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FINAL REPORT

STUDY OF STORAGE AND HANDLING OF THE 260-IN.-DIA SOLID ROCKET MOTOR

Volume 1

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ABSTRACT

Evaluations were made of the methods of handling the 260-in.- (6.6-m) dia solid-rocket motor stage between the Aerojet/Dade County Plant and the NASA-KSC Launch Complex 37, Pad B. Also, handling methods were investigated for alternative destinations and motor design including: (1) the NASA-KSC Saturn V crawler/transporter, (2) the U. S. Air Force Western Test Range, and (3) the 260-in.-(6.6-m) dia segmented motor configuration. Initially, three separate handling methods were identified and evaluated. The optimum handling method selected from the three methods was further defined and refined. Detailed static and dynamic stress analyses were accomplished to support the handling-method evaluation and to determine the effect of critical handling and storage loads on the stage. The results show that the 260-in.- (6.6-m) dia solid-rocket motor stage can be reliably and economically handled, transported, stored, and erected using tooling, equipment, and facilities that are within the existing state-of-the-art.

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I. SUMMARY

The study of storage and handling of the 260-in.- (6.6-m) dia solid rocket motor was initiated in June 1969 under Contract NAS3-12052. The objective of the program was to determine the most economical and reliable method of handling the motor stage, for transportation from the processing site to the launch site, and to formulate design concepts and logistics plans on the basis of the method selected. The program scope was divided into four tasks, as follows: Task I - evaluation of various handling concepts, Task II - examination of alternative destinations and motor designs, Task III - motor stress analyses, and Task IV - definition of the most economical and reliable handling method.

Three separate stage handling methods, each with the potential of being the most reliable and economical, were established after completing a review of previous studies of handling large heavy loads. The handling methods were devised from within the state-of-the-art to meet the objectives of low cost, low risk of motor damage, safety, and high schedular consistency. Over long distances, only water transportation with the stage mounted horizontally on a barge, was considered. The three handling methods selected for evaluation included the use of three stage lifting devices, two types of transporters, two methods of placing the stage on the barge, and two types of barges. Each of the three methods was refined and comparatively assessed. The optimum handling method was determined by an engineering trade-study that was conducted on the basis of results of the comparative assessment.

The Task II study showed that the selected handling method could be used to transport the stage to the U. S. Air Force Western Test Range (WTR)* with only a slight increase in the risk of motor damage resulting from the

*Definitions of abbreviated terms are given in Appendix F.

longer time at sea. Establishing the launch site at WTR and providing stage access to the launch site are subject to resolution of several significant problems. Transportation of the stage to the NASA-KSC Saturn V crawler-transporter (C-T) does not require any changes in the basic handling method concept. The costs for nonrecurring tooling, equipment, and facilities are similar for the C-T destination and the NASA Launch Complex (LC) 37 destination. As expected, costs for nonrecurring tooling, equipment, and facilities for handling the segmented motor are significantly less than for the unitized motor. However, the segmented motor study did not include consideration of increased program costs associated with segmented motor processing, inspection, and assembly.

The static and dynamic stress analyses confirmed that the stage can withstand the handling, transportation, storage, and erection loads. The minimum margin of safety in the motor propellant grain occurs under the condition of horizontal storage (3 yr). Case-buckling considerations limit the allowable transverse acceleration to 2.2 g, which is considered to be adequate for transportation acceleration loads.

The selected handling method consists of the following items:

A. Stiff-leg derrick at the Aerojet Dade County Plant (DCP).

B. Roll-Ramp mobile gantry at the NASA Kennedy Space Center (KSC).

C. New barge.

D. Truck-rail transporter without a midcylinder support for the stage.

The selected handling method does not involve areas where development would be required to advance the state-of-the-art. Thus, the principal objective in the handling-method development program would be the early definition of the handling-method design criteria and design of the handling method elements.

On the basis of evaluations accomplished in this program, conclusion is made that the 260-in.- (6.6-m) dia solid-rocket motor stage can be reliably and economically handled from the stage-progessing site through erection on the launch pad using tooling, equipment, and facility concepts that exist today and that are within the state-of-the-art. It is also concluded that the stage can withstand the expected loads of handling, transportation, storage, and erection. Minor motor-design changes can be accomplished that will facilitate handling and that will provide improved margins of safety in specific areas of the stage.

II. INTRODUCTION

The handling of any large and heavy piece of equipment normally presents significant problems. The handling of large rocket motor stages is sometimes particularly difficult because of limitations in the number and location of allowable lift and support points, limitations in allowable acceleration and vibration loads and the necessity for environmental control. Handling of the 260-in.- (6.6-m) dia solid-rocket motor stage does not present problems that are especially unique, it is simply the largest and heaviest solid-rocket motor developed to date.

Various concepts for handling large solid-rocket motors have been studied and the results presented in the literature of the industry. These efforts narrowed the range of reasonable approaches for handling the 260-in.- (6.6-m) dia stage. The size and weight of the stage precludes the use of mixed modes of handling and dictates that an economical and reliable approach to handling must consider all details of the motor configuration, such as the attachment of handling rings to the motor case. This study considers all aspects of motor handling from the time the cast motor is lifted from the Aerojet/Dade County Plant (DCP)* propellant casting (C&C) facility through placement of the stage on the launch pedestal at the NASA-Kennedy Space Center (KSC).

Aerojet Solid Propulsion Company is uniquely familiar with the 260-in.- (6.6-m) dia motor, the motor processing facility, and the handling requirements and limitations imposed by the motor design details. The Chrysler Corporation/ Space Division (CCSD), Cape Canaveral, Florida, was subcontracted to assist with the handling method study so that activity involving launch site operations could be accomplished with the same degree of authority as other aspects of the program.

The study program was begun by establishing three separate handling methods, refining and assessing the three methods, and selecting the most economical and reliable handling method. The selected method was then further defined and refined. Also, the impact on the selected handling method was established when considering alternative destinations, i.e., the U. S. Air Force Western Test Range (WTR) and the NASA-KSC Saturn V crawler-transportor (C-T), and when considering an alternative segmented motor design. Detailed static and dynamic stress analyses were accomplished to determine the effect of critical handling method loads and vibrations on the motor stage.

The results of this program provide a sound base from which to establish the detailed design criteria for the stage/handling method interface and the subsequent design, construction, and demonstration of the handling-method elements for the 260-in.- (6.6-m) dia stage.

*Definitions of abbreviated terms are given in Appendix F

III. TECHNICAL DISCUSSION

A. PROGRAM OBJECTIVES

The objective of this program was to determine the most economical and reliable method of handling the 260-in.- (6.6-m) dia stage from the motor processing site to the vehicle launch site and to formulate detailed designs and logistics plans utilizing the handling method. The objective was fulfilled by accomplishing the following:

1. Evaluating three separate handling methods, each with the potential of being the most economical and reliable method.

2. Evaluating alternative destinations and motor designs, including the U. S. Air Force Western Test Range (WTR)* and NASA-KSC Saturn V crawler/transporter (C-T) destinations and segmented motor designs.

3. Accomplishing detailed motor stage static and dynamic stress analyses.

4. Defining the selected handling method including establishing tooling, equipment, and facility design configurations; preparation of a logistics plan; definition of critical elements of development and operation of the handling method; refinement of costs and development schedule; and determining motor design details affected by handling.

B. TECHNICAL APPROACH

1. Program Background

Various methods of lifting, supporting, and rotating large solid motors have been evaluated in the past. Generally, these studies have

*Definitions of abbreviated terms are given in Appendix F.

been concerned with handling and transporting the stage at various locations; e.g., at the stage processing facility or at the launch facility. Also, some of the methods studied have required advancement in the state-of-the-art and therefore would involve very high development costs. References (1) through (8)* are reports of some of the previous studies of handling large solid motors.

Proper selection of a handling method involves consideration of the basic motor design, the methods of motor processing, the impact of handling methods on motor static and dynamic stresses, and the uniformity of handling methods at all required locations.

It is apparent that the position and location of the stage at the completion of motor processing and stage assembly have an important influence on the operations necessary to handle the stage and to prepare the stage for shipment. In addition, the method of handling at the processing facility can have a significant influence on subsequent handling operations.

In any motor program, it is desirable that the handling equipment and techniques selected should not impose loads that exceed the capability of the structure as designed for flight loads. Detailed static and dynamic stress analyses are required to determine motor stresses and stress distributions caused by the various handling loads encountered.

This program was established to study stage handling methods and to select the optimum handling method when considering the important interfaces that exist between the handling method, the stage design, the processing facility, and the launch facility.

*References are defined in Appendix G.

2. Program Ground Rules and Assumptions

The following ground rules and assumptions establish the bases for defining and evaluating the stage handling methods:

a. The term "handling method" as used in this study will encompass the operations involved in removing the cast motor from the Aerojet/Dade County Plant (DCP) cast and cure (C&C) facility through placement of the stage on the launch pad at the Kennedy Space Center (KSC). Exceptions will be taken under Task II, in which the U. S. Air Force WTR and the KSC C-T alternative destinations will be investigated.

b. The vehicle stage considered in this study will be the 3.4 million lb (1.54 million kg) propellant load, 260-in.- (6.6-m) dia/SIVB booster stage described in the Douglas Missile and Space Systems Division Final Report SM-51896.[5] All stage components are described in the referenced report.

c. The basic segmented motor configuration evaluated under Task II of this program will be the segmented version of the 260-in.- (6.6-m) dia booster motor defined in Aerojet-General Corporation Report NAS7-513 FR-1.[9]

d. The stage will be assembled in the DCP C&C facility; the motor is cast in the vertical position with the nozzle up.

e. Only water transportation of the stage will be considered, except with respect to the processing, storage, and launch facilities. In the Task II segmented motor study, overland transportation will be considered.

f. The stage will be in the horizontal position on the barge during shipment.

g. All ordnance, including the motor igniter, safe-and-arm system, destruct system, and staging rockets will be assembled at KSC after placement of the stage on the launch pad.

h. The vehicle will be launched from the NASA-KSC Launch Complex (LC)-37, Pad B.

i. Handling-method tooling, equipment, and facility requirements will be evaluated on the basis of motor usage rates of six per year for 5 yr and a motor storage shelf life of 3 yr. Assumption is made that the motors maintained in storage will be obtained from within the production of six motors per year for 5 yr.

j. Any modifications to the basic definition of the vehicle or of the launch pad area will be made only with prior approval of the NASA-LeRC Project Manager.

C. RESULTS

1. Evaluation of Various Handling Concepts (Task I)

Task I, Evaluation of Various Handling Concepts, was accomplished to determine the most economical and reliable method of handling the 260-in.- (6.6-m) dia solid-rocket motor stage.

Handling method operations include stage extraction from the DCP C&C facility, environmental protection, stage storage, transportation, preparation for receiving inspection operations at NASA-KSC, and the handling necessary to place the stage in launch position.

Evaluation of various handling methods and selection of the optimum handling method were accomplished through effort in four major areas: (1) identification of three handling methods, (2) refinement of these three handling methods, (3) comparative examination of the three handling methods, and (4) engineering trade-studies to select the optimum handling method.

The 1649-in.-long (41.9-m-long) 260/SIVB baseline stage configuration is shown in Figure 1. The configuration shown in Figure 1 reflects modification of the Reference (5) baseline configuration to the extent that an aft motor skirt is included to provide for attachment of the aft handling ring (see Section III.C.4.f, Motor Design Details Affected by Handling). The maximum diameter for the aft flare (355 in. or 9.0 m) and all other length and diameter envelope dimensions were maintained as specified for the Reference (5) baseline configuration.

The weight of the stage in the shipping and handling configuration is given in Table I. The 3.985 million lb (1.812 million kg) weight excludes the 7.1% growth factor, motor igniter and ordnance items, and TVC fluid that are identified in the Reference (5) weight breakdown. The weight of the handling ring given in Table I is based on the weight of a handling ring with a constant cross-section that is sized to permit lift-adapter clearance with the 355-in.- (9.0-m) dia (maximum) aft flare.

a. Identification of Three Handling Methods

Various handling concepts were evaluated to establish three separate handling methods, and effort was directed toward meeting the objectives of low cost, low risk of motor damage, safety, and high schedular consistency for each handling method. Previous handling studies accomplished by Aerojet-General Corporation, The Martin Co., Douglas Aircraft Co., Bellcom Inc., and others, were reviewed to derive applicable results of the previous studies and to preclude redundancy of work in this program. Three separate handling methods were established for further refinement and consideration; these are shown in block diagrams in Figures 2, 3, and 4 and in sketches in Figures 5, 6, and 7. Each method includes all necessary operations from removal of the stage assembly from the C&C facility at DCP to placement of the stage on the launch pad at KSC. It was assumed that stage assembly had been completed and accepted prior to removal of the stage from the C&C facility. The three handling methods include: (1) three methods of stage hoisting and rotation between the vertical and horizontal positions, (2) two types of stage transporters, (3) three methods of supporting the stages on the transporter, (4) two methods of placing the stage on the barge, and (5) two types of barges.

(1) Handling Method No. 1 (Figures 2 and 5)

(a) Stage Removal from C&C Facility

The assembled stage will be lifted from the C&C pit with a 2000-ton capacity (1,816 Mg), double-boomed, stiff-leg derrick (American Hoist and Derrick Co.) located adjacent to the C&C pit. Special lifting adapters will be attached to the aft handling ring trunnions. The derrick design is composed of existing components and therefore represents a minimum design and development effort. Limitations on the derrick reach under full load will require the transporter to be close to the C&C facility, but sufficient reach will be available.

The motor will have internal gas pressurization to provide midcylinder support (pressurized while in the C&C facility). A nozzle plug will be used as a gas seal and weather protector. An environmental closure will be used in the forward skirt area.

(b) Stage Placement on Barge

The barge will be positioned and secured in the graving dock adjacent to the C&C pit, and then ballasted and stabilized on the bottom of the graving dock. The motor transporter, consisting of two sets of cradle type "A" frames joined by structural members, will be located at the end of the barge nearest the C&C pit. This type of transporter is less complex and less expensive than the truck-and-rail type. The 260-in.-(6.6-m) dia stage will then be hoisted out of the C&C pit in the vertical position, lowered onto the transporter trunnion cradles nearest the pit, and rotated to the horizontal position. Movement of the stage from the C&C pit directly to the transporter on the barge will eliminate land movement in the vicinity of the C&C facility.

(c) Preparation for Shipment

The stage will be secured to the transporter, moved on 3-in.- (7.62-cm) dia hardened steel rollers to the center of the barge, and secured for shipment. Winches located on the barge deck will be used to pull the motor transporter over the rollers. Winches and rollers are a proven inexpensive method for moving relatively short distances. Next, the barge-mounted environmental cover will be installed. The internal gas pressurization source and instrumentation will be connected and checked out. The ballast will then be pumped from the barge permitting it to float free in the dock.

(d) Barge

An existing U.S. Navy Auxiliary Repair Dock (ARD) with required structural and functional modifications will be used to transport the stage to the KSC. The sea going-type barge is an unpowered 488-ft- (149-m) long by 81-ft- (24.7-m) wide structure with a draft (empty) of less than 6 ft (1.83 m). The barge deck will be modified by incorporating a structural truss system for distributing the stage/transporter loads. The stage will be enclosed in an environment cover on the barge well deck. Use of the existing ARD barge precludes development and construction of a special new barge. The barge is adequate for the shipment of the stage. However, any special tooling and facilities must conform to the structure and configuration of the existing barge.

(e) Barge Route

The loaded barge will be towed via the DCP on-plant canal extension and Canal C-111, north on the Intracoastal Waterway, and to the Atlantic ocean through the Biscayne Channel 8 miles (12.87 km) south of Miami. The barge will proceed northward in the Atlantic ocean and will enter KSC via the Port Canaveral harbor and lock facilities.

This ocean route minimizes barge size restrictions, but the open sea may induce higher g loads in comparison to routing via the Intracoastal Waterway. The ocean route also minimizes the potential hazards to populated areas and minimizes traffic congestion on the Intracoastal Waterway.

The 260-in.- (6.6-m) dia stage will arrive at KSC via the Port Canaveral facilities. The KSC canal system is shown in Figure 8. The facilities of the Cape Kennedy Air Force Station (CKAFS) AF Hangar and the Solid Rocket Motor Storage area are depicted in Figures 9 and 10.

The stage will be received at the Port Canaveral/KSC lock. Turnover to the Air Force Eastern Test Range (ETR)/KSC safety and KSC quality control personnel will be effected at the lock. The gross estimated distance through the CKAFS canal system is as illustrated in Figure 8. Potential storage at the AF Hangar area or the CKAFS solid propellant storage area would be as depicted in Figures 9 and 10.

The barge will be docked in a canal slip at KSC, ballasted and stabilized on the bottom of the graving dock.

(f) Off-Loading at KSC

A bridge structure between the barge and off-loading dock will be installed. The stage/transporter tie-downs will be removed, and the stage/transporter will be off-loaded using steel rollers and winches.

The stage will be routed into a KSC storage and checkout building if the schedule indicates that the stage will not go to the launch pad within 2 weeks. The storage and checkout building will be capable of controlling the temperature and humidity environment within the range required.

Stages that will be used within 2 weeks will go directly to the launch area dock. After off-loading, each stage will be visually inspected.

(g) Rotation to Vertical Position and Placement on the Pad

The stage will be moved on steel rollers to the rotating pit at LC-37 and positioned for rotation to vertical position.

The stage transporter will be anchored, and the forward trunnion bearings will be freed in preparation for rotation.

To rotate stage to the vertical position, the mobile gantry incorporating the "Roll-Ramp"[(10)] device will be positioned at the forward-end lift point and prepared for the lift operation. The lifting sling/bar will be connected, and the lift operation initiated. Loads will be continuously monitored throughout the lift. Clearances will be visually checked throughout the lift. The stage will be rotated about the aft handling ring trunnions to the vertical position.

The mobile gantry with Roll-Ramp device will be used to transport the stage to the launch pad and to position the stage over the pad support points. The stage-to-mobile gantry bracing will be removed, and the stage will be lowered by the Roll-Ramp mechanisms to a position just above the pad support hard points. Alignment will be checked and monitored, and stage final placement will be effected. The lifting sling/bar will then be removed.

(2) Handling Method No. 2 (Figures 3 and 6)

(a) Stage Removal and Preparation for Shipment From the C&C Facility

gantry crane with a Roll-Ramp mechanism will be used and operated (similar to Handling Method No. 1 at KSC) to remove the stage from the C&C facility. After lifting the stage from the C&C pit, the forward trunnions will be placed into the cradles of the truck-rail type transporter. Bracing will be used to preclude movement of the transporter. The gantry will then be used to rotate the stage to the horizontal position, while moving over the transporter.

The truck-rail transporter incorporates a pneumatic bladder for midcylinder support. The stage/transporter will be moved onto the ARD barge in a manner similar to that described for off-loading at KSC in Handling Method No. 1 except that the bridge structure will be a rail-type structure. After positioning the transporter on the barge, preparation for shipment will be similar to Handling Method No. 1 except for the specific differences associated with securing the truck-rail transporter on the barge, connecting supply lines, and adjusting the pressure in the mid-cylinder pneumatic bladder.

(b) Stage Shipment Through Placement on the Pad

The barge, barge route, receiving inspections, off-loading, erection, and placement on the launch pad are similar to Handling Method No. 1 except for the following:

1 Receiving inspection will include inspection of the pneumatic bladder and truck-rail transporter tie-down.

2 Off-loading is similar except that the truck-rail system will be used.

(3) Handling Method No. 3 (Figures 4 and 7)

(a) C&C Facility and Removal of the Stage

The C&C facility for this handling method is designed to preclude the requirement for handling the stage with a stiff-leg derrick or gantry. The stage will be handled by winches only. The C&C facility would be similar to the existing C&C facility except that the pit would be elongated and curved to permit rotation of the stage into the pit.

The insulated motor case will be brought into position at the C&C facility on the truck-rail transporter. Lift slings will be connected between the forward and aft trunnions and winches. Using the winches, the motor case will be raised horizontally a sufficient distance for the trunnions to clear the transporter cradles. Then, the transporter will be removed from the C&C area.

Using the forward winch system, the forward end of the motor case will be lowered until the motor case is vertical. The forward winch system will then be disconnected from the motor case. The motor case will then be lowered onto the motor support base ring at the bottom of the C&C facility.

Processing of the motor, including stage assembly and checkout, will be accomplished in the same manner as in Handling Methods No. 1 and 2. After acceptance of the stage, the stage will be raised and positioned on the transporter in a sequence of operations just the reverse of that described above for installation of the motor case in the C&C facility.

(b) Installation of the Stage on the Barge

The barge shown in Figure 7 for Handling Method No. 3 is of new construction and is designed to be used on the intracoastal/ ocean route. Also, the barge is designed to be ballasted to the bottom of the graving dock and to support the stage weight from the stern to the center of the barge.

The transporter is the same as used in Handling Method No. 2 except that a sling instead of a pneumatic bladder will be used for midcylinder stage support. After installation of the stage on the transporter, the load in the sling will be adjusted to a predetermined value.

(c) Transport to KSC

The barge route, receiving inspection, and off-loading at KSC are similar to Handling Method No. 2, except that the receiving inspections will involve inspection of the transporter sling instead of the pneumatic bladder.

(d) Rotation and Erection at the Launch Pad

The 2000-ton-capacity (1,816 Mg) stiff-leg derrick will be used at the launch site to rotate the stage to the vertical position and to place the stage on the launch pad. Other aspects of the use of the stiff-leg derrick for placement of the stage on the launch pad will be similar to those used at the C&C facility in Handling Method No. 1 except that a rotating pit will be required for aft-flare clearance during rotation.

b. Refinement of Three Handling Methods

Refinement of the three handling methods was accomplished to further define the factors that influence handling, transportation, and storage of the 260-in.- (6.6-m) dia motor stage. Additionally, the refinement of the three handling methods forms a basis for the subsequent comparative evaluation and selection of the optimum handling method (see Section III.C.1.c.)

(1) Handling Method Sequence of Operations

The detailed sequence of operations for each of the three handling methods selected for evaluation as a part of Task I, Evaluation of Various Handling Concepts, is provided in Appendix A. The sequence of operations starts with the barge positioned in the graving/loading dock adjacent to the C&C facility and with the assembled, checked-out, inspected, and accepted stage ready for removal from the C&C facility.

The sequence of operations (see Section III.C.4.b for refined sequence of operations) in Appendix A defines the operations for each of the three handling methods required to (1) ship the stage from DCP to the KSC LC-37B, and (2) ship the stage from the DCP to the KSC storage facility Operations required for other stage destinations, i.e., (1) KSC/LC-37B to DCP, (2) KSC storage to DCP, (3) KSC storage to KSC/LC-37B, and (4) KSC/LC-37B to KSC storage, are identical to those contained in Appendix A but must be reversed or otherwise rearranged for the appropriate destination.

All stage handling operations (Appendix A) would be accomplished in accordance with process planning and inspection documents. Although not specifically identified in the sequence of operations, acceptance inspections of appropriate individual process items would be accomplished prior to proceeding to subsequent operations. However, major inspection points, e.g., (1) securing the stage to the transporter, (2) securing the transporter to the barge, and (3) receiving inspections, are identified in the sequence of operations.

The cycle times for the operations defined in the sequence of operations are shown in Figures 11, 12, and 13 for handling methods No. 1, 2, and 3, respectively. The cycle times for operations at DCP through placement of the stage on the launch pad at KSC vary from 23 calendar days for Handling Methods No. 1 and 2 to 27 days for Handling Method No. 3. Although operations beyond placement of the stage on the pad at KSC are not within the scope of this program, disassembly of the derrick for protection during launch was included in the Handling Method No. 3 time cycle since this involves a major handling method element.

(2) Tooling, Equipment, and Facilities

The tooling, equipment, and facilities, together with the quantity required and the Task I estimated nonrecurring costs, are shown in Tables 2, 3 and 4.

The LC-37B facility at KSC was reviewed with respect to using the double-boom stiff-leg derrick of Handling Method No. 3. This review resulted in three orientations of the derrick/pad arrangement as shown in Figures 14, 15, and 16. In all three concepts evaluated, the load booms of the 270 ft (82.3 m) stiff-leg derrick would have to be removed and the derrick protected against the thermal environment during vehicle launch. Also, in all three configurations, the load-boom foundation is near the launch pedestal, which results in complication of the load-boom/pedestal foundations.

The advantage of Configuration No. 1 (Figure 14) is that rotation of the stage for erection would take place over the flame pit, thus eliminating the necessity for a rotating pit. The principal disadvantage is that a removable stage/transporter rail foundation would be required to span the flame pit. This approach would be complex, costly, and time consuming at the pad.

The general pad area is rearranged in Configuration No. 2 (Figure 15) such that the flame pit opening is removed from the immediate area of the derrick. With this approach, the flame tunnel passes underneath the existing KCS mobile service structure (MSS) rail foundation and would require considerable pad facility modification.

Configuration No. 3 (Figure 16) would result in the best compromise. In this arrangement, the flame pit opening is between the derrick load boom and strut foundations. Problems associated with the derrick load cables spanning the flame pit during launch would be alleviated since the derrick is disassembled and protected prior to launch. It should be noted that in all three configurations, the stage is positioned in line with the derrick.

(3) Inspection and Checkout Requirements

The stage would be assembled at the C&C facility, except for ordnance items (motor igniter, safe and arm system, destruct system and staging separation system), which will be installed with the stage on the launch pad. Stage subsystems will be checked (functionally bench tested, where possible) and inspected for acceptance prior to installation on the motor. This approach will permit early detection of component malfunction and correction, which will minimize assembly and checkout time in the C&C and, thus, minimize C&C facility occupancy and turn around time. The liquid injection TVC system can be flow checked only as a bench assembly or when upright in the launch position. After stage assembly, the stage will be checked out and inspected prior to removal from the C&C facility. The latter inspection should not normally repeat component bench tests made prior to assembly but will include inspection of integrated systems and circuits, leak check, torque check, and visual inspection for damage from assembly. Stage checkout and inspection in the C&C facility is preferable to inspection after stage removal and placement in the horizontal position. Disassembly of rejected components and subsequent reassembly would best be accomplished in the vertical position. Assembly stands, equipment and lift devices are less complex and less expensive for vertical assembly than for horizontal assembly.

Only visual inspections are planned subsequent to stage removal from the C&C facility and through stage placement on the launch pad. No stage checkout operations are planned prior to stage placement on the launch pad. Considerable time and additional checkout and inspection equipment would be required if stage checkout were conducted following each handling and moving operation. This is considered costly and superfluous since the components and systems must be designed to withstand normal handling and shipping. The logical place for final stage inspection is on the launch pad after all handling operations are complete. Again, assembly and disassembly of rejected components and systems are best accomplished in the vertical position. The first opportunity for complete check of the TVC system, ordnance, and circuitry is after placement on the pad. Visual detailed inspection of the propellant grain interior can best be accomplished after removal of the forward igniter port plug and nozzle plug by vertically lowering and hoisting an inspector through the motor interior. It is not planned to conduct a detailed grain inspection after stage removal from the C&C facility and prior to positioning on the launch pad except visually through an inspection port. Otherwise, the removal of igniter or nozzle plugs would be required, resulting in loss of the internal dry nitrogen gas and protection from humidity and rain. Close visual inspection of the stage while in the horizontal position would require an inspector to walk on the grain interior. This would subject the grain to unnecessary stress and contamination and would be extremely difficult in the forward fin area of the grain.

Data for comparison of the handling methods with respect to inspections and checkouts required from the C&C facility to the KSC launch pad are as follows:

Alignment and tie-down operations are more readily accomplished with the truck-rail transporter than with the roller transporter. Tracks provide positive alignment.

Stage alignment requirements for rotation from the C&C facility to the transporter are less complex with the winch system than with the derrick or gantry. Guy wire and spacer requirements should be similar for all three lift methods.

Transfer of the stage from the C&C facility directly to the transporter on the barge (Handling Method No. 1) eliminates installation and alignment inspections of a dock-to-barge bridge structure as required in Handling Methods 2 and 3.

The internal gas pressure is simple to check and monitor and is also required for humidity control. Internal pressure of the bladder center support would also be easy to check, but represents an additional inspection operation. Caution would have to be exercised to prevent bladder damage and leakage. Inspection of the integrity of the sling and adjusting the support to a predetermined load is more complex and less positive than adjusting pressure in the stage interior or in the pneumatic bladder.

As previously indicated, the receiving inspections at KSC will involve visual inspections of the stage and handling system for integrity and for any damage that may have been sustained during transit. The list of inspection requirements is shown in Table 5.

Acceptance of the stage at KSC will be based on the inspections identified in Table 5. In the event these visual inspections or analysis of recorded environmental data show the motor to be suspect, it is assumed that the motor will be returned immediately to the DCP for additional inspection or repair. If minor repairs are required, e.g., retightening (retorquing) of bolts, reinstallation of attachment-bolt lockwires, etc., assumption is made that these operations will be accomplished either at the KSC inspection area adjacent to the rotating pit or at the KSC storage area.

Inspections required between the C&C facility and the launch pad are as follows:

(a) Removal from C&C Facility and Placement on Transporter

Check the barge and transporter alignment, bracing, and ties.

Check the lift device sling, cabling, spacers, and guy wires before and during stage removal from the C&C facility and transfer onto transporter.

(b) Movement of Stage/Transporter onto Barge

Inspect the stage-to-transporter tie-down.

Check the bridge, transporter, and barge alignment.

(c) Preparation for Shipment

Inspect the transporter-to-barge tie-down.

Inspect shipping instrumentation, equipment, and internal nitrogen pressure.

Inspect the environmental shelter attachment to barge.

(d) During Barge Transit

Periodically inspect and monitor the shipping instrumentation, equipment, and internal nitrogen pressure.

Periodically inspect the stage-to-transporter and transporter-to-barge tie-downs.

(e) Preparation for Offloading at KSC

Inspect the barge alignment and ties to the dock.

Inspect the bridge alignment and securing ties between barge and dock.

Inspect the stage and transporter tie-downs and the integrity of handling rings, trunnions, and shipping closure for evidence of shipping damage.

Inspect the motor midcylinder support integrity, if used.

Conduct KSC Receiving Inspection on the barge.

(f) After Unloading Stage/Transporter at KSC

Review the transportation-environment monitoring records (temperature, humidity, acceleration, and internal nitrogen pressure).

Conduct additional Receiving Inspection.

(g) Rotation, Transport to the Pad, and Placement on the Pad

Inspect the roadway or rail for cleanliness, obstacles, and alignment for moving the stage/transporter to the rotating pit

Check the securing ties and bracing of the transporter at rotating pit.

Check the lift device sling, cabling, spacers, and guy wires before and during stage rotation, lifting, and placement on launch pad.

Check removal of the transporter, lift sling or adapters, and lift devices from immediate area.

(h) Storage at KSC

Check the stage dry nitrogen pressure set-up.

Check the temperature and pressure monitoring instrumentation set-up.

(4) Environmental Requirements

Temperature and humidity environmental restrictions on the motor were defined. The environmental limits are (1) temperature, 60 to 100°F (289 to 312°K) and (2) humidity (motor interior), 45% R.H. (or less) indefinite exposure and 89% R.H. (maximum) for 2.5 days, maximum. The methods of environmental protection planned for the stage from removal at the C&C facility through placement on the launch pad are provided in Table 6.

A sun shade will be used for reflecting solar radiation. The motor interior will be controlled to within the maximum relative humidity limit by sealing the nitrogen purged motor at 1.5 psig ($1.035\ N/cm^2$, gage) minimum nitrogen pressure. All metal parts will be painted, covered, or otherwise protected to prevent corrosion.

Consideration was given to the environmental requirements for long-term motor storage at KSC. The duration of the long-term storage was defined as a maximum of 6 months for any one motor. It was concluded that storage for this extended period should be under sheltered conditions. Provision should be made for weather protection and for maintenance of a temperature environment of 80 $\pm$ 20°F (300 + 267°F) with a maximum relative humidity of 45%.

On the basis of the propellant-grain stress analysi (Appendix B) conclusion was made that the motors need not be rotated during storage at KSC. The expected grain deformation resulting from horizontal storage is small, and will become negligible once the stage is rotated to the vertical position for launch.

The overall environmental protection requirements were reviewed with respect to their effect on each of the three handling methods. There is little difference in the impact of the environmental requirements on the three handling methods considered.

(5) Inclement Weather Hazards

Inclement weather hazards are defined as wind, rain, and lightning. These conditions were evaluated with respect to the various handling techniques. The following considerations are important with respect to handling during inclement weather.

Lifting and handling equipment must be designed to withstand hurricane-force winds. Stage handling during high winds would be difficult and dangerous. It is estimated that safe operations with the derrick or gantry cannot be accomplished in winds or gusts exceeding 30 mph (13.4 m/sec). Winching operations for stage handling would be safer than the gantry or derrick in winds of 30 mph (13.4 m/sec) or more, but would still be difficult.

Cross wind limits for safe barge towing on the Intracoastal Waterway and maximum sea state conditions during ocean transit were not identified; however, maximum utilization of weather forecasts will permit scheduling of the 4-day barge trip between DCP and KSC during periods when safe navigation can be expected. Harbors along the route can be identified for safe berthing in the event weather conditions change suddenly during transit.

Lightning rods will be provided at the various facilities to protect the stage during an electric storm.

Comparison of the three handling methods with respect to inclement weather hazards is discussed in the following:

(a) Hurricane Force Winds

The dynamic pressure corresponding to a 150 mph (67 m/sec) wind is approximately 60 lb/sq ft (2880 N/m^2) or 0.4 psi (0.276 N/cm^2). Derricks, cranes, and winches can be designed with sufficient strength to withstand this dynamic pressure but must be stabilized and anchored to prevent toppling or lateral movement. The derrick will require lowering of the booms to ground supports and lashing. This will require more time and manpower than the other lift devices. The gantry would be rolled to a designated dead-man anchoring location; the gantry truck load equalization hydraulic system would then be depressurized and the gantry secured. The Roll-Ramp mechanism, lift slings, and other movable components must be locked and secured. The gantry preparation and securing should be slightly faster than for the derrick. The winch system is the easiest lift device to protect from hurricane winds. Covers would be installed and the system locked and lashed in place.

The transporters must be secured to the ground or barge to prevent movement. Lashing would be similar for the roller transporter and the truck-rail transporter. The truck-rail transporter hydraulic system would be depressurized similar to that of the gantry system.

Barge-to-dock tie-downs must be available and sufficient to withstand hurricane winds. Where possible, the barge should be ballasted to the botton of the dock for better stability. Securing the barge with or without the stage should not be a problem.

The motor or stage is best protected while in the C&C facility below ground. The C&C facility for Handling Methods No. 1 and 2 rather than the swing elongated C&C facility for Handling Method No. 3 would provide better protection. Special provisions must be made for lashing, padding, and covering the nozzle and components exposed above ground. The casting building can be placed over the motor or stage for additional protection. If the stage has been removed from the C&C facility and is on the transporter, it could be returned to the C&C facility below ground for safest protection. The winch system would provide the fastest and easiest method for returning the stage to the C&C facility. If on the ground (Handling Methods 2 and 3) the stage/transporter could be rolled onto the barge, lashed and tied-down, and the environmental cover installed. The environmental cover must be hurricane proof. If the stage has been lifted from the C&C facility and lowered onto the transporter on the barge (Handling Method No. 1) then the transporter would be rolled to the center of the barge and secured, the environmental cover would be installed, and the barge ballasted to the bottom of the dock.

The transportation time between DCP and KSC is estimated to be 4 days. If the stage is in-transit on the barge, sufficient warning time should be available to proceed to the KSC or return to the DCP. It is not assumed that the barge will be caught in a hurricane while enroute.

(b) Wind Velocity Limits During Lift and Rotation at DCP and KSC

The magnitude of dynamic loads can be made negligible by limiting the maximum speed under full load of both the load and the boom tackle (derrick system) to 3 ft/min (0.015 m/sec). The gantry Roll-Ramp speed (vertical) and winch cable play will also be limited to 3 ft/min (0.015 m/sec). The dynamic pressure due to wind should be kept to less than 2 lb/sq ft (95.8 N/cm^2), (30 mph) (13.4 m/sec) during lifting and handling operations.

The derrick, gantry, and winch systems can operate satisfactorily at the 3 ft/min (0.015 m/sec) lift speed. The winch system is easiest to operate. Winch operations for stage handling would be safer than the gantry or derrick in winds of 30 mph (13.4 m/sec) or more, but would still be difficult. Stabilizing guy lines will be used on all lift systems to minimize swaying, impact, and extraneous load stresses. A bracing structure will be used while transporting the stage with the mobile gantry.

Transporting the stage on the truck-rail transporter is easier in low winds (0-30 mph) (0-13.4 m/sec) than on the roller transporter. Lifting and emplacing roller sections would be more difficult during high wind or wind gusts.

(c) Cross Wind and Sea-State Limits on the Intracoastal/Ocean Barge Route

Cross wind limits for safe barge towing on the Intracoastal Waterway and maximum sea-state conditions during ocean transit were not identified; however, maximum utilization of weather forecasts will permit scheduling of the 4-day barge trip between DCP and KSC during periods when safe navigation can be expected. Harbors along the route can be specified for safe berthing in the event weather conditions change suddenly during transit. It is evident that the large sail area of the existing ARD barges can present a considerable navigation problem in the narrow (100 ft wide) (30.5 m) channels with a significant cross wind.

Acceleration data on a Saturn S-IV-5 stage shipment [11] indicated a maximum of 1.24 g's. Because of the much heavier weight of the 260-in.- (6.6-m) dia stage, it is expected that the shipping acceleration (g's) will be less.

(d) Rain

Prior to lifting the stage from the C&C facility, the stage will be internally pressurized and sealed against the environment of rain and humidity. Handling the stage during rain should not be a problem. The crane, derrick, or winch systems must be so designed and capable of operating in such an environment. Extra caution must be exercised by personnel during handling in the rain to prevent accidents due to slipping and falling. Methods that require the least number of personnel operations are most desirable. Lifting the stage from the C&C facility by the derrick and placement directly on the transporter on the barge should require the least time and number of operations. No bridge installation betweeen the dock and barge would be required with this method. However, moving the transporter on roller sections would require a greater number of operations. In addition, alignment and guidance in the rain on roller sections would be more difficult than by the truck-rail method.

(e) Lightning Hazard

If lightning were to strike a 260-in.-(6.6-m) dia stage, it would probably travel along the outside of the chamber or raceway. It is doubtful that the motor would ignite, but local heat damage to accessories, chamber hot spots, and chamber/grain unbonding is possible. Therefore, all facilities and handling and shipping equipment will be equipped with lightning rods to protect the stage during an electrical storm. All the lift devices are easily grounded. The winch system at DCP permits the stage to remain horizontal on the ground, therefore the lightning hazard is not as great as when the stage is lifted vertically out of the C&C facility. Lightning hazard should not be a significant criteria in selecting the method of handling.

(6) Motor Storage at KSC

With the concurrence of the NASA/LeRC Project Manager, it was assumed for the purpose of this study that motor storage at KSC will involve up to three motors at any one time and that the maximum storage period for any one motor will be 6 months. The maximum storage quantity was based on having one motor ready for transfer to the launch complex, one spare motor, and one reject awaiting rework, repair, or return to the manufacturing facility.

In planning the storage area location and facility characteristics, it was first necessary to establish whether the motors will be stored separately or together. If the motors were stored separately with sufficient isolation, a fire or other disaster would involve only one motor. However, three separate storage facilities with barge access would be required. This would cost far more than a single storage area capable of handling three motors. Also, location of three suitable storage sites at KSC would be difficult. In view of the very small probability of a catastrophic occurrence, together with the likelihood that three motors will seldom be in storage at one time, it was decided to provide for a single storage location.

KSC Safety Office personnel have indicated that a 5% TNT equivalency value would be approved and concurred with by KSC Safety as the basis for establishing the explosive hazard distances for 260-in.- (6.6-m) dia motors in storage. In discussions with the KSC Safety Office, it was indicated that the Air Force applies 0% equivalency to the 120-in.- (3.05-m) dia solid-rocket motors used on the Titan IIIC launch vehicle. At the Titan IIIC Complex, the governing consideration is the hypergolic fuels of the core stages, and not the solid strap-on motors.

The total propellant weight of three 260-in.- (6.6-m) dia motors in storage will be 10.2 million lb (4.46 million kg). For a TNT equivalency of 5%, the equivalent TNT quantity under this condition is 510,000 lb (232,000 kg). Based on the KSC Explosives Safety Handbook[12] the required separation distance from the nearest inhabited building is 5,410 ft (1,650 m). The expected blast overpressure at this distance based on the Kingery correlation[13] is 0.58 psi (0.4 N/cm^2). This overpressure level was deemed by the KSC Safety Office to be within adequate limits for personnel safety. The overpressure contour radii were also calculated for three overpressure levels frequently used as criteria for explosive hazards analysis. These values, again based on the Kingery correlation, are shown below:

Peak Side-On Overpressure, psi(N/cm^2)	Radius of Overpressure Contour, ft(m)	Hazard Level
2.0 (1.38)	2,160 (658)	Safe for personnel in windowless, lightly reinforced concrete structures.
0.4 (0.274)	7,030 (2140)	Safe for unprotected personnel.
0.2 (0.138)	11,600 (3540)	Safe for unrestricted access.

Based on evaluation of these overpressure contours and separation distances, two tentative sites were identified for the 260-in.-(6.6-m) dia motor storage and checkout facility at KSC. One site (Figure 17) is at the CKAFS Solid Propellant Storage Area on the east bank of the Banana River. The availability of access roads and utilities at this location would minimize the costs of establishing the storage facility. However, selection of this site could require relocation of some inhabited facilities that fall within the 5,410 ft (1650 m) hazard radius. The alternative site (also shown in Figure 17) is across the Banana River and would not conflict with any existing facilities. There would, however, be additional costs for the required access roads, and for water, power, and telephone lines. These trade-offs are discussed further in Section III.C.4.a.

The configuration of the storage and checkout building is shown in Figure 18. The all-weather facility includes air-conditioning equipment with a 200-ton cooling capacity to maintain the storage environment at 80 ± 20°F (300 ± 267°K) with a maximum relative humidity of 45%. Each of the three motor bays contains a road bed for either the steel roller or truck-rail type of transporter. The motors will remain on their transporters during storage. Removal of the motors from the transporters was considered and rejected because of the complexity of the necessary equipment, the additional risk of motor damage, and the reduction in program flexibility resulting from off-transporter storage.

The primary hazard to the motors in the storage area is fire and inadvertent ignition. Maximum fire precautions will be exercised within a 2,000 ft (610 m) radius of the storage facility. Personnel access within the 5,140 ft (1,650 m) explosive hazard radius will be limited to those with a specific operational assignment in the area.

Storage considerations have little impact on the selection of the optimum handling method. The only effect envisioned is a small cost differential between the two types of roadbeds required for the alternative transporter concepts.

(7) Commonality of Tooling, Equipment, and Facilities

Data showing the commonality of tooling, equipment, and facilities between the DCP and the KSC storage area and launch area are presented in Tables 7, 8 and 9 for Handling Methods No. 1, 2 and 3, respectively. The commonality of tooling, equipment, and facilities is also summarized for the three handling methods in Table 10.

The use of common items reduces the initial design, procurement, and installation costs as well as the inventory value of required spare parts. In addition, the use of common items can reduce the extent of personnel training required and results in increased reliability of operation of the handling method. As seen in Table 10, Handling Method No. 2 exhibits the highest degree of commonality between the DCP and the KSC location.

(8) Handling of 1.6 M and 5.0 M lb (726 Mg and 2268 Mg) Propellant-Weight Motor

The first task in this refinement activity was to establish the configurations of the two different propellant weight motors. The resulting motor dimensions and weights are shown in Figure 19.

The 1.6 M lb (726 Mg) motor was scaled down from a previous design of a 260-in.- (6.6-m) dia motor with a forward fin/cylindrical bore grain in a 260-SL (short length) size chamber. The resulting 1.6 M lb (726 Mg) motor has a chamber cylinder length of 403 in. (10.3 m), as compared with 510 in. (13.0 m) for the 260-SL motors. The conical nozzle has an 11:1 expansion ratio. TVC and electrical equipment is packaged in a 260-in.- (6.6-m) dia cylindrical aft housing. Total motor handling weight exclusive of handling rings is 1,762,000 lb (800.000 kg).

The 5.0 M lb (2268 Mg) motor was scaled up from a 260-in.- (6.6-m) dia growth-version motor design prepared under Contract NAS7-513. This growth-version design contained 4,535,000 lb (2,060,000 kg) of propellant, so only a small extrapolation was required to achieve the desired configuration. The 5.0 M lb (2268 Mg) motor incorporates a conical nozzle with an 11:1 expansion ratio and an exit plane diameter of 360 in. (9.15 m). To accommodate the necessary equipment around this large nozzle, the aft-flare base diameter was increased from 355 to 380 in. (9.03 to 9.65 m). Total motor handling weight exclusive of handling rings is 5,460,000 lb (2,480,000 kg).

An evaluation was made of the changes necessary to the major components for each handling method to provide the capability for handling the alternative propellant-weight motors. The results of this analysis are summarized in Tables 11, 12, and 13. As anticipated, the small motor can be handled with few changes, but the large motor requires significant modifications to almost every element of the handling systems.

Handling Method No. 3 is clearly the least flexible of the three approaches. Modification to the C&C facility winch system is required even for the 1.6 M lb (726 Mg) motor. The major changes needed to handle the 5.0 M lb (2268 Mg) motor exceed those required with the other two methods.

Handling Method No. 2 appears to require fewer significant changes than Method No. 1 for handling the 5.0 M lb (2268 Mg) motor. In both cases, a 50% increase in the height and capacity of the mobile gantry is necessary. However, Handling Method No. 1 also requires a 50% increase in the lift height and load capacity of the stiff-leg derrick at the C&C facility. This increase exceeds the capability of the developed components that make up the derrick system for the baseline motor handling method. This does not necessarily mean that Method No. 1 has to be more costly to modify than Method No. 2. However, the advantages of Method No. 1 in the area of motor handling at the C&C facility are reduced.

Estimation of the differences in the cost (based on the Task I unrefined cost estimates) of modifying each handling method is shown with comparison to the baseline motor in Tables 14, 15, and 16 for Handling Methods 1, 2, and 3, respectively. It is apparent from the cost evaluation that the capability of handling 5.0 M lb (2268 Mg) motors could be built into any of the handling systems for far less than the cost of modifying the system later.

c. Comparative Examination of Three Handling Methods and Selection of the Optimum Method

Early in the program it became evident that it would be desirable to conduct comparative assessments and trade-offs for each of the major elements of the three handling methods rather than conduct assessments and trade-offs for each of the three handling methods in total. Assessment and trade-off of each element would permit the flexibility to select optimum elements from each handling method and to combine those elements into an optimum handling method based on the results of the assessment and engineering trade study. The detailed assessment and trade study information is provided in Appendix C.

Each element of the handling methods was comparatively examined with respect to specific criteria. The comparative examination criteria were: (1) total estimated cost including recurring and nonrecurring costs, (2) estimated cost for handling-method modifications to handle 1.6 M lb (726 Mg) and 5.0 M lb (2268 Mg) propellant-weight motors, (3) assessment of risk of motor damage due to imposed loads, weather, and human factors, (4) assessment of safety hazards, (5) assessment of development risk, (6) assessment of logistics and schedule problems, and (7) estimated development time.

The important influencing factors were identified and formed the basis for evaluating each assessment criterion. Tables 1 through 7 of Appendix C show the results of the assessment of the handling-method elements with respect to each individual criterion. Back-up information regarding the rating of each criterion is provided following each assessment criterion table (Tables 1 through 7) of Appendix C. It should be noted that elements common to each of the three handling methods, e.g., barge canals and storage facilities, were not included in the assessment or subsequent engineering trade-study.

Each assessment criterion was first evaluated on a common basis without any weighting of the factors involved. A value of 90 was selected to represent the best rating for any factor and this value was used consistently throughout the comparative assessment for all criteria. The costs used in the assessment of total estimated recurring and nonrecurring costs were established on the basis of the function accomplished. The individual-handling method element-cost ratings include all tooling, equipment, and facilities necessary to accomplish that function.

The total rating of each individual assessment was incorporated in the engineering trade-study without any further adjustment of the rating except to establish the weighted distribution of each assessment criterion according to its relative importance. The weighted percentage ratings assigned to each assessment criterion were: (1) estimated cost - 100%, (2) estimated cost for modifications to handle alternative weight motors - 40%, (3) risk of motor damage - 95%, (4) safety hazards - 90%, (5) risk of unsuccessful development - 80%, (6) logistics and schedule problems - 70%, and (7) development time - 60%.

The handling method trade-study is shown in Table 8 of Appendix C. The optimum handling method recommendations based on the results of the trade-study were:

2000-ton (1,816-Mg) stiff-leg derrick at DCP

Mobile gantry with Roll-Ramp actuator at KSC

Truck-tail type transporter at DCP and KSC

New barge design

Internal pressurization as a means of midcylinder support in the event such support is required

The recommendations for the optimum handling method were approved by the NASA/LeRC Project Manager with the following exceptions:

The definition of the requirement and type of midcylinder motor support was deferred pending completion of the motor stress analyses (see Section III.C.3).

Selection of the modified ARD barge vs a new barge design was deferred to Task IV (see Section III.C.4.a) with a continued effort to determine the availability and existing condition of the ARD barge.

2. Examination of Alternative Destinations and Motor Design Task II

Task II was accomplished to determine selected handling method modifications when considering: (1) transport of the 260-in.- (6.6 m) dia stage to the WTR, (2) transport of the 260-in.- (6.6-m) dia stage to the NASA C-T, and (3) transport of a segmented configuration of the 260-in.- (6.6-m) dia stage to the NASA-KSC LC-37B.

a. United States Air Force Western Test Range (WTR)

(1) Launch Pad Location

The terrain of the USAF WTR was surveyed for the purpose of selecting a likely launch pad location. The terrain is hilly with a characteristic cliff varying in height from about 19 to 150 ft (5.8 to 45.7 m) near the shore line. The exception to this characteristic sharp drop is in the Santa Ynez River valley that extends to the river mouth at the ocean. Two likely launch pad locations were identified and are shown in Figure 20. These locations are: (1) in the Santa Ynez River valley, and (2) in the Boathouse area along the coast just south of Point Arguello.

From the standpoint of handling-method simplicity, location of the launch pad in the Santa Ynez River valley would be most desirable. Access to the area from the ocean is available without the necessity for traveling long distances inland and the area is relatively flat. The terrain elevation from the shore line to approximately 7300 ft (2230 m) inland varies from about 3 ft to 19 ft (0.9 to 5.8 m) above mean sea level (Figure 21). The inland terrain elevation gradually increases beyond 7300 ft (2230 m) from the shore line.

Access to the pad area in the valley could be readily provided by means of a dredged channel. The ocean entrance to the channel would have to be protected by a jetty and breakwater. A graving/offloading dock facility and mobile gantry, similar to the concept identified for use at the KSC, would be required at WTR for offloading, stage rotation, and erection of the stage on the launch pad. Paved roads and water and electric utililies are available in the vicinity but not necessarily in the immediate area that would be selected for the launch complex.

The soil structure in the valley is gravelly sands and silty sands; therefore, the ability to place adequate mobile gantry, truck-rail transporter, and launch pad foundations in the valley area will have to be investigated and verified prior to acceptance of the area as a launch site. Currently, there is an ocean-front section of the beach adjacent to the mouth of the Santa Ynez River that is used as a County recreation area (see Figure 21). The recreational use of the area would likely have to be denied in the event the valley was used as a launch site. Also, in discussion with the Civil Engineering Branch at Vandenberg Air Force Base (VAFB), it was learned that the valley is subject to flooding in periods of abnormally high rainfall. It was indicated that tentative long-range flood-control plans call for placing a dam upstream on the Santa Ynez River that would minimize problems associated with flooding. A public railroad (Figure 21) runs along the coastline of VAFB and crosses the Santa Ynez River a short distance inland from the shore line. Channel access to the valley from the ocean would require that either the public railroad be rerouted around VAFB or that the existing trestle be replaced by a bascule, or similar type, rail bridge.

Discussions with Civil Engineering and Range Safety personnel at VAFB revealed several important factors that would require thorough investigation and approval prior to acceptance of the Santa Ynez River valley as a launch site. The areas of investigation are not limited to, but include:

(a) Quantity-Distance Safety Standards

TNT equivalency ratings for the booster stage and the launch vehicle would have to be evaluated and accepted by the Safety Office. After establishing the quantity-distance safety standards, the position of the launch site will have to be evaluated with respect to the explosive and fire hazard to personnel and existing structures.

(b) Toxicity

The type and degree of toxicity of the booster stage products of combustion will have to be determined. Then, the dispersal of the toxic products will be evaluated to determine the toxic hazard within the base boundary and nearby populated towns (see Figure 20).

(c) Launch Trajectory

The launch trajectory (launch azimuth) vs launch site will have to be investigated to assure that the vehicle remains within the established impact line envelope during launch and flight over land.

(d) Overflight of Existing Facilities

Vehicle launch into a polar orbit from the Santa Ynez River valley would require overflight of some existing launch facilities. The potential hazard to existing facilities would have to be investigated and approved by the appropriate WTR agencies.

The alternative choice for a likely launch pad location is just south of the point at the Boathouse area on Point Arguello. Typically, in this area, the rocky beach extends inland a very short distance and is bounded by a steep cliff approximately 50 ft (15.3 m) high, (Figure 22). Inland from the cliff, the terrain is hilly, (Figure 23). Access to this area would be accomplished by one of the two means: (1) offloading in the Santa Ynez River valley, as described above, and transporting the stage on the truck-rail transporter an estimated 11.5 miles (18,500 m) to the launch area (the transporter would have to climb fairly steep grades or the rail-bed would have to be elevated and constructed to a specific grade), and (2) offloading along the coast near the Boathouse. Offloading near the site would require new graving/offloading dock facilities and a harbor protected by jetties and a breakwater. Additionally, facilities would be required to either: (1) elevate the stage a distance equivalent to the 50 ft (15,3 m) cliff height, (2) lift the stage in combination with excavation to reduce the lift height, or (3) complete excavation of the area. Facilities to elevate the stage/transporter/rail foundation, e.g., elevation in steps using jacks, are expected to be very costly. Also, excavation in the area is expected to be very costly since an extensive amount of shale may be encountered. It is apparent that more knowledge of the ground structure is required before a decision could be made regarding the optimum offloading location and optimum handling methods in the Boathouse area.

The public railroad also travels near the coast in the Boathouse area, (Figure 23). However, in the Boathouse area, it appears that the railroad would have to be rerouted unless excavation of the area was selected or safety considerations permitted use of the railroad near the launch site. The excavation would have to be deep enough to allow the stage/transporter to clear the rail trestle, or, a bascule-type rail bridge would have to be used. After moving the stage/transporter to launch pad level, a mobile gantry similar to that specified for use at KSC would be required for stage rotation to the vertical position and placement of the stage on the launch pad. Paved roads and water and electricity are available in the vicinity, but not necessarily in the immediate area selected for the launch pad.

The technical areas that would have to be evaluated and approved by the appropriate WTR agencies prior to establishing the launch site in the Point Arguello area are the same as identified above for the Santa Ynez River valley. The exception is that nearly all polar launches from WTR would overfly the 260-in.- (6.6-m) dia stage launch area.

(2) Changes in the Selected Handling Method

It is expected that the handling methods selected for use in handling and transporting the stage between the DCP and KSC would also be used to transport the stage to the WTR. The differences would principally be the harbor facilities at either the Santa Ynez River valley or Boathouse areas and stage elevation facilities (or excavation) at the Boathouse area. Selection of a stage storage site at WTR was not established as part of the scope of this task, however, it is apparent that location of a stage storage site would be hampered by limited available space where access to the area could be reasonably obtained.

It is not considered possible to make estimates concerning WTR handling-method costs and development time since the location of the launch site cannot be resolved within the scope of this program.

(3) Shipping Schedule

The shipping schedule for one complete round trip from the DCP to WTR and return is shown in Figure 24. The cycle is estimated to take 82 days. This includes 5 days, each, for loading and offloading, 1 day each way in the inland waterway between the DCP and the Atlantic Ocean, and 35 days barge travel time each way.

Based on this schedule, it is estimated that the additional tooling and facilities required (excluding facilities required by the selection of a specific WTR launch site) for the alternative WTR destination are one additional set of heavy duty handling rings and one additional barge. Assuming a launch rate of six motors per year for 5 years, a very unlikely improvement of 22 days in the schedule would be required before it would be theoretically possible to meet the schedule with only one barge. Then, it would require 100 percent time utilization for 5 years. This is not considered practical since it would not leave any time for maintenance, repair, or bad-weather delays.

(4) Environmental Protection

Only passive environmental protection is planned for the 260-in.- (6.6-m) dia motor during the 4-day barge trip from the DCP to KSC. More extensive environmental control will be needed during the barge trip to the alternative WTR destination. In addition to the extended duration of the trip to WTR, the shipment is likely to encounter wider extremes in weather conditions during the approximately 4,500 mile (8,200 km) voyage.

For shipment to KSC, the motor will be inside a protective cover that will shade the motor from direct sunlight and prevent ocean spray from impinging on the motor. The interior of the motor will be purged and pressurized to 1.5 psig (1.035 N/cm^2, gage) with dry nitrogen. During the barge trip to WTR, it will, in addition, be necessary to provide air conditioning equipment to maintain the temperature within the protective cover between 60 and 100°F (289 and 311°K). The relative humidity will be controlled to a maximum of 45%. The protective cover over the motor will be essentially air-tight and will be thermally insulated to improve the efficiency of the conditioning system.

(5) Risk of Motor Damage

There are no specific conditions that are expected to be encountered on the trip to WTR that would impose a greater risk of motor damage than the trip from the DCP to KSC. The barge and stage support/tie-down tooling will be capable of withstanding loads associated with normal ocean travel. However, the barge and stage support/tie-down structure is not intended to operate in severe storm conditions.

The short duration trip from the DCP to KSC permits maximum use of weather forecasting to minimize the possibility of encountering a storm while on the open sea. The estimated 35 days on the open sea to WTR does increase the possibility, on a statistical basis, that at sometime storm conditions could be encountered where it may not be possible to reach safe shelter and where stage damage may occur.

Although it is considered to be a relatively minor concern, it is possible that motor damage could occur from failure of the environmental control air conditioning system at a time when it was required and when the nature of the failure would not permit repair of the system while enroute.

III.C. Results (cont)

b. Saturn V Crawler-Transporter at KSC

The Saturn V C-T is located at KSC in the LC-39 area. The motor stage will be shipped by barge to KSC via the same route defined for the selected handling method and reported under Task I in Section III.C.1.a. The stage will be routed northward in the Banana River Canal to the receiving station at the Saturn V facility area shown in Figure 25. The existing canal will be widened from the Titan IIIC complex turn-off to the Saturn V receiving station, a distance of 26,000 feet (7,940 m). Additionally, a new 3000 ft (915 m) canal is required for access to the C-T as shown in Figure 26. The graving/offloading dock at the LC-39 area is shown in Figure 27.

The handling methods recommended in Task I (Section III.C.1.c) for handling and shipping the 260-in.- (6.6-m) dia stage between the DCP, the storage facility at KSC, and the KSC LC-37 area are also recommended for handling and shipping the stage to the Saturn V C-T. The major elements of the handling method involved with operations at KSC are identified below:

Graving/offloading dock at the Saturn V receivion station.

New barge.

Truck-rail stage transporter.

Truck-rail transporter foundation.

Rotation pit.

Mobile gantry with Roll Ramp actuators.

Mobile gantry rail foundation.

The stage handling method from the graving/offloading dock to the Saturn V C-T is shown in Figure 28. Figure 29 illustrates the stage on the C-T. It should be noted that the requirement to define the configuration of the C-T stage support structure is not within the scope of this program. The Slide Base (new) and the Transportation Spacer (new) shown in Figure 29 are concepts that could be incorporated with the use of the C-T. However, for purposes of this study, it was assumed that placement of the stage on the C-T support structure would be no more complex or costly than placement on the LC-37 Pad B support structure, with regard to the interface between the stage aft support skirt and the C-T support structure.

The estimated nonrecurring cost for the C-T alternative destination is shown in Table 17. It should be noted that the costs shown in Table 17 are based on costs developed in Task I and do not necessarily represent final cost estimates for comparable elements developed in Task IV (see Section III.C.4.d).

An analysis of each operation involved in handling and shipping the stage to the C-T site reveals that there are no areas where development risks, logistics, safety hazards, and development time would be significantly different than for the LC-37 primary site. It should be noted that the analysis covers operations only through placement of the stage on the C-T and does not include consideration of the C-T stage support structure or any operations beyond placement of the stage on the C-T.

c. Segmented Motor Configuration

Each element of the handling method selected in Task I was evaluated to determine if net cost, reliability, or safety advantages exist when considering handling of a segmented 260-in.- (6.6-m) dia stage.

Increasing the number of segments would reduce the size and weight of each segment and would permit the use of smaller, less expensive, lifting, handling, and shipping equipment; however, a larger number of handling operations and equipment would be required. Increasing the number of segments increases the basic motor weight due to the added weight of the chamber joints and propellant restrictors. The additional inert stage weight results in a loss in burnout velocity as compared to that provided by the monolithic motor. Therefore, a larger and heavier segmented motor is required to provide the same performance as the monolithic motor.

(1) Segmented Motor Design

Both three- and eight-segment configurations were evaluated initially to determine segment size and weight. The three- and eight-segment configurations shown in Figures 30 and 31, respectively, are similar to the segmented motor evaluated under Contract NAS7-513[9]. The chamber segments are joined by pin and clevis joints as shown in Figure 32. The propellant grain segments are restricted on the ends by a 0.75 in. (1.9 cm) thickness of IBC-101 insulation and a 1.00 in. (2.54 cm) thickness of Vibradamp pad, which is compressed on assembly to a 0.50 in. (1.27 cm) thickness. For this study, the propellant grain configuration was assumed to be similar to that of the monolithic grain except for the end restrictors. No attempt was made to redesign the propellant grain for the three- and eight-segment motors. As stated above, the added weight of the chamber joints and grain restrictors requires a larger motor to provide the same performance as the monolithic motor. This additional weight is reflected in the designs shown in Figures 30 and 31, which indicate the adjusted motor length and nozzle size. The aft segment represents a complete assembly, less TVC injectant, roll control propellant, and ordnance devices. The aft-flare assembly will be joined to the aft chamber segment and will be handled and shipped as a unit.

The three-segment design (Figure 30) consists of three equal-length chamber segments of 440.89 in. (11.2 m). The forward and center segments would weigh 1,247,300 lb (565,000 kg) and 1,358,000 lb (615,000 kg), respectively. The aft regment assembly would be 811.16-in. (20.6-m) long and would weigh 1,306,400 lb (593,000 kg). The nozzle would have a 90.43-in. (2.3-m) throat diameter, a 299.78-in. (7.6-m) exit diameter (ε = 11.0), and a length of 370.27 in. (9.4 m). The three-segment stage would be 38.41 in. (0.975-m) longer and 123,800 lb (56,100 kg) heavier than the monolithic design. The additional stage weight consists of 101,800 lb (46,200 kg) of propellant and 22,000 lb (10,000 kg) of inert components.

The eight-segment design (Figure 31) consists of a forward segment with a joint 11-in. (27.4-cm) aft of the forward equator, an aft segment with a joint 11-in. (27.4 cm) forward of the aft equator, and six equal-length center segments. The forward segment would be 141.12-in. (3.58-m) long and would weigh 307,700 lb (140,000 kg). Each center segment would be 195.27-in. (4.97-m) long and would weigh approximately 608,700 lb (277,000 kg). The aft segment and flare assembly would be 488.41-in. (12.4-m) long and would weigh 309,000 lb (140,000 kg). The nozzle would have a 93.61-in. (2.38-m) throat diameter, a 310.32-in. (7.88-m) exit diameter (ε = 11.0), and a length of 383.26 in. (9.74 m). The eight segment stage would be 133.6 in. (3.4-m) longer and 433,200 lb (196,500 kg) heavier than the monolithic design. The additional weight would consist of 353,800 lb (161,000 kg) of propellant and 79,400 lb (36,000 kg) of inert components.

(2) Selected Segmented Motor Design

After a cursory evaluation of handling requirements for the three- and eight-segment designs, the eight-segment configuration was elected for further detailed study. The main advantage of segmenting, with respect to this study, is in reducing the size and weight of the components to be handled and shipped. The three-segment design has segments that are still relatively large and heavy, requiring large lifting devices and handlin equipment. Smaller segments permit cost savings in the lifting device, trans porter, road bed, and truck-rail foundation and are traded against quantities of tooling and increased labor costs for processing, handling, and assembly. It is not intended to indicate that the selection of the eight-segment motor configuration evaluated in this study represents the optimum segmented motor design for either motor performance or total program cost considerations. The limited scope of this effort is intended to . . . "determine if net cost reliability or safety advantages . . ." with respect to stage handling when a segmented 260-in.- (6.6-m) dia motor is considered in lieu of the unitized motor. The eight-segment configuration provides a more effective basis for this evaluation than would the three-segment configuration. Handling-ring estimated weights for the various segments of the eight-segment configuration are:

Forward segment	40,000 lb (18,200 kg)
Center segment	79,000 lb (35,800 kg)
Aft segment	47,000 lb (21,300 kg)

(3) Shipping Method

Overland shipping of the segments by road, rail, and air were initially evaluated. The motor segments are considered too large and too heavy for shipment from the DCP to KSC by any means other than by barge. The schedule for shipment of the segments is shown in Figure 33. This schedule reflects the use of a barge the equivalent size required to ship the unitized motor stage and is based on carrying all eight motor segments per shipment as shown in Figure 34. The barge route would be identical to that selected in Task I for shipment of the unitized stage.

The use of a smaller size barge with a smaller number of segments per shipment is not expected to be economical over the 5-year program from the standpoint of recurring labor costs and tow tug charges. Additionally, it is expected that the segments can be lifted from the barge individually without the necessity of having the barge ballasted to rest on a graving dock.

Initially, road transport of the segments from the KSC storage facility to the LC-37 launch pad was considered. Accordingly, a pneumatic tired transporter utilizing existing road systems at KSC Merritt Island (MILA) and the CKAFS was investigated.

The basic results of the analysis are presented in Appendix D. The overall conclusion derived from this secondary analysis was that barge transport of the segmented motor from KSC-MILA storage to LC-37B would be the most practical and economical method of segment transport, even for the short distances involved within the KSC.

(4) Segment Handling Method

The GSE items for handling and receiving will increase to allow for more slings and adapters to accommodate the segmented motor configuration. Also, the electrical grounding system will be slightly more elaborate to provide continuous grounding of all the segments.

The rotating pit required for rotation of the unitized motor will not be required for rotation of the segments. A segment rotation A-frame will be provided at the launch site for rotation of the segments to the vertical position. The aft-segment assembly will have one handling ring attached to the motor case and one ring attached to the aft end of the aft flare. Similarly, the forward segment will have one handling ring attached to the aft end of the segment case and one handling ring attached to the forward skirt. Because the forward and aft segments will have different dimensions, special adapters for the segment rotation A-frame will be provided for rotation of the forward and aft segments to the vertical position.

Two basic methods have been investigated for overland movement of segments in proximity to the DCP processing site and the KSC launch and storage sites; these are the overhead traveling crane and truck-rail transporter. In each of the two methods, the truck-rail transporter is used to move the segment from the launch area dock to the launch pad, whereas the overhead traveling crane is used to move and position segments within the storage building. The two methods are discussed below:

(a) Handling by Overhead Traveling Crane

At the DCP, the overhead traveling crane is provided with sufficient track length to service the propellant processing, stage assembly, and barge loading areas (Figure 35). The segments will be placed on support frames previously positioned on the barge. Loading (and offloading) segments on the barge individually in this manner will eliminate the necessity for a graving dock, barge alignment equipment, and a barge-to-dock bridge structure. Also, this concept of barge loading and offloading would be used at the KSC storage and launch area docks.

After arrival of the segments at the KSC storage facility dock, each segment will be removed from the barge using an overhead traveling crane. The overhead crane track extends from the loading/offloading dock a distance of 200 ft (61.0 m) to the storage building and continues the full length of the storage building. After lifting the segment from the barge, the segment will be transported into the storage building and positioned on storage saddles using the overhead traveling crane. Removal of the segments from storage will be accomplished following the reverse of the procedure described above.

Segments arriving at the launch area dock will be offloaded using an overhead traveling crane. The overhead crane is provided with 200 ft (61.0 m) of track, which is sufficient to span the dock and the segment transporter loading area. After removal from the barge, each segment will be lowered into position on a segment truck-tail transporter. Then, each segment will be moved on the truck-rail transporter to the launch pad. Using the lifting device at the pad, the segment will be removed from the transporter, positioned in the A-frame rotation fixture, rotated to the vertical position, and then lifted and assembled on the launch pad.

The listing of equipment and facilities required and the estimated nonrecurring costs for the handling method are shown in Table 18.

(b) Handling by Truck-Rail Transporter

Segments will be handled in the C&C at the DCP using the overhead traveling crane. After completion of propellant processing, the segment will be loaded on the truck-rail transporter. Sufficient transporter track is provided to route the segment through the trim and final assembly building, and to the barge loading dock (Figure 36). Prior to segment loading, the barge will be positioned, aligned, and ballasted to rest on the graving dock. The barge-to-dock rail bridge structure will then be installed, and the segments will be rolled onto the barge and secured in position.

After arrival at the KSC storage area dock, the barge will be positioned, aligned, and ballasted to rest on the graving dock. The barge-to-dock rail bridge structure will then be installed, and the segments will be rolled off the barge on the truck-rail transporter and moved to the storage building. The segments will be removed from the transporter and placed in storage position on saddles using the storage building overhead traveling crane. It should be noted that alternative methods of handling the segments within the storage building were considered and reject One approach that was rejected was to move the segments straight into the building in-line on the transporter rail. This approach offered no flexibil ity since, in the worst case, eleven segments would have to be removed from the building to remove the last segment. To avoid this problem, another approach considered the use of a mobile transporter turntable. In this approach, the turntable (with segment and rail transporter) would be rolled to the storage position and rotated 90 degrees; then the segment would be rolled off the turntable onto the rails in the storage bay. This approach was rejected because of the cost and complexity of the system and because any maintenance and repair on the mobile turntable would require the use of a crane.

The barge arriving at the launch area dock would be positioned, aligned, and ballasted to rest on the graving dock. The barge-to-dock rail bridge structure would then be installed, and the segment transporter would be rolled off the barge onto the loading/offloading dock. Segment transport to the pad, segment removal from the transporter, and segment rotation and placement on the launch pad would be identical to the method described above in Section III.C.2.c.(4).(a) for the overhead traveling crane method.

A listing of the equipment and facilities required and of the estimated nonrecurring costs for the truck-rail transporter method is shown in Table 19.

(5) Selection of the Segment Handling Method

The overhead traveling crane handling method was selected as the desirable method for motor segment handling. The selection was based principally on the lower nonrecurring costs. Safety and reliability considerations are not appreciably different between the overhead traveling crane and the truck-rail transporter methods.

A simplified, truck-less support frame would be used on the barge to support the segments. After arrival at the KSC launch area dock, the stage/support frame assembly would be removed from the barge and placed on the truck assemblies of a rail transporter (Figure 37). A special transporter adapter will be used with the forward segment to adjust the length between trunnions. A separate transporter with added length between trunnions and with increased width betweeen aft-flare handling-ring trunnion cradles will be used with the aft segment.

The stage storage requirements at KSC were identified as a maximum of 12 segments. The total of 12 segments is equivalent to one complete stage (eight segments), plus one each forward, aft, and center segment (three segments) and one reject segment.

The segment storage site will remain the same as selected for storage of the unitized motor. Even though the blast over-pressure is less for the 12 segment storage than for storage of three unitized motors, the over-pressure factor is considered insufficient to warrant relocation of this facility. Although inadvertent ignition of the motor is improbable, the factor of inadvertent flight is further reduced for segment storage since each segment contains only a portion of the total motor propellant and because the individual segment assembly would develop very little thrust in the event of inadvertent ignition. The segmented storage building floor space is approximately two-thirds of the unitized motor requirement, Figure 38. As previously discussed, the storage building will have an overhead traveling crane to provide the flexibility of selectively moving segments in and out of storage. The handling rings will rest on storage saddles as shown in Figure 39.

The barge-mounted environmental cover for the stage will differ slightly from the unitized motor requirement. It is planned to ship the segments using essentially the same type of unitized motor cover except that the top of the cover will open to provide access to the segments. In addition, a small sunshade will be required for use on the barge when moving segments individually from storage to the launch facility and vice versa.

The 1000-ton (908-Mg) capacity stiff-leg derrick wa selected for segment handling and motor assembly at the KSC LC-37B. The problem of having to reach over the booster (Figure 40) being stacked can be circumvented by the offset alignment of the transporter system and the stiff-leg derrick. This configuration is illustrated in Figure 41.

A fully rotating erection crane, Manitowoc Ringer concept (Figure 42), having sufficient load carrying capacity at the necessary operating radius was investigated to a limited extent. Some information was obtained on this equipment through the W. L. Sly Machinery Company of Tampa, Florida. The information provided indicates that the existing (barge-mounted) Manitowoc Model Seacrane 600 has the required capacity and operating radius. However, sufficient information was not obtained to permit further evaluation.

Utilization of the Manitowoc Ringer concept would require erection and removal from the pad area prior to each launch. A special load carrying foundation would be required at the pad. This foundation would have to accommodate the 2.5 M lb (1133 Mg) dead weight of the Ringer plus the 0.75 M lb (227 to 340 Mg) load of the heaviest motor segment. While a cost estimate was not provided, indications are that the Ringer type crane will have a relatively high initial cost.

The estimated costs (based on Task I cost estimates) for segment handling methods (Tables 18 and 19) were developed to determine the impact of segmenting on the recommended unitized motor handling method (selected in Task I). No attempt was made, or intended, to perform a trade-study of overall program costs between the unitized and segmented motor configurations. It is apparent that the smaller weight of the motor segments as compared to the unitized motor permits use of lighter weight, and therefore less costly, handling tooling and equipment. However, it should be recognized that costs associated with (1) production of a larger segmented motor to obtain performance equal to the unitized motor, (2) higher cost case fabrication, (3) more extensive inspection requirements, and (4) increased recurring and nonrecurring costs associated with motor processing and assembly, are important factors that can significantly influence the outcome of a segmented vs unitized motor program trade-study.

The risk of motor damage is greater with the segmented motor configuration due to the increased number of required handling operations; however, the extent of damage for any one incident would be considerably less except for some mishap during assembly of the final segment on the launch pad that could damage the entire motor.

The segmented motor has potential failure modes associated with the case segment joint and the segment grain-face restrictors that do not exist with the unitized motor. On a qualitative basis, these two failure modes will result in a lower level of reliability for the segmented motor than for the unitized motor. This assessment is made assuming no difference between the segmented and unitized motors other than the aspect of segmenting. It is apparent that segmenting is well understood and that sufficient margins of safety could be incorporated in the segmented motor design to obtain any reasonably desired level of reliability.

3. Motor Stress Analyses (Task III)

Static and dynamic structural analyses were accomplished to establish the structural integrity of the motor (propellant grain and motor case) when subjected to critical handling method operations. Critical stage handling operations included: (1) vertical hoisting, (2) motor inverting, (3) horizontal transport, (4) vertical storage, and (5) horizontal storage.

The structural analyses were scheduled such that pertinent data results were available at the conclusion of Task I, Evaluation of Various Handling Concepts, so that these results could be considered in the assessment of the three handling methods and selection of the optimum handling method. The remainder of the structural analyses were accomplished in support of the Task IV, Definition of the Most Economical and Reliable Handling Method, to provide complete and detailed information on the motor stresses and strains when using the tooling and equipment of the selected handling method.

A technical discussion of the motor stress analyses is provided in summary form in this section. The complete static and dynamic stress reports are provided in Appendixes B and E, respectively.

a. Motor Static Stress Analyses

(1) Propellant Grain Analysis

The initial portion of the grain stress analysis was directed toward evaluation of the three handling methods considered in Task I. For the purposes of this comparative evaluation, a simplified analytical approach was used; a fully bonded propellant grain was assumed, and the strain concentration in the grain fins was not accounted for. The results of this analysis, which are summarized in Table 4 of Appendix B, indicate that Handling Method No. 1 (stage support at the skirts only) is acceptable from a propellant-grain stress standpoint. However, Handling Methods No. 2 and 3 (midcylinder support with slings or bladder) both induce unacceptable strain levels in the propellant bore in the region of midcylinder support.

A detailed propellant-grain stress analysis was performed for all loading conditions that will occur with the selected handling method. The analysis is based on a minimum propellant temperature of 60°F and takes into account the effects of strain concentrations in the finned portion of the grain. The motor insulation system was assumed to include forward and aft released boot configurations defined in Reference (5). The results of the analysis, which are summarized in Table 7 of Appendix B, confirm that the 260-in.- (6.6-m) dia stage can be handled, transported, and stored in accordance with the selected handling method without damage to the propellant grain. The minimum margins of safety for both bore strain and bond stresses occur during long-term, 3-yr horizontal storage. The maximum bond stress exists at the aft-boot release point, while the highest bore strain occurs at the aft end of the finned section of the grain. As discussed in Section III.C.4.f (Page 109), the propellant-to-liner bond tensile stress (minimum margin of safety) can be reduced and the storage life of the motor can be extended by a modification of the aft boot design.

(2) Motor Case Analysis

The three basic methods for supporting the stage in the horizontal position, i.e., (1) support at the skirts only, considering both internal pressurization of the motor and no internal pressurization (2) support at the skirts with a pneumatic bladder midcylinder support, and (3) support at the skirts with a sling midcylinder support, were evaluated on the basis of motor case shell stresses and elastic stability (see Appendix B). Elastic stability was evaluated on the basis of statistical considerations of available classical stability theories modeled for 90 and 99% probability allowables. The 90% probability value was considered adequate for stage handling. The additional case buckling capacity developed by use of internal pressurization was analyzed. Also, the case stiffening effect of the propellant grain was analyzed and found to be negligible.

The Handling Method No. 1 (stage support at the skirts only) configuration was analyzed by assuming the motor weight to be uniformly distributed between the handling ring center lines. The nozzle and TVC weights were assumed to be concentrated at a point 150 in. (3.8 m) aft of the aft handling ring. The Handling Method No. 1 allowable transverse acceleration loads determined by bucking allowables are as follows:

Internal Pressure psi (N/cm^2)	Allowable Transverse Acceleration, g
0 (0)	2.2
20 (13.8)	3.4
50 (34.5)	3.9
100 (69.0)	4.7

Handling Methods No. 2 and 3 (pneumatic bladder and sling midcylinder support, respectively) were analyzed assuming the entire stage weight (including the handling rings) was uniformly distributed over an effective length of 1160 in. (29.5 m). It was assumed that 1/3 of the total weight would be reacted at a central support and at each of the two handling rings. The local stresses due to the central support were evaluated by means of a computer program to handle band loads on thin walled cylinders (see Appendix B, pg B-20). For this solution, the 1/3 weight central reaction was assumed to be supplied by uniform pressure over a 120° (2.1 rad) arc, 100-in. (2.5-m) lon

The allowable transverse acceleration loads determined for Handling Methods No. 2 and 3 by buckling allowables are as follows:

Internal Pressure psi (N/cm^2)		Allowable Transverse Acceleration, g
0	(0)	1.1
20	(13.8)	1.7
50	(34.5)	1.9
100	(69.0)	2.3

The allowable transverse acceleration loads given above for Handling Methods No. 1, 2, and 3 show that the use of a finite length midcylinder support system instead of a skirt (only) support system will result in lower allowable transverse acceleration handling and transportation loads. This condition is caused by the additional local bending stresses developed in the motor case shell structure at the edge of the central support load reaction.

b. Dynamic Stress Analysis

The dynamic analyses were accomplished to evaluate the 260-in.- (6.6-m) dia motor barge transportation methods with respect to structural dynamic considerations and to recommend a method that would result in successful towed barge shipments of the stage (see Appendix E).

The analyses were conducted for both longitudinal and transverse axis vibratory excitation environments. In all phases of the analyses, it was assumed that the motor would be supported in the horizontal position on a rigid barge by rigid support rings bolted to the forward and aft motor skirts. The four barge transportation methods that were considered in this dynamic analysis program were: (1) internal pressurization of the motor, (2) pneumatic support of the motor, (3) structural (sling) support at the center of the motor, and (4) no intermediate support or internal pressurization.

Emphasis was directed toward a comprehensive analytical determination of the propellant dynamic response characteristics and propellant dynamic stress. The method of dynamic analysis used in the study is based on a lumped-mass representation of the motor and propellant and a liner visco-elastic characterization of the propellant. Direct analog (force-current electro-mechanical analogy) circuit representations of the lumped-mass models of the motor were formed and the systems of linear algebraic equations derived from the anolog circuits were solved at each selected discrete frequency on an IBM System 360/65 computer.

The excitation frequencies associated with the towed barge transportation vibration environment are expected to occur in a frequency range of 0.1 to 9 cps[11]. The calculated fundamental longitudinal and transverse axis resonant frequencies of the motor vary from 1.77 to 7.0 cps.

The results of the analyses showed that an internal pressurization (Handling Method No. 1) of 10 psi (6.9 N/cm^2) had a negligible effect on the transverse-axis structural stiffness characteristics of the motor. No significant change in either the fundamental transverse-axis resonant frequency or dynamic amplification factor was calculated for the case in which the motor was internally pressurized to 10 psi (6.9 N/cm^2). The capability of the motor to withstand the vibration environments expected during barge transporation would not be improved through internal pressurization of the motor.

The addition of the intermediate pneumatic support (Handling Method No. 2) of the motor was shown to have a negligible effect on the dynamic response characteristics of the motor. The extremely low spring rate of the pneumatic support system did not have a significant effect on the first transverse axis resonant frequency of the motor and could not be recommended for use during barge transportation.

The major effort of these analyses was directed toward a structural dynamic evaluation of the effect of a structural support (Handling Method No. 3) installed at the center of the motor. Parametric studies were performed in the transverse axis of the motor for a series of structural support spring rates in the range of 2 M to 12 M lb/in. (320,000 to 1,920,000 MN/m). The highest spring rate, 12 million lb/in. (1,920,000 MN/m) was considered to be the most effective and was used throughout this study. A value of 8% critical damping was assumed for the motor intermediate structural support.

The principal results obtained from this analysis are listed in comparative form in Table I, Appendix E, for the unsupported and supported motor configurations. These results show that the addition of an intermediate structural support (sling - Handling Method No. 3) had a negligible effect on the longitudinal axis dynamic response characteristics and on the maximum calculated dynamic propellant stresses. However, the addition of the intermediate structural support produced the following changes in the transverse axis dynamic response characteristics of the motor.

(1) Increase in the fundamental transverse axis resonant frequency from 4.5 to 7.0 cps.

(2) Decrease in the dynamic amplification factor at the transverse axis resonant frequency from 4.65 to 3.70.

(3) Small decreases in dynamic stress/g amplitudes for the maximum propellant-liner bond direct (25.6 to 20.5 psi/g) (17.7 to 14.1 $N/cm^2/g$) and shear (5.2 to 3.2 psi/g) (3.6 to 2.2 $N/cm^2/g$) stresses.

III.C. Results (cont)

Although the changes in transverse axis dynamic response characteristics resulting from the addition of the intermediate structural support are favorable changes, the reductions in propellant-liner bond dynamic stresses are not considered to be of sufficient magnitude to justify a recommendation for the use of the intermediate structural support.

It is expected that the maximum acceleration levels that would occur during barge transportation of the 260-in.- (6.6-m) dia stage would be substantially less than the ± 0.51 g longitudinal and ± 1.24 g transverse isolated peak values reported for the Saturn S-IV-B stage.[11] However, for conservatism, the structural dynamics evaluation of the unsupported, unpressurized 260 stage was accomplished using acceleration levels of 0.85 g and 1.25 g (longitudinal and transverse, respectively).

For longitudinal-axis evaluation, maximum propellant-liner direct stress and shear stress values were low compared to the stress allowables (see Appendix E, pp E-17 and -18). In the transverse axis evaluation, maximum propellant-liner shear stress was low compared to the allowable stress, and direct stress was 32.0 psi (22.0 N/cm^2) (input of 1.25 g at 4.5 cps) compared to 61.0 psi (42.0 N/cm^2) allowable (see Appendix E, pp E-18 and -19).

The results of the very conservative dynamic analyses show that the 260-in.- (6.6-m) dia motor, unpressurized and without midcylinder structural support, is capable of withstanding the vibration environment that could be expected during towed-barge transportation.

4. Task IV - Definition of the Most Economical and Reliable Handling Method

The most economical and reliable handling method selected in Task I was further defined and refined in Task IV. This work was accomplished in five major areas of effort: (1) identification of the design configurations of handling method tooling, equipment, and facilities, (2) preparation of a handling method logistics plan, (3) refinement of the estimated costs, (4) preparation of a development plan, and (5) definition of the motor design details affected by handling.

The handling method tooling, equipment, and facility designs shown and discussed in this section are design concepts only. Additional work in a future program is required to establish detailed design criteria, accomplish the detailed engineering design, and verify the tooling and equipment designs by detailed structural analyses. There was no existing tooling or equipment that could be used in the handling method without modification. Section III.C.4.a, Identification of Design Configurations (which follows), identifies specific areas where existing equipment is modified for use in the handling method.

a. Identification of Design Configurations

(1) Dade County Plant (DCP)

Arrangement of the handling tooling, equipment, and facilities at the DCP C&C is shown in Figure 43. Handling method equipment and facilities shown include the 2000-ton (1,816-Mg) capacity stiff-leg derrick, stage transporter rail foundation (including modification of the existing C&C foundation), and the loading/graving dock.

The stiff-leg derrick shown in Figure 43 is capable of lifting the complete stage assembly to the height necessary to place the stage on the transporter. The barge canal, dock, and transporter track are placed in line with the derrick boom so that the stage is handled in a single plane only.

A derrick capable of handling the required load over the required distances is not in existing service. However, the American Hoist and Derrick Company, St. Paul, Minn., has a feasible design of a double-boom stiff-leg derrick as shown in Figure 44. The 2000-ton (1,816-Mg) capacity double boom stiff-leg derrick is assembled by combining existing derrick components. In this system, the struts and main boom assemblies are obtained from American Hoist and Derrick Co. Models 407 and 509 derricks, respectively. The derrick hoist system is comprised of four two-drum Model 650A hoists. These hoists are equipped with a d.c. generator and d.c. motor drives. The solid-state control system of the d.c. drives enables continuous (stepless) speed variations and permits hoisting, lowering, and positioning of the load with a high degree of accuracy. The drum assemblies, clutches, and operational and emergency brake systems of the hoists have demonstrated a high degree of reliability through extensive use in the field by commercial operators.

During vertical lifting of the stage with the 2000-ton (1,816-Mg) capacity stiff-leg derrick, the actual load suspended on each of the two booms will have to remain equal to preclude overloading either of the booms. This can be accomplished by line reeving and by linking together the two separate load tackles of each boom with an equalizing beam system, as illustrated schematically in Figure 45. Also, overloading of the derrick and the trunnions can occur during rotation of the stage from horizontal to verti cal and vice versa. During rotation, the vertical and horizontal movements o the derrick mainfalls and booms must be coordinated to preclude overloading b monitoring the lift-sling loads and making the appropriate corrections to vertical and/or horizontal movements.

In the layout of the equipment and facilities at the DCP C&C pit, the optimum arrangement would be to locate the barge graving dock adjacent to the C&C such that the 260-in.- (6.6-m) dia stage could be placed directly on the transporter positioned on the barge. The load table for the 2000-ton (1,816-Mg) capacity stiff-leg derrick limits the full-load reach of the derrick to 42 ft (12.8 m) outward from the center line of the C&C pit. The required location of the transporter trunnion cradle relative to the pit center line, to comply with maximum derrick full-load reach, is shown in Figure 43 (edge of the transporter truck maximum 2-ft (0.61 m) from pit I.D.). As shown, removal of all but 2 ft (0.61 m) of the 10-ft (3.05-m) wide pit-top collar foundation (at the center line of the transporter) would be required to position the transporter trunnion cradles at the maximum 42-ft (12.8-m) reach of the derrick. Installation of the canal adjacent to the pit with removal of a substantial portion of the collar foundation at a local area was considered questionable. However, this aspect of loading the stage directly on the barge should be re-evaluated in any future program where sufficient scope is provided to complete a more detailed design and analysis.

The transporter truck-rail foundation shown in Figure 43 is integrated with the remaining pit foundation. This approach will result in maintaining the same effective pit-top collar foundation. The transporter rail foundation will extend 200 ft (61 m) from the edge of the C&C pit to the loading/graving dock. The rail foundation is discussed in more detail in the following section.

(2) Stage Transporter

The transporter would be used to support the motor stage at all times from placement of the stage on the transporter at the DCP C&C pit to removal of the stage from the transporter at the launch pad area. Also, the transporter would be used to support the motor during any storage periods. A fairly simple transporter design evolved from the Task IV refinement and from the results of the Task III motor stress analysis that was accomplished in support of Task IV (see Section III.C.3). The motor stress analyses showed that the motor could withstand the expected handling and transportation loads without the necessity for a transporter midcylinder support. In addition, the static stress analysis verified that there were no harmful propellant grain-slump effects during the maximum horizontal storage period and that stage revolving capability was not required as a part of the transporter design.

The transporter design concept is shown in Figure 4(The truck system of the transporter would be similar to the rail trucks that have been used successfully on the KSC LC-37 mobile service structure (MSS) to transport weight in excess of 10 million lb (4,530 Mg). The weight of the 260-in.- (6.6-m) dia stage in the transport configuration would be about 4.0 M lb (1,816 Mg) and the weight of the transporter would be about 500,000 lb (227 Mg), resulting in a total weight of 4.5 M lb (2,020 Mg) on the transporter rails. The transporter will run on a four-rail track. Like the LC-37 MSS, the track will be made from 171-lb (77.5-kg) rail and each set of two rails will have a 6-ft (1.83-m) gage. The two 6-ft (1.83 m) gage track sections will be constructed on a 35 ft (10.7 m) center as required by the width of the stage transporter. The rail and rail foundation are shown in Figure 47.

The 4.5 M lb (2,020 Mg) stage/transporter weight would require the use of 32 steel 36-in.-dia (91.5-cm-dia) wheels of the type used on the existing KSC LC-37 MSS. This results in a load of 140,600 lb (63,800 kg) per wheel. The wheels would be grouped into two four-wheel truck assemblies under each trunnion. A typical truck assembly is shown in Figure 48. The truck hydraulic lift cylinders (shown in Figure 48) would provide load equilization to each wheel when transporting the 260 stage. The hydraulic lift cylinders are rated for 5,000 psi (3450 N/cm^2), are 15 in. (38.1 cm) in dia, and have an effective area of 182 in.^{2} (1170 cm^2). The transporter drive force would be provided by electric drive wheels in each of the four truck assemblies.

A steel A-frame box-beam structure would be used to support the stage weight and to transfer the stage weight to each of the four truck assemblies. The cradles at the top of the A-frame at each end of the transporter would engage the handling ring trunnions to support the stage and to act as pivot points during rotation of the stage from horizontal to vertical and vice versa. The A-frame cradles would be positioned 15.5 ft (4.73 m) above the transporter rail surface to provide sufficient stage clearance above ground and during rotation operations. Each of the four transporter A-frames would have provisions for connection of external structural members to anchor the transporter during stage rotation at DCP and at KSC and during barge shipment. Also, the transporter design incorporates longitudinal structural members to tie the forward and aft transporter trucks together. These longitudinal members and lightweight transverse structural members are installed on the transporter frame for movement of the transporter when the transporter is unloaded.

(3) 260-in.- (6.6-m) dia Stage Transport Barge

Initially, both an ARD barge and a new barge were to be evaluated in Task IV to establish the optimum barge design for stage transport. The overall measurements of ARD barges range from a 482 ft (147 m) length, with a 71 ft (22 m) beam, and a 5.3 ft (1.61 m) draft in a light condition to a 488 ft (149 m) length, with an 81 ft (24.7 m) beam, and a 5.8 ft (1.77 m) draft in a light condition. Considerable design and construction information was obtained on a typical ARD barge built in 1944. However, specific information regarding the existing condition of an ARD barge was not obtained. In response to an inquiry, the Gulf Atlantic Towing Corporation (GATCO), Jacksonville, Florida, indicated that it would be impractical to estimate the ARD barge modifications required, or the cost of modifications to transport the 260-in.- (6.6-m) dia stage without knowing the actual condition of the barge.

General cost estimates regarding the conversion of barges for use in the Saturn program were obtained from GATCO. The Navy ocean-going YF-NB barges with a 265 ft (80.7 m) length, a 50 ft (15.2 m) beam, and a 4 ft (1.22 m) draft in the light condition were modified for use in the Saturn program. The cost of converting the barge Promise was $1,500,000, which included air conditioned quarters and galley, and an elaborate ballasting system, plus the replacement of a considerable amount of steel plate. In 1965, three of these YF-NB barges were converted into shuttle barges. These barges do not have quarters or house, but do have a ballasting system. The cost of converting these three barges was a total of $750,000. The estimate in 1965 for converting only one barge was $300,000. An estimate for converting the same barge today would be between $350,000 and $375,000. It should be noted that the decks of these barges were strengthened to carry a load of approximately 300 tons (272 Mg) in a concentrated area. The corresponding requirement for the 260-in.- (6.6-m) dia stage transport barge is approximately 2,250 ton (2040 Mg).

In October 1969, Rudolph F. Matzer and Associates, Inc., of Jacksonville, Florida, was contracted to accomplish a preliminary design study and to prepare a preliminary design of an ocean-going barge with the specific function of transporting the 260-in.- (6.6-m) dia motor stage. The study was planned to provide (1) a rough general arrangement, (2) an estimated cost for construction of the barge, and (3) an estimated cost for final engineering.

The preliminary design of the new barge with special rail track deck is shown in Figure 49. The barge design includes the necessary ballast tanks, special coatings in the ballast tanks, all ballast piping, valves and fittings, and two 60 HP (44.8 kW), 3,000 GPM (11.4 m^3/min), electric powered ballast pumps (shore power operated). The following barge characteristics were estimated in the evaluation study:

Length Overall	286 ft (87 m)
Breadth	60 ft (18.3 m)
Depth	15 ft (4.57 m)
Light Ship Draft	1 ft, 8-in. (0.55 m)
Full Load Draft	6 ft, 6-in. (1.98 M)
Light Ship Weight	720 L. ton (730,000 kg)

The barge was designed for American Bureau of Shipping approval and to suit the U. S. Coast Guard requirements for a manned barge. For manned operation, the barge must include such items as guard rails, life saving equipment, living accomodations, electrical power, and fire fighting equipment. Preliminary estimates indicate that the delivery schedule for a barge such as this would be approximately 10 months preceded by 2 months engineering design.

After receipt of the barge design from Rudolph F. Matzer and Associates, Inc., the bow end of the barge was modified to permit loading/unloading of the stage from either end of the barge. This involved extension of the rail beam structure approximately 30 ft (9.15 m) and modification to permit removal of a 9 ft (2.74 m) section of bow fairing above the water line during unloading operations.

The barge is designed to rest on a full-width, three-beam support of the graving dock as shown in Figure 50 for stern loading operations. Offloading at the bow end is shown in Figure 51. The preliminary design of the barge includes the limited structural support of the buoyant force in addition to the three-point graving dock support. The graving dock support beams shown in Figures 50 and 51 would be fitted with wash-off connections to remove any accumulated silt for assurance of firm barge support.

During loading and unloading operations, the barge and dock rails must be aligned and in the proper horizontal and vertical position. Alignment and horizontal positioning will be accomplished using an optical alignment system with optical targets on the dock and barge. Vertical positioning will be accomplished by initial control of the distance between the graving dock support caps and the top of the rails. The barge and dock rails will be designed such that when the barge is in position on the graving dock only a short spacer section of rail will be required to connect the barge and dock rails.

(4) Barge Canal System

Figure 52 shows the canal system which will provide navigable access from the DCP to the Atlantic Ocean via a portion of the Intracoastal Waterway south of Miami, Florida. The canal system from the DCP C&C facility to the Intracoastal Waterway will consists of three segments; (1) a new canal section; (2) existing Canal C-111, and (3) Canal C-111 extension.

The new canal section connecting the two C&C facilities to Canal C-111 will be constructed to match the 100 ft (30.5-m) width by 12 ft (3.7 m) depth of the existing Canal C-111. The Canal C-111 extension through Manatee Bay to Barnes Sound has been completed. However, the desired depth was not attained because coral formations were encountered. A profile survey of the canal extension completed in June 1967 shows a minimum depth of -5.95 ft (-1.8 m) MSL at low tide. Safe operation of the barge requires that this depth be increased to -8.0 ft (-2.44 m).

Currently, there is an earthen dam (plug) across Canal C-111 about 1/2 mile south and east of the double bascule bridge over U. S. Highway No. 1 (see Figure 52). The plug is used by the U. S. Corp of Engineers to control water flow and at present, about a 1 ft (0.355-m) differential is maintained between the water upstream and downstream of the plug. Also, the plug is used to prevent salt water intrusion. The Corp of Engineers will remove and replace the earthen dam at their expense up to four times a year. However, the use specified in this program requires that the earthen dam be replaced by a gate. The gate selected is a conventional structure consisting of two gates hinged at each side of the channel. The sill under the gates is set at -14 ft (-4.27 m) MSL and the gate extends to +5.0 ft (+1.52 m) above MSL.

The canal route continues from the terminus of Canal C-111 extension at the southeast edge of Manatee Bay across open water to the intersection with the Intracoastal Waterway at the south end of Barnes Sound (Figure 52). Then, the route continues north along the Intracoastal Waterway and exits to the Atlantic Ocean through Biscayne Channel located about 8 nautical miles (14.8 km) south of Miami Harbor. Dredging at several places for short distances along the Intracoastal Waterway is required to obtain the 8 ft (2.44 m) project depth.

Only two bridges are encountered along the barge route between the DCP and the exit to the Atlantic Ocean; (1) a bascule bridge with a 90 ft (27.4 m) horizontal clearance spanning Canal C-111 at U. S. Highway No. 1, and (2) a fixed bridge with a 90 ft (27.4 m) horizontal clearance and a 55 ft (16.8 m) vertical clearance spanning the Intracoastal Waterway at North Key Largo Beach. Neither bridge represents any navigational hazard to shipment of the 260-in.- (6.6-m) dia stage.

In the Atlantic Ocean, the barge will be towed along the east coast of lower Florida to the Port Canaveral Lock. The Port Canaveral Lock is 90-ft (27.4-m) wide by 600-ft (183-m) long, which is more than adequate to handle the transport barge.

The barge routing to the KSC storage area and to the launch area is shown in Figure 53. After clearing the Port Canaveral Lock and harbor facilities, the barge route continues north along the existing KSC Saturn Barge canal. The existing canal is 125-ft (38.1-m) wide by 12-ft (3.7-m) deep, which is adequate for operation of the stage transport barge and tug. As shown in Figure 53, a 5000-ft (1525-m) long section of a new canal is required to connect the existing Saturn barge canal with the 260-in.- (6.6-m) dia stage storage area on MILA. Also, 16,300 ft (4970 m) of new canal is required to connect the LC-37 launch area with the existing canal. The new launch area canal intersects the existing canal just north of the NASA-Causeway East Bridge. Construction of two new bascule-type bridges is required along the new launch area canal. The new canals to the KSC storage area and launch area will be constructed to match the dimensions of the existing Saturn barge canal.

(5) Storage at KSC

Refinement of the KSC storage site resulted in relocation of the site from the CKAFS solid propellant storage area selected in Task I (see Section III.C.1) on the east bank of the Banana River to the west side of the Banana River on MILA proper (Figure 53).

Discussion with KSC planning office personnel verified that underground communication lines do not exist and will not be a problem at the selected storage site on MILA. A tabulation of Air Force/NASA facilities that would have to be replaced at the CKAFS site is shown in Table 20. The change to MILA as the primary storage site results in a direct net cost savings of \$3,793,000 as shown in Table 21. The quantity of motors to be stored, storage building configuration, and quantity/distance safety standards used for establishing the MILA storage site are the same as was described in Section III.C.1. The blast overpressure radii at the MILA site are shown in Figure 53.

Refinement of the storage building/storage dock general arrangement is shown in Figure 54. The graving/loading dock is arranged such that the stage can be offloaded directly in line with any of the three motor storage bays. This concept precludes the need for a sharp-turning radius capability of the truck-rail transporter or other complex facility for shifting the position of the stage/transporter.

(6) KSC Launch Area (LC-37, Pad B)

The general arrangement in the area of LC-37, Pad B, is shown in Figure 55. The arrangement in the launch area is based on locating the graving/loading dock as near as possible to the launch pad while retaining maximum utilization of required existing facilities. The barge would be positioned and aligned in the graving dock bow first so that the aft end of the stage is facing the launch pad. After ballasting the barge to rest on the graving dock, the transporter would be rolled off the barge onto the 200-ft (61-m) long section of transporter rail foundation and positioned adjacent to the rotating pit. The stage would then be rotated to vertical, transported to the launch pad, and placed on the launch pad using the Roll-Ramp mobile gantry.

(a) Rotating Pit

The design concept of the rotating pit is shown in Figure 56. After structurally bracing the transporter, the mobile gantry lift slings would be connected to the forward trunnions of the stage handling ring and the stage rotated to vertical. The stage would then be hoisted vertically approximately 1 ft (0.305 m) to allow the aft trunnions to clear the transporter trunnion cradles. The stage must then be moved horizontally with the mobile gantry to the open area of the rotating pit where sufficient aft-flare clearance is provided during vertical hoisting of the stage from the rotating pit.

The rotating pit will be of concrete construction, reinforced with a heavy-steel box-beam structure to support the transporter/stage weight. The construction of the rotating pit with chamfered sidewalls is necessary because the stage aft-flare maximum diameter exceeds the transporter rail gage. An alternative straight wall concept was considered in Task IV where the stage is rolled off the barge forward end first and then crosses the rotating pit. This concept was rejected because of the high cost and operational complexity of a removable transporter rail foundation spanning the rotating pit.

(b) Roll-Ramp Mobile Gantry

The Roll-Ramp mobile gantry (Figure 57) would be used at the KSC launch area to rotate the stage from the horizontal to the vertical position, to transport the stage from the rotating pit to the launch pad, and to place the stage on the launch pad. The gantry consists of a four-leg steel tower structure, a heavy-steel crosshead structure, four Roll-Ramp actuators, Acme threaded actuator stems at each corner of the crosshead, a power system for the Roll-Ramp actuators, mobile gantry trucks (prime movers), a stage stabilization system, an instrumentation system, an elevator, work platforms, and facility power cabling.

The heart of the mobile gantry design concept is the Roll-Ramp actuator manufactured by the Roll-Ramp Corporation, a subsidiary of the Philadelphia Gear Corporation. The reliability of Roll-Ramp actuators with 1.5 M lb (682 Mg) capacity has been successfully demonstrated by field service use since 1963. One particularly applicable example of successful operation is at the NASA-Marshall Space Flight Center Saturn V test stand where four 1.5 M lb (682 Mg) actuators with 120-ft-(36.6-m) long by 15-in.-(38.1-cm) dia actuator stems have been used.

The Roll-Ramp actuators produce a continuous linear output in either axial direction along the stem. Each actuator produces an output of equal linear distance when driven by a common power source. Continuous linear motion of the gantry crosshead will be required to handle and position the 260 stage.

Each mobile gantry tower leg would be supported by a rail-type truck assembly, as shown in Figure 58. Each of the four gantry trucks would be made up of six four-wheel truck subassemblies (Figure 48) similar to that described for the stage transporter in Section III.C.4.a.(2) and to that currently used on the LC-37 MSS. The gantry truck design, based on the existing design of the LC-37 MSS, results in a total of 96 steel 36-in.-(91.5-cm) dia wheels with a wheel loading of 150,000 lb (68,200 kg) per wheel.

The gantry truck hydraulic jacking system would perform two basic functions: (1) provide a means of transferring the stage/gantry weight from the park-position anchor supports to the gantry truck wheels, and (2) provide a means of equalizing the load between all of the four-wheel truck subassemblies which support each of the four main truck girders. In addition, a jacking safety system would be installed to provide an emergency means for supporting the stage/gantry weight in the raised position in the event of hydraulic system failure. However, normal operation of the hydraulic system would be necessary to remove the weight of the stage/gantry from the safety system and for transferring the load back to the park position anchor supports.

When the gantry is not in operation and is in the park position, fixed structural support foundations (anchors) will be used to support the entire weight of the gantry. When the gantry is to be removed from the anchors for operation, the hydraulic system will be actuated and remains under pressure during operation of the gantry.

The mobile gantry is designed to operate on two pairs of 6 ft (1.83 m) gage, 171 lb (77.7 kg), standard crane rails constructed on 50 ft (15.3 m) centers. The gantry-rail park and transport found tions are shown in Figure 59. The 1270-ft (387-m) long mobile gantry rail track (see Figure 55) will be required to place the mobile gantry a safe distance away from the launch pad for protection from potential fire and blast hazards during launch. The park position at the end of the 1270 ft (387 m) track (existing LC-37, Pad A location) is considered to be the maximum reasonable separation and is based on similar considerations used to establish the pad separation distance for the existing LC-37 MSS.

(7) Environmental Protection Tooling and Equipment

Prior to removal of the stage from the C&C facility, the stage will be purged with dry nitrogen and then pressurized and sealed at 1.5 psig (1.035 N/cm^2) nitrogen pressure to maintain the motor interior relative humidity at or below the specified 45% maximum allowable for indefinite exposure of the propellant grain. A forward igniter port cap (Figure 60) and a nozzle plug (Figure 61) will be installed to seal the stage. A lightweight full forward head cover will be attached at the forward skirt area to preclude inadvertent accumulation of foreign material in the forward skirt area and to shed rain during subsequent operations on the pad at KSC. The forward head cover will remain on the stage up to the point of vehicle assembly.

After installation of the stage-transporter on the barge, a barge-mounted dry nitrogen source will be connected to a pressure regulator installed on the nozzle plug to maintain 1.5 psig (1.035 N/cm^2) internal pressure. A lightweight environmental cover (sun shade) will be attached to the barge to shade the motor from direct sunlight and to block ocean wave over-spray from impinging on the motor.

Prior to off-loading from the barge, 1.5 psig (1.035 N/cm^2) minimum internal pressurization will be verified and the nitrogen source disconnected from the pressure regulator. The stage/transporter will be moved under a portable sun shade (simple canopy type) adjacent to the rotating pit where visual inspection and stage disconnect from the transporter will be accomplished.

b. Logistics Plan

(1) General Requirements

All logistics support and launch operations personnel that would normally be scheduled to participate in the receipt, transport, handling, and erection of the stage will have been trained in their specific functions and briefed with respect to the hazards associated with Class II propellants and the precautions that must be exercised when handling, transporting, or erecting the stage.

The logistics support and operations crew will, at all times, be supported by representatives from the Contractor/KSC NASA Safety Offices, and Quality Control Offices. The operations crew will perform each major handling function in accordance with previously established and approved operations procedures.

(2) Specific Operations

The sequence of the stage handling method operations from the DCP, C&C facility, through placement on the KSC launch pedestal is depicted in Figure 62.

The basic operations to be performed fall within the following general categories:

Stage handling with the stiff-leg derrick.

Barge unloading/loading.

Barge transportation.

Erection preparations.

Stage erection with Roll-Ramp mobile gantry.

Stage transport/pad emplacement.

Basic operations support requirements throughout the stage receiving and erection cycle are generally as follows:

(a) Support

Heavy equipment

AFETR range support

AFETR security escort - two required - front and rear

AFETR Fire Department - in convoy and at pad

Weather forecast

Other support peculiar to function being performed

(b) Safety

AFETR, KSC, and Contractor pad safety

Hard hats, safety belts

Safety verification - trained personnel onl

(3) General Facility Requirements and Equipment

General logistics requirements are as follows:

Receiving and inspection crew and equipment

Safety representatives, AFETR, KSC, and Contractor

Harbor tugs

Barge/dock alignment

Barge/dock rail spacer sections

M-26 tugs and/or winches

Truck-rail cleaning system

Storage facility.

- Power/lights/water
- Environmental conditioning
- Desiccant breathers, if required
- Temperature monitoring equipment
- Relative humidity monitoring equipment
- Internal pressurization monitor
- GN_2 source for internal pressurization
- Janitorial services
- Guard/sentry service, 24 hour

Communications systems, as required

Gasoline/hydraulic oil, as required

Torque wrenches, as required

Electrical grounding system

Tug lines, as required

Cable assemblies, as required

Ocean going barge

Truck-rail transporter

Stage sunshade

(4) Sequence of Operations - DCP to KSC Launch Area

(a) Removal of the stage from the DCP C&C and placement on the barge.

Inspect graving dock support beam caps and clean as required.

Push barge stern first into position in graving dock.

Optically align barge center line with transporter track center line.

Install barge-to-dock ballast guide rails and ballast barge to rest on graving dock. Install barge tie-down structure. Recheck alignment.

Install barge-to-dock spacer sections of transporter rail.

Connect electric power to transporter drive wheels. Actuate transporter hydraulic system and move transporter off barge in position onto anchor support. Install transporter tie-down structure.

Engage aft trunnion lift adapters and derrick mainfall load tackles. Raise stage vertically from C&C facility a sufficient distance to clear transporter forward trunnion cradles.

Boom the stage into position over the transporter forward trunnion cradles and lower the stage vertically until forward trunnions engage transporter cradles.

Rotate stage until aft trunnions engage the transporter aft trunnion cradles. Disengage derrick mainfall load tackles.

(b) Preparation for Shipment

Install transporter forward and aft trunnion cradle caps. Remove transporter tie-down structure and return to storage.

Connect electric power to transporter drive wheels. Actuate transporter hydraulic system and move transporter in position on barge. Release hydraulic pressure and lower transporter onto barge anchor support. Disconnect transporter drive wheel electric power. Install stage/transporter tie-down structure.

Connect dry nitrogen source to pressure regulator on aft nozzle plug. Pressurize stage interior, as required, to 1.5 psig (1.035 N/cm^2) minimum. Connect vibration accelerometers, temperature sensors, and pressure transducers to data recording system.

Install stage forward-head lightweight segmented environmental closure. Attach environmental closure to igniter boss pressure plug and to forward skirt area.

Install stern doors on barge-mounted environmental shelter.

Remove barge-to-dock tie-down structure, barge-to-dock ballast guide rails, and barge-to-dock spacer sections of transporter rail and return to storage.

Float barge by pumping out ballast. Connect tug to barge.

(c) Barge Route

Proceed out Canal C-111 to canal gate located approximately 1/2 mile (0.804 km) south and east of U. S. Route No. 1.

Open gate and proceed through; then close gate.

Exit Canal C-111 extension into Intracoastal Waterway near Flat Point in Manatee Bay.

Proceed northward on Intracoastal Waterway to Biscayne Channel.

Proceed through Biscayne Channel to the Atlantic Ocean.

Proceed north along the east coast of Florida to Port Canaveral.

Proceed through Port Canaveral/KSC lock to the Saturn barge channel in the Banana River headed north.

Continue on the existing barge channel and the channel access to launch complex area dock.

Move barge bow first into the graving dock area.

Preparation for Offloading at KSC

Inspect graving dock support beam caps and clean as required.

Remove barge bow fairing above the water line. Push barge bow first into position in graving dock.

Optically align barge center line with transporter track center line.

Install barge-to-dock ballast guide rails and ballast barge to rest on graving dock. Install barge tie-down structure. Recheck alignment.

Install barge-to-dock spacer sections of transporter rail.

Remove bow doors of barge-mounted environmental shelter.

Pressurize stage interior, as required, to 1.5 psig (1.035 N/cm^2) minimum and disconnect dry nitrogen line from pressure regulator on aft nozzle. Disconnect vibration, temperature, and pressure instrumentation.

Remove stage/transporter tie-down structure. Actuate transporter hydraulic system. Connect electric power to transporter drive wheels and move stage/transporter into position under the environmental sun shade at the rotating pit. Disconnect electric power from transporter drive wheels.

Release hydraulic pressure and lower transporter onto anchor support. Install transporter tie-down structure.

(e) Rotation, Transport to Pad, and Placement on Pad

After completing receiving inspection, remove transporter trunnion caps. Move sunshade clear of stage.

Actuate gantry-truck hydraulic system and move Roll-Ramp gantry into position over stage. Engage forward trunnion lift adapters and gantry load blocks.

Rotate stage to vertical with Roll-Ramp gantry; then raise stage vertically, using Roll-Ramp actuators, a sufficient distance for the aft trunnions to clear the transporter trunnion cradles.

Connect bracing structure between stage and gantry. Move stage/gantry to center of open area of rotating pit. Disconnect bracing structure.

Raise stage vertically to proper elevation for placement on the launch pad. Connect bracing structure between stage and gantry.

Move the stage/gantry into position over the launch pad.

Remove the stage bracing structure. Lower the stage onto the pad support points using Roll-Ramp actuators.

Disconnect trunnion lift adapters and gantry load blocks. Move gantry to park area. Release hydraulic pressure and lower gantry onto anchor support.

(5) Sequence of Operations - DCP to KSC Storage Area

The sequence of operations for transporting the stage from the DCP to the KSC storage facility will be the same as described above between DCP and the launch pad except: (1) the barge will exit the existing Saturn barge canal at KSC and enter the new barge canal to the storage facility on MILA, and (2) the stage transporter will be moved into the storage bay of the storage building and the transporter will be lowered to rest on anchor supports.

(6) Sequence of Operations - KSC to DCP

The handling operations required to transport the stage from the KSC launch area and the KSC storage facility to DCP will be just the reverse of the sequence of operations described above in Section III.C.4.b.(4) and (5)., respectively.

(7) Barge Transportation Responsibililies

The overwater movement of the 260-in.- (6.6-m) stage from the DCP to the KSC will involve three principal participants:

(1) the NASA, (2) the stage contractor, and (3) the marine contractor. The division of responsibility and interfaces between the three principal participants outlined in the following discussions are anticipated for the production program. In general, stage loading and unloading, stage movement by barge, stage maintenance and environmental monitoring, and maintenance of marine equipment will be responsibilities of the stage and marine contractors. It is assumed that NASA will have overall responsibility for transportation of the stages between the DCP and KSC. Living accommodations for the barge crew on the relatively short trip between DCP and KSC will be provided in a mobile trailer that will be moved onto and off the barge, as required, during stage loading and unloading operations. Meals for the stage contractor crew will be provided by the marine contractor on board the tug boat.

(a) NASA Responsibilities

The NASA will be responsible for:

Instigating any action necessary to ensure that the stages are delivered safely and on schedule.

Designating a NASA representative, as required, to coordinate and to act on specific problems that may arise to ensure safe and timely deliveries of the stage.

Providing U. S. Coast Guard and U. S. Weather Bureau participation as required.

Coordinating with the appropriate KSC agency for operation through the Port Canaveral Harbor and Lock facilities and for operation within the KSC barge canals.

Providing dock facilities and dock services as required for loading and unloading stages at KSC.

(b) Stage Contractor Responsibilities

The stage contractor will be responsible for:

The safety and integrity of the stage during water movement.

Publishing, updating, and maintaining an approved stage transportation plan.

Establishing a training program as required to provide and maintain qualified operations personnel.

Developing transportation schedules, preparation of move orders, and issuing requests for NASA service.

Obtaining and maintaining necessary security clearance, operating licenses, and move permits.

Accomplishing water movements in accordance with the Aerojet/NASA approved transportation plan.

Accomplishing all pre-loading and postloading inspections and checkout of stage handling equipment and facilities.

Requesting barge ballasting, verifying that the barge is ready for loading and unloading, loading and unloading the stage, securing the stage/transporter, and hookup and monitoring of environmental instrumentation.

Surveillance and maintenance of the stage tie-down rigging, instrumentation, and the keeping of logs.

(c) Marine Contractor Responsibilities

The marine contractor will be responsible for:

Making available tugs with the required qualifications, obtaining approval of the tug and route, and obtaining all necessary operating certificates and permits.

Providing qualified personnel for operation of the barge and tug.

Positioning and securing the barge at the dock, ballasting for loading and unloading, and all aspects of operation of the barge and tug in transit.

Posting and maintaining safety regulations and assignment of all personnel to emergency stations.

Responding to emergencies and performing emergency repairs where necessary to maintain integrity of the barge and tug.

Responding to the stage contractor's request to slow, change course, or seek safe harbor when required to maintain integrity of the stage. Making barge and tug operations personnel available to the stage contractor in the event conditions arise that jeopardize the stage.

Notifying the stage contractor and NASA representative of all unusual conditions that may jeopardize the stage, vessel, or personnel.

Maintaining daily logs of all details of operation.

Ensuring that spare parts and materials are on board the barge and tug for normal operation as well as performing any anticipated emergency repairs.

(8) - Stage and Handling Equipment Inspection

Inspections required between the DCP C&C facility and the KSC destinations are as follows:

(a) Removal from C&C Facility and Placement on Barge

Inspect graving dock for obstructions and graving dock support beams for accumulation of silt.

Inspect barge and transporter rail alignment and barge tie-down structure. Check installation of spacer sections of transporter rail between barge and dock.

Check transporter truck main hydraulic systems and hydraulic safety system. Inspect transporter trunnion cradles.

Check derrick mainfall load tackles, cabling, and guy wires before removal of the stage from the C&C.

Check installation of transporter tie-down structure.

Inspect stage-to-transporter tie-down rigging.

(b) Preparation for Shipment

Inspect transporter-to-barge tie-down rigging.

Check environmental monitoring instrumentation and stage internal nitrogen pressure.

Inspect environmental shelter attachment to barge, tie-down of living quarters trailer, and tie-down of any other barge cargo.

(c) During Barge Transit

Periodically inspect and monitor environmental instrumentation and stage internal nitrogen pressure.

Periodically inspect, visually, the stage and transporter and integrity of the tie-down rigging between the stage and transporter and the transporter and barge.

(d) Preparation for Offloading at KSC

Inspect graving dock for obstructions and graving dock support beams for accumulation of silt.

Inspect barge and transporter rail alignment and barge tie-down structure. Check installation of spacer sections of transporter rail between barge and dock.

Inspect stage and transporter tie-down rigging and integrity of handling rings, trunnions, and transporter for evidence of shipping damage.

Accomplish receiving inspection on the barge in accordance with Figure 63.

(e) After Unloading Stage/Transporter at KSC

Review transportation environment monitoring records (temperature, humidity, acceleration and internal nitrogen pressure).

Accomplish receiving inspection per Figure 64.

Rotation, Transport to the Pad, and Placement on the Pad

Inspect transporter and gantry railway for cleanliness and obstruction. Inspect rotating pit for obstruction.

Check mobile gantry truck main hydraulic system and hydraulic safety system.

Check integrity of transporter tie-down rigging.

Check integrity of mobile gantry load blocks. Check electric power to Roll-Ramp actuator drive motor.

Check to ensure that transporter trunnion cradle caps are removed.

Check to assure minimum stage hoisting to clear launch pad structure.

Check installation of stage bracing structure between the stage and gantry tower legs.

(f) Storage at KSC

Check dry nitrogen supply line connection to nozzle plug pressure regulator.

Check installation of temperature and internal pressure monitoring instrumentation.

Visually inspect, periodically, stage and stage components for evidence of corrosion or damage and for evidence of stage component fluid leakage.

Periodically inspect and monitor environmental instrumentation.

(g) Cycle Times

The cycle times for the operation defined in the logistics plan are shown in Figure 65. The elapsed calendar time from initiation of handling operations at DCP to placement on the pad at KSC is 16 days. The schedule shown in Figure 65 is compatible with the refined handling methods and with the quantity of tooling, equipment, and facilities identified for the selected handling method.

Critical Elements of Development and Operation

(1) Critical Elements

The handling tooling, equipment, and facility concepts of the optimum handling method were selected in accordance with the objectives of low cost and high reliability. To meet these objectives, elements of the selected handling method were derived from concepts that are well within the existing state-of-the-art. Therefore, there are no anticipated areas of critical development required. Rather, the principal effort in the early phases of the program would be directed toward thoroughly defining the handling design criteria and then accomplishing the tooling, equipment, and facility detailed designs to satisfy the stated criteria.

Specific areas are identified and discussed in the following where particular attention should be given when establishing the design criteria and accomplishing the detailed design.

(a) Derrick and Gantry Lifting Device

During lifting of the stage and rotation of the stage from horizontal to vertical (or vice versa), overloading of the handling ring trunnions and lifting device or imparting excessive torsion moment could occur from: (1) angular displacement between the lift adapters and trunnion center lines, (2) difference in height above ground of the derrick or gantry lift adapters, (3) difference in deflection along the load path from the lifting device to either trunnion, (4) angular deviation between the center lines of forward and aft trunnions, (5) angular deviation between the center lines of the trunnions and transporter support cradles, and (6) differences in attitude of the two booms of the derrick. During the design phase, a study will be required to determine the optimum trade-off between stage/lifting device allowable load and control of trunnion/handling equipment manufacturing tolerances to minimize maximum load.

The stiff-leg derrick at DCP and the Roll-Ramp mobile gantry at KSC will be designed and constructed to satisfy all applicable codes and standards, e.g., American Institute of Steel Construction (AISC); American Standards Association Safety Code for Cranes, Derricks, and Hoists; and the American Welding Society. Both the derrick and gantry will be designed for operation at a proof test load of approximately 5,000,000 lb (2,270,000 kg). The actual 4,000,000 lb (1,820,000 kg) stage weight represents 80% of the proof-test load.

The structural components of the derrick and gantry will be designed so that the applied stresses do not exceed 90% of the allowable (AISC) stresses at the proof-test load. The machinery components will have a minimum safety factor of 3 at material yield.

(b) Derrick and Gantry Instrumentation

Loads can vary during rotation of the stage from vertical to horizontal (or vice versa) about the transporter cradle/trunnion pivot point. The loads in excess of stage weight that are imparted to the stage and lifting device depend on the manufacturing tolerances (discussed above) and the skill of the operator in coordinating the vertical and horizontal movements of the lifting device. To obtain minimum loads, it is evident that the horizontal and vertical movements of the lifting device would have to result in a true arc with the center of the arc at the transporter cradle/trunnion pivot point.

The operation of the derrick and gantry will have to be assessed to determine all normal operating conditions and all likely inadvertent operating conditions that could result in overloading of the stage and/or lifting device. An instrumentation system will have to be developed that provides a simple display in real time to the lifting device operator. The load and position sensors will be located at appropriate plac on the stage and on the lifting device so that any tendency toward over loading can be observed and immediately corrected by the operator.

(c) Transporter and Gantry Truck Wheel Loading

The transporter and gantry truck wheel loads discussed in Section III.C.4.a, above, are based on dead weight load (stage weight plus estimated transporter and gantry weight) only. Although the dead weight loads represent the greatest part of the total wheel load, additional specific loads should be included in the transporter and gantry truck design.

The additional wheel loads include:

Wind Loads - Because of the sail area of the stage and gantry (or transporter) structure, wind loading will increase the wheel loads on the downwind, or leeward, trucks.

Braking (Deceleration) Loads - The decleratio forces resulting from emergency brake application will impose an additional vertical load on the truck wheels.

Vertical Wheel Displacement - It should be assumed that one wheel of the four-wheel truck subassembly can be displaced vertically some finite amount because of inadvertent foreign material on either the wheel or rail and because of unequal deflection of the rail. Displacement of one wheel above the plane of contact of the other three wheels will increase the load per wheel.

Barge Vertical Acceleration - The vertical acceleration of the barge during water transport will increase the transporter wheel load.

(d) Barge Vibration Environment

Currently, the input vibration environment (both amplitude and frequency) that will be experienced by the stage during barge transport is unknown. As discussed in Section III.C.3.b, a peak acceleration of 1.24 g vertical acceleration was recorded at one instance during barge transport of a Saturn stage.(11) With the vastly greater weight of the 260-in.- (6.6-m) dia stage, engineering judgment indicates that vertical acceleration of the barge and cargo should be less than 1.0 g for normal operation (excluding storm conditions). During the handling method demonstration, discussed below, actual barge operations with a "dummy" stage should be accomplished in various sea states and prevailing wind conditions whereby barge acceleration data would be accumulated to establish limit criteria on transportation.

(2) Program Plan

This section discusses the program plan for development, fabrication, and demonstration of the critical elements of the handling method. In the preparation of this plan, it is assumed that the stage configuration will have been defined, including the design of the forward and aft stage handling rings. The plan is established as a logical sequence from definition of design criteria, through checkout and demonstration of the critical elements.

The program schedule for design, fabrication, and erection, and checkout demonstration is shown in Figure 66. Although only critical elements are discussed in this section, the schedule shown in Figure 66 is considered adequate to include design, fabrication, and checkout of all elements of the handling method.

The critical handling method elements included in the program plan are: (1) the stiff-leg derrick at DCP, (2) stage transporter, (3) the transport barge, and (4) the Roll-Ramp mobile gantry at KSC. To accomplish the checkout and demonstration of these elements, other elements of the handling method will have to be completed, e.g., loading/graving docks, canals, transporter and gantry rail systems, and the rotating pit at KSC.

The design phase of the program plan will include definition of design criteria, preparation of detailed procurement drawings, and customer review and approval of procurement drawing

The stage criteria that influence the design of all elements of the handling method include: (1) stage envelope, (2) stage weight and mass distribution, (3) handling ring outside diameter, (4) handling ring trunnion diameter and length, (5) distance between trunnion center lines, and (6) handling ring/trunnion installed tolerances. In addition to the stage criteria, the design criteria listed in the following are considered the minimum necessary to initiate design of the critical handling method elements:

Stiff-Leg Derrick at DCP:

Maximum stage lift height

Minimum reach for vertical lift

Maximum full-load reach

Maximum one-half-load reach

Load control instrumentation requirements

Operational and performance requirements

Stage Transporter:

Maximum transporter weight limitations

Stage/transporter tie-down requirements

Transporter tie-down requirements

Maximum load per truck wheel

Truck wheel gage

Truck drive and braking performance requirements

Operational and performance requirements

Transport Barge:

Maximum barge width and length limitations

Maximum loaded draft

Cargo weight and mass distribution

Barge dynamic characteristics

Loading/graving dock interface requirements

Operational and performance requirements

Roll-Ramp Mobile Gantry:

Maximum stage lift height

Maximum load per truck wheel

Truck wheel gage

Truck drive and braking performance requirements

Load control instrumentation requirements

Operational and performance requirements

After establishing all applicable design criteria, the handling-method tooling, equipment, and facility elements will be defined by preparation of envelope drawings and interface control drawings for each specific element.

The envelope drawings will define all details of configuration, performance, and test requirements necessary to enable development of detail designs. In addition, reliability, maintainability, and environmental requirements will be specified to the extent necessary to ensure that design details can be developed.

_ie interface control drawing will detail physical and functional interface engineering requirements and all interface dimensional data applicable to the envelope; mounting and mating of subsystems; complete interface engineering requirements, such as mechanical, electrical, electronic, hydraulic, pneumatic, optical, etc.; and any other characteristics that affect the operation of the element or cofunctioning element.

It is anticipated that NASA will review the design activity at various specified stages of completion. All completed designs will be reviewed and approved by NASA. The schedule (Figure 66) provides ample overlap with the design activity so that review and approval can be accomplished as each element is completed.

(b) Request for Bid and Subcontract Award

After completing the detailed procurement drawings, the request for bid will be forwarded to a number of qualified contractors. Selection of the successful bid will be made after careful review and assessment of technical capability, understanding of requirements, cost and schedule, resources, and past experience. Award of contract to the successful bidder will be made after review and approval by NASA.

(c) Detailed Design, Fabrication, and Erection

The successful bidder will accomplish the detailed component design and prepare the detailed fabrication and erection drawings in accordance with the requirements specified on the applicable envelope and interface control drawings. The schedules for construction and erection will be established so that required interface elements will be completed in time for erection and checkout of succeeding elements. It is expected that the Roll-Ramp gantry at KSC and the derrick at DCP will be the longest lead-time elements.

(d) Check-Out and Demonstration

A detailed check-out and demonstration plan will be prepared by the stage contractor for each handling method element to assure that each element and the subsystems of each element meet the specified performance and reliability requirements. Subsystems may be tested prior to assembly or after erection of the handling method element, as specified in the check-out and demonstration plan.

A more important aspect of the check-out and demonstration plan is to ensure that the critical handling method elements, i.e., derrick, transporter, barge, and mobile gantry, operate satisfactorily while handling the 260-in. (6.6-m) dia stage. Although an actual stage would not be available, a fired motor case from the development program could be ballasted to simulate the weight and mass distribution of the stage. The fired case would be ballasted to weigh a total of 5 million lb (2.27 million kg).

The ballasted case would be used to proof-load the derrick at DCP and then for check-out and demonstration of rotating the stage to horizontal onto the transporter. The ballasted case/transporter would be loaded on the barge and transported to KSC to check-out and demonstrate operation and structural integrity of the transporter and operation, structural integrity, and stability and control of the barge. The ballasted case/transporter would then be used at KSC to check-out operations at the rotating pit and to check out and demonstrate operational and structural integrity of the Roll-Ramp mobile gantry.

The demonstration of the critical handling method elements as described above would result in an effective tooling, equipment, and facility tryout as well as provide the opportunity to work out operational "bugs" in the system prior to the handling of the actual stage.

d. Selected-Handling-Method Refined Costs

The refined cost estimates presented in this section for the selected handling method are based on 1970 dollars. It has been recognized that many of the handling-method equipment and facility items identified in the selected handling method would likely be Government-furnished items. Also, many of the labor and engineering functions associated with the handling of the stage, particularly at KSC, may be accomplished by NASA personnel. However, no attempt was made in developing the refined cost to distinguish Government-furnished items or recurring Government labor costs.

The handling-method estimated costs include (1) initial stage contractor design, construction monitoring, and handling method demonstration labor costs, (2) handling method tooling, equipment, and facility nonrecurring costs, (3) recurring handling method labor costs, and (4) recurring tooling, equipment, and facility maintenance costs.

(1) Nonrecurring Design, Engineering Construction Surveillance, and Check-Out and Demonstration Costs

The estimated nonrecurring labor costs for engineering design, engineering construction surveillance, and handling-method check-out and demonstration are provided in Table 22. The total cost of $860,000 is based on the assumption that the stage and stage handling rings will be completely defined at the start of the handling method design.

The design effort costs reflected in Table 22 include definition of the design criteria and preparation of envelope and interface control drawings for each element of the handling method. Also included are the labor costs for stage contractor coordination with NASA during NASA design review and approval and during subcontractor bid review and approval. Stage contractor engineering surveillance is provided during the entire 20-month construction phase.

Also, the estimated nonrecurring labor costs for check-out and demonstration of the complete handling method with the 260-in.-(6.6-m) dia proof-load dummy stage are shown in Table 22. Included are both operations and engineering labor. For convenience and uniformity, all operations labor includes burdens and profit, like the other costs shown in Table 22.

(2) Nonrecurring Tooling, Equipment, and Facility Costs

The handling method elements, quantity of each element, and estimated cost of each element, which comprise the $33.431 million total tooling, equipment, and facility nonrecurring costs are shown in Table 23. These are installed costs and include subcontractor design, fabrication, transportation, erection, and fabrication-subcontractor profit. No other factors are applied to these costs.

In the preparation of the handling method nonrecurring costs, it is assumed that any required existing facility demolition, i.e., LC-37 Pad A area, has been accomplished and the costs for any such demolition are not included here. The design descriptions of the handling method elements that form the basis for the estimated nonrecurring tooling, equipment, and facility costs are provided in Section III.C.4.a.

(3) Handling Method Recurring Labor Cost

The handling method recurring labor costs for the 30-motor, 5-year program are shown in Table 24. The recurring costs are based on the estimate of the labor required to accomplish each function of stage handling, transportation, and erection for each motor. The recurring costs were approached in this manner rather than on a "level-of-effort" basis since it is assumed that the labor involved will be engaged in other aspects of the vehicle program during periods when stages are not being handled or transported.

The total recurring cost for the 5-year program $1.38 million, or approximately $46,000 per stage. Project engineering and quality assurance participation are included in the recurring cost estimate.

Costs for services of the marine contractor's tug and crew have been excluded from the recurring cost. It is apparent that tug services for transporting the stages to KSC would be integrated for efficient utilization with other aspects of the program; e.g., transporting chambers from the manufacturing plant to the DCP processing facility and shuttle service within the DCP processing facility. It was considered that an estimate of marine contractor's cost for handling the stage only (which would include significant standby time) could impose an unnecessarily high burden on the handling method recurring costs. It should be noted, however, that costs for the stage monitoring crew, which is required for barge shipment, have been included in the handling method recurring costs shown in Table 24.

(4) Handling Method Recurring Maintenance Costs

The handling-method tooling, equipment, and facilit maintenance costs shown in Table 25 represent the costs necessary to provide adequate preventive maintenance over the 5-year program period. In establishing the maintenance costs, maintenance percentage rates were applied to the total cost of the handling-method elements. The maintenance rates used were established on the basis that all elements were new and completely checked out.

The total 5-year program maintenance cost is $3.065 million, which results in an average annual maintenance cost of $613,000. The preventive maintenance cost shown in Table 25 is not intended to include major replacement item cost or tooling, equipment, and facility modification cost. It is apparent that the maintenance cost rate would increase if use of the items is extended beyond the specified 5-year period.

(5) Cost Summary

The total handling-method refined cost identified in this task is $38.736 million of which $4.445 million and $34.291 million are recurring and nonrecurring costs, respectively. The program costs are generally grouped in three categories: (1) costs at the DCP processing facility, (2) costs at KSC, and (3) common costs.

The breakdown of costs in each category are (1) $11.329 million at DCP, (2) $20.730 million at KSC, and (3) $6.677 million for common costs. The common category includes items such as the barge, stage transporters, environmental covers, and waterway outside the boundary of either the DCP or KSC.

e. Cost Comparison of Selected Handling Method and Segmented-Motor Handling Method

Under Task I and II effort (Sections III.C.1 and 2), the cost of the segmented-motor handling method (Table 18) could only be compared to the three Task I handling-method unrefined costs (Tables 2, 3, and 4). It is of interest here to compare the estimated segmented-motor handling-method costs to the selected unitized-motor handling-method refined costs. The tooling, equipment, and facility nonrecurring costs are $17,377,000 for segmented motor handling method and $33,431,000 for the selected unitized-motor handling method (Table 23).

The cost for the segmented-motor handling method listed above is unrefined and is based on the limited effort specified by the Task II scope of work. The attractiveness of the segmented motor handling method cost should be tempered by the knowledge that these costs are unrefined and that obvious cost increases associated with the motor, motor hardware, and motor processing facilities as well as motor processing, assembly, and inspection recurring costs are not included.

f. Motor Design Details Affected by Handling

The results of the handling method evaluations and the motor stress analyses indicate the desirability of certain detail changes in the 260-in.- (6.6-m) dia motor design. The recommended changes from the motor/stage design presented in Reference (5) fall into the following categories:

(1) Revision of the propellant boot release design.

(2) Redesign of aft-flare attachment to the motor case.

(3) Reduction in the major diameter of the aft flare.

The propellant grain stress analysis accomplished for the selected handling method shows that the minimum margin of safety would occur during long-term horizontal storage. As shown in Table 7 of Appendix B, the maximum propellant-to-liner bond tensile stress during 3 year horizontal storage would be 24 psi (16.6 N/cm^2). This is equal to the minimum bond strength under the long-term loading condition, therefore the margin of safety is zero. This minimum margin exists because of a bond stress concentration at the aft boot release location. In the horizontal position, the upper portion of the aft end of the grain would be cantilevered from the boot release point. The margin of safety at this point could be substantially increased by revolving the motor periodically during long-term horizontal storage to shift the stress concentration to different angular locations. However, a better approach to increasing this margin of safety would be to modify the aft boot configuration to reduce the magnitude of the bond stress concentration. The stress analysis results shown in Table 6 of Appendix B indicate that a fully bonded grain would have a maximum bond tensile stress of only 8.2 psi (5.66 N/cm^2) under long-term horizontal storage conditions. It is clear that a substantial margin of safety in bond tensile stress could be achieved by reducing the length of the aft boot release from that shown in the original motor design of Reference (5). While this change would increase the bore strain at the aft end of the grain, the level would still be less than the acceptable strain level existing in the finned section at the forward end of the grain.

The method proposed in Reference (5) for attaching the aft flare to the motor case is shown in Figure 67. This configuration is unacceptable for two reasons: first, the design induces large stress concentrations in the pressure vessel in the region of the attachment flange, and second, the design makes no provision for installation of the aft handling ring necessary for lifting and supporting the stage. The proper aft flare attachment concept is shown in Figure 68. A cylindrical skirt would be joined to the pressure vessel through a carefully configured transition section that would minimize the discontinuities in the pressure vessel membrane. The skirt length is sufficient to allow installation of the necessary handling ring. The aft flare attaches to the aft end of the skirt and affects neither the handling ring nor the pressure vessel integrity.

The size of the aft flare has proven to be an important consideration in the study of 260-in.- (6.6-m) dia motor/stage handling operations. The major diameter of the aft flare identified in Reference (5) is 355 in. (9.03 m). This has been a controlling dimension in many areas of the handling method definition. Lifting adapters, handling rings, transporters, gantries, and rotating pits are all affected by the aft-flare diameter. A reduction in aft-flare major diameter would simplify handling equipment designs and reduce costs in all of these areas. Various approaches could be considered in an effort to reduce the aft flare diameter. LITVC system packaging could be reviewed to determine if a more compact arrangement is possible. A change to movable nozzle TVC could reduce the internal volume required in the aft flare. Redesign of the roll control system could result in significant reduction in flare size; a monopropellant on-off roll control system would require fewer tanks and less propellant than the system proposed in Reference (5). The main motor nozzle exit cone could be changed from a conical shape with an 11:1 expansion ratio to a smaller contoured configuration with no loss in flight performance. Another approach would be to segment the flare to minimize its size during handling and transportation; the final portion of the flare could then be installed after the stage was on the gantry at KSC.

Among factors to be considered prior to selection of a reduced aft-flare diameter is the evaluation of any changes in vehicle aerodynamics. Also, a reduced flare diameter would tend to reduce the clearance between the nozzle exit cone and the launch pedestal during vehicle lift-off. Comprehensive evaluation of all design and operational details associated with modification of the aft flare is beyond the scope of the current study. However, the potential advantages of reducing the flare diameter appear to justify further investigation of the aft-flare configuration.

IV. CONCLUSIONS

A. STAGE HANDLING METHOD

The operations necessary to move the 260-in.- (6.6-m) dia solid-rocket motor stage between the DCP and the NASA-KSC can be reliably and economically accomplished. All tooling, equipment, and facilities necessary to handle, transport, store, and erect the stage on the launch pedestal can be obtained from within the existing state-of-the-art.

On the basis of the Task I evaluation of various handling methods and the engineering trade study accomplished to select the optimum method, conclusion is made that the following elements should be used to handle the 260-in.- (6.6-m) dia stage: (1) the stiff-leg derrick at DCP, (2) the Roll Ramp mobile gantry at KSC, (3) the truck-rail type stage transporter, and (4) a new barge designed specifically to transport the stage. The barge mu be designed to off-load at either end to avoid costly alternatives for re-orienting the stage at KSC with respect to the rotating pit.

The barge will be towed via the DCP on-plant canal extension an Canal C-111, north on the Intracoastal Waterway, and to the Atlantic Ocean through Biscayne Channel 8 miles (12.87 km) south of Miami. The barge will then be towed northward along the east coast of Florida and will enter KSC via the Port Canaveral Harbor. The exit to the ocean through Biscayne Channel will minimize potential hazards to populated areas and will minimize traffic congestion along the Intracoastal Waterway.

B. MOTOR STRESS ANALYSES

Static and dynamic stress analyses verify that the 260-in.- (6.6-m) dia motor stage can withstand the critical loads imposed by vertical hoisting, inverting, horizontal transport, vertical storage, and horizontal storage.

It is concluded from the propellant and case static stress analyses that handling the stage with support only at the skirts is acceptable. The use of a finite-length pneumatic bladder or sling-type midcylinder support causes additional stresses and strains in the area of the central support and reduces the capability of the stage to withstand the imposed handling loads.

With the selected handling method (support at the skirts only), the minimum margins of safety for propellant bore strain and bond stresses occur during long-term 3-year horizontal storage. The maximum bond stress occurs at the aft-boot release point, whereas the highest bore strain occurs at the aft end of the finned section of the grain. The motor case elastic stability and shell stress analysis shows that the stage can tolerate a 2.2 g transverse acceleration with the selected handling method. The use of motor internal pressurization increases the allowable transverse accelerations, but the use of a finite-length midcylinder support reduces the allowable transverse acceleration.

The dynamic analyses show that the stage can withstand all dynamic loads expected during towed-barge transportation using the selected handling method. Both internal pressurization and the pneumatic bladder midcylinder support have a negligible effect on dynamic response characteristics of the motor stage. The intermediate structural support (sling) reduces the transverse-axis resonant frequency and the dynamic amplification factor. However, the decrease in stress/g is not sufficient to warrant recommending the use of a sling type structural support.

C. INSPECTION AND CHECKOUT

The motor (including propellant grain) will be inspected and accepted concurrently with stage assembly in the C&C facility. All mechanical and electrical stage components will be bench-tested, where possible, and accepted prior to stage assembly. All stage components will be inspected and accepted prior to assembly. After assembly, and prior to removal of the stage from the C&C, all required inspections, e.g., integrated systems and circuits, torque, leak checks, and visual damage from assembly, will be completed.

Only visual inspections are intended subsequent to stage removal from the C&C through placement of the stage on the launch pedestal since the accepted stage must be capable of withstanding normal handling and shipping. The logical place for final stage transportation inspection is on the launch pad after all handling operations are complete.

D. ENVIRONMENTAL REQUIREMENTS

The temperature and humidity (motor interior) environmental restrictions on the motor are: (1) temperature, 60 to 100°F (280 to 312°K) and (2) humidity, 45% R.H. (or less) indefinite exposure and 89% R.H. (maximum) for no more than 2.5 days.

The motor will be sealed and the interior will be protected with dry nitrogen at 1.5 psig (1.035 N/cm^2, gage). All metal parts will be painted, covered or otherwise protected to prevent corrosion. The barge-mounted environmental shelter is necessary for reflecting solar radiation and to prevent ocean spray from contacting the stage. It is not intended that the barge-mounted environmental shelter be sealed or that the environment within the shelter be controlled. The additional element of environmental protection is a simple sunshade that will be used to shade the motor during visual inspection and rigging-disconnect operations adjacent to the rotating pit. It was concluded that the motor should be stored under shelter with the interior of the storage building maintained at 80 $\pm$ 20°F (300 $\pm$ 267°K) and with a 45% maximum relative humidity.

E. MOTOR STORAGE

In view of the very slight probability of a catastrophic occurrence, it was concluded that a single site at KSC for storage of up to three 260-in.-(6.6-m) dia stages would be more desirable than three separate storage facilities. Suitable locations at KSC for three separate storage facilities would be difficult to obtain and the cost would be considerably greater than the single facility cost. The storage site selected is on the west side of the Banana River on MILA proper. Quantity/distance safety aspects of the storage site were evaluated on the basis of a 5% TNT equivalence value for the total propellant weight of the three stages.

F. ALTERNATIVE DESTINATIONS AND MOTOR DESIGN

U. S. Air Force Western Test Range (WTR)

Two likely launch pad locations at WTR are: (1) in the Santa Ynez River Valley near the coast, and (2) in the Boathouse area along the coast just south of Point Arguello. The Santa Ynez River Valley location is more desirable from the standpoint of handling method simplicity. Construction methods cannot be defined for either area because of unknown soil structure. Additional technical problems that need resolution prior to selection of the launch site are: (1) quantity/distance safety standards, (2) toxicity, (3) launch trajectory and (4) flight over existing facilities.

Except for the differences that may exist because of construction methods at WTR, the selected handling method elements should be acceptable for use with the WTR alternative destination. The longer shipping time to WTR will require one additional barge, one additional set of stage handling rings, and temperature and humidity control within the barge-mounted environmental shelter. It was not possible to make estimates on WTR handling-method costs and development time since the location of the launch site could not be resolved within the scope of this program.

2. Saturn V, C-T at KSC LC-39

The selected handling method is also recommended for use with the Saturn V C-T alternative destination with the following modifications: (1) a new canal section is required to the LC-39 area rather than to the LC-37 area, (2) the mobile gantry must be wider to clear the C-T and must be considerably taller for the aft end of the stage to clear the top side of the C-T, and (3) the required length of mobile gantry track is less at the LC-39 than at LC-37.

The cost differential based on Task I unrefined estimated costs is $305,000 higher for the LC-37 area than for the LC-39 area as shown in the following:

Item	SAT-V-C/T, LC-39 Cost, $ in Thousands	Primary LC-37 Cost, $ in Thousands
Canal System	163	908
Mobile Gantry	11,760	10,750
Mobile Gantry Track	300	1,270
Canal Bridges	0	600
	3,223	13,528

It should be noted again that the costs given above are based on Task I unrefined costs. Refinement of the costs may result in slight changes in the total estimates. Also, it should be noted that any required modification to the C-T or C-T roadway are not included in this study.

3. Segmented Motor Configuration

An overhead traveling crane is recommended as the optimum method of handling segments in proximity to motor processing, launch, and storage facilities. Even with an eight-segment motor configuration, the segments are too large and heavy to reasonably ship by any means other than by barge. The 1000-ton (908 Mg) capacity stiff-leg derrick was selected to lift the segments from the transporters and assemble the stage on the launch pad.

For comparison purposes, the cost of nonrecurring tooling equipment and facilities are $17,377,000 for the unrefined segmented motor handling method and $33,431,000 for the refined selected unitized motor handling method. It is apparent that the smaller weight of the motor segments, as compared with the unitized motor, permits use of smaller and less costly handling equipment. However, it must be noted that obvious segmented-motor program-cost increases associated with the motor, motor hardware, motor processing facilities and motor processing, assembly, and recurring inspections are not included in this comparison.

G. CRITICAL ELEMENTS OF DEVELOPMENT AND OPERATION

None of the elements of the selected handling method are considered to be critical areas of development and operation. The principal effort in the early phases of the program should be directed toward thoroughly defining the handling design criteria and then toward detailed designs for tooling, equipment, and facilities.

An important aspect of the development program is to ensure an adequate checkout and demonstration of the handling method elements. A fired motor case from the motor development program could be ballasted and used to proof-load and check-out the operation of the handling method elements.

The handling method development program is expected to span 36 months from initiation of design through check-out and demonstration of the handling method

H. SELECTED HANDLING METHOD COSTS

The handling method costs identified below are based on 1970 dollars and include burdens and profit only where noted.

1.	Nonrecurring Design, Construction Monitoring, and Demonstration Labor	860,000	(including burden and profit)
2.	Nonrecurring Tooling, Equipment, and Facilities	33,431,000	
3.	Recurring 5-Year Program Labor	1,380,000	(including burden and profit)
4.	Recurring 5-Year Maintenance	3,065,000	
	Total	38,736,000	

The total program costs are grouped in three categories: (1) \$11.329 million at DCP, (2) \$20.73 million at KSC, and (3) \$6.677 million for common costs. The common category includes items such as the barge, stage transporters, and waterway outside the boundary of either the DCP or KSC.

1. Motor Design Details Affected by Handling

It is concluded that the reference motor design must be revised to include an aft skirt so that the aft handling ring can be attached to the stage. Other areas where design changes may be desirable are; (1) revision of the propellant boot release design to reduce the magnitude of the propellant-to-liner bond stress concentration, and (2) reduction in the major diameter of the aft flare to simplify handling equipment designs and reduce the overall cost of the stage handling method.

TABLE 1. - WEIGHT BREAKDOWN OF STAGE IN SHIPPING AND HANDLING CONFIGURATION

Item		Weight-Lb
Insulated Chamber		227,140
Steel Case	199,445	
Insulation	26,012	
Liner	1,680	
Nozzle Assembly		56,720
Nozzle	19,810	
Forward Exit Cone	14,620	
Aft Exit Cone	22,290	
Structure		8,250
Aft Cone	6,901	
Base Heat Protection	1,100	
Tunnels	248	
Equipment and Instrumentation		13,190
Roll Control System	571	
TVC System	9,748	
Misc. Equipment and Systems	2,868	
Handling Rings		280,000
Propellant		3,400,000
Total Stage Weight		3,985,300

TABLE 2. - TOOLING, EQUIPMENT AND FACILITIES, HANDLING METHOD NO.

Item	Quantity	Estimated Cost	Remarks
2000-Ton Derrick at C&C	2	$ 5,000,000	A-DD
Canal Dredging			
DCP to Intracoastal Waterway			
Existing	-	321,000	
New	-	570,000	
Intracoastal Waterway			
Existing	-	545,000	
KSC			
Existing		250,000	
New	-	658,000	
Graving Docks	3	2,535,000	DCP, LC37B, Storage
Loading/Unloading Docks	2	1,572,000	LC37B, Storage
Barge - Modified ARD	1	1,400,000	
Barge Alignment Equipment/Cabling	2	200,000	DCP and KSC
Gate in Canal C-111	1	500,000	
Environmental Cover - Lightweight	1	10,000	
Stage Pressure Plug, Nozzle Aft	5	375,000	
Stage Plug - Fwd	5	25,000	
Barge Environmental Cover	1	100,000	
Stage Transporter	5	1,250,000	(2 transit, 3 storage)
Sun Shade Device	1	75,00	
Hardened Steel Rollers	24 sets	240,000	Barge and KSC
Bridge Barge to Dock	2	150,000	KSC, LC37B and Storage
Transporter Roadway	-	2,900,000	KSC, LC37B and Storage
Storage Facility	1	2,000,000	Adequate for three 260 stages
Tractors and Winches	-	280,000	
Rotating Pit	1	50,000	KSC, LC37B
Mobile Gantry, System and Trucks	1	10,750,000	KSC, LC37B
Mobile Gantry Track	1	1,270,000	KSC
Lifting Adapters	2 sets	155,000	DCP and KSC
Bridge	2	600,000	KSC
Electrical Grounding System	-	20,000	DCP and KSC
		$33,801,000	

TABLE 3. - TOOLING, EQUIPMENT AND FACILITIES, HANDLING METHOD NO. 2

Item	Quantity	Estimated Cost	Remarks
Mobile Gantry, System and Trucks	3	$32,250,000	2 at DCP and 1 at KSC
Canal Dredging			
DCP to Intracoastal Waterway			
Existing		321,000	
New		570,000	
Intracoastal Waterway			
Existing		545,000	
KSC			
Existing		250,000	
New		658,000	
Graving Docks	3	2,535,000	DCP, LC37B and Storage
Loading/Unloading Docks	3	2,358,000	DCP, LC37B and Storage
Barge, Modified ARD	1	1,400,000	
Barge Alignment Equipment/Cabling	2	200,000	DCP and KSC
Gate in Canal C-111	1	500,000	
Stage Nozzle Plug	5	375,000	
Stage Plug Fwd	5	25,000	
Environmental Cover - Lightweight	1	10,000	
Barge Environmental Cover	1	100,000	
Stage Transporter	5	3,750,000	Excluding Rails
Bridge-Barge to Dock	3	225,000	DCP, LC37B and Storage
Truck-Rail Foundations	-	3,060,000	Mobile Gantry and Transporter at DCP, LC37B and Storage
Storage Facility	1	2,000,000	Adequate for three 260 stages
Tractors and Winches	-	280,000	
Rotating Pit	1	50,000	
Sun Shade Device	1	75,000	
Lifting Adapters	2 sets	155,000	DCP and KSC
Bridge	2	600,000	KSC
Electrical Grounding System		20,000	DCP and KSC
		$52,312,000	

TABLE 4. - TOOLING, EQUIPMENT AND FACILITIES, HANDLING METHOD NO. 3

Item	Quantity	Estimated Cost	Remarks
2000-Ton Derrick Installed	1	$ 2,500,000	KSC
2000-Ton Lifting Device	2	5,760,000	A-DD
Canal Dredging			
DCP to Intracoastal Waterway			
Existing		321,000	
New		570,000	
Intracoastal Waterway			
Existing		545,000	
KSC			
Existing		250,000	
New		658,000	
Graving Docks	3	2,535,000	DCP, LC37B and Storage
Loading/Unloading Docks	3	2,358,000	DCP, LC37B and Storage
Barge - New Construction	1	2,000,000	
Barge Alignment Equipment/Cabling	2	200,000	DCP and KSC
Gate in Canal C-111	1	500,000	
Environmental Cover - Lightweight	1	10,000	
Stage Nozzle Plug Aft	5	375,000	
Stage Plug Fwd	5	25,000	
Barge Environmental Cover	1	100,000	
Stage Transporter	5	3,000,000	
Bridge - Barge to Dock	3	225,000	DCP, LC37B and Storage
Storage Facility	1	2,000,000	Adequate for three 260 stages
Tractors and Winches	-	280,000	
Rotating Pit	1	50,000	
Sun Shade Device	1	75,000	
Lifting Adapters	2 sets	155,000	DCP and KSC
Bridge	2	600,000	KSC
Electrical Grounding System	-	20,000	DCP and KSC
Truck-Rail Foundation		3,060,000	DCP, LC37B and Storage
		$28,262,000	

TABLE 5. - STAGE RECEIVING INSPECTION AT KSC

1. <u>Inspection on Barge Prior to Off-Loadin</u>

   a. Inspect motor and stage components for evidence of shipping damage or corrosion.

   b. Inspect motor mid-cylinder support:

      (1) <u>Handling Method No. 1</u> - internal pressurization level; determine cause of any significant drop from initial pressure.

      (2) <u>Handling Method No. 2</u> - bladder pressurization level; determine cause of any significant drop or variation from initial pressure.

      (3) <u>Handling Method No. 3</u> - integrity of hammock (sling); evidence of any damage.

   c. Verify security of handling rings, trunnions, and shipping closures.

   d. Visually inspect grain and motor interior viewing through aft closure inspection port.

2. <u>Receiving Inspection After Off-Loading from Barge</u>

   a. Review transportation environment monitoring records (temperature and acceleration).

   b. Inspect external surfaces and compartments; check for dents, scratches, loose wiring or fittings, hydraulic fluid leaks, contaminations, or any other shipping and handling damage.

TABLE 6. - ENVIRONMENTAL PROTECTION - TEMPERATURE AND HUMIDITY (Sheet 1 of 2)

I. DADE COUNTY PLANT

A. PRIOR TO INSTALLATION ON BARGE

1. Install forward igniter port cap and nozzle plug.

2. Purge motor interior with dry air or nitrogen.

3. Pressurize motor interior to 1.5 psig (1.035 N/cm, gage) minimum and seal motor.

4. Install light-weight full closure (attached at forward skirt area) to provide environmental protection to motor forward area during subsequent operations at KSC up to the point of vehicle assembly on the pad.

B. AFTER INSTALLATION ON BARGE

1. Connect dry air or dry nitrogen source to pressure regulator installed on nozzle plug to maintain 1.5 psig (1.035 N/cm, gage) minimum internal pressure.

2. Install barge mounted sun shade over motor to shade motor from direct sunlight and to block ocean wave over-spray from impinging on the motor.

II. KSC

A. OFF-LOADING THROUGH PLACEMENT OF THE LAUNCH PAD

1. Prior to off-loading, pressure motor interior, as required to 1.5 psig (1.035 N/cm, gage) minimum; seal motor and disconnect dry air or dry nitrogen source.

2. Provide sun shade over motor at the facility where visual inspection and stage disconnect from transporter is accomplished (adjacent to rotating pit).

3. Leave motor interior sealed through rotation and placement of the stage on the launch pad.

TABLE 6. - ENVIRONMENTAL PROTECTION - TEMPERATURE AND HUMIDITY
(Sheet 2 of 2)

II, KSC (cont.)

B. STORAGE

Storage facilities are required to maintain and monitor motor environment within the following restrictions:

	Relative Humidity	Temperature
Propellant surface	45% max	80 ± 20°F (300 ± 267°K)
Chamber exterior (24 hr mean)		80 ± 20°F (300 ± 267°K)

TABLE 7. - COMMONALITY OF TOOLING, EQUIPMENT AND FACILITIES, HANDLING METHOD NO. 1

Item	DCP	KSC Storage Area	KSC Launch Area
Barge	X	X	X
Graving Dock	X	X	X
Unloading Dock		X	X
Barge Alignment Equipment/Cabling	X	X	X
Bridge-Barge to Dock		X	X
Handling Rings	X	X	X
Stage Nozzle Plug	X	X	X
Environmental Cover	X	X	X
Transporter Rollers	X (on barge)	X	X
Stage Roller Transporter	X (on barge)	X	X
N_2 Pressurization Equipment	X	X	X
Tractors and/or Winches	X (on barge)	X	X
Lifting Adaptors	X	X	X
Electrical Grounding Systems	X	X	X

TABLE 8. - COMMONALITY OF TOOLING, EQUIPMENT AND FACILITIES, HANDLING METHOD NO. 2

Item	DCP	KSC Storage Area	KSC Launch Area
Barge	X	X	X
Graving Dock	X	X	X
Unloading Dock	X	X	X
Barge Alignment Equipment/Cabling	X	X	X
Bridge-Barge to Dock	X	X	X
Handling Rings	X	X	X
Stage Nozzle Plug	X	X	X
Environmental Cover	X	X	X
Transporter Truck-Rail System	X	X	X
N_2 Pressurization Equipment	X	X	X
Air Pressurization Equipment (Transporter with Bladder Cradle)	X	X	X
Lifting Adaptors	X	X	X
Mobile Gantry & Truck-Rail System	X		X
Electrical Ground Systems	X	X	X
Electric Power Supplies	X	X	X

TABLE 9. - COMMONALITY OF TOOLING, EQUIPMENT AND FACILITIES, HANDLING METHOD NO. 3

Item	DCP	KSC Storage Area	KSC Launch Area
Barge	X	X	X
Graving Dock	X	X	X
Unloading Dock	X	X	X
Barge Alignment Equipment/Cabling	X	X	X
Bridge-Barge to Dock	X	X	X
Handling Rings	X	X	X
Stage Nozzle Plug	X	X	X
Environmental Cover	X	X	X
Transporter and Truck-Rail System	X	X	X
N_2 Pressurization Equipment	X	X	X
Lifting Adaptors	X	X	X
Electrical Grounding Systems	X	X	X
Electric Power Supplies	X	X	X

TABLE 10. - COMMONALITY OF TOOLING, EQUIPMENT AND FACILITIES AT DCP AND KSC

Item	Handling Method No. 1	Handling Method No. 2	Handling Method No. 3
Barge	X	X	X
Graving Dock	X	X	X
Unloading Dock		X	X
Barge Alignment Equipment/Cabling	X	X	X
Bridge-Barge to Dock		X	X
Handling Rings	X	X	X
Stage Nozzle Plug	X	X	X
Environmental Cover	X	X	X
Transporter Rollers	X		
Stage Roller Transporter	X		
Stage Truck Transporter and Rail System		X	X
N_2 Pressurization Equipment	X	X	X
Air Pressurization System		X	
Tractor and/or Winches	X		
Lifting Adaptors	X	X	X
Electrical Grounding Equipment	X	X	X
Mobile Gantry and Rail System		X	
Electric Power Supplies for Truck-Rail Systems		X	X

TABLE 11. - MODIFICATIONS TO HANDLING METHOD NO. 1
TO HANDLE 1.6M AND 5.0M LB MOTORS

Handling System Component	Modifications for 1.6M lb (0.727 million kg) Motors	Modifications for 5.0M lb (2.72 million kg) Motors
Handling Rings	No significant change required.	New increased capacity rings needed.
Stiff-leg Derricks	No significant change required.	New increased capacity derricks required. Developed components no longer applicable.
Transporters	Shortened frame required.	New larger transporters required.
Barge	Relocate load take-out and tie-down positions.	Relocate and strengthen load take-out and tie-down positions.
Mobile Gantry	No significant change required.	New, taller, increased capacity gantry required.
Rotating Pit	No significant change required.	Rotating pit enlargement required.
Storage facility	No significant change required.	Building length increase required. Quantity-distance considerations could limit capacity to 2 motors.

TABLE 12. - MODIFICATIONS TO HANDLING METHOD NO. 2 TO HANDLE 1.6M AND 5.0M LB MOTORS

Handling System Component	Modifications for 1.6M lb (0.727 million kg) Motors	Modifications for 5.0M lb (2.72 million kg) Motors
Handling Rings	No significant changes required.	New increased capacity rings needed.
Mobile Gantries (DCP and KSC)	No significant changes required.	New, taller, increased capacity gantries required.
Transporters	Shortened frames required.	New larger transporters required.
Barge	Relocate load take-out and tie-down positions.	Relocate and strengthen load take-out and tie-down positions.
Rotating Pit	No significant change required.	Rotating pit enlargement required.
Storage facility	No significant change required.	Building length increase required. Quantity-distance considerations could limit capacity to 2 motors.

TABLE 13. - MODIFICATIONS TO HANDLING METHOD NO.

TO HANDLE 1.6M and 5.0M LB MOTORS

Handling System Component	Modifications for 1.6M lb (0.727 million kg) Motors	Modifications for 5.0M lb (2.72 million kg) Motors
Handling Rings	No significant change required.	New increased capacity rings needed.
Winch System	Relocate forward winch.	Increased capacity winches needed. Forward winch relocation required. Cast pit rotation trench radius increase required.
Transporters	Shortened frame required.	New large transporters required.
Barge	Relocate load take-out and tie-down positions.	Increased capacity barge required.
Stiff-leg Derrick	No significant change required.	New increased capacity derrick required. Developed components no longer applicable.
Rotating Pit	No significant change required.	Rotating pit enlargement required.
Storage Facility	No significant change required.	Building length increase required. Quantity-distance considerations could limit capacity to 2 motors.

TABLE 14. - HANDLING METHOD NO. 1 ESTIMATED COST COMPARISON, ALTERNATIVE MOTOR WEIGHT

Item	Task I Baseline Motor, Cost	Method Modification Cost: 1.6M lb Motor, Cost	Method Modification Cost: 5.0M lb Motor, Cost
Derrick at DCP	$ 5,000,000	0	$12,500,000
Graving Docks	535,000	0	4,970,000
Loading Docks	572,000	0	3,060,000
Barge	400,000	$ 35,000	2,060,000
Stage Pressure Plug, Nozzle Aft	375,000	275,000	440,000
Barge Environmental Cover	100,000	0	95,000
Stage Transporter	1,250,000	125,000	840,000
Hardened Steeel Rollers	240,000	0	120,000
Bridge-Barge to Dock	150,000	0	220,000
Transporter Roadway	2,900,000	0	5,710,000
Storage Facility	2,000,000	0	1,200,000
Rotating Pit	50,000	0	125,000
Mobile Gantry at KSC	10,750,000	0	21,200,000
Mobile Gantry Track	1,270,000	0	2,570,000
Lift Adaptors	155,000	45,000	206,000
Totals (Nonrecurring Costs)	$29,747,000	$480,000	$56,316,000

TABLE 15. - HANDLING METHOD NO. 2 ESTIMATED COST COMPARISON, ALTERNATIVE MOTOR WEIGHT

Item	Task I Baseline Motor, Cost	Method Modification Cost	
		1.6M lb Motor, Cost	5.0M lb Motor, Cost
Mobile Gantry at DCP and KSC	$32,250,000	0	$63,600,000
Graving Docks	2,535,000	0	4,970,000
Loading Docks	2,358,000	0	5,100,000
Barge	1,400,000	35,000	2,060,000
Stage Pressure Plug, Nozzle Aft	375,000	275,000	440,000
Barge Environmental Cover	100,000	0	95,000
Stage Transporter	3,750,000	300,000	,500,000
Bridge, Barge to Dock	225,000	0	330,000
Truck-Rail Foundations	3,060,000	0	5,910,000
Storage Facility	2,000,000	0	1,200,000
Rotating Pit	50,000	0	125,000
Lift Adaptors	155,000	45,000	206,000
Totals (Nonrecurring Costs)	$48,258,000	$655,000	$89,536,000

TABLE 16. - HANDLING METHOD NO. 3 ESTIMATED COST COMPARISON, ALTERNATIVE MOTOR WEIGHT

Item	Task I Baseline Motor, Cost	Method Modification Cost 1.6M lb Motor, Cost	Method Modification Cost 5.0M lb Motor, Cost
Derrick at KSC	$ 2,500,000	0	$ 6,250,000
Winch System at DCP	5,760,000	$1,440,000	9,200,000
Graving Docks	2,535,000	0	4,970,000
Loading Docks	2,358,000	0	5,100,000
Barge	2,000,000	35,000	2,060,000
Stage Pressure Plug, Nozzle Aft	375,000	275,000	444,000
Barge Environmental Cover	100,000	0	95,000
Stage Transporter	3,000,000	225,000	4,400,000
Bridge, Barge to Dock	225,000	0	330,000
Trucks-Rail Foundation	3,060,000	0	5,910,000
Storage Facility	2,000,000	0	200,000
Rotating Pit	50,000	0	125,000
Lift Adaptors	155,000	45,000	206,000
Totals (Nonrecurring Costs)	$24,118,000	$2,020,000	$40,290,000

TABLE 17. - COST ESTIMATE FOR SATURN V C/T ALTERNATIVE DESTINATION

Title	Qty	Estimated Cost (In Thousands)	Remarks
Barge, Ocean Going		2,000	
KSC Canal System			
Existing - LC-37 40,000 ft		296	Based on $/cu yd
Existing - LC-39 26,000 ft		192	Corps of Engrs
New - LC-39 3,000 ft		675	
Graving Dock at Storage	1	845	
Graving Dock at LC-39	1	845	
Unloading Dock at Storage	1	786	
Unloading Dock at LC-39	1	786	
Barge Alignment	-	50	1 set required
Bridge - Barge-to-Dock	1	100	
SRM Sunshade Device	1	75	
Storage/Checkout Building	1	2,000	Adequate for 3 SRM's
Tractors and/or Winches	-	280	
Handling/Receiving GSE - Stage Components		25	1 set
Rotating Pit	1	50	
Mobile Gantry, System and Trucks	1	11,760	Reference CCSD
Electrical Grounding System		10	
Truck-Rail Transporter	5	2,000	
Truck-Rail Foundation - Storage and Receiving Station		1,650	
		$24,425	

TABLE 18. - SEGMENTED MOTOR - OVERHEAD TRAVELING CRANE HANDLING METHOD

Item	Quantity	Estimated Cost	Remarks
Overhead Crane (installed)	1	$ 550,000	DCP
Overhead Crane Track (1000' @ $1000/ft installed)		1,000,000	DCP
Loading Dock (Processing Plant)	1	500,000	DCP
Loading Dock (Storage Bldg)	1	500,000	KSC
Overhead Crane (Storage Bldg)	1	550,000	KSC
Overhead Crane Track (550' @ $1000/ft installed)		550,000	KSC
Storage Saddles	12 @ $50,000	600,000	KSC
Loading Dock (Launch area)	1	500,000	KSC
Overhead Crane (Launch area dock)	1	550,000	KSC
Overhead Crane Track (200' @ $1000/ft installed)		200,000	KSC
Transporter (Aft Segment)	2 @ $100,000	200,000	KSC
Transporter (Center Segment)	9 @ $95,000	855,000	KSC
Transporter Adapters (Fwd Segment)	2 sets @ $50,000	100,000	KSC
Transporter Tracks (1100' @ $300/ft)		330,000	KSC
Rotating Fixture and Adapters for Fwd and Aft Segments		110,000	KSC
Derrick at Launch Pad		1,500,000	KSC
Canal Dredging:			
Dade to Intracoastal Waterway			
Existing		321,000	
New		570,000	
KSC			
Existing		250,000	
New		658,000	
Gate in Canal C-111		500,000	DCP
Environmental Cover-Lightweight	56 @ $10,000	560,000	
Environmental Cover-Barge		175,000	
Shipping Saddles	8 @ $65,000	520,000	
Sunshade-Segment		25,000	
Storage Facility		1,333,000	KSC
Tractor and Winches		280,000	
Lift Adapters		150,000	
Electrical Grounding		40,000	
Bridges	2	1,400,000	KSC
Barge	1	2,000,000	
		$17,377,000	

TABLE 19. - SEGMENTED MOTOR - TRUCK-RAIL TRANSPORTER HANDLING METHOD

Item	Quantity	Estimated Cost	Remarks
Overhead Crane (Cast Bldg. installed)	1	550,000	DCP
Overhead Crane Track (200' @ $1000/ft installed)		200,000	DCP
Loading Dock	1	786,000	DCP
Graving Dock	1	845,000	DCP
Transporter Track (1000' @ $300/ft)		300,000	DCP
Transporter (Aft Segment)	3 @ $100,000	300,000	
Transporter (Center Segment)	15 @ $95,000	425,000	
Transporter Adapters (Fwd Segment)	3 sets @ $50,000	150,000	
Overhead Crane (Storage Bldg)	1	550,000	KSC
Overhead Crane Track (200' @ $1000/ft)		200,000	KSC
Transporter Tracks (200' @ $300/ft)		60,000	KSC
Loading Dock (Storage Bldg)	1	786,000	KSC
Graving Dock (Storage Bldg)	1	845,000	KSC
Storage Saddles	12 @ $50,000	600,000	KSC
Loading Dock (Launch Pad)	1	786,000	KSC
Graving Dock (Launch Pad)	1	845,000	KSC
Transporter Tracks (Launch Pad) (1100' @ $300/ft)		330,000	KSC
Rotating Fixture and Adapters for Segments		110,000	KSC
Barge to Dock Bridges	3 @ $75,000	225,000	DEP & KSC
Barge Alignment Equipment	2 @ $100,000	200,000	DCP & KSC
Derrick at Launch Pad		1,500,000	KSC
Canal Dredging			
Dade to Intracoastal Waterway			
Existing		321,000	
New		570,000	
KSC			
Existing		250,000	
New		658,000	
Gate in Canal C-111		500,000	DCP
Environmental Cover-Lightweight	56 @ $10,000	560,000	
Environmental Cover-Barge		175,000	
Sunshade-Segments		25,000	
Storage Facility		333,000	KSC
Tractor and Winches		280,000	
Lift Adapters		150,000	
Electrical Grounding		40,000	
Bridges	2	1,400,000	KSC
Barge	1	2,000,000	
		$19,855,000	

TABLE 20. - FACILITIES REQUIRING RELOCATION AT CKAFS STORAGE SITE

Bldg. No.	Building Function	Sq. Ft.	Year Built	Initial Cost	1970 Est. Cost
1058	A, B, C, D & E Ordnance Test Area	733	1959	$48,000	$91,000
72650	Missile Storage	3,365	1960	107,000	192,000
72665	Engine Storage	.,711	1960	97,000	174,000
72680	Engine Storage	.,711	1960	97,000	174,000
72905	Administration Control	1,864	1958	46,000	93,000
77375	Propellant Inspection Bldg #1	2,927	1961	192,000	324,000
77380	Propellant Inspection Bldg #2	2,580	1961	198,000	334,000
80505	Missile Research Test Shop	3,200	1964	250,000	355,000
72810	Loading Dock	3,200	1958	108,000	217,000
80700A	Control Building		1962	919,000	390,000
61875	Satellite Support Fac.	7,273	1960	143,000	258,000
67210	Missile Checkout	4,071	1962	137,000	218,000
				Total	$3,820,000

Since the Air Force has a continuing use for these facilities, they would have to be relocated to support the Minuteman, Thor-Delta and other associated Air Force solid rocket programs.

TABLE 21. - CKAFS AND MILA STORAGE SITE COST COMPARISON

Item	CKAFS Storage Site	MILA Storage Site	MILA Site Cost Delta
New Barge Canal	10,000 ft	5,000 ft	$63,000 (saving)
Storage Facility Dock	1 required	Same	No Delta
Truck-Rail System		Same	No Delta
Storage and Checkout Facility	$2,000,000	Same	No Delta
New Paved Roadway	Minor Extension - 2 Lane	1/2 miles	$45,000 (increase)
Facility Water	Minor Extension - 4 in. Line	1/2 miles	$15,000 (increase)
Facility Power	Minor Extension - One Substation/Transformer	1/2 miles	$30,000 (increase)
Facilities Requiring Relocation	See Table No. 20	None	$3,820,000 (saving)
		Total Estimated Delta	$3,793,000 (saving)

TABLE 22. - NON-RECURRING DESIGN, CONSTRUCTION MONITORING, AND DEMONSTRATION LABOR COSTS

Item	Labor Cost, 1970 Dollars
Engineering Design	$486,000
2. NASA Coordination	46,000
3. Subcontractor Bid Request and Review	87,000
4. Engineering Surveillance During Construction	166,000
5. Handling Method Checkout and Demonstration	75,000
otal (Incl. Burdens and Profit)	$860,000

TABLE 23. - HANDLING METHOD TOOLING, EQUIPMENT, AND FACILITY NON-RECURRING COSTS

Item	Quantity	Total Est. Cost $
2000-Ton Derrick (installed)	2	$ 6,550,000
Mobile Gantry	1	8,770,000
Transporter and Gantry Tracks		2,095,000
Canal Dredging		
DCP to Intracoastal Waterway		
Existing		321,000
New		785,000
Intracoastal Waterway		
Existing		545,000
KSC		
New		614,000
Graving/Unloading Docks	4	4,712,000
Barge (new)	1	534,000
Barge Alignment Equipment	4	300,000
Gate in Canal C-111	1	500,000
Environmental Cover-Lightweight	1	25,000
Shipping Cover Forward - Pressure Type	5	50,000
Shipping Cover Aft - Pressure-Type	5	375,00
Barge Environmental Cover and Sun Shade	1	175,000
Stage Transporter	5	2,875,000
Storage Facility	1	2,000,000
Tractor and Winches	1	280,000
Rotating Pit	1	250,000
Lift Adapters	2 sets	155,000
Canal Bridge	2	1,400,000
Electrical Grounding System		20,000
Handling Method Proof-Load Dummy Stage	1	100,000
Total Non-Recurring Cost		$33,431,000

TABLE 24. - HANDLING METHOD 5-YEAR (30 MOTOR) PROGRAM

RECURRING LABOR COST

		Recurring Cost, 1970 Dollars
1.	Stage removal from C&C, placement on transporter, and movement onto barge	$ 138,000
2.	Stage/transporter tie-down and preparation for shipment	210,000
3.	Stage monitoring crew	288,000
4.	Preparation for offloading and offloading at KSC	166,000
5.	Stage rotation, movement to pad, and placement on the pad	324,000
6.	Placement of empty transporter on barge and preparation for return shipment	144,000
7.	Placement of 12 stages in storage at KSC	52,000
8.	Movement of 12 stages out of storage at KSC	58,000
	Total Recurring Cost (Inc. Burdens and Profit)	$1,380,000

TABLE 25. - RECURRING MAINTENANCE COST

	Average Annual Maintenance Cost, 1970 Dollars	5 Year Program Maintenance Cost 1970 Dollars
Stiff-leg Derrick at DCP	$151,000	755,000
Mobile Gantry at KSC	187,000	935,000
Transporter and Gantry Track	22,000	110,000
Graving/Loading Dock	47,000	235,000
Barge	27,000	135,000
Barge Alignment Equipment	15,000	75,000
Gate in Canal C-111	13,000	65,000
Environmental Covers and Stage Pressure Plugs	16,000	80,000
Stage Transporters	55,000	275,000
Storage Facility	35,000	175,000
Rotating Pit	6,000	30,000
Canal Bridges	28,000	140,000
General Mechanical and Electrical	11,000	55,000
Total Cost	$613,000	$3,065,000

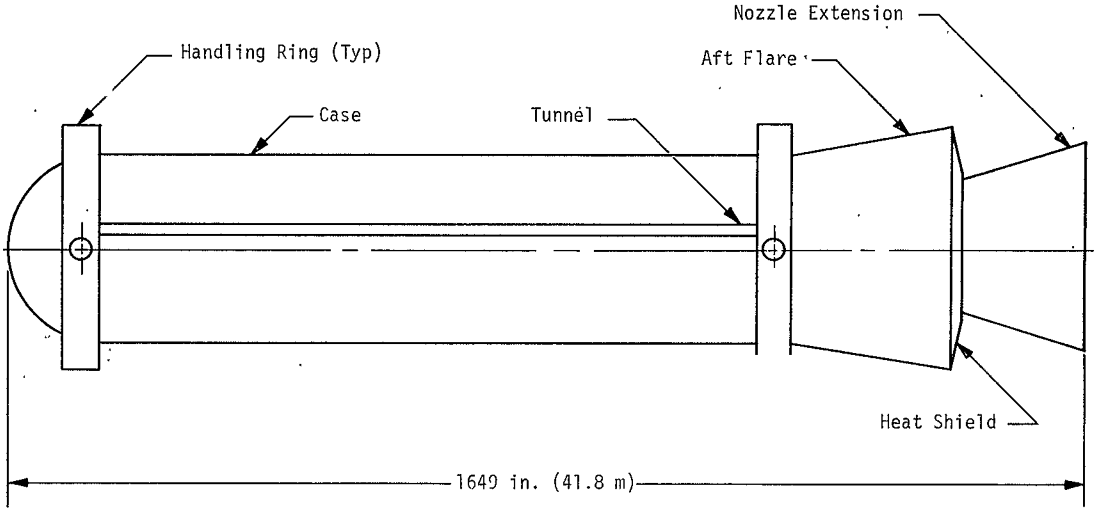


Figure 1. - 260/SIVB Baseline Stage Configuration

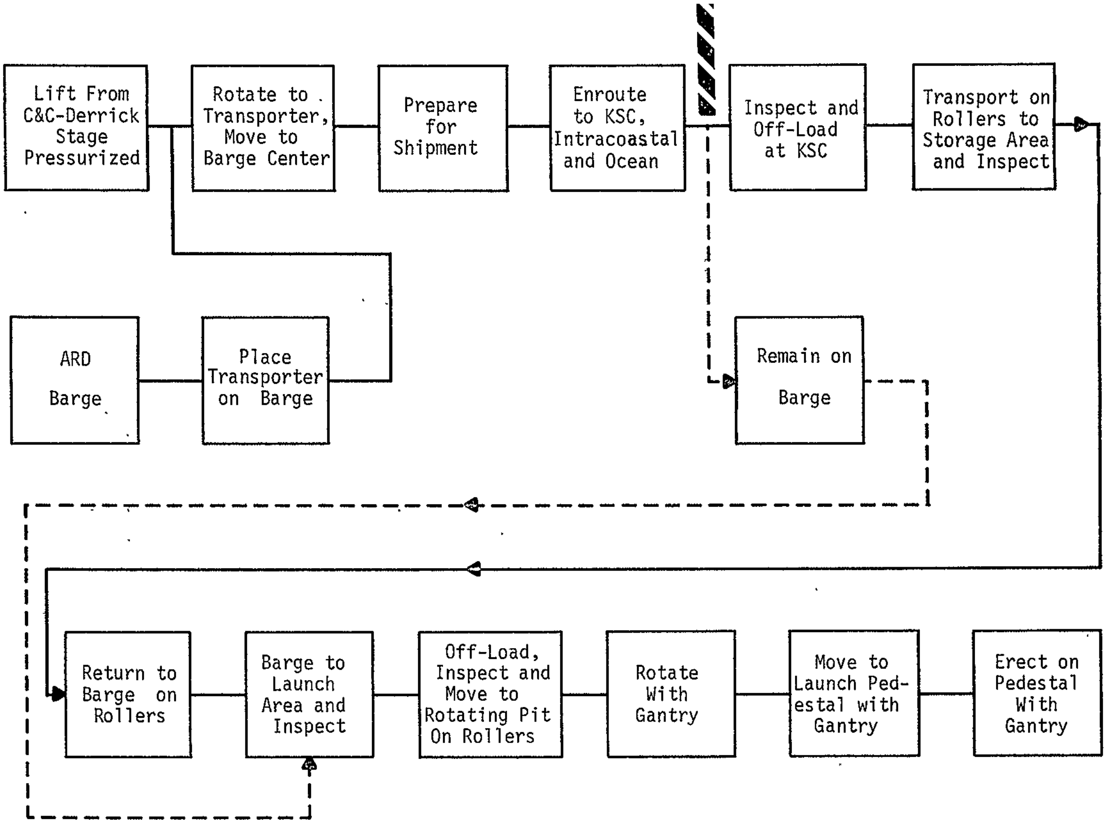


Figure 2. - Handling Method No. 1 Block Diagram

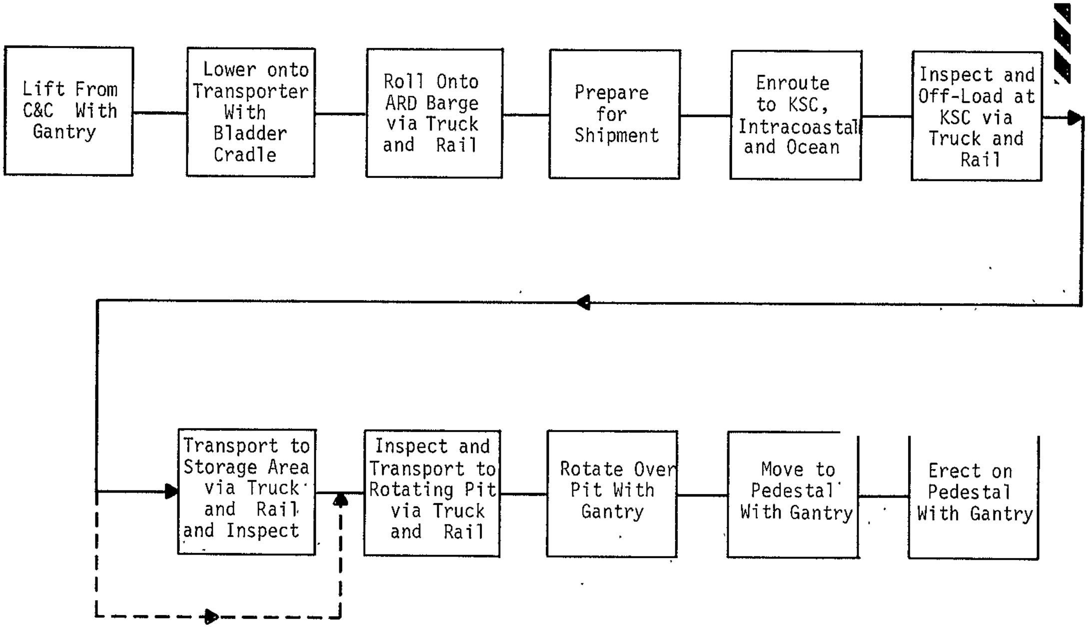


Figure 3. - Handling Method No. 2 Block Diagram

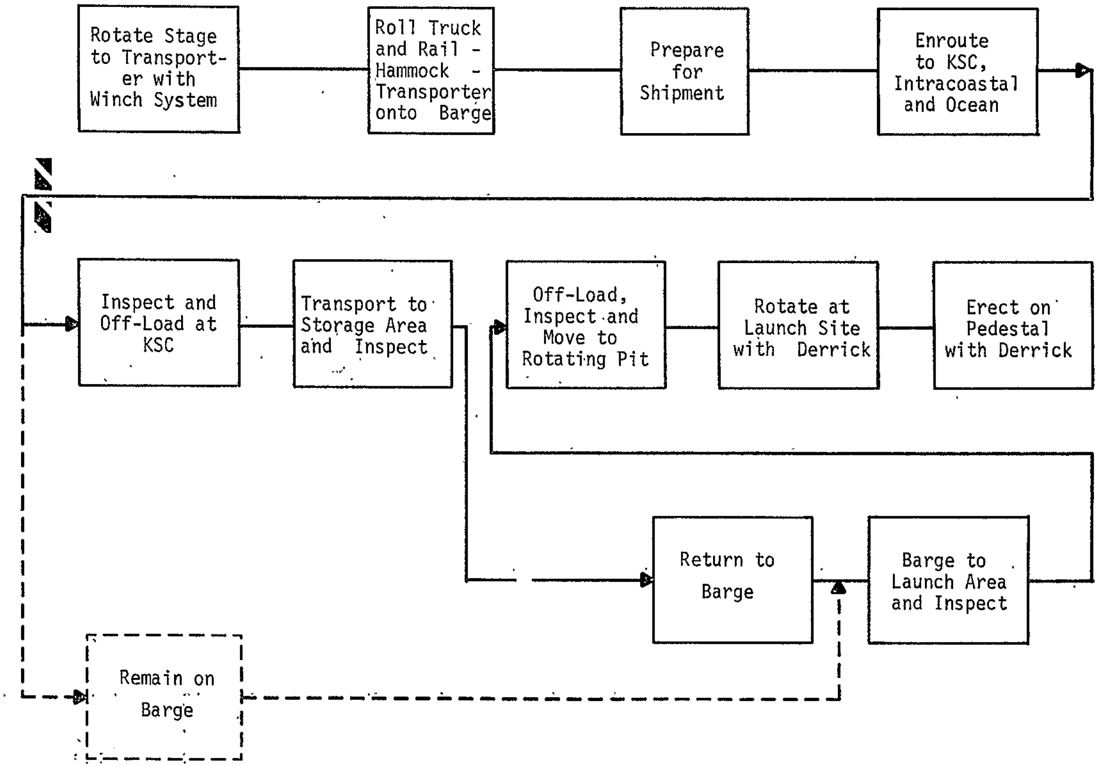


Figure 4. - Handling Method No. 3 Block Diagram

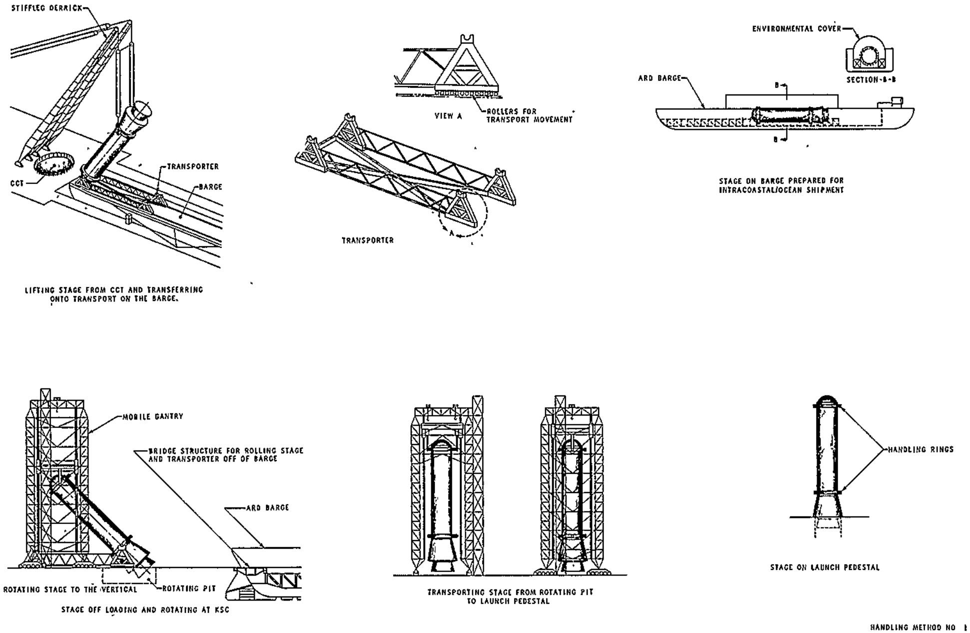


Figure 5. - Handling Method No. 1

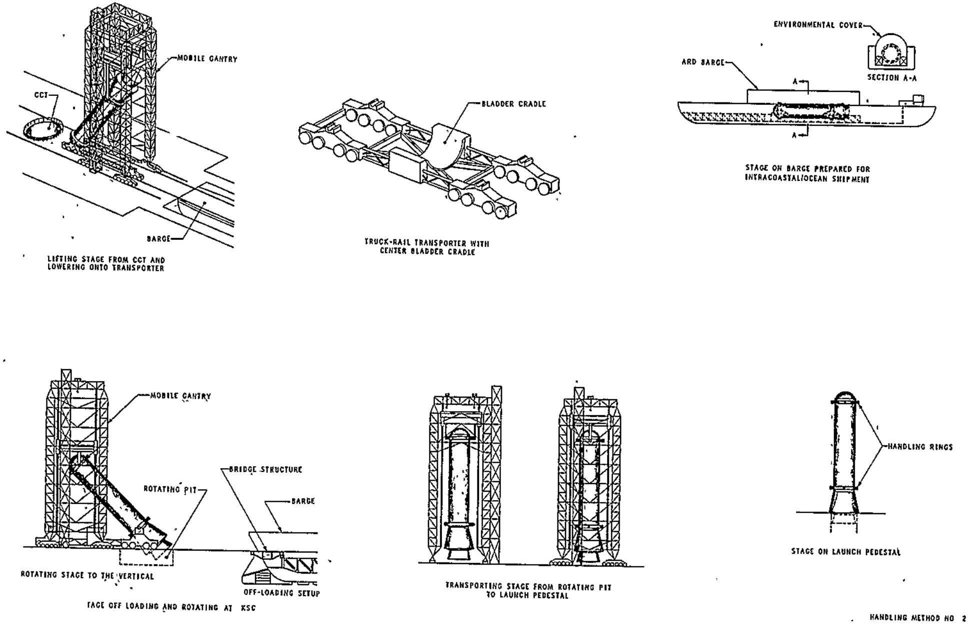


Figure 6. - Handling Method No. 2

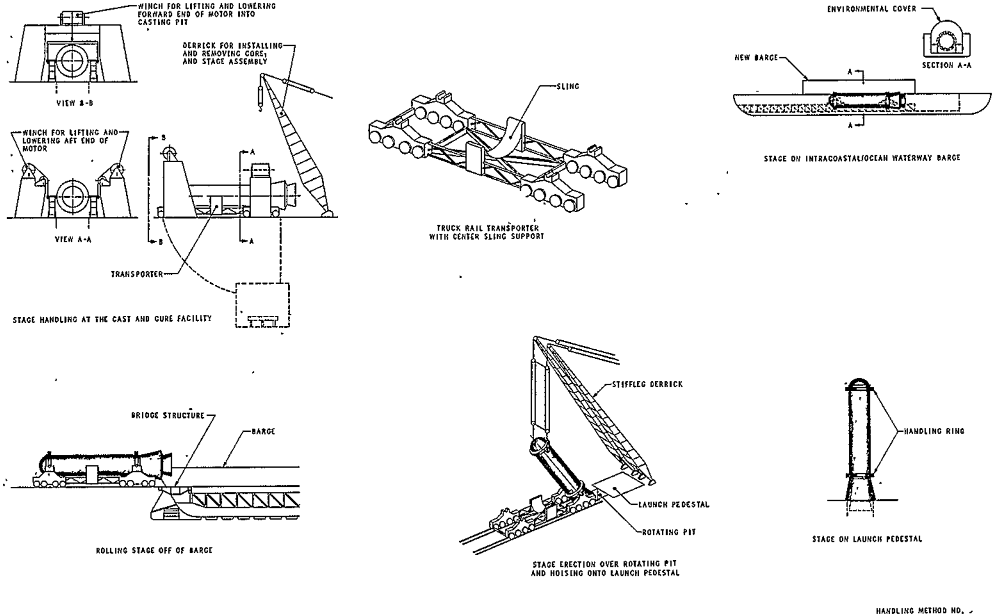


Figure 7. - Handling Method No.

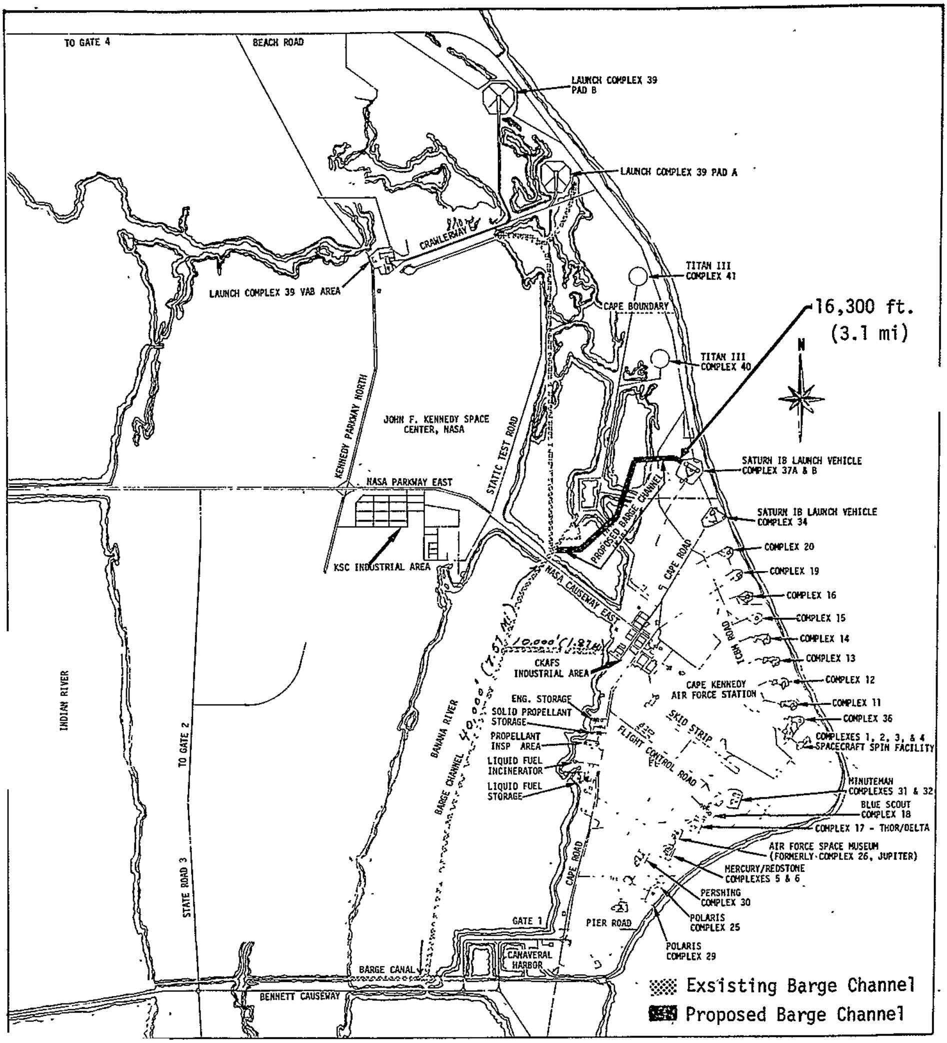


Figure 8. - Barge Channel to KSC LC-137B

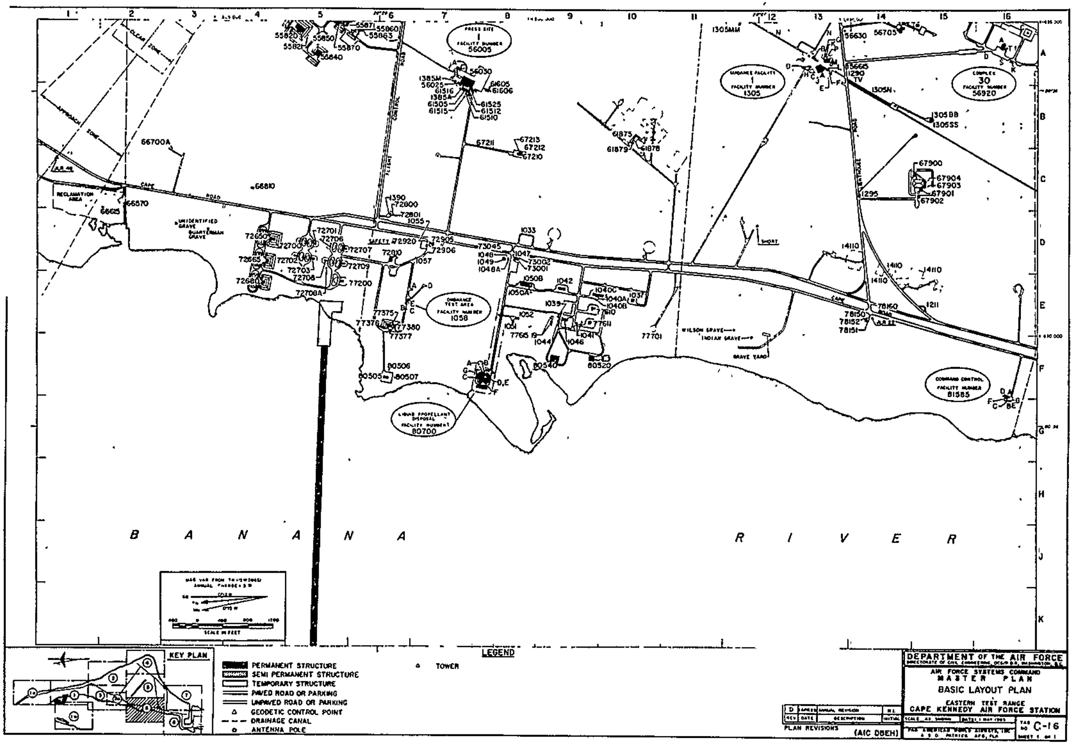


Figure 9. - CKAFS Solid Propellant Storage Area

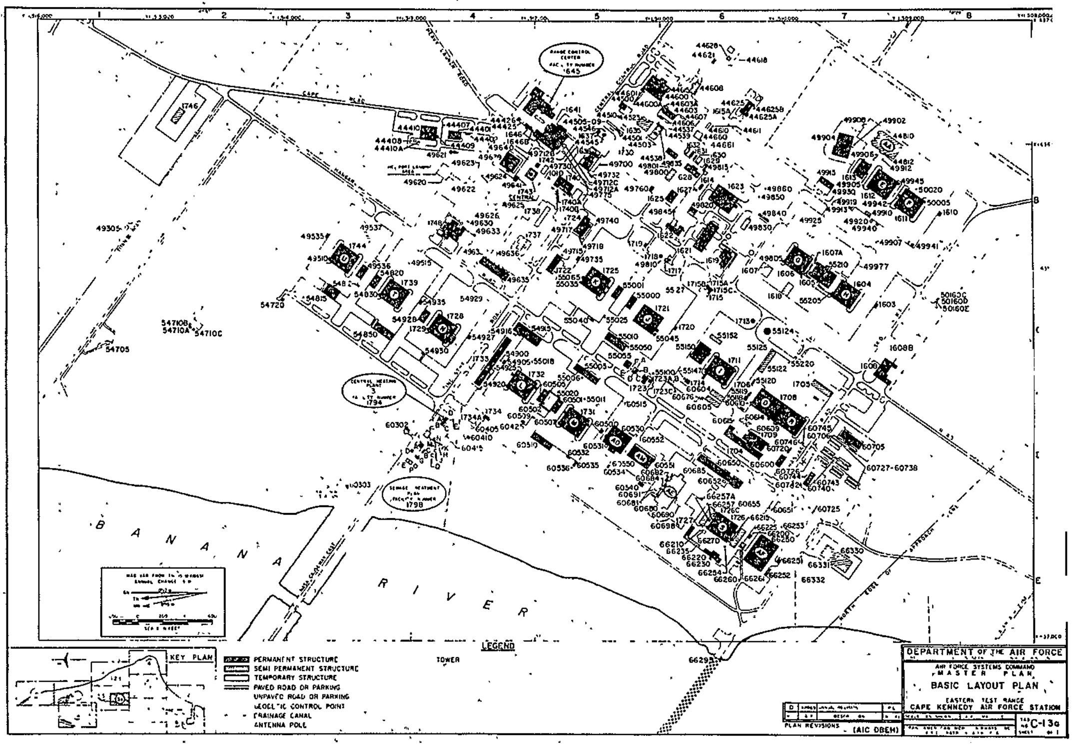
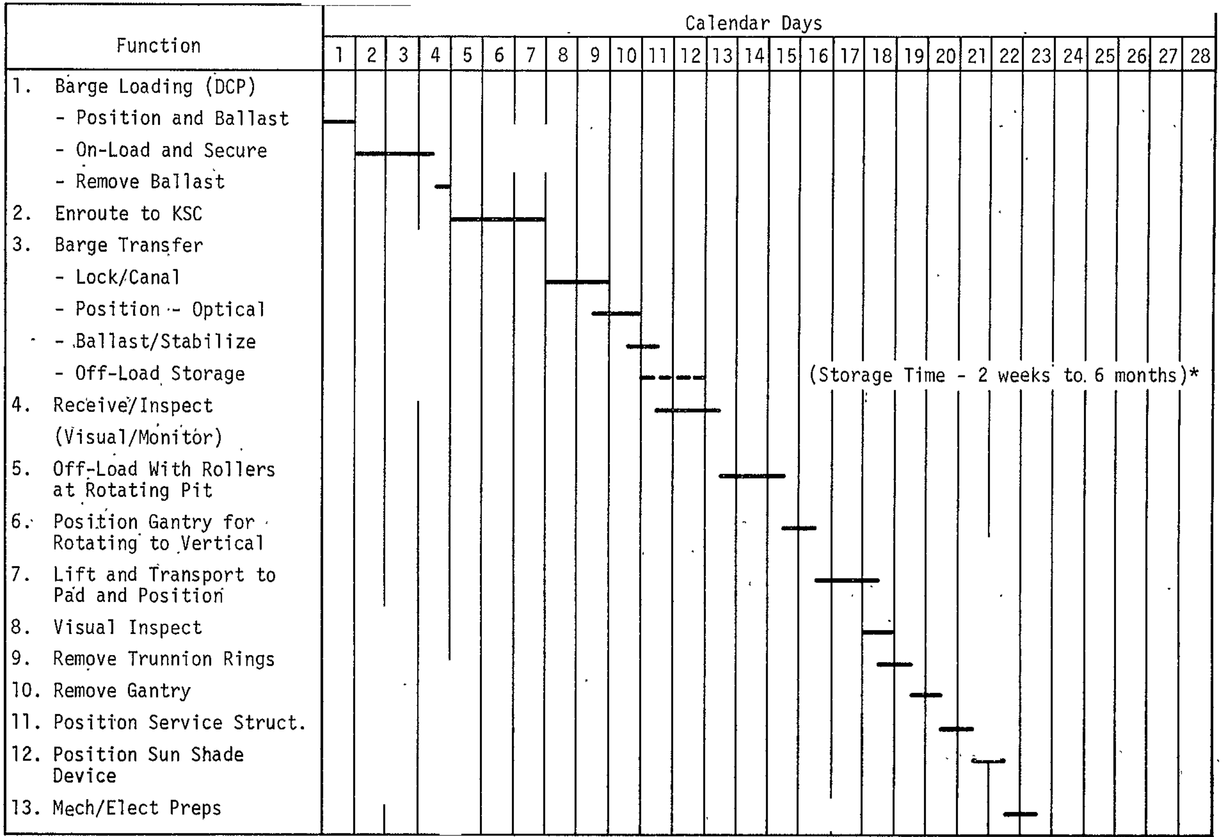
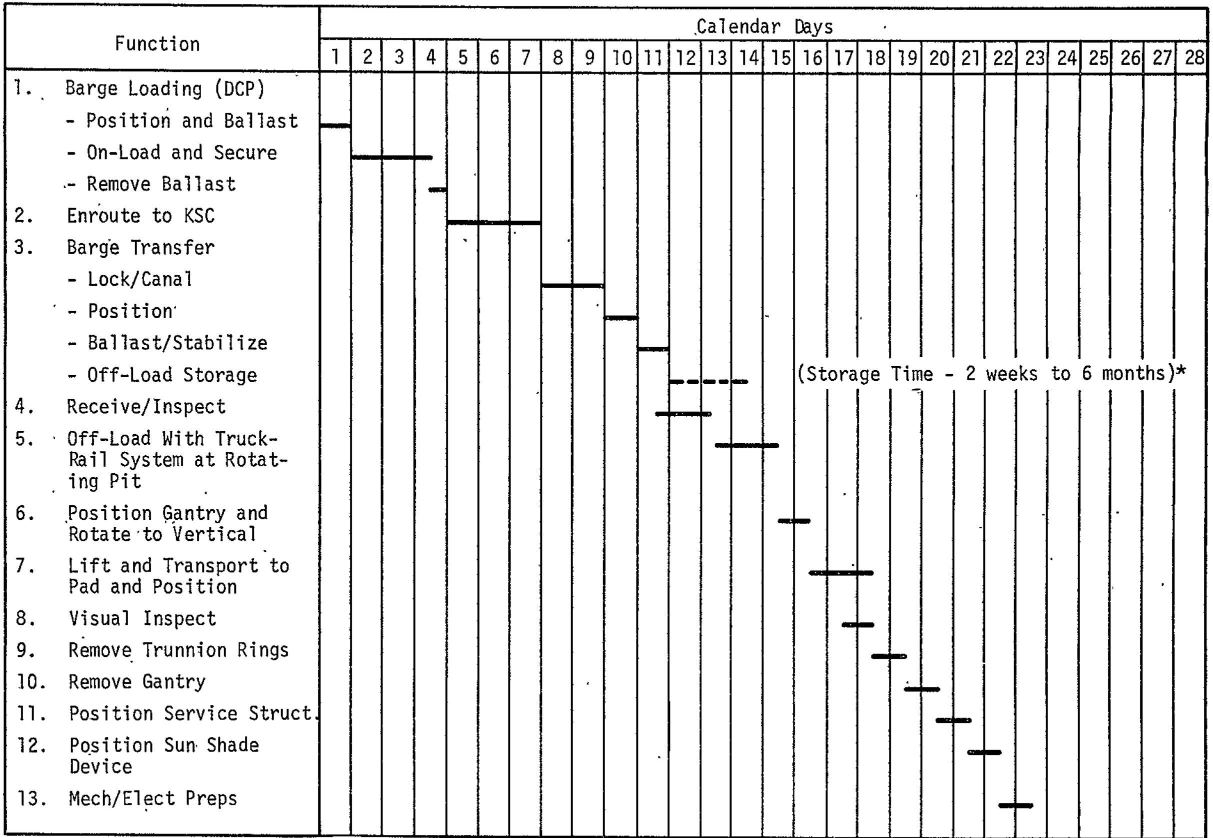


Figure 10. - CKAFS Industrial Area Off-Loading (Existing Dock and Channel)



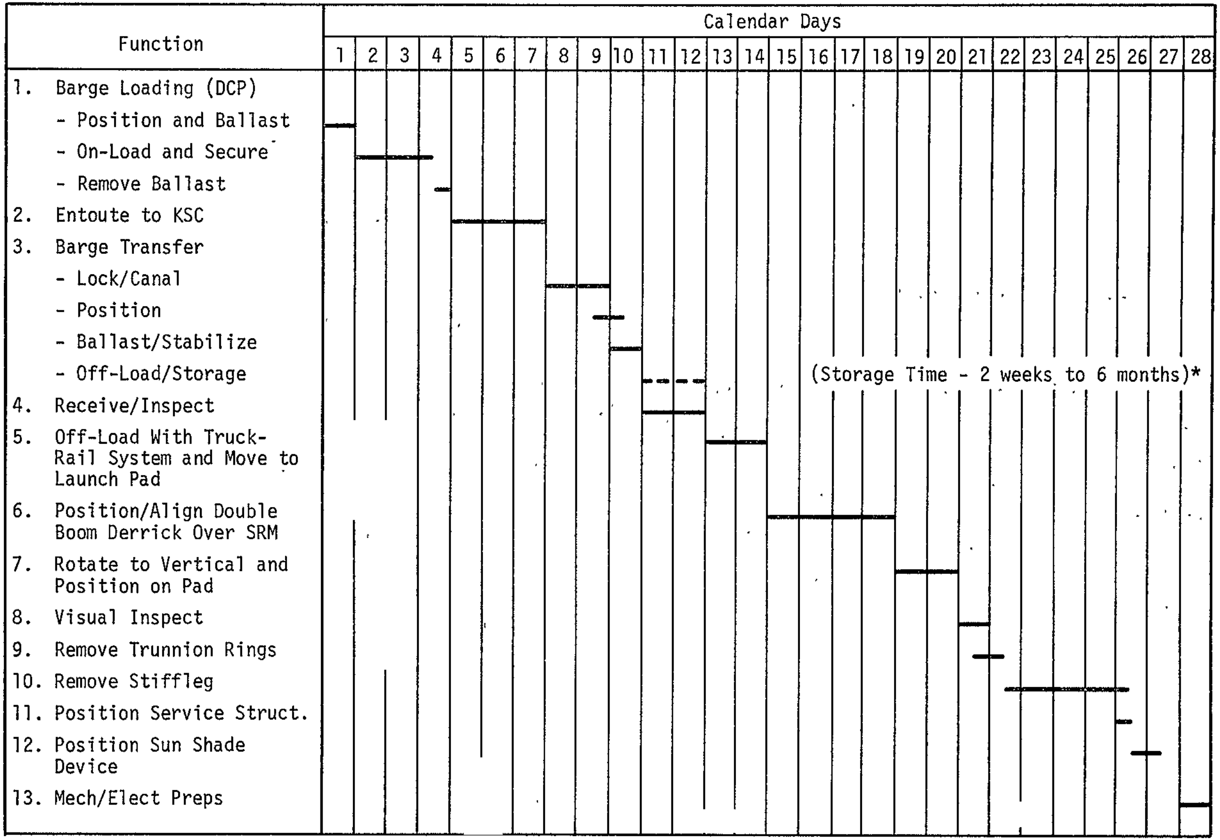
Items 1 and 2 calendar day equals three eight (8) hour shifts. Items 3 through 13 calendar day equals one eight (8) hour shift.
*Storage time is not included in this basic (gross) estimate.

Figure 11. - Process Time Cycle for Handling/Erection Method No. 1, DCP to Launch Pad



Items 1 and 2 calendar day equals three eight (8) hour shifts. Items 3 through 13 calendar day equals one eight (8) hour shift.
*Storage time is not included in this basic (gross) estimate.

Figure 12. - Process Time Cycle for Handling/Erection Method No. 2, DCP to Launch Pad



Items 1 and 2 calendar day equals three eight (8) hour shifts. Items 3 through 13 calendar day equals one eight (8) hour shift.
*Storage time is not included in this basic (gross) estimate.

Figure 13. - Process Time Cycle for Handling/Erection Method No. 3, DCP to Launch Pad

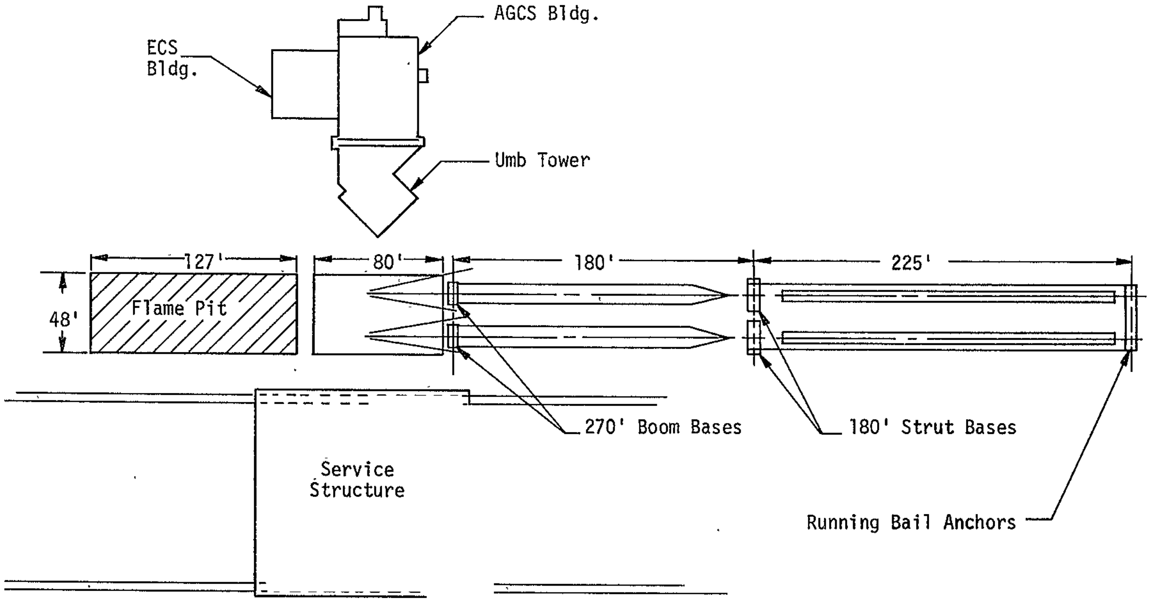


Figure 14. - Stiffleg Derrick/Launch Pad Configuration No. 1

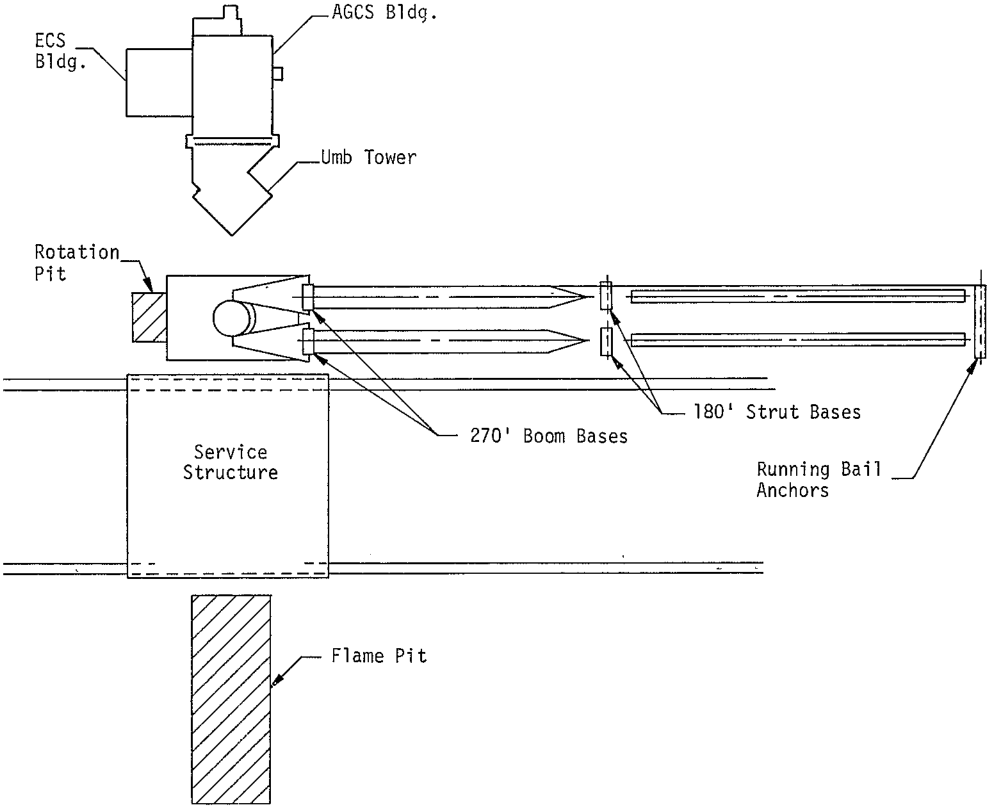


Figure 15. - Stiffleg Derrick/Launch Pad Configuration No. 2

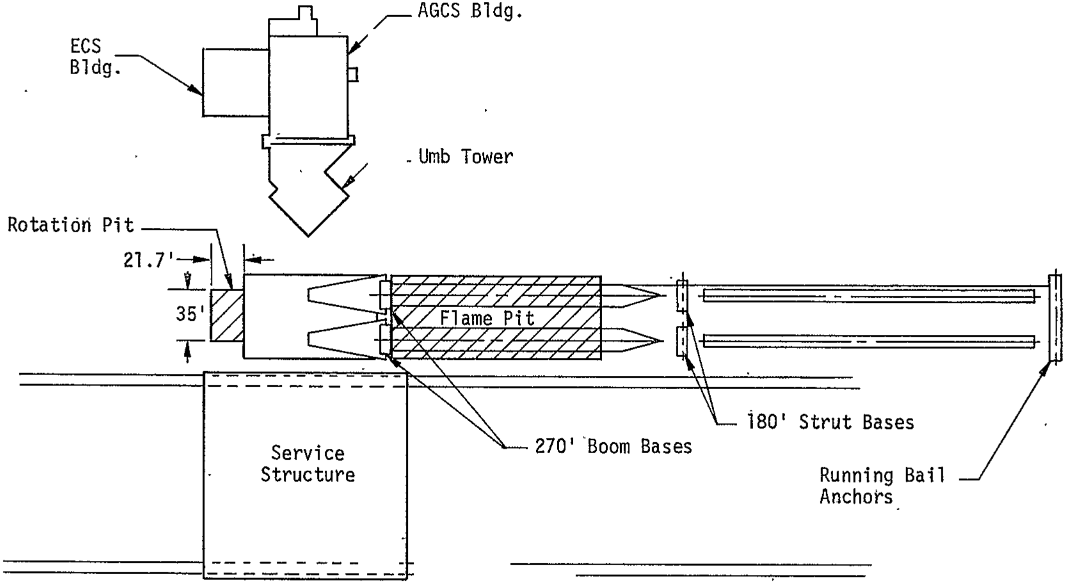


Figure 16. - Stiffleg Derrick/Launch Pad Configuration No.

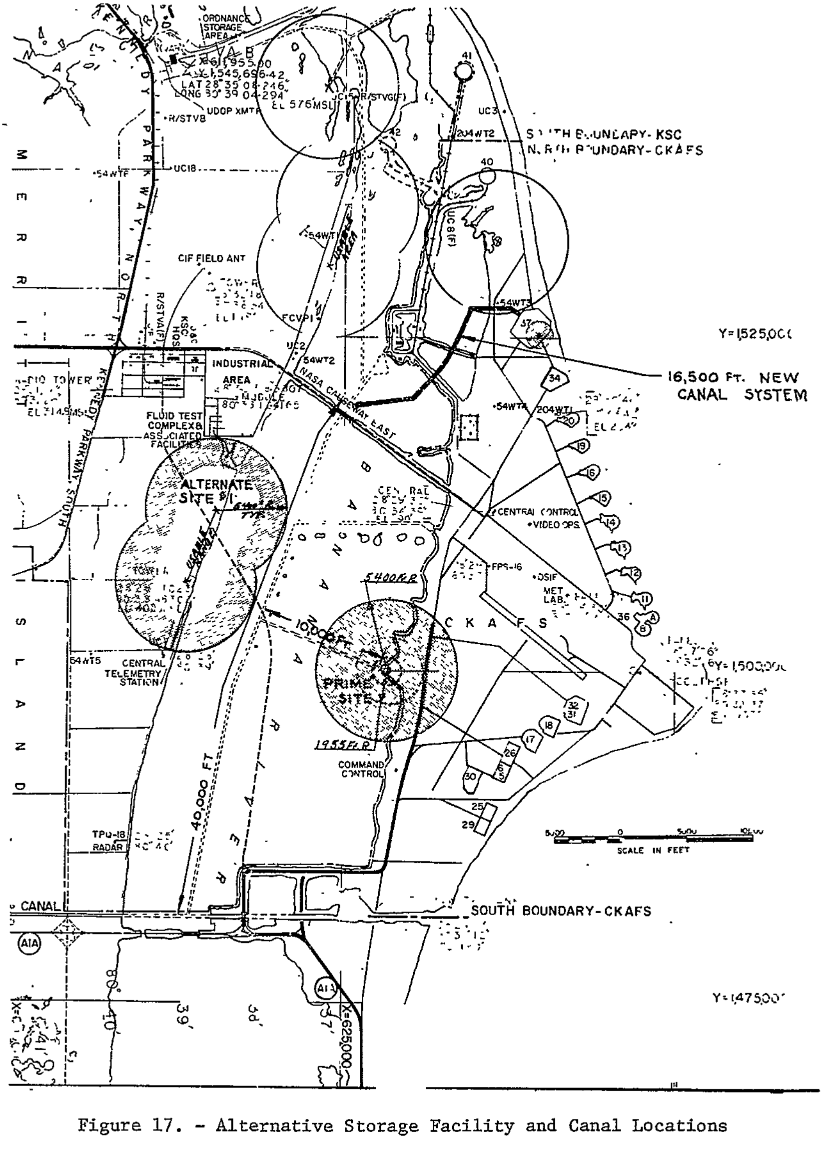


Figure 17. - Alternative Storage Facility and Canal Locations

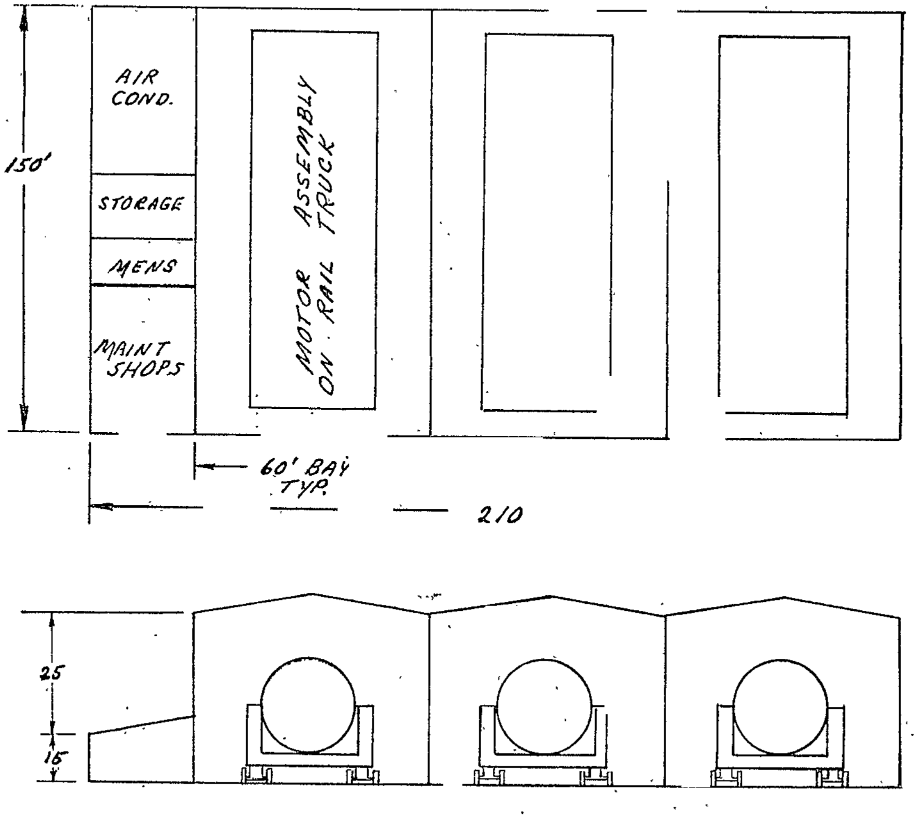
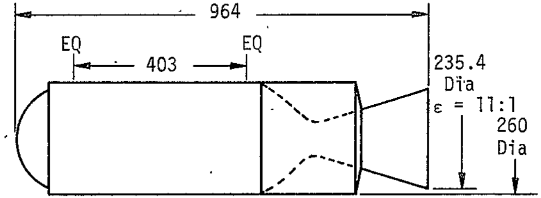
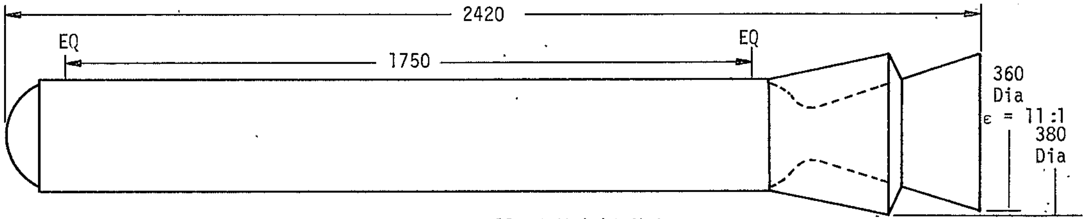


Figure 18. - Storage and Checkout Building Configuration



1.6 M lb Propellant Weight Motor
(1,762,000 lb Handling Weight)



5.0 M lb Propellant Weight Motor
(5,460,000 lb Handling Weight)

Note:
Dimensions in Inches

Figure 19. - 1.6M lb and 5.0M lb Propellant Weight Stage Configurations

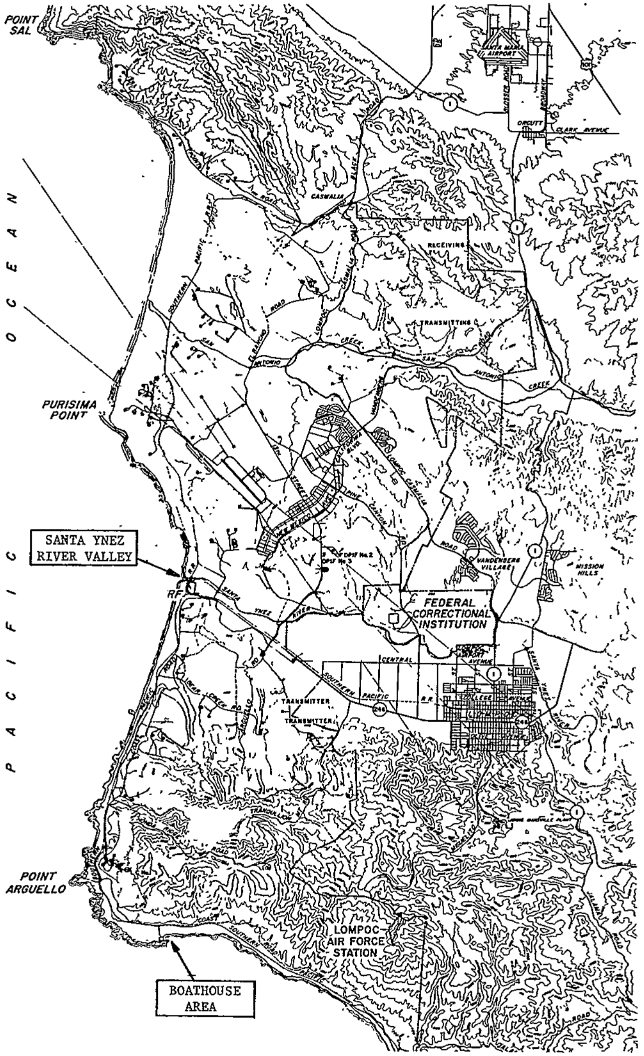
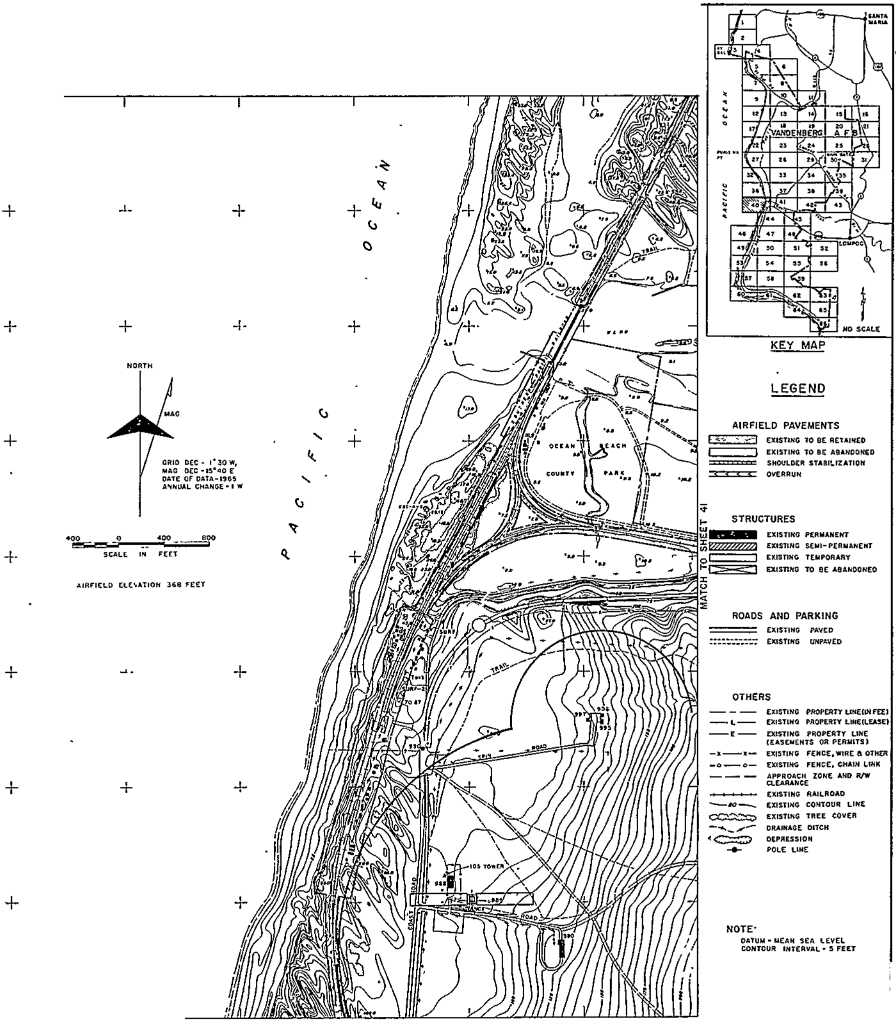


Figure 20. - WTR and Adjacent Areas



_gure 21. - Santa Ynez River Valley Terrain Elevation

Sheet 1 of 2

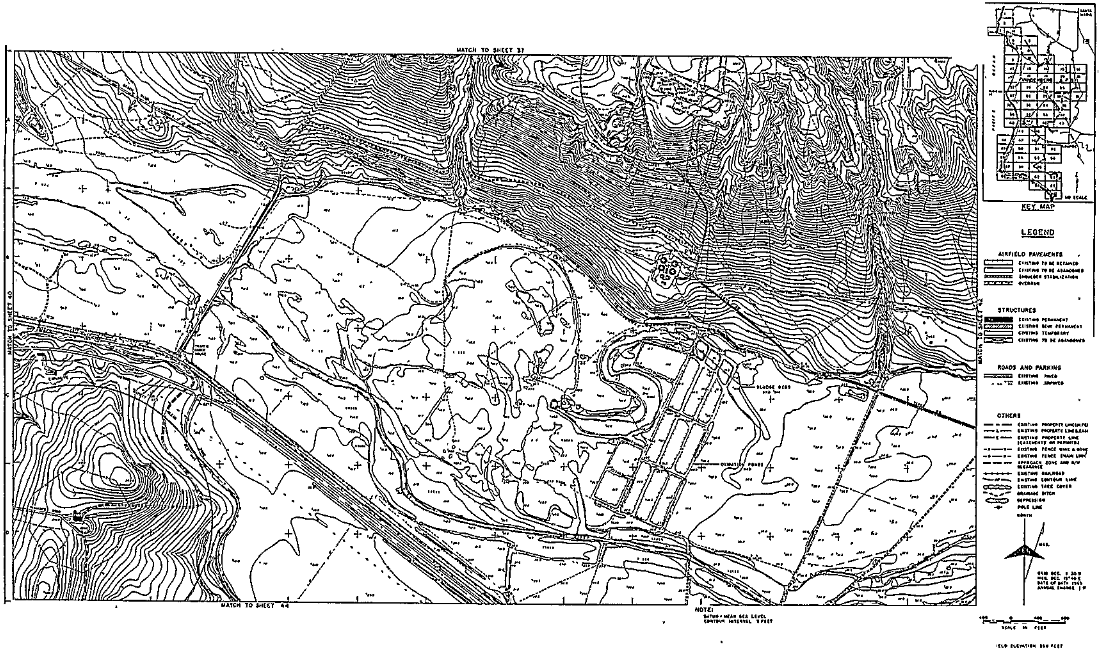


Figure 21. - Santa Ynez River Valley Terrain Elevation

Sheet 2 of 2

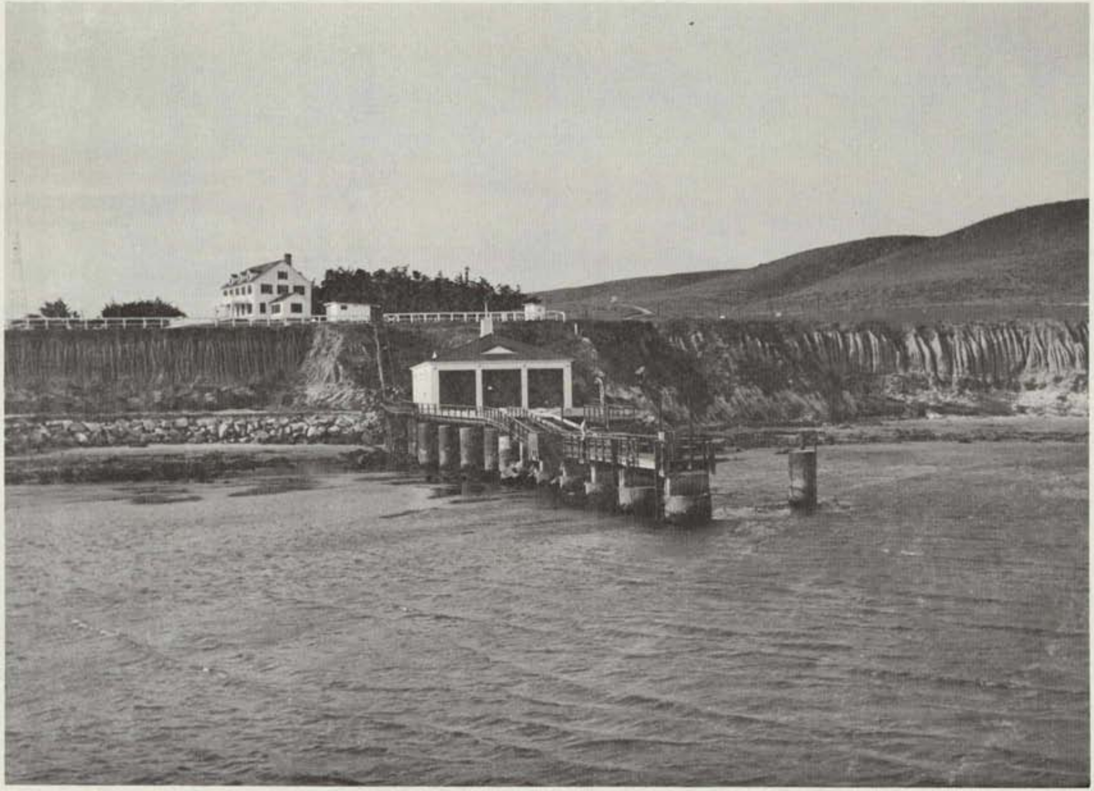


Figure 22. - Boathouse Area Coastline South of Point Arguello

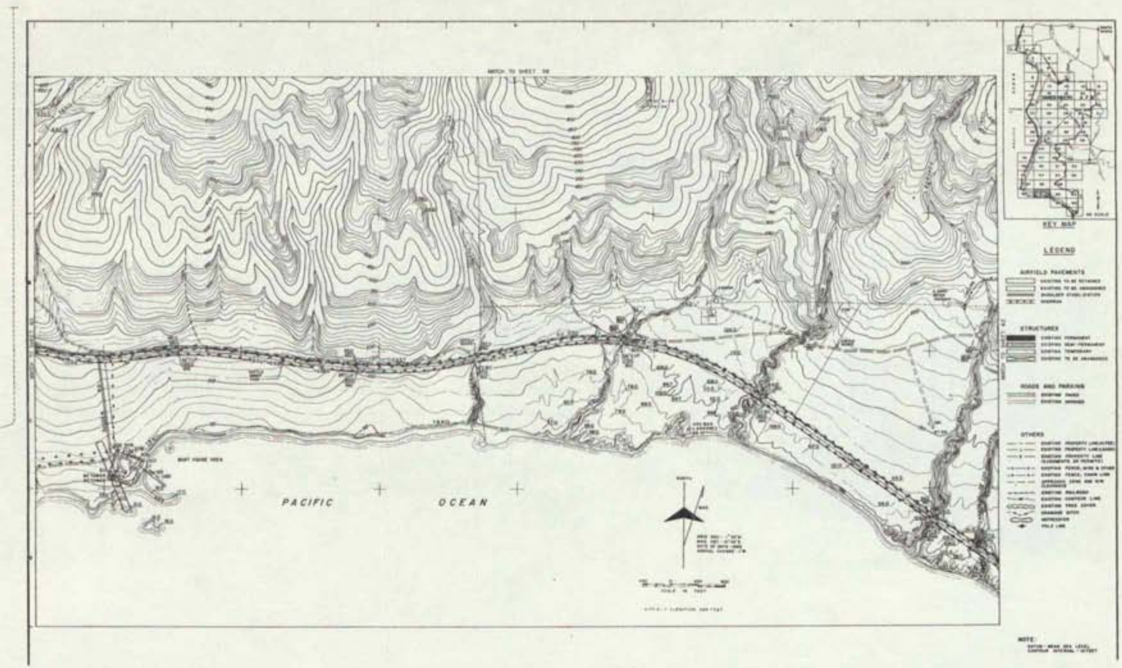


Figure 23. - Boathouse Area Terrain Elevation

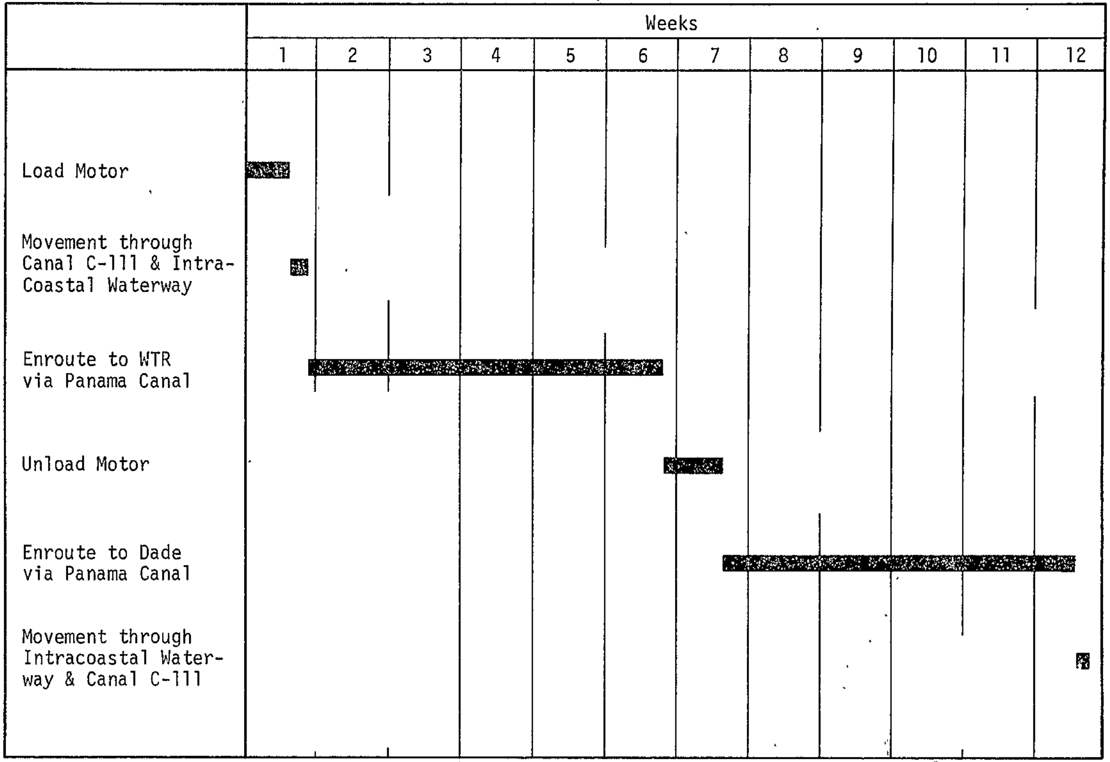


Figure 24. - 260 Stage Transportation Schedule - DCP to WTR

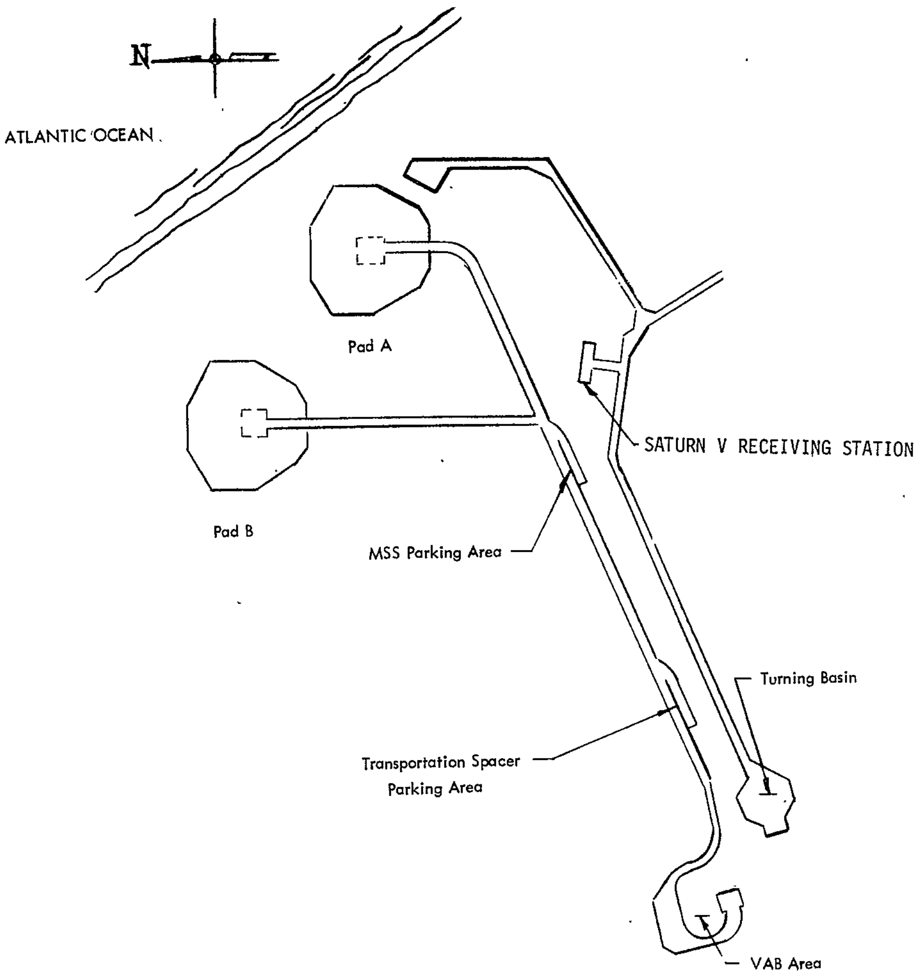


Figure 25. Saturn V Receiving Station (LC-39)

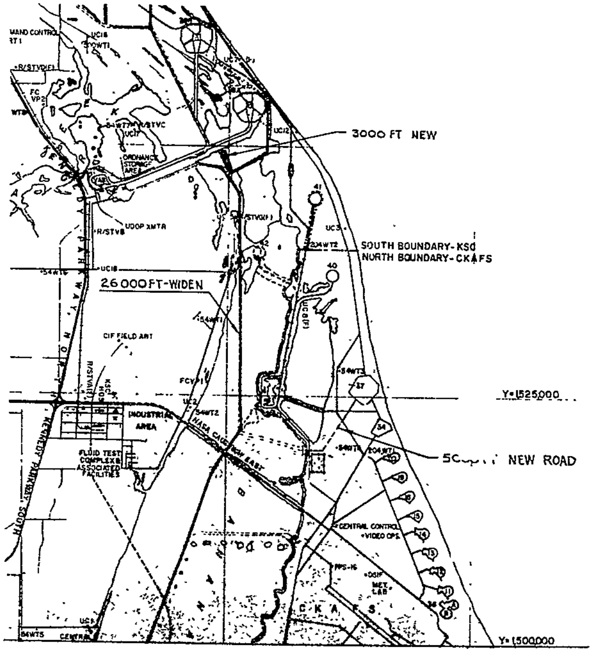


Figure 26. - Canal Extension for LC-39 Alternative Destination

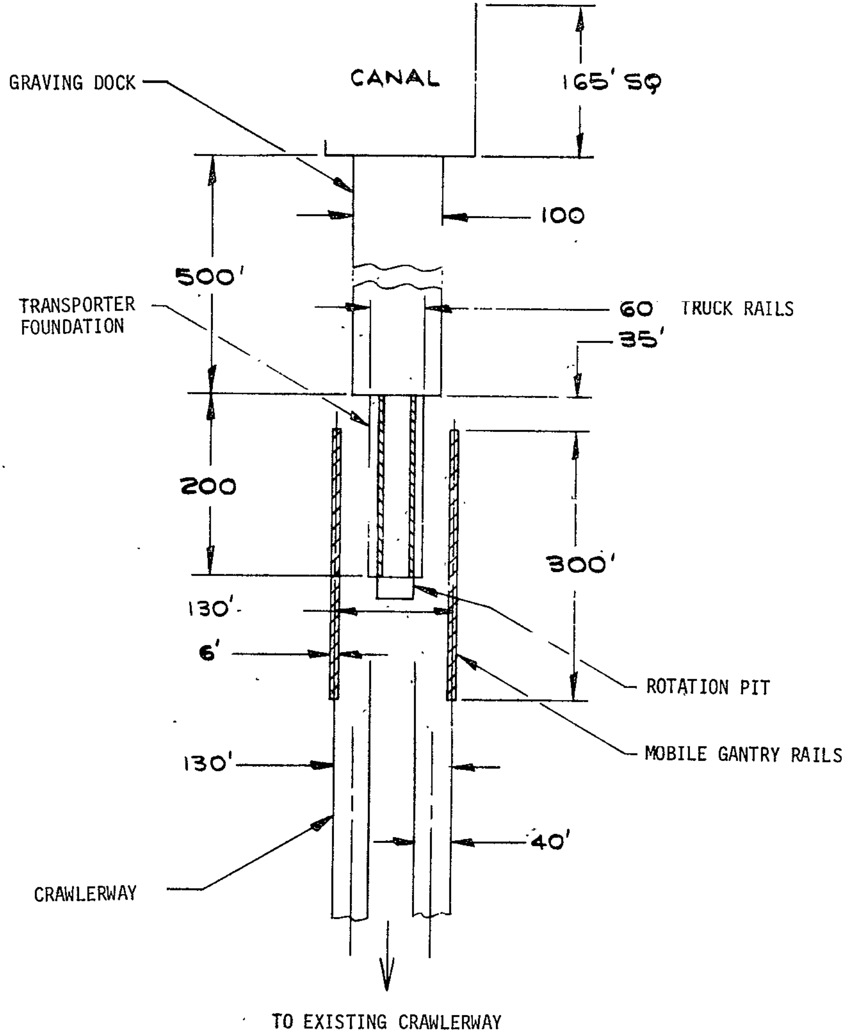


Figure 27. - 260 Stage Dock Area, LC-39

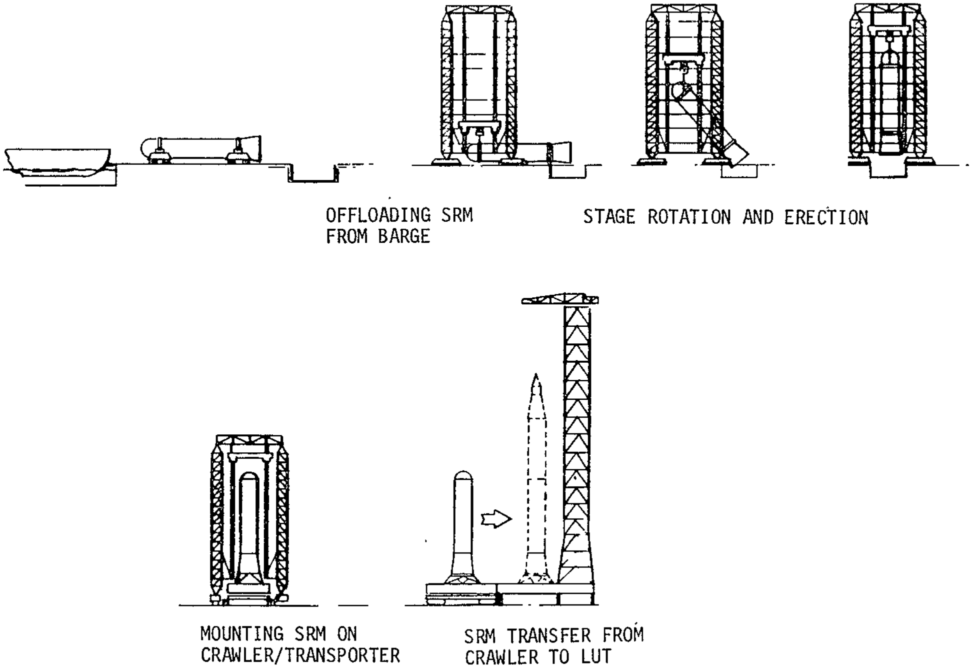


Figure 28. - 260 Stage Sequence of Operations, LC-39

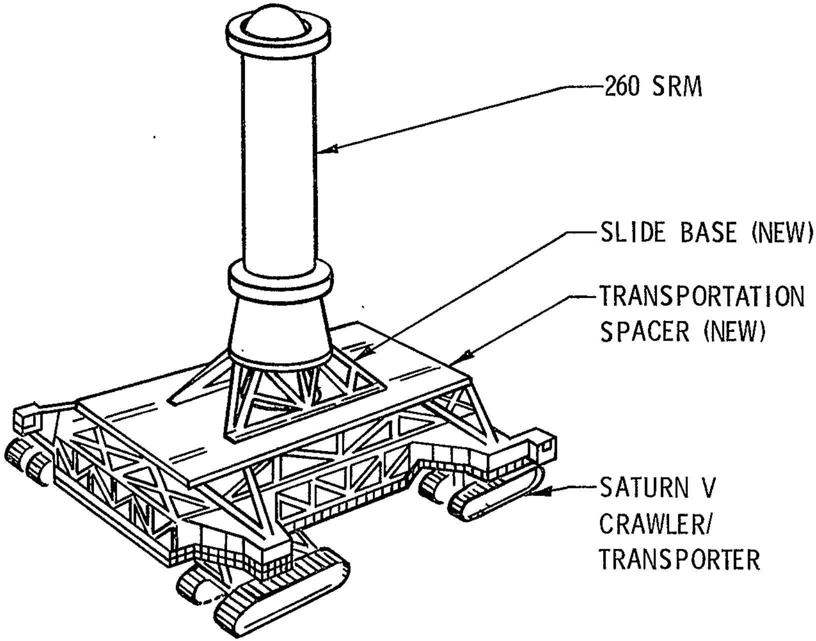


Figure 29. - 260 Stage in Transport Mode, LC-39

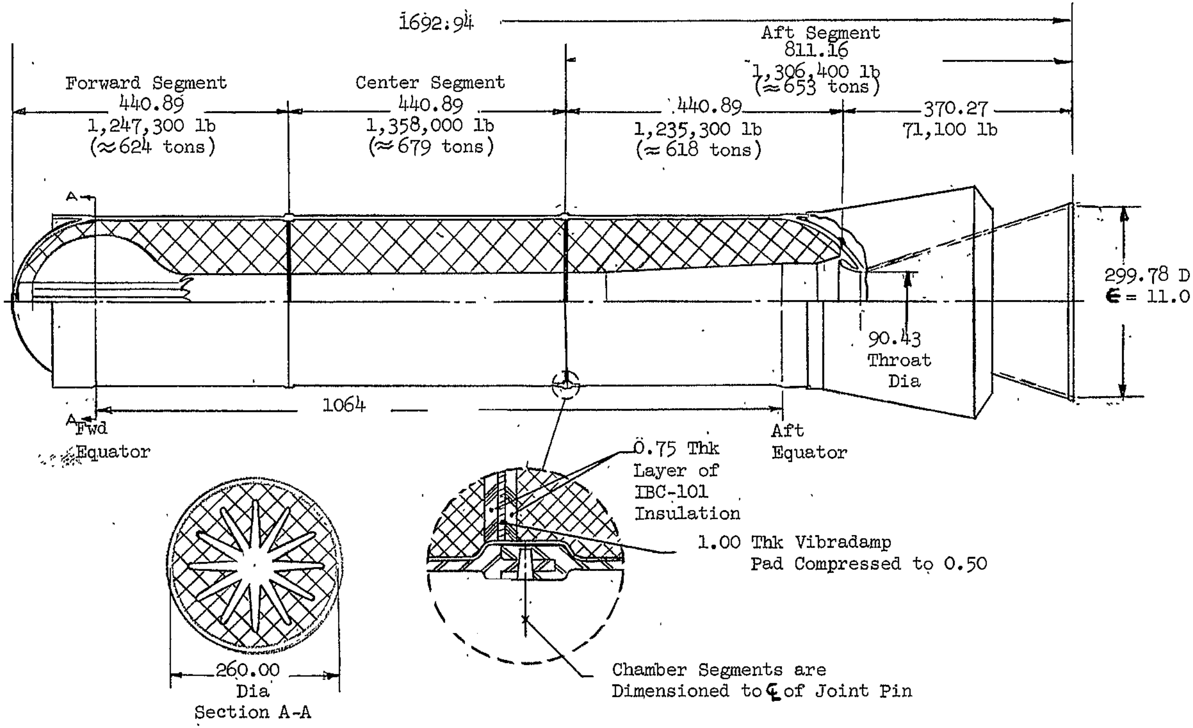


Figure 30. - Three Segment Configuration of 260 Stage

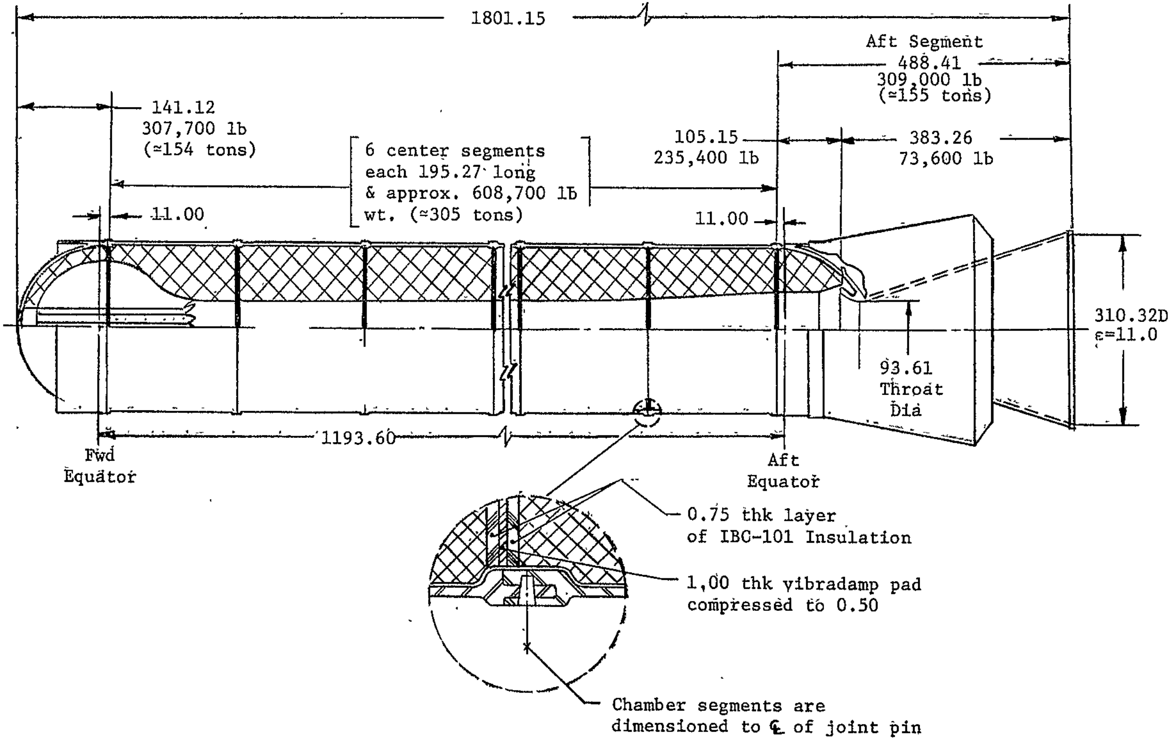
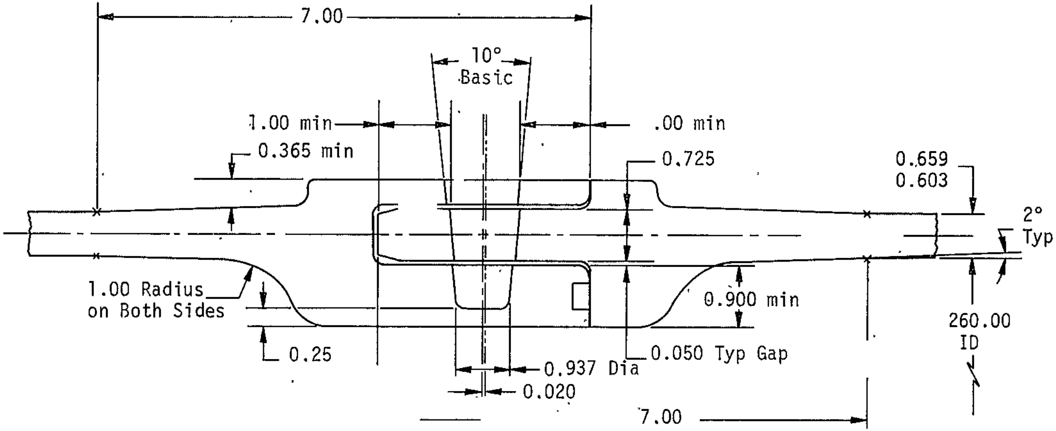


Figure 31. - Eight Segment Configuration of 260 Stage



Joint Material: 18% 200 Grade Ni Steel; Fty = 220K psi min
Pin Material: 18% 250 Grade Ni Steel; Fty = 250K psi min
420 pins equally spaced

Figure 32. - Segment Joint Design for 260-in. (6.6m)-dia Chamber

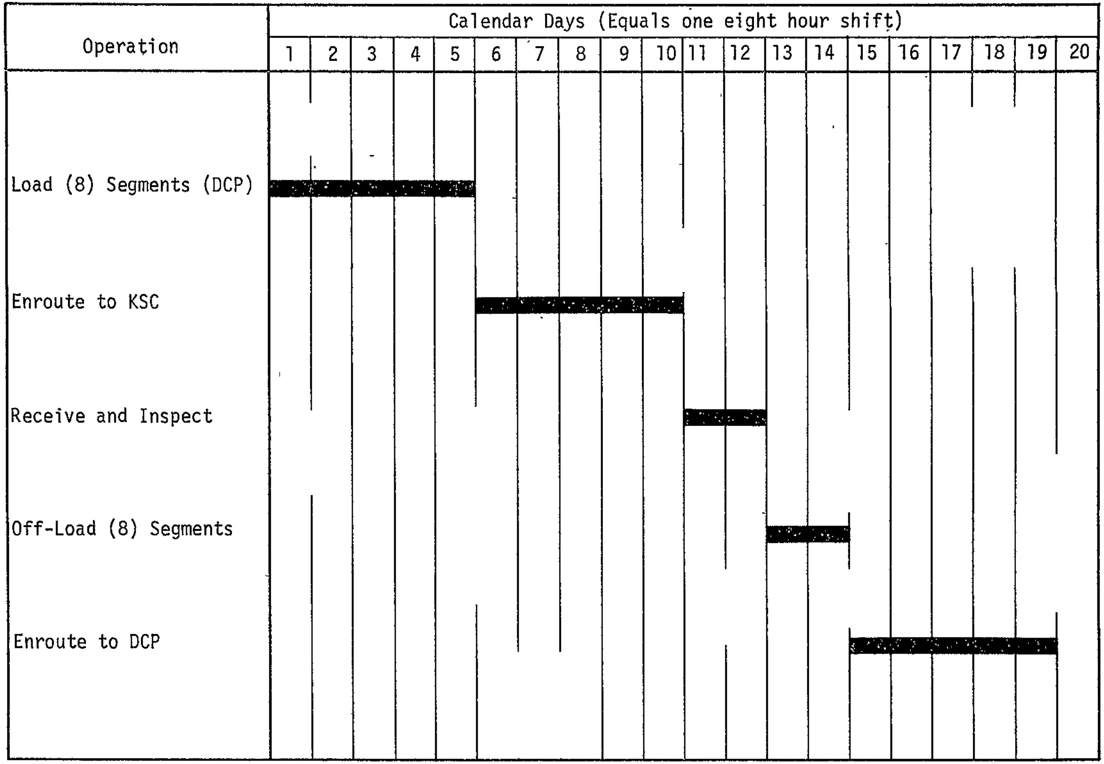


Figure 33. - Segmented Motor Transportation Schedule
(Dade County Plant to KSC)

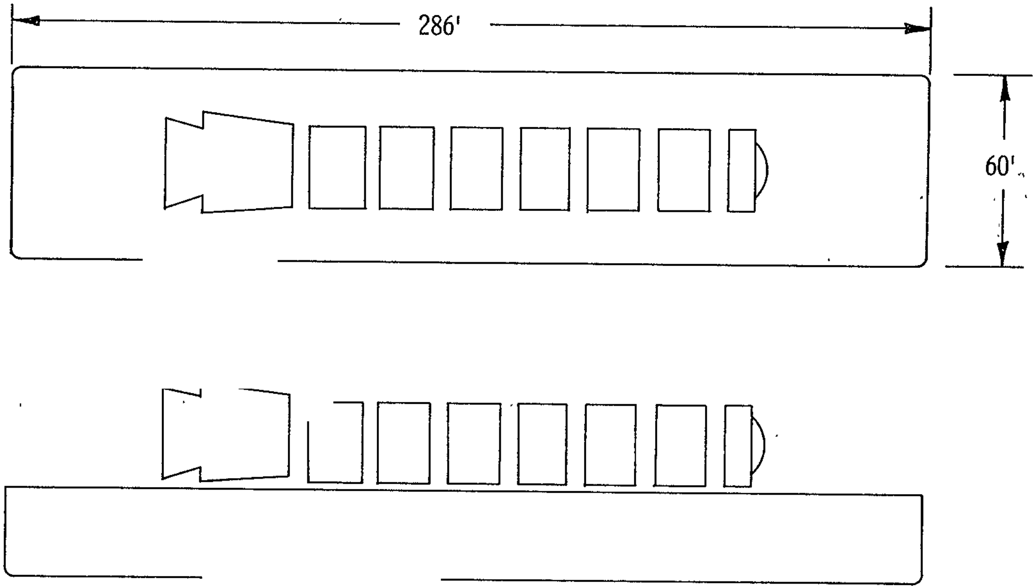


Figure 34. - Barge Transport - Segmented Motor

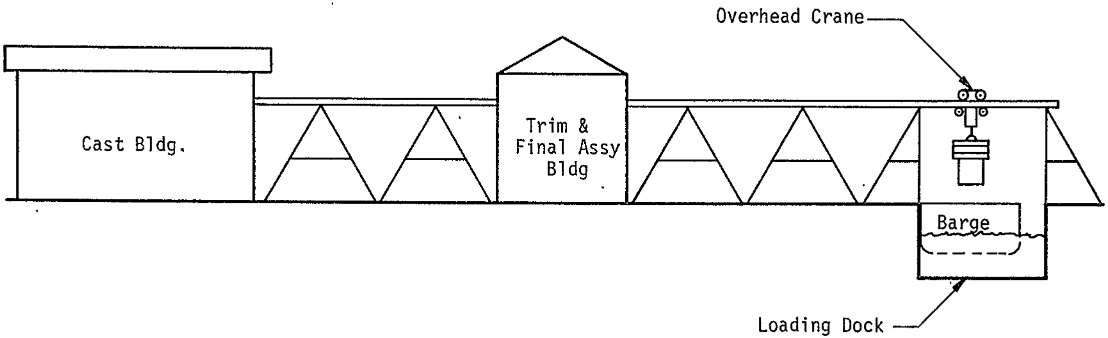


Figure 35. - Overhead Crane Method at DCP

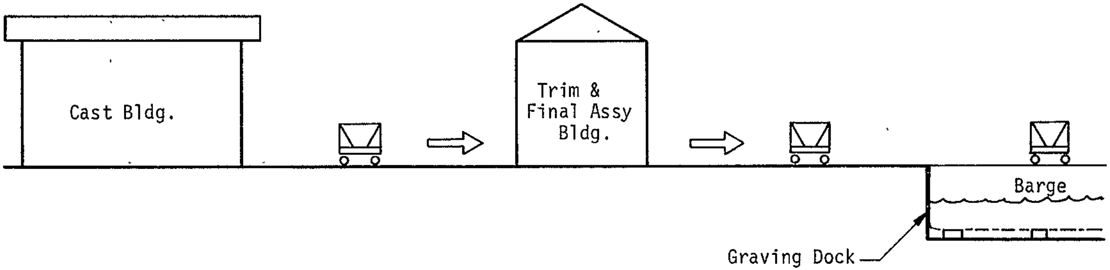


Figure 36. - Truck-Rail Method at DCP

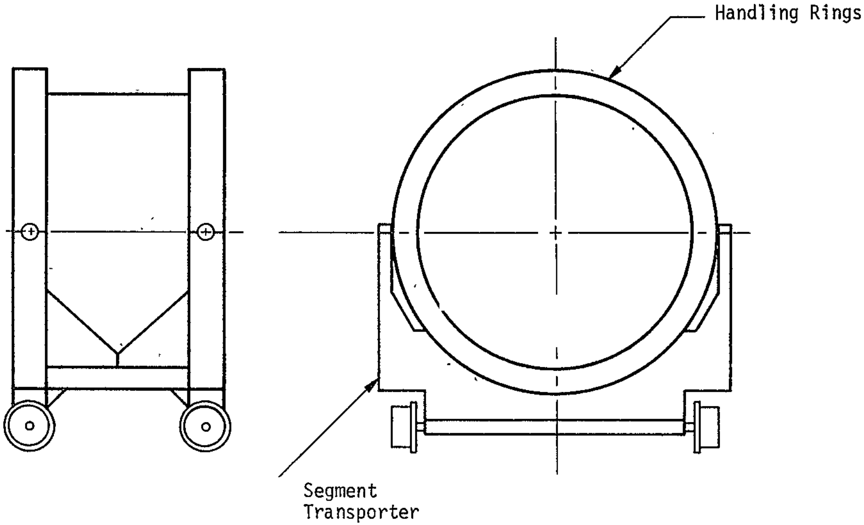


Figure 37. - Segment Transporter

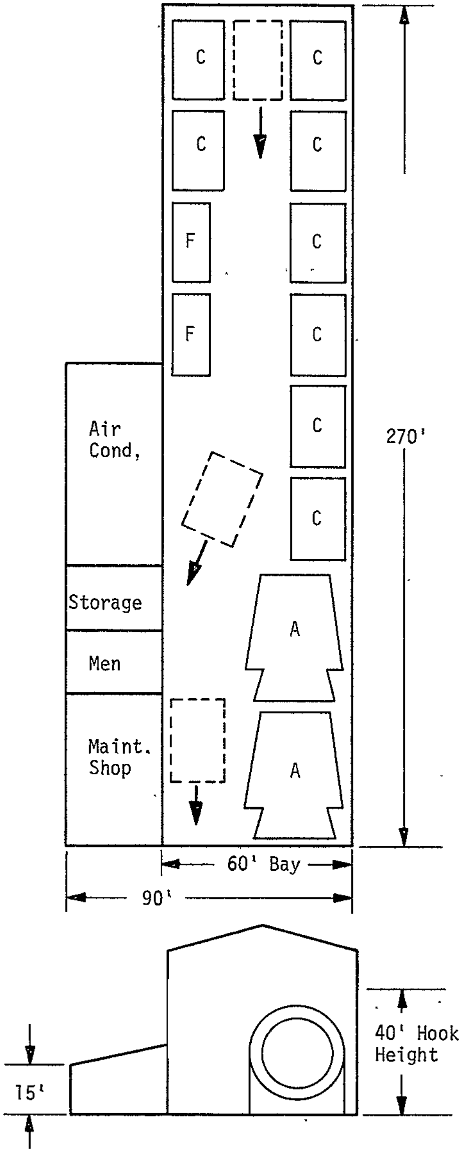


Figure 38. - Storage Facility - Segmented Motor

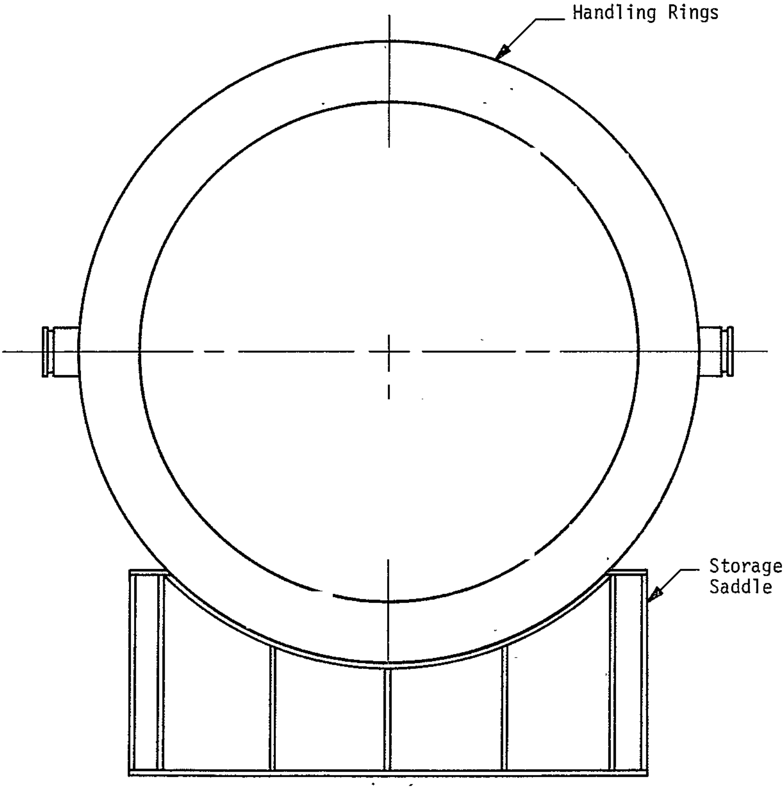


Figure 39. - Segment Positioned on Storage Saddle

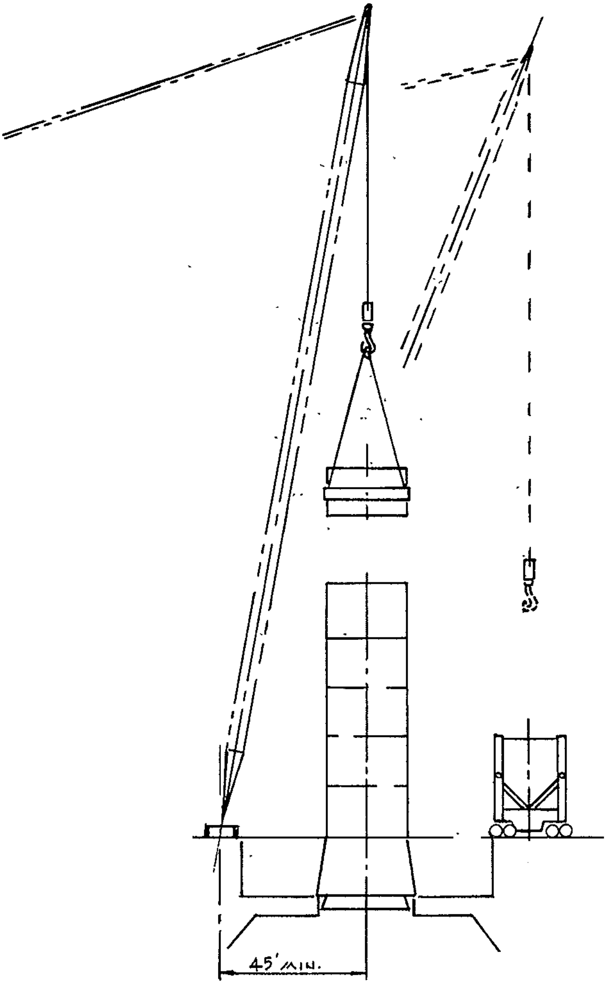


Figure 40. - Segment Assembly Over Center

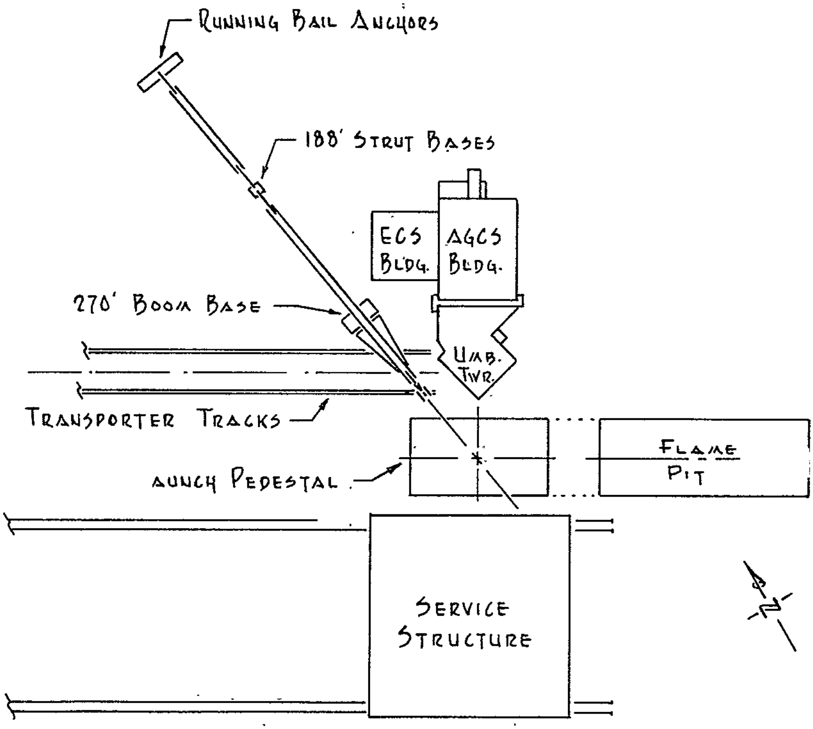


Figure 41. - Offset Alignment of Stiff-Leg Derrick at LC-37B

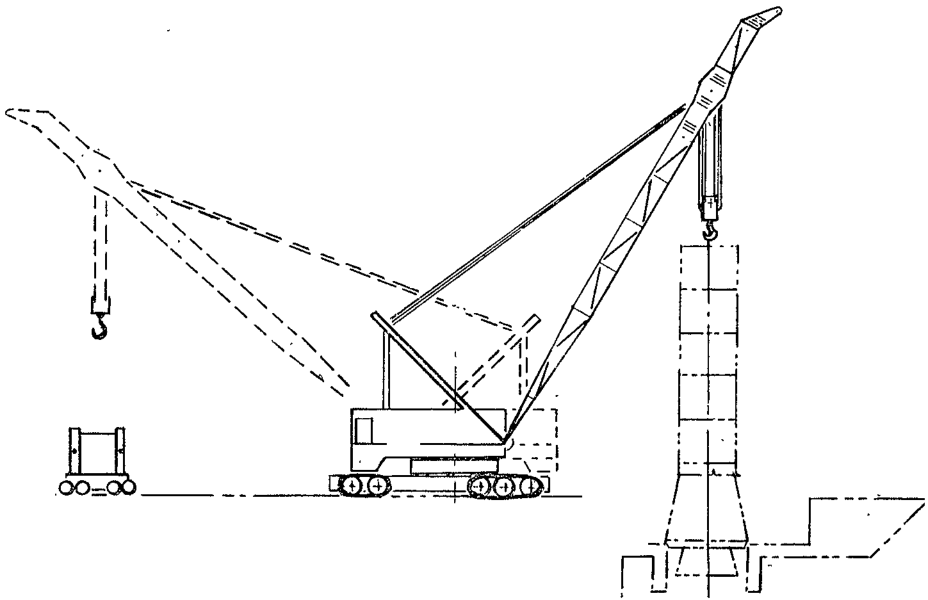


Figure 42. - Manitowoc Ringer Crane Concept - Pad Operation

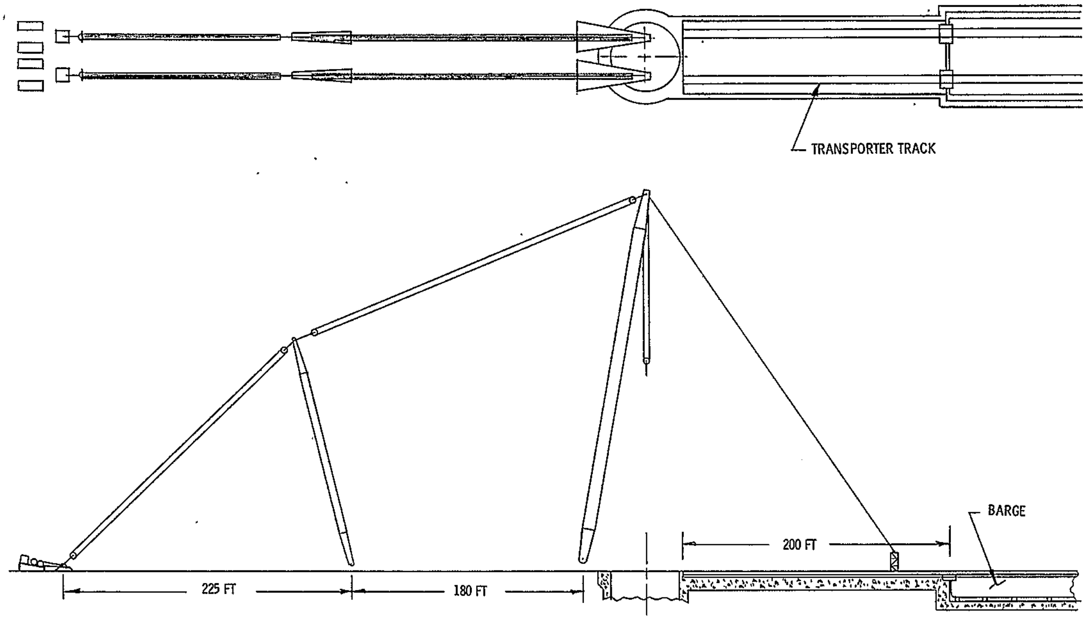


Figure 43. - Handling Method Arrangement at DCP

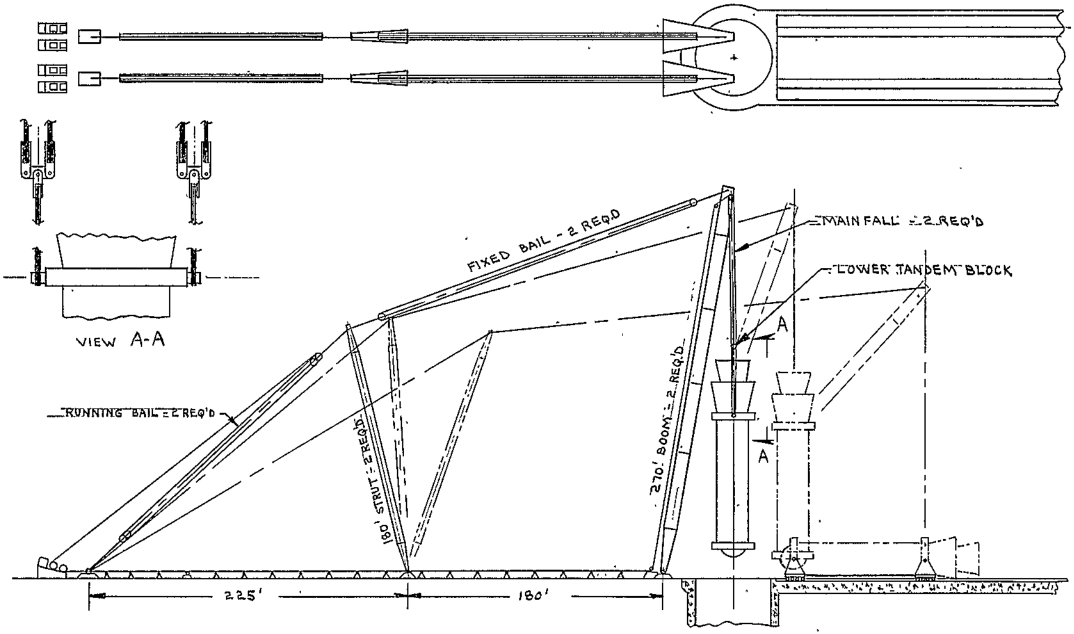


Figure 44. - Double Boom Stiff-Leg Derrick Design

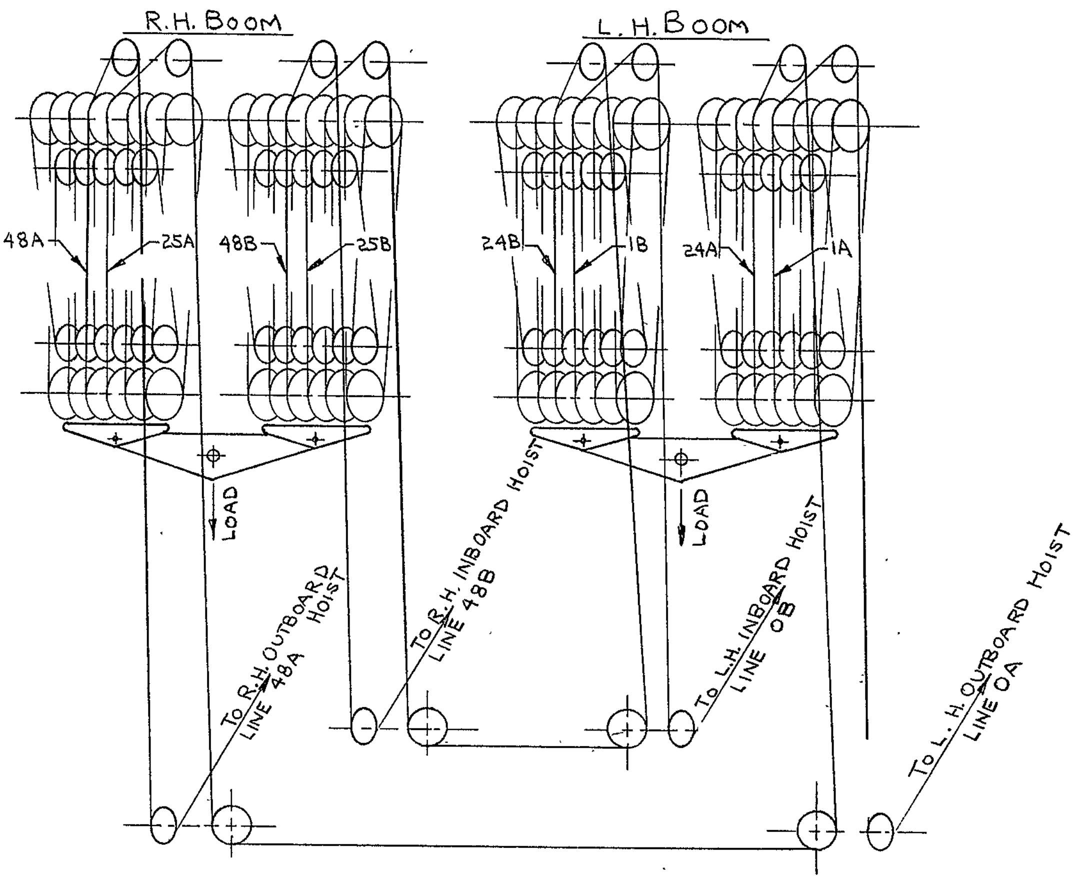


Figure 45. - Derrick Mainfall Line Reeving

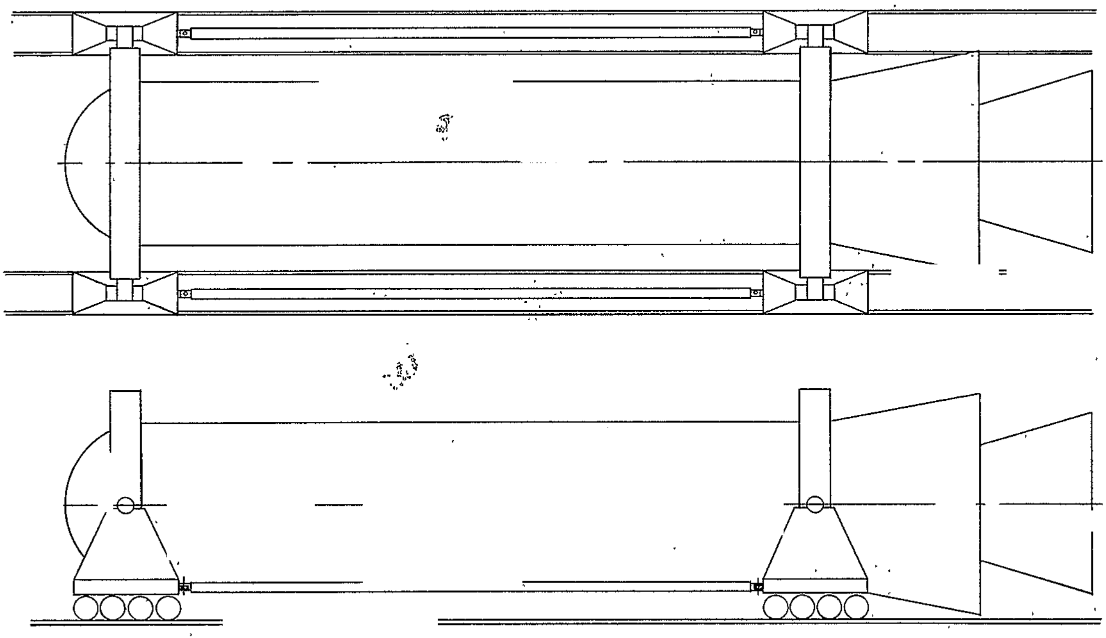
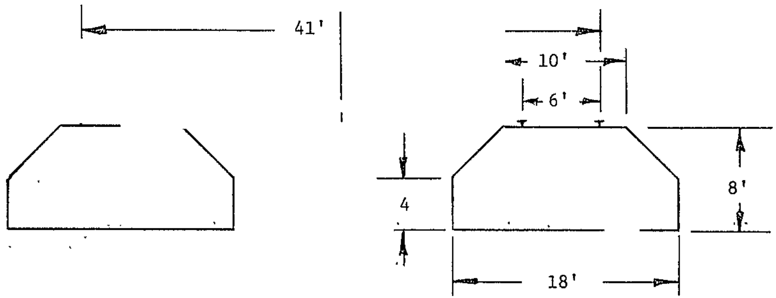


Figure 46. - 260 Stage Truck-Rail Transporter Design Concept



'igure 47. - Transporter Rail and Rail Foundation

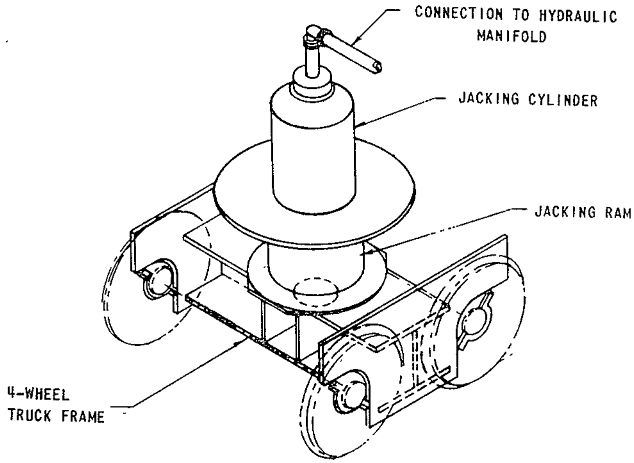


Figure 48. - Typical Jacking Cylinder and Truck Frame Arrangement

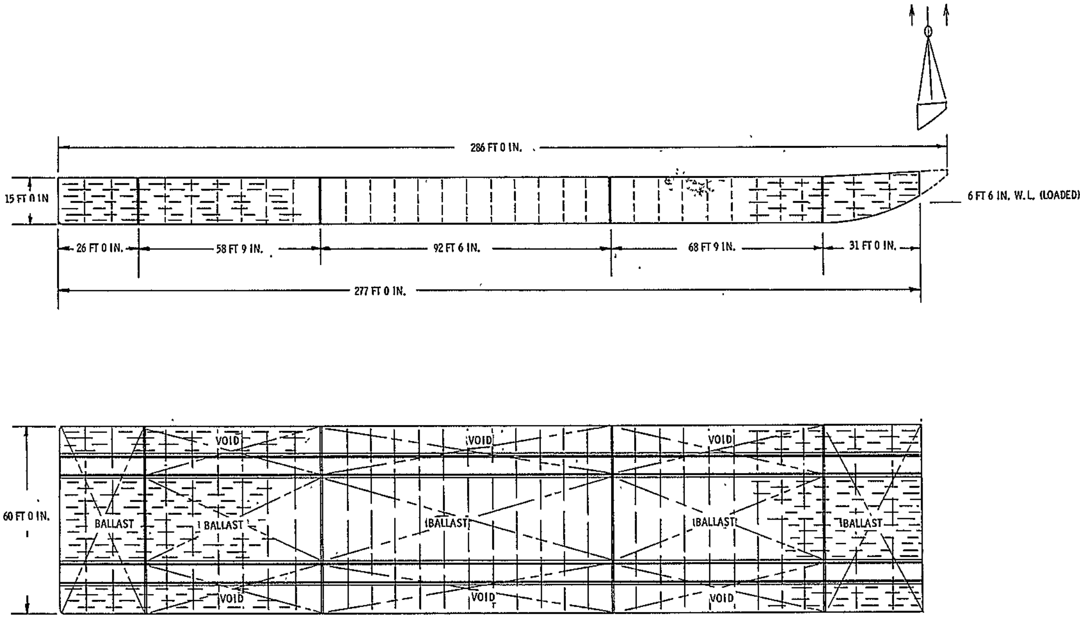


Figure 49. - 260 Stage Transport Barge Design Concept

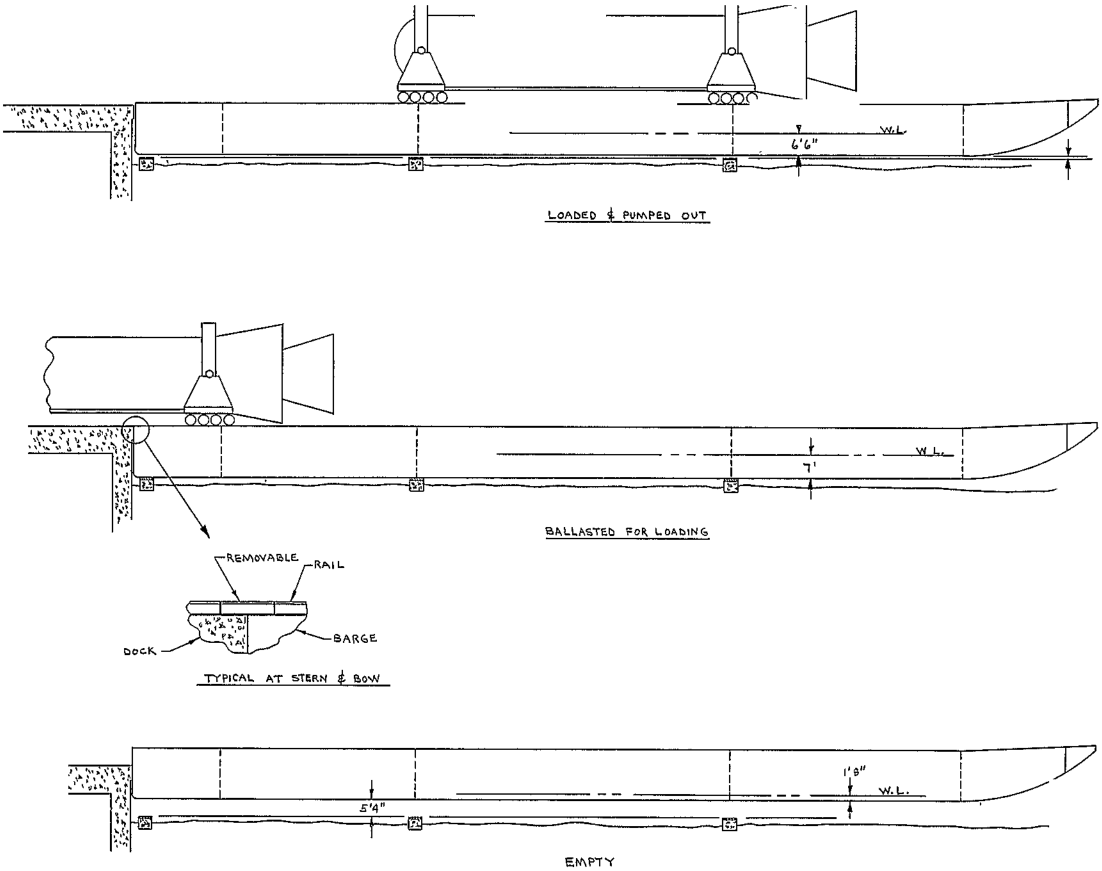


Figure 50. - Barge Graving Dock Design

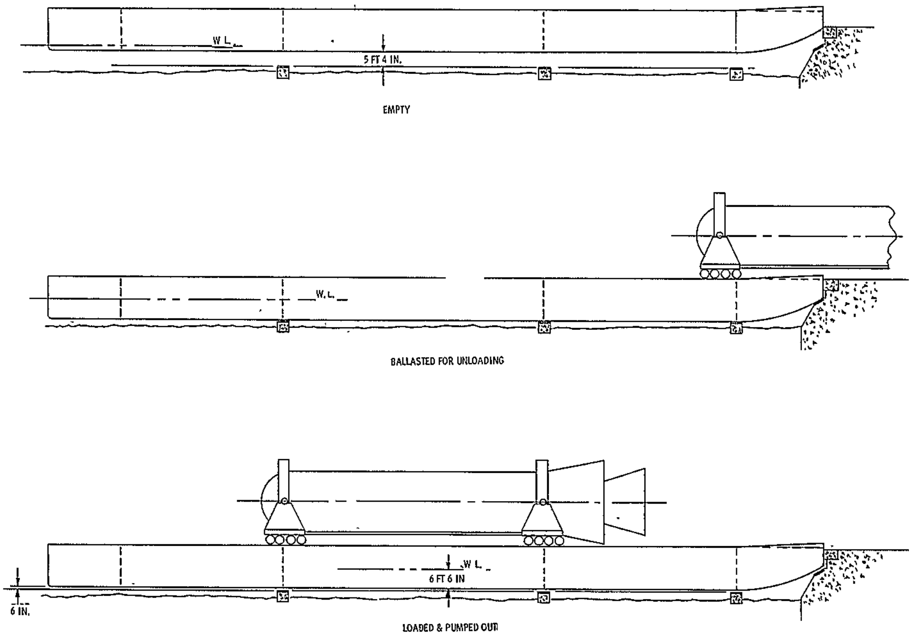


Figure 51. - Offloading at Bow End of Barge

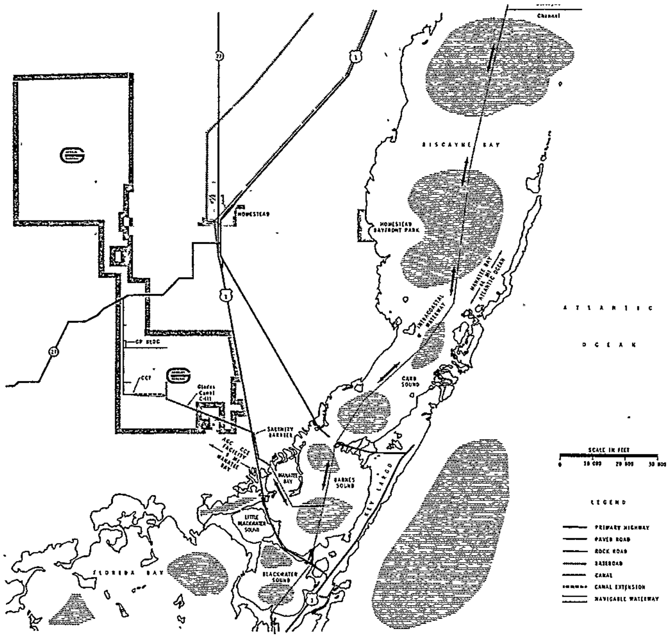


Figure 52. - Canal System from DCP to Atlantic Ocean

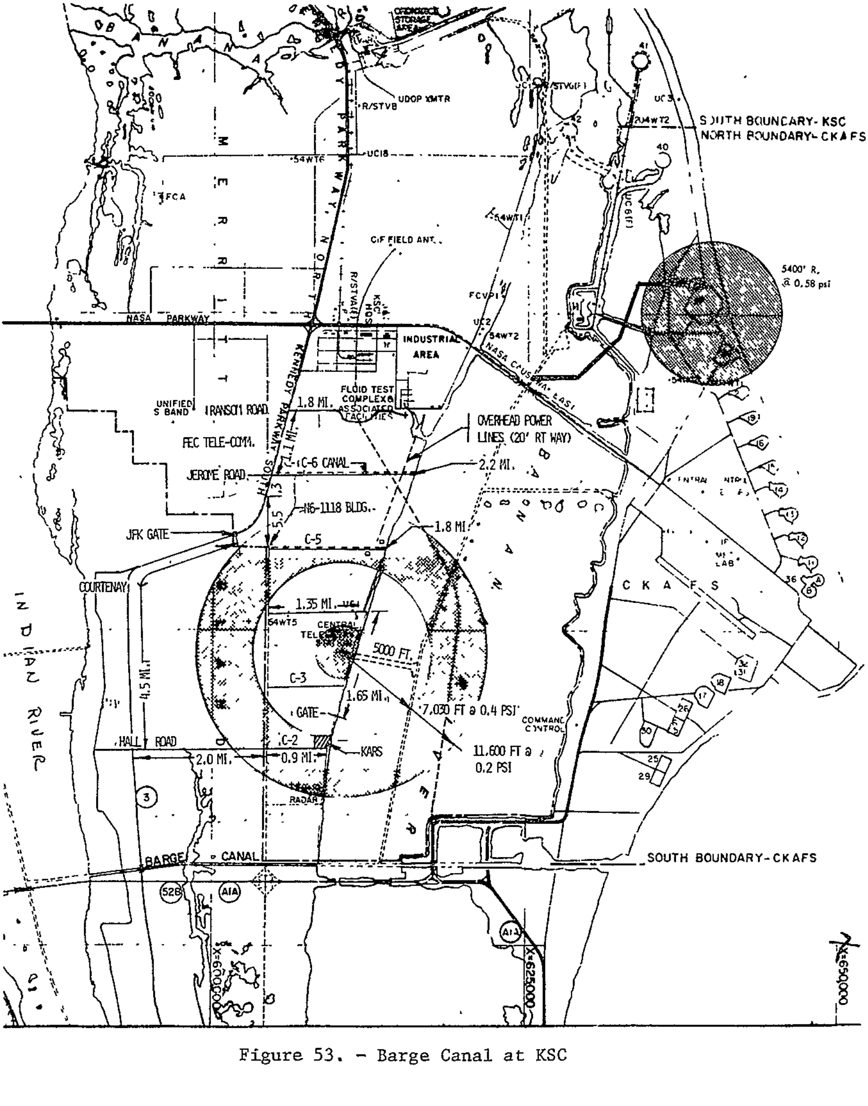


Figure 53. - Barge Canal at KSC

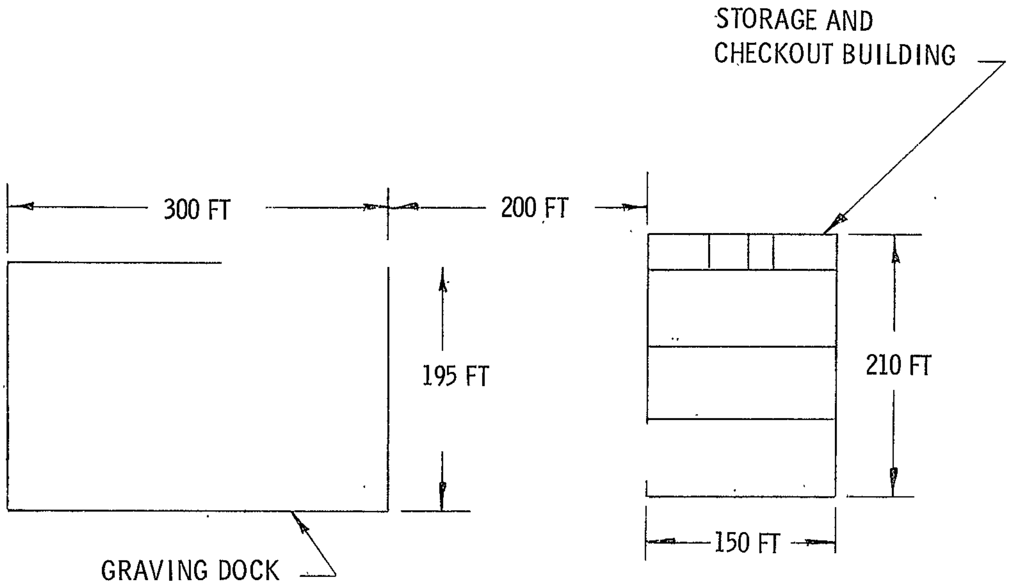


Figure 54. - General Arrangement of KSC Storage Area

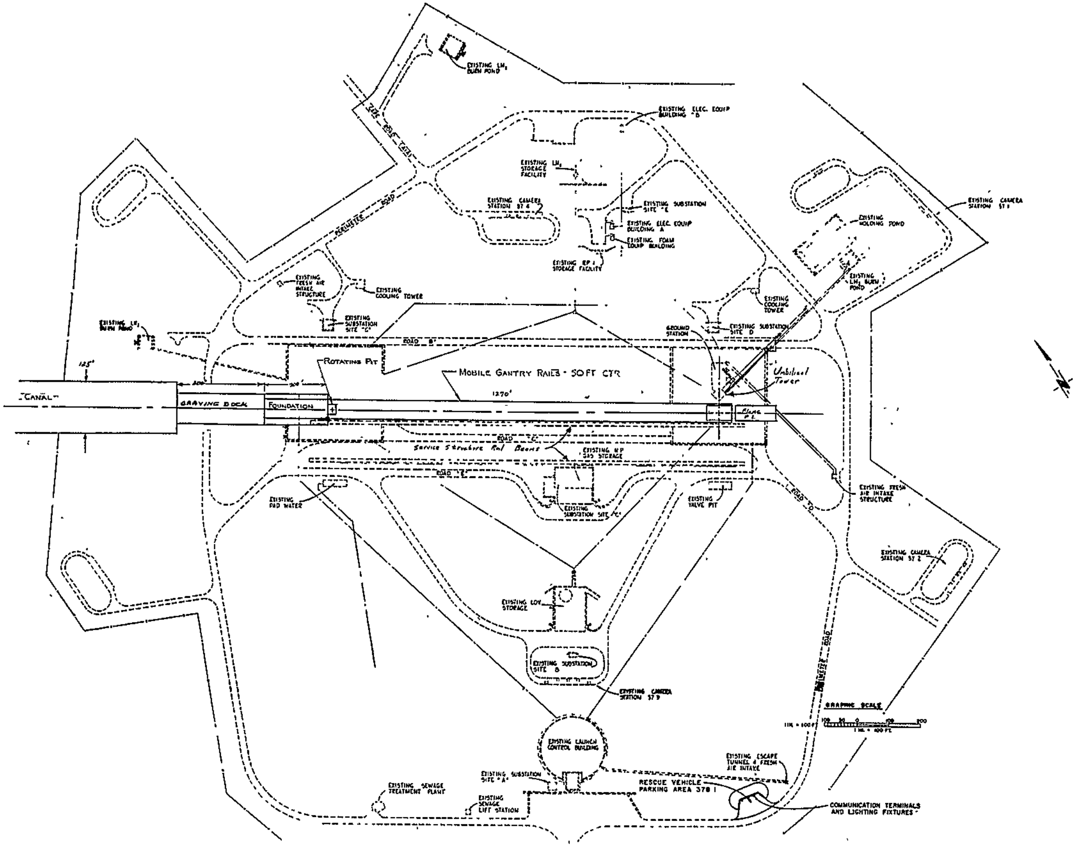


Figure 55. - Arrangement at KSC Launch Area

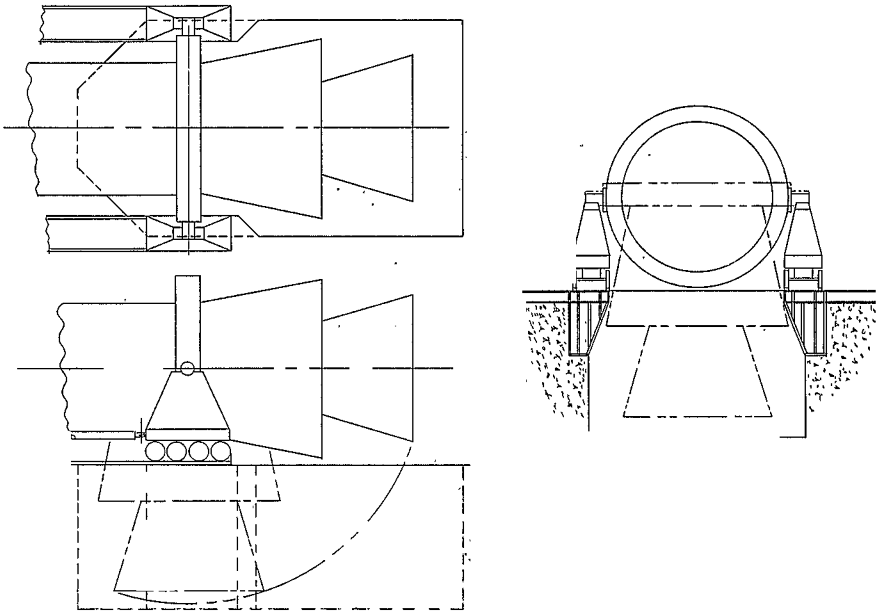


Figure 56. - Stage Rotating Pit

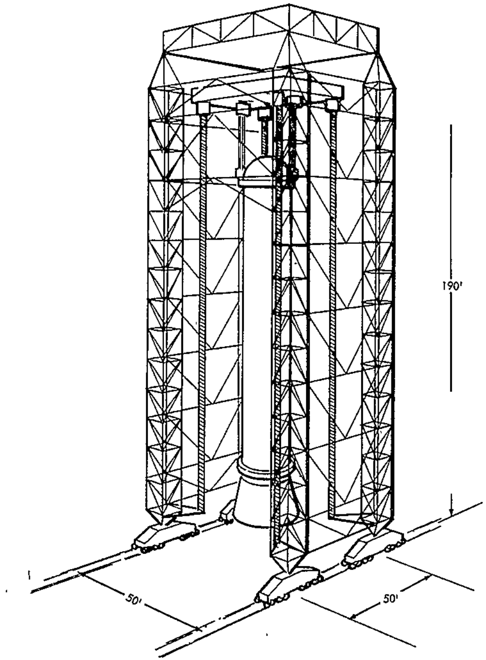


Figure 57. - Roll-Ramp Mobile Gantry

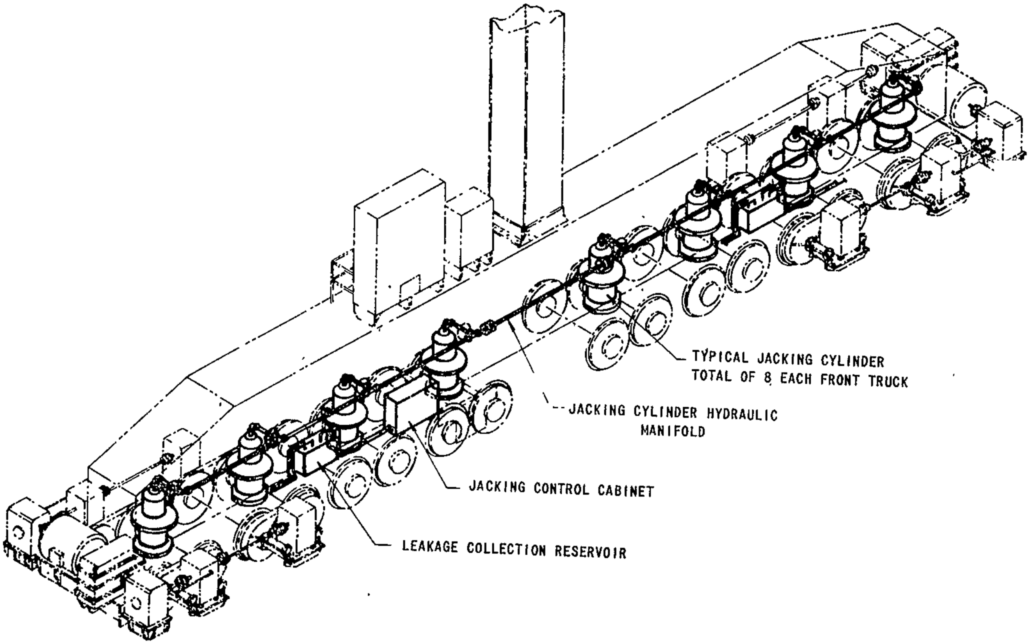


Figure 58. - Mobile Gantry Truck Assembly

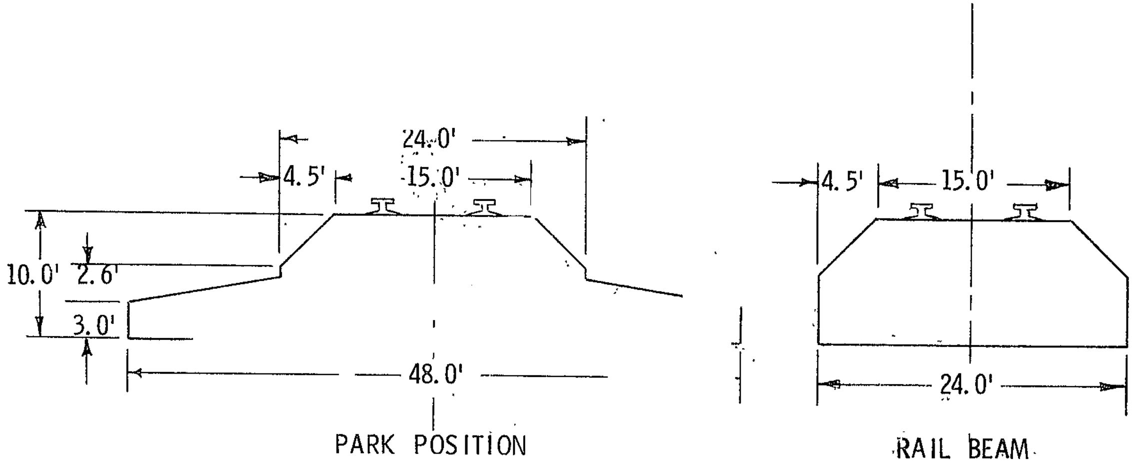


Figure 59. - Mobile Gantry Rail and Rail Foundation

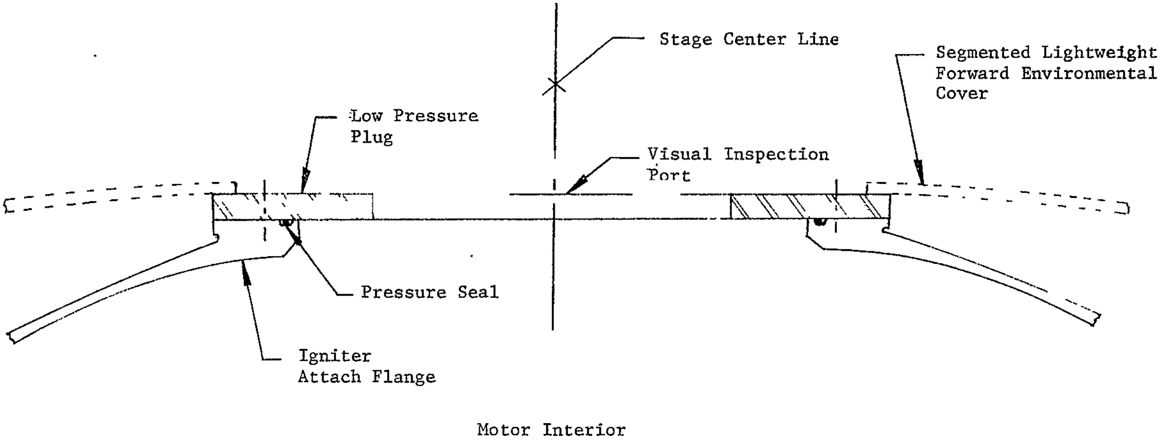


Figure 60. - Low Pressure Igniter Port Plug

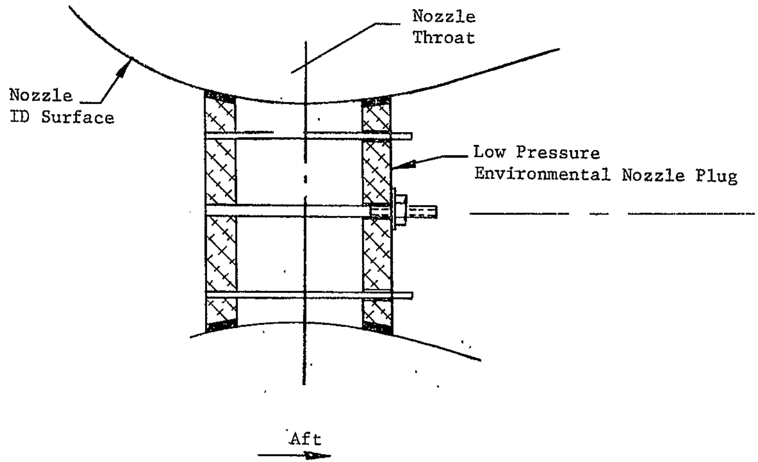


Figure 61. - Low Pressure Nozzle Plug

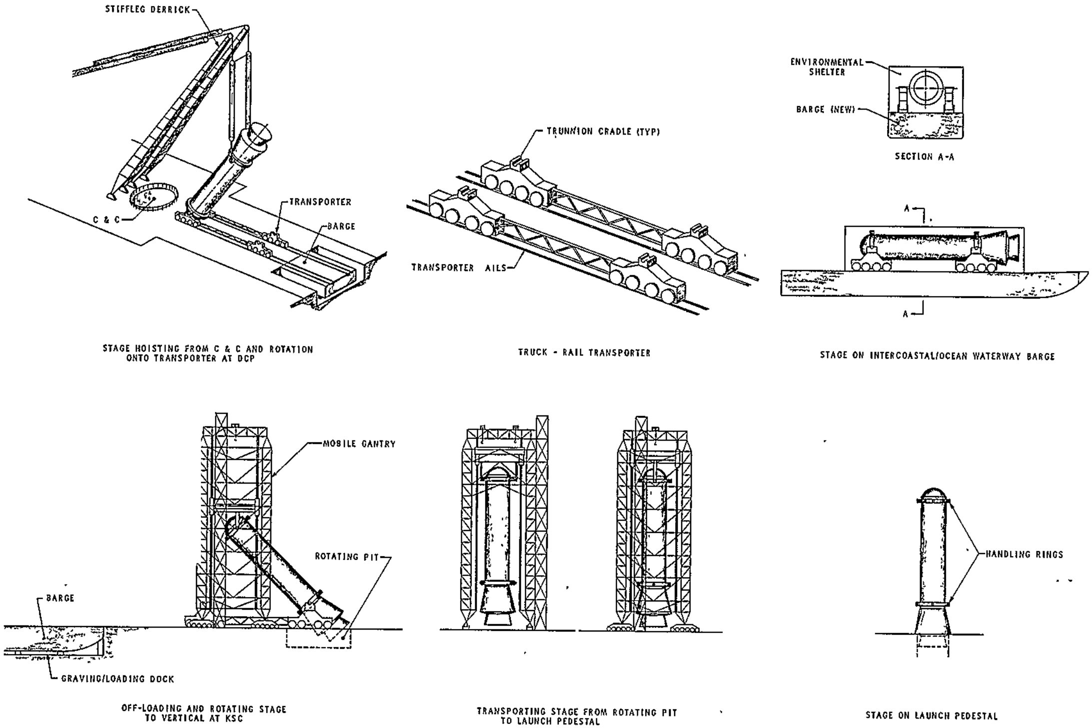


Figure 62. - Sequence of Handling Method Operations

PREPARED BY		aerojet solid propulsion company	QCI NO. 260 Stage	REV.
APPROVED BY	DATE	QUALITY CONTROL INSTRUCTIONS	SHEET 1 OF 2	
TITLE RECEIVING INSPECTION ON THE BARGE			EFFECTIVITY 260 Stage	

INSTRUCTION	INSP BUY-OFF
I. PURPOSE	
To provide instructions for performing a receiving inspection while the stage is on the barge at the KSC dock.	N/A
II. REFERENCE DOCUMENTS	
A. Assembly Report	N/A
III. GENERAL INSTRUCTIONS	
A. The receiving inspection shall commence as soon after barge docking as possible.	N/A
B. The inspector will stamp each item under specific instructions as it is completed.	N/A
C. All discrepancies will be documented and reported to the Inspection Unit Supervisor.	N/A
D. The Assembly Report shall be referred to when discrepancies are found to insure against duplicating discrepancy reporting.	N/A
IV. SPECIFIC INSTRUCTIONS	
A. Visually inspect the entire stage for any shipping damage.	
1. Forward Skirt	
2. Forward Case	
3. Center Case	

SAMPLE

REV	PAGES	DESCRIPTION	AUTH	DATE

Figure 63. Sample Quality Control Instruction (Sheet 1 of 2)

QCI NO.
260 Stage

QUALITY CONTROL INSTRUCTIONS
CONTINUATION SHEET

SHEET 2 OF 2

INSTRUCTION	INSP BUY-OFF
4. Aft Case	______
5. Aft Flare	______
6. Heat Shield	______
7. Nozzle	______
B. Visually inspect aft compartment major components for shipping damage, corrosion or contamination.	______
C. Visually inspect the grain and motor interior through the closure ports.	______
D. Visually inspect the handling rings trunnions and closures for security of connection and proper installation.	
E. Inspect the motor pressure:	
1. Internal pressure level is still near the initial pressure for transportation (see Assembly Report).	______
F. Verify internal inert gas pressure is on motor interior above atmospheric pressure.	______

SAMPLE

Figure 63. Sample Quality Control Instruction (Sheet 2 of 2)

PREPARED BY		aerojet solid propulsion company	QCI NO. 260 Stage	REV.
APPROVED BY	DATE	QUALITY CONTROL INSTRUCTIONS	SHEET 1 OF 2	
TITLE RECEIVING INSPECTION AFTER OFF-LOADING FROM THE BARGE			EFFECTIVITY 260 Stage	

INSTRUCTION	INSP BUY-OFF
I. PURPOSE To provide instructions for performing a receiving inspection of the stage after barge unloading at KSC.	N/A
II. REFERENCE DOCUMENT A. Assembly Report B. Pre Off-Load Receiving Inspection	N/A
III. GENERAL INSTRUCTIONS	
A. Any discrepancy found that is not listed in the Assembly Report must be documented and reported to the Inspection Supervisor.	N/A
B. Care must be exercised by all personnel while inspecting the stage and components.	N/A
IV. SPECIFIC INSTRUCTIONS A. Verify transportation records are packaged and sent to Quality Engineering	
Temperature	____
2. Humidity	____
3. Acceleration	____
B. Visually inspect the following areas and surfaces for dents, scratches, corrosion, handling damage, seal integrity and positive pressure indication:	

SAMPLE

REV	PAGES	DESCRIPTION	AUTH	DATE

Figure 64. Sample Quality Control Instruction (Sheet 1 of 2)

QCI. NO. 260 Stage	QUALITY CONTROL INSTRUCTIONS CONTINUATION SHEET	SHEET OF

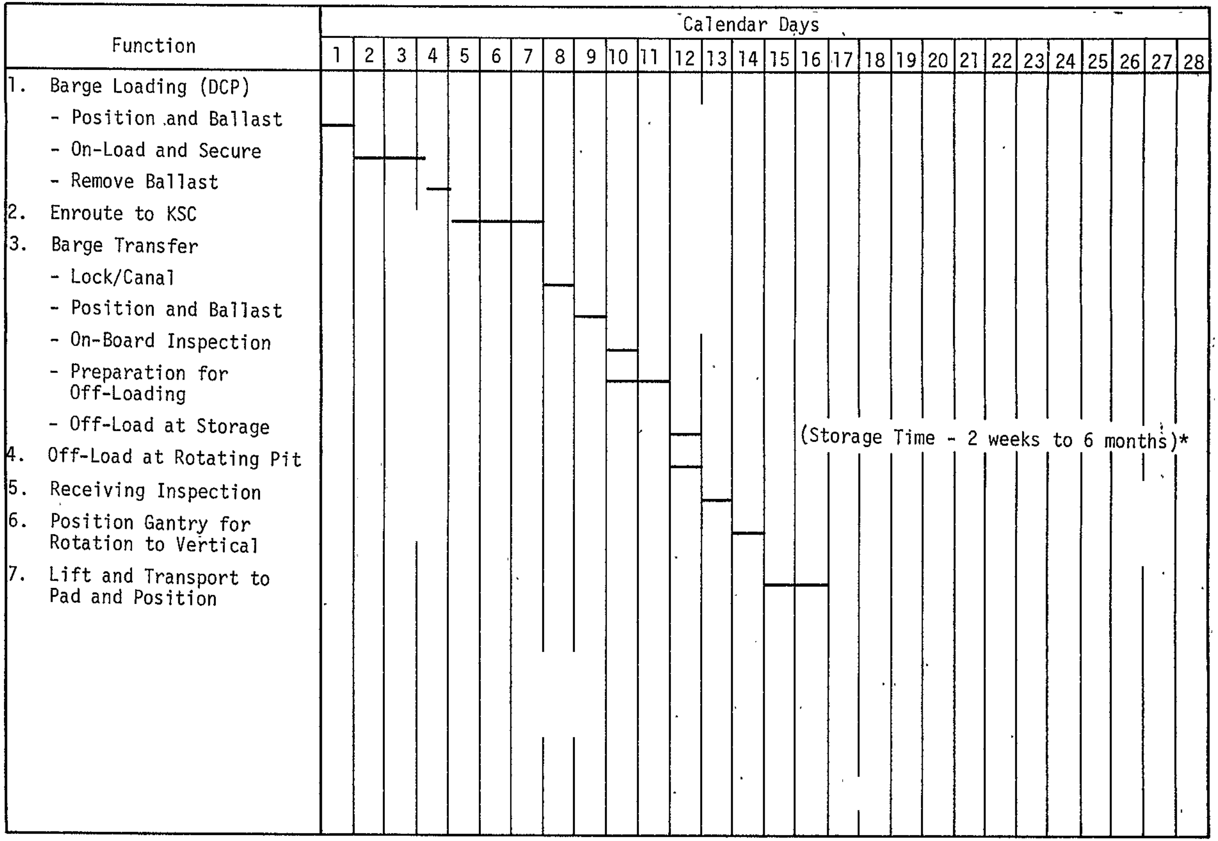
INSTRUCTION	INSP BUY-OFF
1. Forward Skirt	______
2. Forward Case	______
3. Center Case	______
4. Aft Case	______
5. Aft Flare	______
6. Heat Shield	______
7. Nozzle	______

C. Visually inspect inside the aft compartment for loose wires and clamps, loose fittings, hydraulic leaks, corrosion contamination or handling damage.

D. Visually inspect the grain and motor interior through the closure ports.

SAMPLE

Figure 64. Sample Quality Control Instruction (Sheet 2 of 2)



*Storage time is not included in this basic (gross) estimate.

Figure 65. - Cycle Time

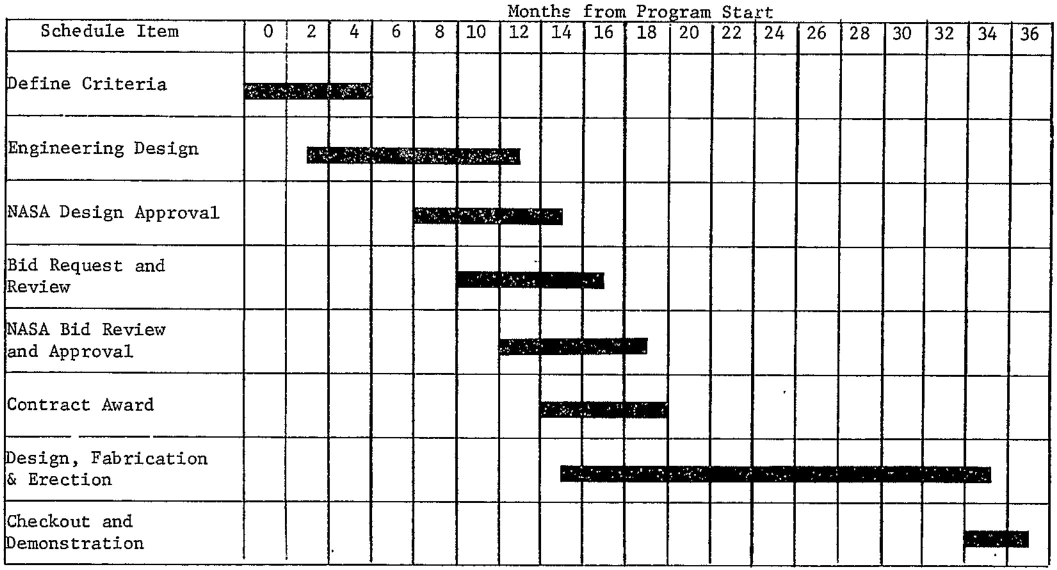
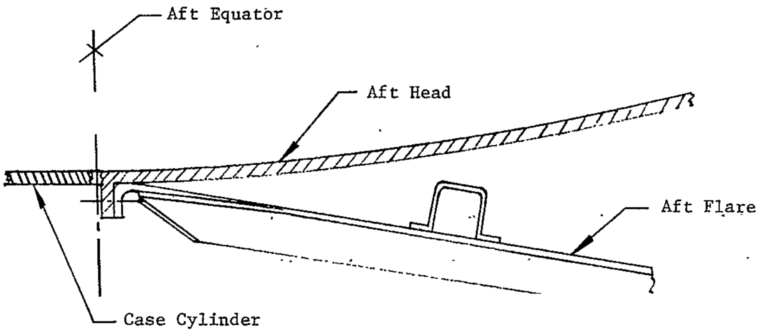
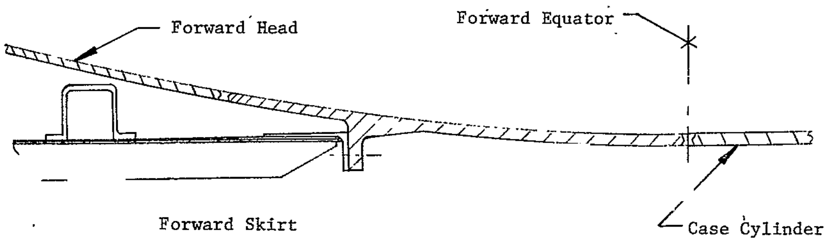


Figure 66. - Program Schedule for Handling-Method Design, Fabrication and Erection, and Demonstration



a. Aft Flare Attachment



b. Forward Skirt Attachment

Figure 67. - Baseline Motor Case - Aft Flare and Forward Skirt Attachments

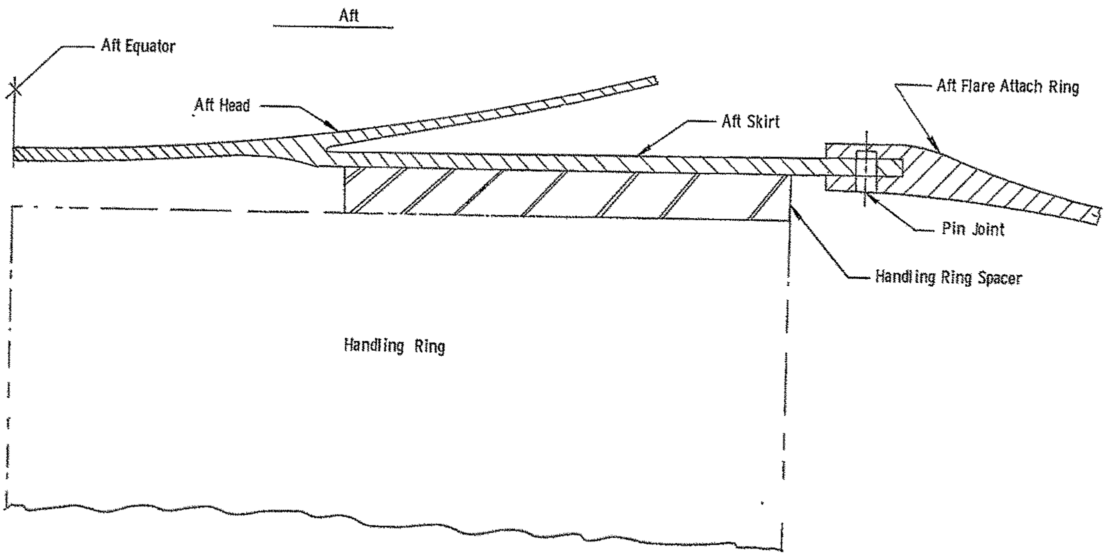


Figure 68. - Recommended Method for Aft-Flare Attachment

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