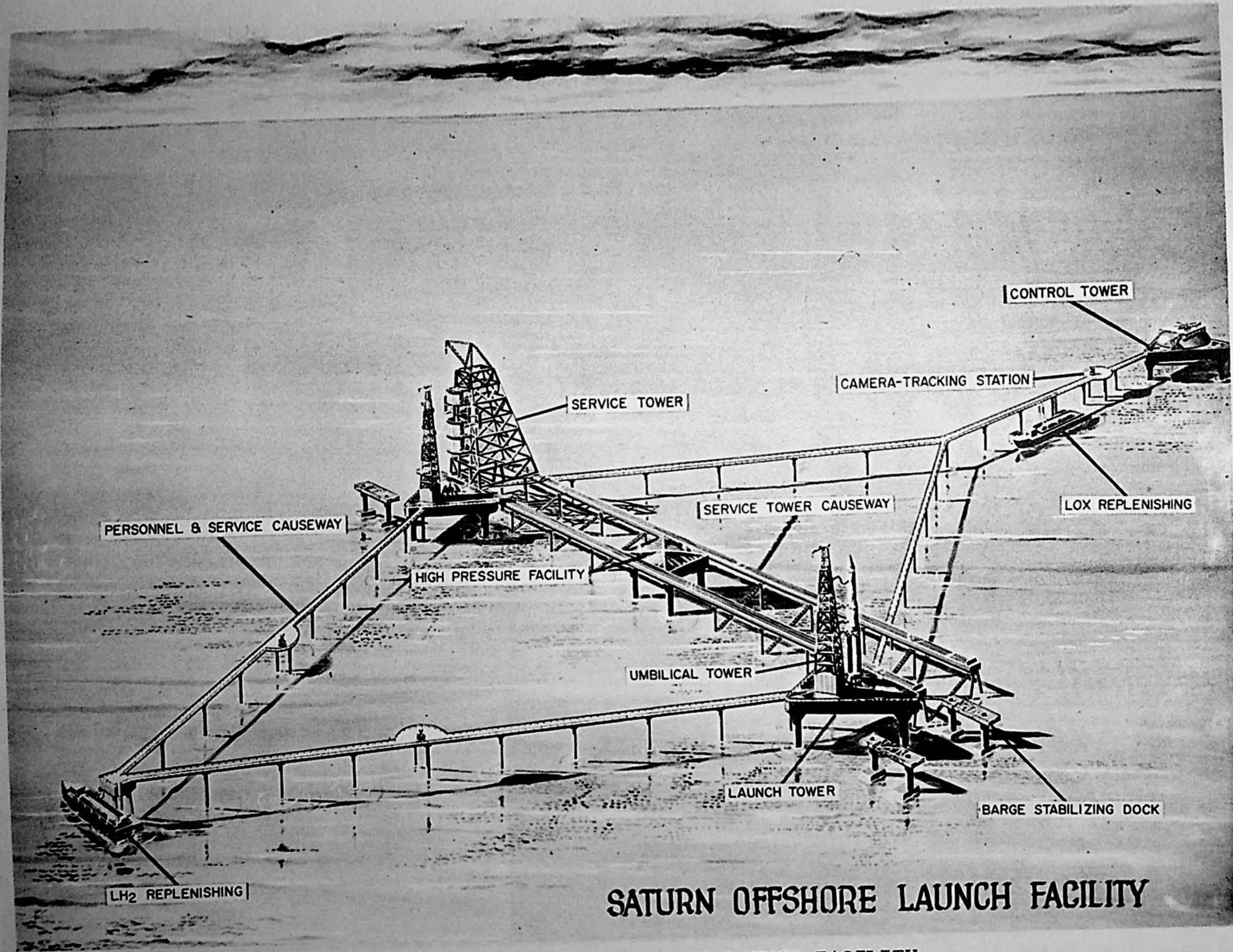


Figure 24. SATURN OFF-SHORE LAUNCH FACILITY

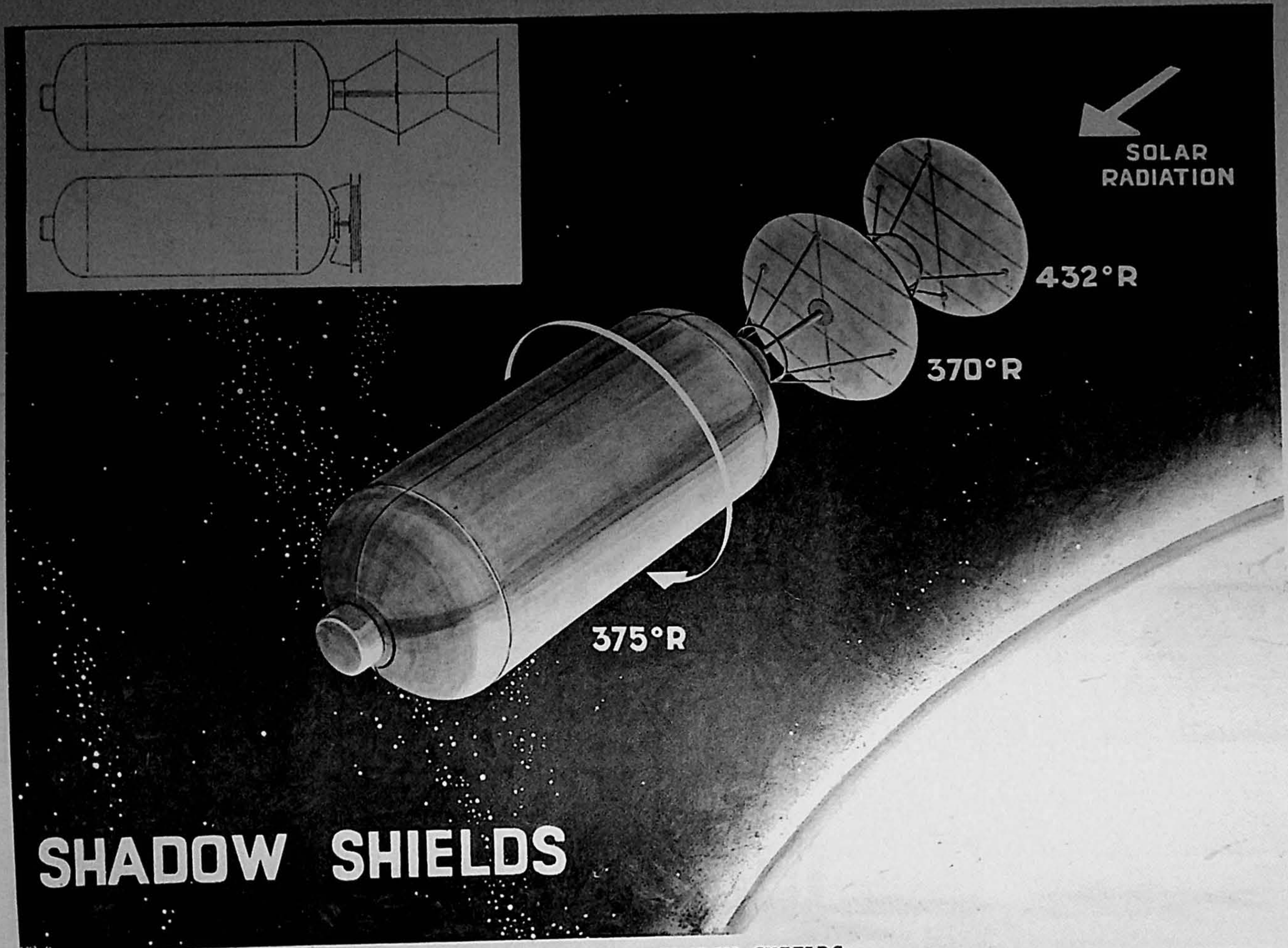


Figure 25. SHADOW SHIELDS

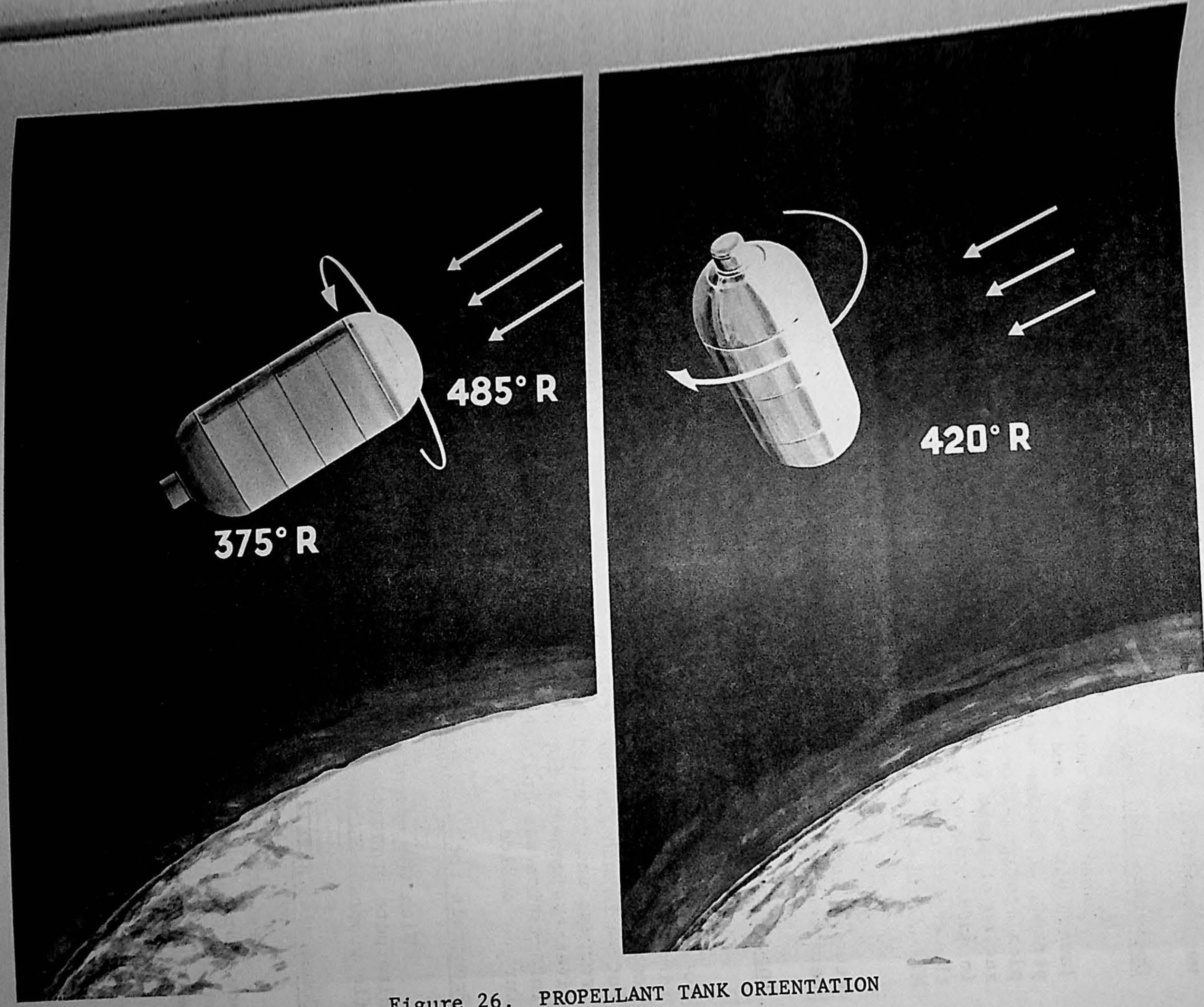


Figure 26. PROPELLANT TANK ORIENTATION

A preliminary analysis entitled "Liquid Hydrogen Sub-Cooling Requirements" was completed.

Optimized Land Based Facilities

Based upon requirements for high sustained firing rates of one vehicle launch per week and salvo orbital launching of 6 to 7 vehicles in a three week period, it became necessary to conceive and develop new concepts for launch complex configurations and checkout procedures, and concepts for the optimum utilization of these facilities and existing Cape real estate. These concepts were in addition to the facility requirement for SATURN C-1 which is represented in the artist concept of Complex VLF 37 shown pictorially in Figure 27. Report No. MIN-LOD-DL-1-61 is a summary of the results and findings of this study effort.

2. A considerable amount of effort and time is spent in "quick look" studies and daily system analysis programs. Examples of this type of work performed by this office are as follows:

Inputs to the Dyna-Soar Program

Concerning the possibility of using the SATURN as a booster for the Dyna-Soar vehicle, it became necessary to determine the impact of such a configuration on existing GSE and launch facilities, the extent and cost of necessary modifications, and the capability of the system in handling such a payload. Future Launch Systems Study Office analyzed the overall requirements for this program, and directed the efforts of project engineers within LOD-D who were given assignments for detailed treatment of specific problem areas. All this information was collected, collated, published, and transmitted to the Cape for further action.

Proposals for SATURN Support Arm Changes Required by Finned Boosters

With the advent of fin requirements for the Dyna-Soar booster, studies and alternate proposals for support arm changes were made. An example of one specific proposal is shown in Figure 28.

Commercial Satellite Programs

Periodically, the initiation of a new program places the requirement for preliminary cost analysis and concept planning on this office, which completed an annual and total cost estimate for GSE and facilities to support the above mentioned program.

Figure 27. SATURN LAUNCH FACILITY - COMPLEX 37

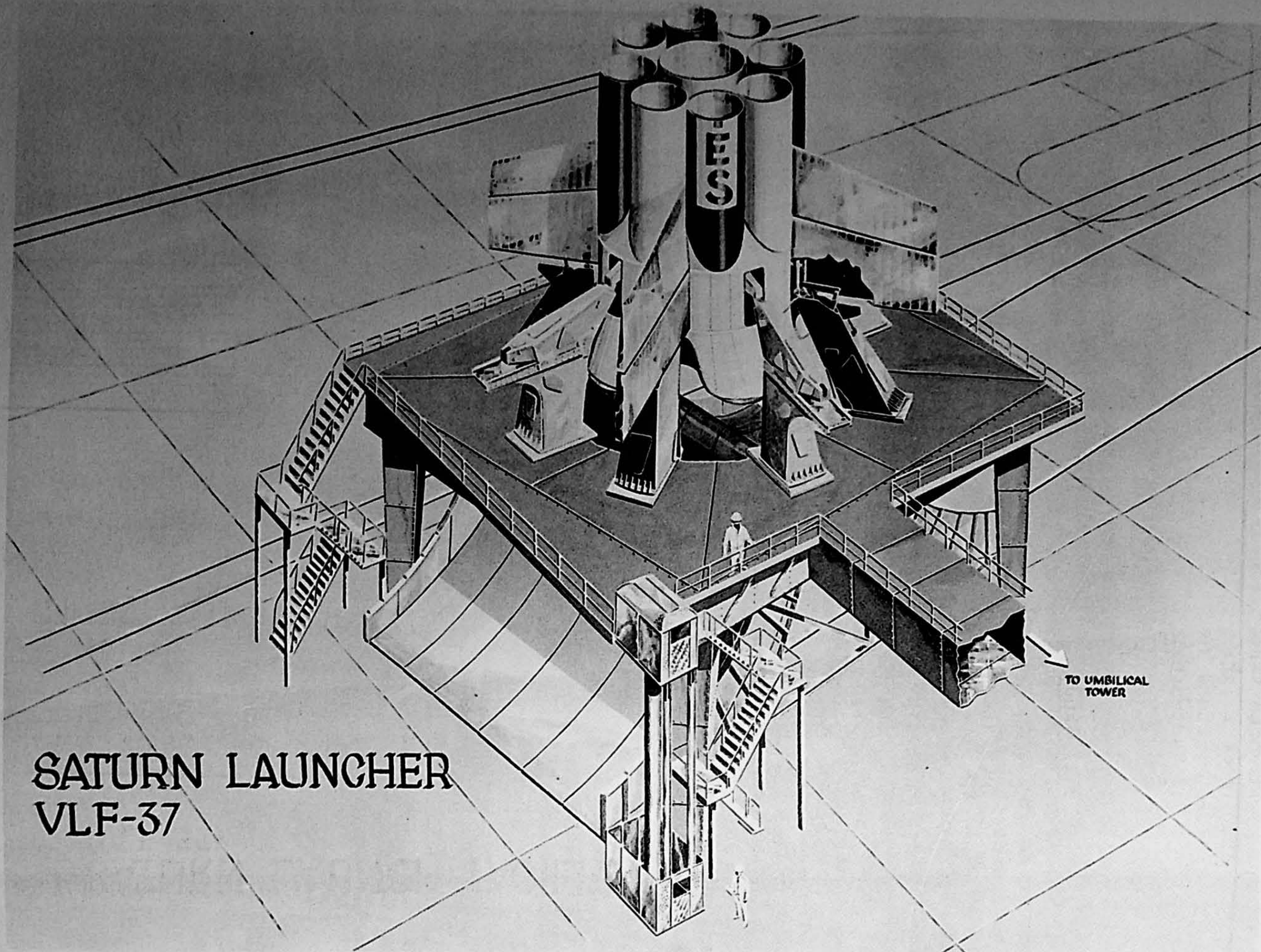


Figure 28. SATURN LAUNCHER - VLF 37

TURN GSE Handbook

A handbook covering all major SATURN GSE was edited, published, and re-eased through this office. Graphic illustration and art work is performed or such publications.

and Expansion Study

With the advent of more and larger space vehicle systems, real estate vailability at the Cape is becoming a serious matter for concern. In antici-ation of the needs for the future, this office prepared a proposed statement f work for a "Cape Canaveral Land Expansion Study" and forwarded it to M-LOD-DF or comments and coordination with AMR officials.

3. In anticipation of the needs for larger booster systems, increased ayload capabilities, and advanced techniques for lunar landings, etc., NASA rganized a small advanced study committee composed of members from representa-ive areas of the space flight center. This committee does advanced study work, nd plans controls, monitors and evaluates contractor proposals and actual study efforts. Members of the Future Studies Branch actively participated in the fol-lowing committees:

SATURN C-2 Operational Study

This study consisted of comprehensive operational and cost analysis, as a function of launching rates, for the SATURN C-2 space vehicle program.

The end result of this study was an integrated, optimum operational mode, and detailed cost analysis thereof, for each of three specified launch rate programs. A member of the Future Studies Branch was Chairman of this Committee. Study contracts were awarded, with a final report made in July 1961.

Early Rendezvous and Docking Study

A design study was made for joining the payload of two test vehicles in orbit in a manner that they become a single unit. The purpose of this study was to define in detail a method of demonstrating orbital rendezvous at an early date using existing vehicles and technology.

Orbital Launch Operations Study

This study was initiated to obtain design criteria, cost, schedules, and conceptual design data for establishing and maintaining orbital launch operations. A secondary intent was to determine the composition of orbital complexes and to obtain design criteria for establishing and maintaining orbital complexes which have an influence on orbital launch operations.

6-12 Million Pounds Thrust Launch Vehicle Study

This study established some of the design parameters and most promising design philosophies and vehicle configurations in the 6 to 12 million pound thrust class. The results of this study combined with the results of other studies were of assistance to NASA in planning the elements of the national booster program.

Launch Vehicle Size and Cost Analysis

The objective of this study was to investigate the operational and economical parameters influencing the choice of the size of future launch vehicles. The emphasis was on the launch vehicles that could be operational in the 1965 to 1975 time period. Relationships between various cost factors and vehicle size should be established.

2-3 Million Pound Thrust Vehicle Study

This study established the design parameters of a launch vehicle in the two to three million pound thrust class for a mission spectrum including orbital operations, escape type mission, and surface-to-surface earth transportation.

Off-Shore Launch Facilities Study

This study developed optimum concepts for a semi-off-shore and an off-shore launch complex based on utilization of existing GSE and facility design to the maximum practical extent and to make a comprehensive comparison of the two concepts on the basis of economical, operational, and scheduling requirements.

4. Periodically this office is requested to contribute significant technical research data or to make presentations on current advances in the astronautical field as it pertains to future launch systems. Representative of the areas of participation are as follows:

tributions to "Handbook of Astronautical Engineering"

This office contributed four chapters to the aforementioned handbook to be lished by McGraw-Hill in the near future. These chapters covered the fol-ring areas of GSE space technology:

1. Space Vehicle Launchers

2. Space Vehicle Deflectors

3. Orbital Refueling

4. Lunar Surface Transportation

resentation at Annual ARS Meeting

Mr. Georg von Tiesenhausen of this office presented a technical paper at he annual ARS meeting at Washington, D. C. This paper, entitled "Ground Equip-ent to Support the SATURN Vehicle", covered all phases of transporting, handling, rection, checkout, and firing of the SATURN vehicle.

TABLE VI

MAJOR PUBLICATIONS - FY 61

The following listing comprises the majority of publications released by this office during the fiscal year, 1961.

TITLE	DATE	REPORT NUMBER	SECURITY CLASSIFICATION
Orbital Storage of Liquid Hydrogen	Feb 61	NASA-TND-559 MTP-M-LOD-DL-6-61	U
Offshore Launch Facility Study	Apr 61	IN-LOD-DL-6-61	U
Modifications Required on VLF 34 for SATURN C-2 Vehicles	Sep 60	IN-LOD-DL-2-60	C
Ground Support Equipment Handbook	Apr 61	Unnumbered	U
Preliminary SATURN Dyna-Soar Proposal	Feb 61	Unnumbered	C
SATURN Syna-Soar Proposal	Feb 61	Unnumbered	C
Commercial Satellite Program	Jan 61	Unnumbered	U
Orbital Refueling-A Feasibility Study and Design Concept, Phase I	Mar 60	DLM-TN-21-60	U
Orbital Refueling-A Feasibility Study and Design Concept, Phase II	Apr 60	DLM-TN-35-60	U
Proposed Test Facility for Ground Test of Space Support Equipment	Mar 60	DLS-TN-19-60	U
Liquid Hydrogen Subcooling Requirements	Mar 61	Memo to M-LOD-D From M-LOD-DL	U
X Lunar Soft Landing Study	Dec 59	DLS-TN-36-30	U
A Lunar Subsurface Sampling Device	May 60	DLM-TN-36-60	U

ABLE VI - MAJOR PUBLICATIONS - FY 61 (Continued)

TITLE	DATE	REPORT NUMBER	SECURITY CLASSIFICATION
Development Proposal for . 24-Hour Communications atellite System" Ground upport Equipment	Sep 59	DLS-TN-13-59	U
apid Modes of Transportation for the SATURN System		Unnumbered	U
Dry Launcher Deflectors	Jun 59	DLM-TN-22-59	U
Interim Report on Future SATURN Launch Facilities Study	May 61	MIN-LOD-DL-1-61	U

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