TR-1145
February 10, 1972

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PROPOSED
SPACE SHUTTLE CARGO HANDLING CRITERIA AT THE OPERATIONAL SITE

(Preliminary)

Prepared by

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1.0 INTRODUCTION

Current requirements for the space shuttle call for an orbiter with a 15-by 60-foot cargo bay, Figure 1, which can handle cargo weights up to 65,000 pounds. Such cargo can consist of a wide variety of items including satellites, space station modules, research and applications modules, cargo module, personnel, and loaded propulsive rocket stages. The potential wide variance in the type of cargo means that several functions are required of the ground systems which includes loading, unloading, and interim servicing of the items. This has, in turn, lead to a need to be able to perform such functions at about any point in the vehicle processing at the operational site.

2.0 SCOPE

This document presents the criteria for cargo handling at the operational site. Such criteria are meant to form the basis for specifications to meet these program objectives.

3.0 ASSUMPTIONS

These criteria are based on:

a. Program Requirements, Reference A.

b. Propellants and explosives up to Class II can be processed in the Maintenance and Checkout Facility. The more critical items (above Class II) will have to be loaded outside this facility and/or on the launch pad.

c. The generalized vehicle processing flow shown in Figure 2, which was taken from Reference B.

d. Cargo will not be serviced via any special umbilicals (in excess of any required for other needs) during the last few minutes of countdown and launch.

e. Certain types of cargo, such as biological experiments or mechanisms with internal cryogenic tanks that need to be kept filled, may have to be installed and/or serviced as close to the launch time as possible.

f. Weather data presented in Reference C.

g. Facility systems will be used to maintain cargo bay cleanliness when the payload includes items, such as telescopes, that require a clean room environment.

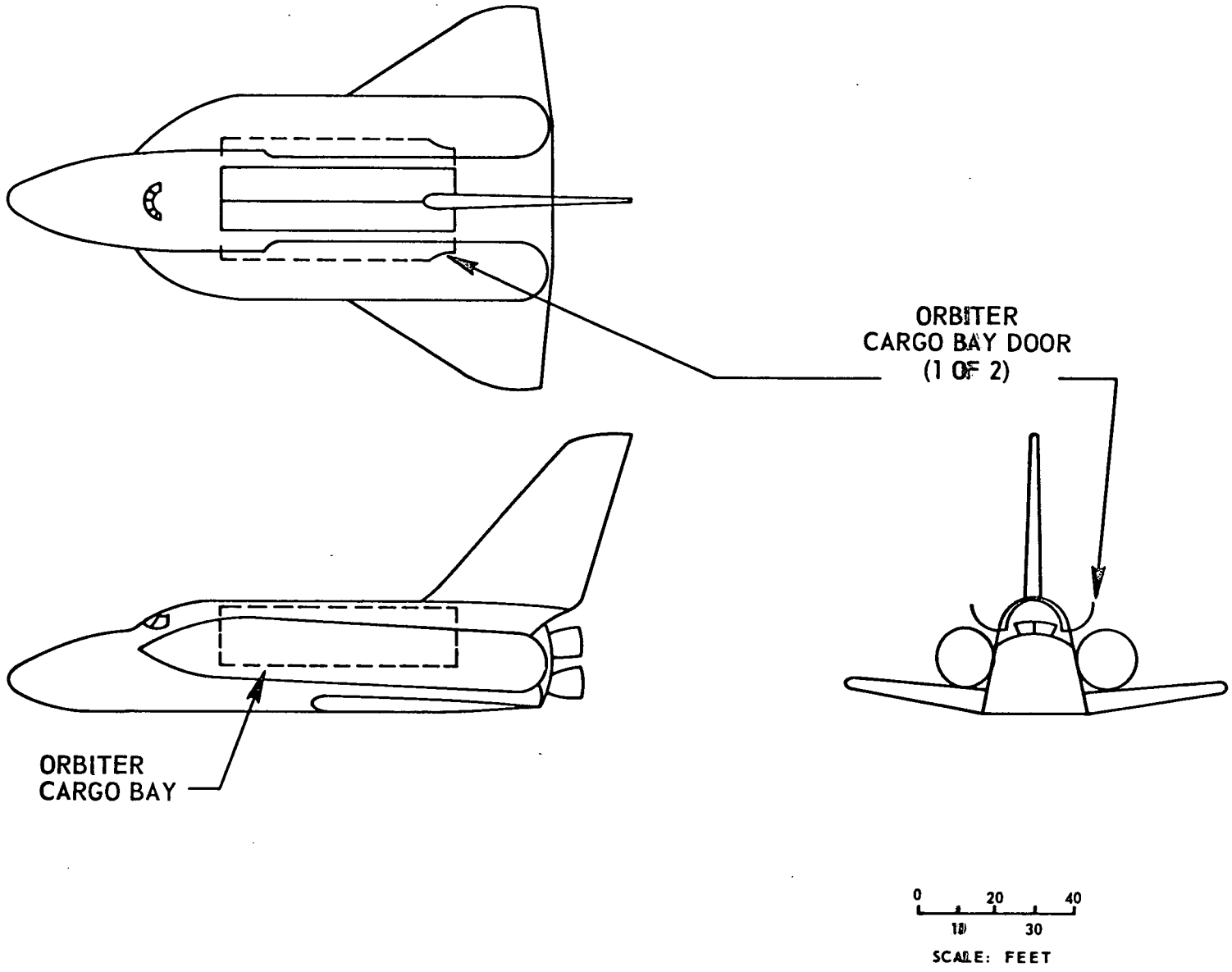


FIGURE 1. GENERAL ARRANGEMENT OF CARGO BAY

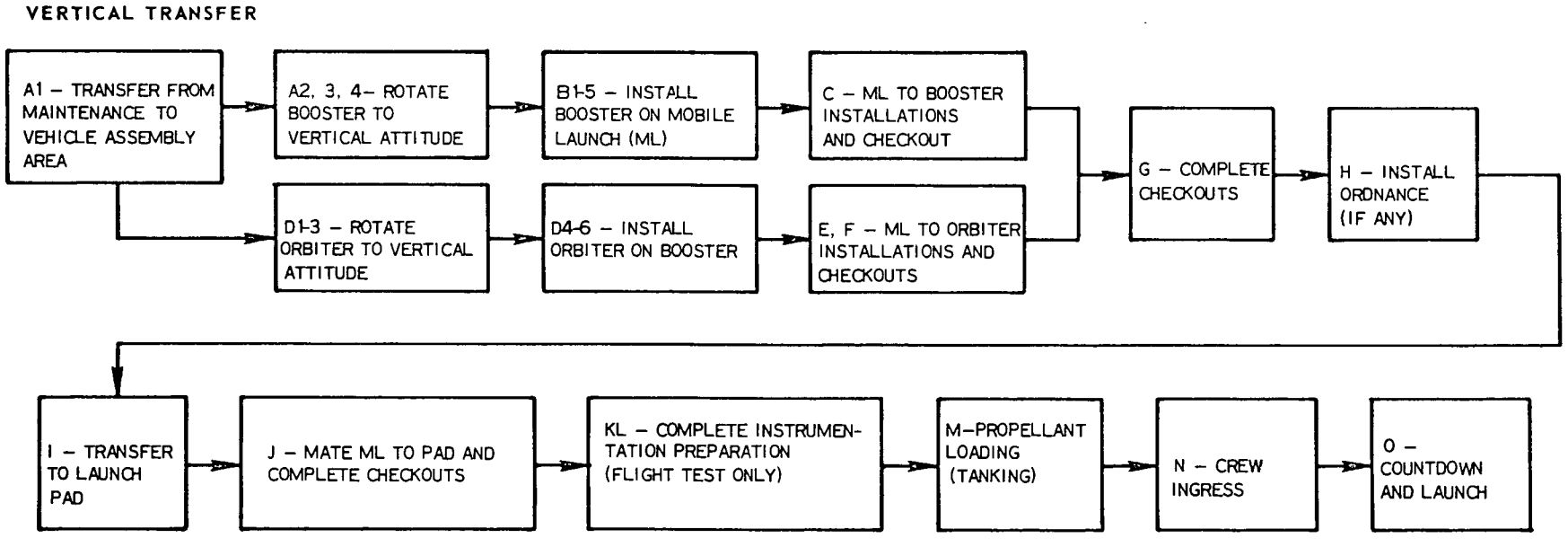


FIGURE 2. GENERALIZED FLOW FOR TRANSFER TO THE LAUNCH PAD

4.0 DISCUSSION & CONCEPTS

4.1 Inside Maintenance and Checkout Facility

The booster and orbiter are to be handled separately until the time for mating just prior to transfer to the launch pad, Figure 2. In this initial maintenance/checkout phase of operations, the orbiter will be in the horizontal attitude and the cargo can be loaded from above using state of the art cranes, following the criteria presented in Section 5. Some type of cover(s) will be required over the open cargo bay to prevent accumulation of dirt, etc., in that area.

Loading may have to take place after the vehicles are mated but prior to transfer to the launch pad. Provisions for handling equipment for this function can best be made a part of the facility design of the appropriate high bay area.

4.2 Transfer to the Launch Pad

Emphasis should be placed on having cargo designs that preclude needing any appreciable degree of attention during the trip to the launch pad. A special need for such items as power, environmental air, etc., would require mobile support equipment that could be carried on the launcher. This would probably also entail drag-on lines of some type because such functions would not normally be a part of the swing arm systems. Such activity is not impossible, but it would create operational problems.

4.3 Placement in the Launch Position

There is a transitory period where the launch pad services are not yet hooked up after the arrival of the space shuttle vehicle. Any attention required by the cargo at this time will have to come from the same equipment used in the transfer.

4.4 On the Launch Pad

Any services required after completion of placement on the launch pad will likely be needed up to or shortly before the final count for the launch. Several other conditions can easily occur at this time, including but not limited to:

a. Activation of a payload
b. Change out of a defective item
c. Access for maintenance
d. Loading of consumables, propellants, and/or ordnance
e. Final adjustments

If passengers are to be carried, the removable items that are needed to support them must be installed as though it were part of the cargo, Reference A. This includes installation of seats, placement and servicing the life support systems, ingress, and egress. It has not been established whether such personnel will travel within the cargo bay or the forward fuselage of the orbiter, but this does not change the basic criteria for ground support, especially emergency egress.

The payload must clear the vehicle structure for insertion or removal from the cargo bay and the movement of the handling equipment in each plane must be precisely controlled. Even more critical is any movement required to transfer the cargo weight on or off the orbiter payload attach points, recognizing that the orbiter will probably be moving due to wind loads.

4.5 General

There will apparently be a large variation with regards to the cargo items weight, shape, or means of suspension for handling. Designs should provide considerable flexibility in the capabilities of the ground handling equipment. If a number of items are to be carried on any one load, they will have to be packed in a manner that will allow handling, access for services and/or removal.

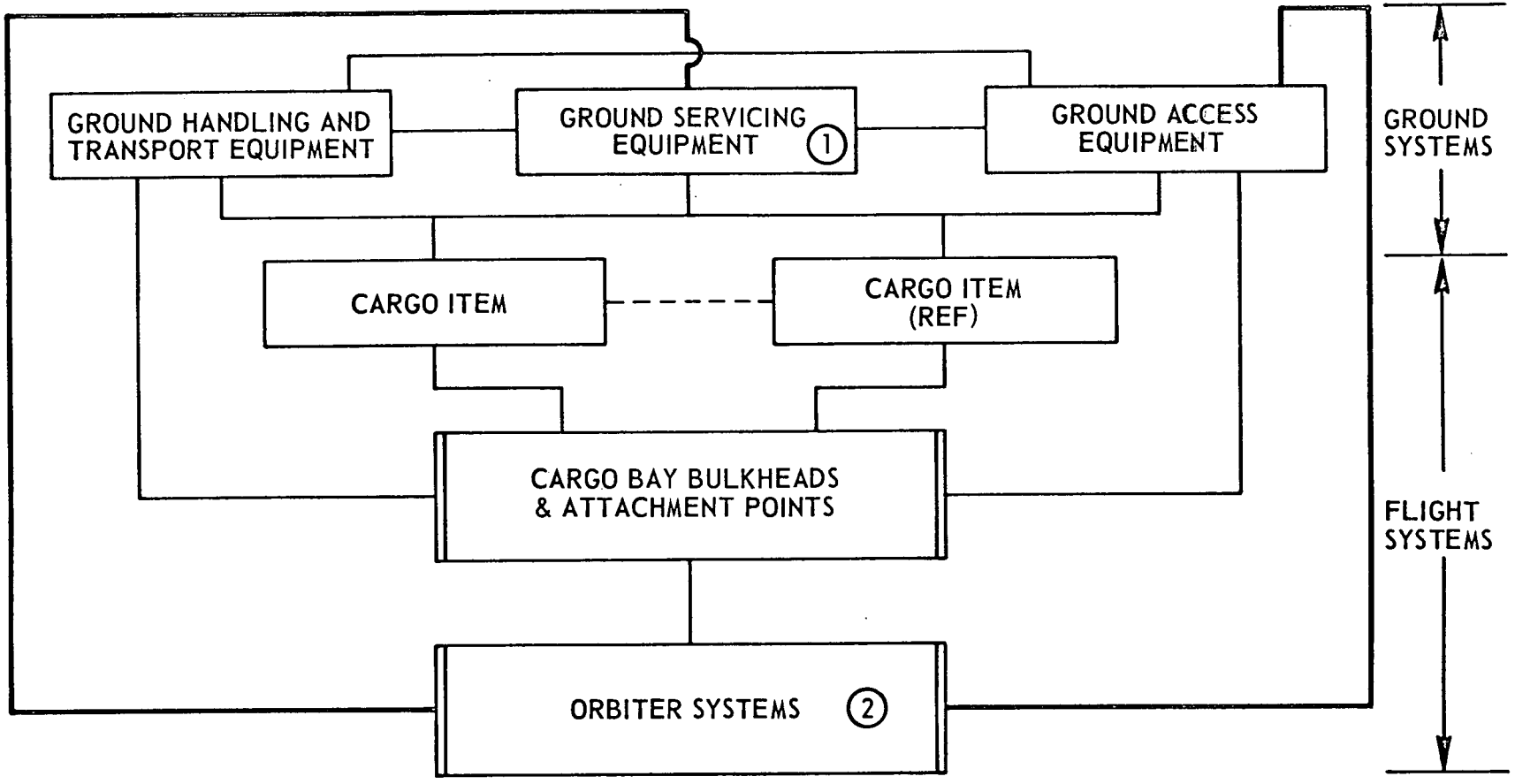
It is apparent that the criteria for appropriate ground handling and servicing equipment cannot be valid unless there are also corresponding restrictions on the cargo items and the orbiter. The interfaces between the cargo, orbiter, and the ground hardware are shown schematically in Figure 3. This is based on the concept that drag-on lines will be used for any special cargo servicing or else the service will be provided by the cargo or orbiter systems.

The ground to flight hardware interface should feature adequate means for transposing structural loads. The handling equipment cannot be allowed to damage the orbiter, either by itself or by transmitting loads through a cargo item. This means that the orbiter must provide some type of means for guiding the movement of the handling equipment up to the point(s) of physical contact. Thus the orbiter hardware should control the points of contact between ground/cargo/orbiter physical interfaces. Subsequent movements of the cargo can apparently be best controlled from the ground site of the interface, thereby controlling the loading across the point(s) of physical contact.

Cargo and the orbiter need to be treated as fragile materials. The ground equipment and any related controls must, therefore, fail safe. Structural safety factors can be conservative making the weight of the ground equipment a secondary consideration. A suitable ground fixture can protect the cargo prior to and during installation in the cargo bay. The ground fixture could remain in place as long as desired, thus providing a controlled access white room to the cargo area, if required, and structually support the cargo bay doors.

5.0 CRITERIA

These criteria were based on the stated assumptions and the concepts set forth in the prior sections of this report. Such criteria are divided into three basic groups: cargo, ground equipment, and orbiter.



NOTES: (1) MOBILE AND/OR FIXED

(2) SOLE SERVICE SOURCE AFTER LAUNCH UNLESS SELF CONTAINED IN CARGO PACKAGE

FIGURE 3. INTERFACES BETWEEN CARGO, GROUND SYSTEMS, AND ORBITER

The criteria to be met with respect to cargo handling are:

a. Orbiter

(1) There shall be in the orbiter a physical means for a place to insert a guide, or have an attachment to the ground handling gear that serves as a reference link. This reference link will, when in the mated position, provide an adequate frame of reference for all subsequent ground systems movements for access, servicing, loading, and unloading cargo. The purpose of this reference link will be to preclude contact between ground and flight hardware at any but designated points and/or overloading any connect points on the orbiter. The reference link shall be capable of use with the orbiter in the horizontal or launch attitudes.

(2) The reference link in the orbiter shall be adequate to permit the ground systems to follow the movements of the flight hardware due to such things as variable wind loads. Sensing of such flight hardware movement by ground systems shall be via the reference link, or by another point of reference as designed by the orbiter designers.

(3) The orbiter designers shall be responsible for providing the necessary interface data and detail design information required to design the corresponding payload items and ground hardware. Such data shall include, but not be limited to, definition of the reference link, attachment points for cargo, structural limitations, all pertinent dimensions, and any appropriate structural dynamic characteristics of the flight hardware.

(4) Cargo attachment points will be designed to accommodate a container consisting of a buildup of modules or a single shell or frame that would use, to the maximum possible degree, the available space. Such modules or single item could weigh up to 65,000 pounds (see paragraph 5.b.).

b. Cargo

(1) Cargo dimensions shall be restricted to the boundaries of the cargo bay, Figure 4, and the attachment points.

(2) Cargo items shall be constructed for mounting within a single cargo entity and/or have attachment points that will interface with the load/unload ground handling equipment and the attachment points within the orbiter.

(3) A single cargo module can weigh up to 65,000 pounds (including its own weight), can and shall be designed for mounting within the cargo bay, and also interface with the ground handling equipment.

(4) Cargo items and single cargo modules shall be able to withstand ground handling operations including rotation about any axis, Figure 4, relative to the orbiter.

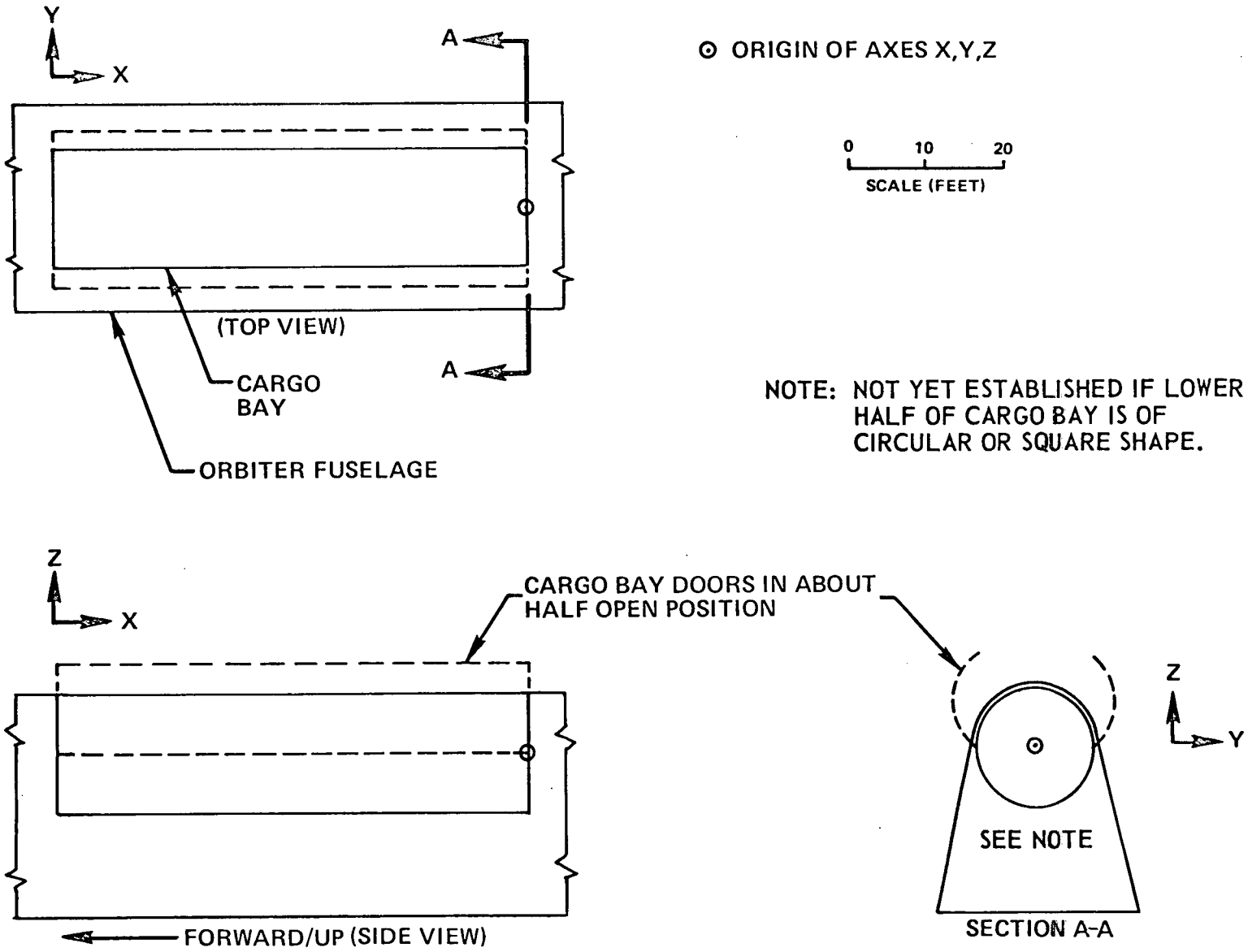


FIGURE 4. CARGO BAY ALIGNMENT FOR GROUND LOADING AND UNLOADING

c. Ground Equipment

(1) The ground equipment shall be capable of transporting individual cargo items and the necessary handling and access capacity to build up cargo modules that are to be inserted into the orbiter cargo bay. Any environmental control or servicing of cargo items during this assembly operation will be via mobile equipment and used on a demand basis.

(2) There shall be a capability at the operational site to transport and handle, indoors or outside, a 15-by 60-foot cargo module that can weigh up to 65,000 pounds. Any environmental control or servicing of cargo items other than weather protection shall be mobile equipment. (Potential wide variety of cargo items presently precludes development of any universal use equipment for this purpose.)

(3) Loading equipment shall be capable of lifting and then rotating a standard cargo module about any axis relative to the orbiter, Figure 4.

(4) Loading and unloading general sequence requirements for on the launch pad or in a facility are given in Table 1. The type of cargo module movements to be accommodated with the vehicles in the vertical attitude are shown in Figure 5. (Figure 5 is for the case of the orbiter tail pointing away from the umbilical tower, but any changes in this orientation or use of two towers is not expected to significantly change the clearance criteria.)

(5) Loading equipment shall also be capable of unloading the orbiter. These functions shall be performed with the orbiter in the horizontal or vertical attitude, on the launch pad, or in the integration area of the Maintenance and Checkout Facility.

(6) The ground side of reference line(s) shall be usable in the horizontal or vertical attitudes, and be utilized to preclude any loadings (force) between the orbiter structure and the cargo, except for designated capabilities at predetermined mounting/attachment points.

This reference link(s) must in turn be supported by, or joined to, a mechanism and structure that will provide the means for:

(a) Providing the movements required to position the fixture for installation (or removal) in the orbiter.

(b) Assuming or transferring the cargo loads without improperly loading or unloading the orbiter structures.

(c) Placement of the hardware to be used for cargo loading/unloading at the launch pad.

(d) Provide for services, as required, to the cargo.

Table 1. General Sequence for Cargo Loading*

Step	Function	Method	Remarks
1	Open cargo bay doors.	Use orbiter system. See paragraph 5.0 C.(10)(a).	Prepare for loading.
2	Install/adjust reference link(s).	Position the links between the flight and ground hardware.	Needed to ensure cargo module can be inserted into the orbiter without damaging the structure.
3	Complete installation of any other loading equipment (ground and/or flight).	Use ground support equipment.	Prepare for loading.
4	Place cargo module in loading position.	Place cargo in vertical attitude outside the orbiter for insertion along the Z axis, Figure 4.	Lower end at X = 0 Upper end at X = -60 Centerline at r = 0 See Figure 4.
5	Insert cargo into orbiter.	Move cargo in the -Z direction until the centerline reaches Z = 0.	No movement in X or r plane except when total system moves due to orbiter movement (such as sway in the wind).
6	Lock cargo to orbiter attachment points.	Use orbiter system to open or close any locking devices.	May require very small movements in any plane (fine adjustments).
7	Transfer cargo weight from ground to flight hardware.	Slight adjustments of position of ground equipment.	All movements at very low velocities to preclude any shock loadings. Ground equipment will have to accommodate to any orbiter movement during the weight transfer.

*Reverse sequence for unloading.

Table 1. General Sequence for Cargo Loading* (Continued)

Step	Function	Method	Remarks
8	Connect interfaces and install servicing equipment (as required).	Drag-on lines and/or hookup through the orbiter systems.	Assumes no umbilicals required for cargo use only unless it is made a part of the orbiter design.
9	Remove any ground equipment not being used in the cargo servicing.	Move in the +Z direction until clear of the cargo bay doors.	See Figure 5.
10	Remove all ground equipment.		Last movement of ground equipment prior to launch.
11	Close cargo bay doors.	Use orbiter system.	Cargo ready for launch (or completion of checkouts).

*Reverse sequence for unloading

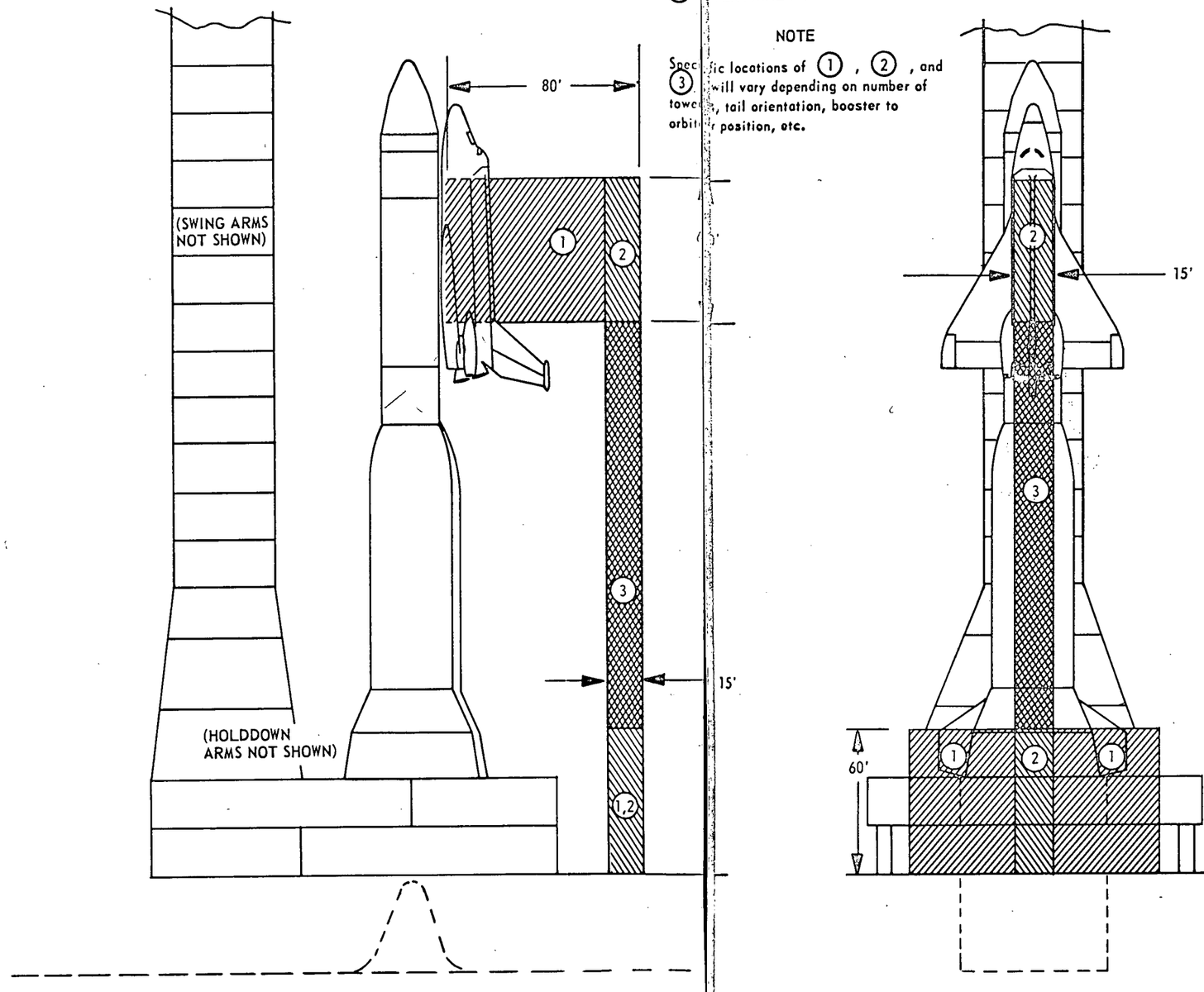


FIGURE 5. ENVELOPE OF MINIMUM SPACE REQUIRED FOR 15x60 FOOT CARGO PACKAGE LOAD/UNLOAD (DOES NOT INCLUDE HANDLING EQUIPMENT SPACE REQUIREMENTS.)