

ROLLING BEAM UMBILICAL SYSTEM

By Bemis C. Tatem, Jr.*

ABSTRACT

The decision to make the Centaur vehicle a Space Transportation System (STS) payload meant that new ground support equipment provisions at Launch Pads Pads 39A and 39B were required. These new equipment provisions were needed to service the Centaur vehicle while it was installed in the Orbiter's payload bay prior to launch. This paper describes the design of a new rolling beam umbilical system (RBUS) being added to the pad fixed service structure (FSS) in order to provide the primary functions of liquid hydrogen (LH₂) fill, drain, and vent. The carrier plate itself is a Government-furnished equipment item and of necessity became a T-0 disconnect. This permits quick offloading in the event of an abort prior to lift-off. In addition to the rolling beam structure, mechanisms, and fluid lines, it was necessary to design and build a carrier plate simulator to support early development testing of the mast at the Launch Equipment Test Facility at Kennedy Space Center.

The RBUS is designed to be compatible with the rotating service structure (RSS) to the extent that the umbilical may be deployed with the RSS mated with the vehicle. It is also designed to clear the RSS as the RSS rotates back out of the way. Accessibility to the Orbiter aft compartment via the 50-1 door had to be maintained.

The RBUS consists of an umbilical assembly that supports the carrier plate on the end of a truss beam extending from a carriage assembly that translates on double rails by means of crane track wheels. A porch structure was added to the FSS to mount the incline portion of the assembly that contains the rails. A suitable storage location on the FSS dictated a 6-degree incline up to the Centaur interface located on the port side of the Orbiter in essentially the same location as the previous T-4 interface on the port side. The rolling beam travels a distance of 11 m (36 ft) to the stowed position in the FSS. Power for acceleration of the rolling beam assembly is provided by a dropweight assembly. A linear disk brake decelerates the rolling beam to its parked or stowed position. Upon initial motion of the carriage, the rolling beam separates itself from the ground supply lines as well as from the vehicle. This was dictated by the long retract distance. This paper presents important design approaches considered but not used, in addition to describing the rolling beam, which is in the process of being implemented.

This RBUS was designed by Planning Research Corporation, Systems Services Company under contract to NASA's Kennedy Space Center in Florida.

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INTRODUCTION

In early 1981, an extensive trade study was conducted to determine the best approach to take to provide for the STS/Centaur LH₂ servicing requirements. Numerous concepts were prepared, and the ones considered most promising are:

- a. Tail service mast (TSM) with Centaur service added
- b. RBUS
- c. TSM mounted reusable payload umbilical mast
- d. TSM mounted expendable payload umbilical mast

TSM With Centaur Service Added. Necessary additional lines would be added to the existing TSM's carrier plates as depicted in figure 1. Lines would be routed down the service masts as shown in figure 2. An overriding disadvantage of this approach was its adverse effect on Orbiter flight weight for the LH₂ service functions.

RBUS. An elevation view of this approach is shown in figure 3 and is described in more detail in this paper. The overriding advantage of this approach is that it is located on the FSS with no impact on the Vehicle Assembly Building (VAB) or the mobile launcher platform.

TSM Mounted Reusable Payload Umbilical Mast. An elevation view of this approach is shown in figure 4. This system is similar to a short rolling beam except it retracts into a hardened housing mounted on top of the TSM. The carriage moves on a small track. Dropweight initiation would be by a trigger actuated by the TSM dropweight. The TSM would require structural additions to support the added weight and blast load due to added sail area of the payload umbilical mast. The installation has major impact on VAB platforms as well as the RSS.

TSM Mounted Expendable Payload Umbilical Mast. The carrier plate support is similar to the rolling beam, but a rotating mast with counterweight is used to retract the carrier plate past the vehicle lift-off drift curve. Lanyards penetrate the top of the TSM and use the TSM dropweights for the normal retraction. This approach is depicted in figure 5. This approach was ruled out because of closeness to the Orbiter wing and impact on the VAB.

The conclusion of these studies was that the RBUS approach was selected to perform the task of providing LH₂ service for the STS/Centaur at Launch Pads 39A and 39B. The design of the prototype RBUS was just completed at the time of submission of this paper. This prototype is to be tested at the Launch Equipment Test Facility this summer.

ROLLING BEAM DESCRIPTION

Major assemblies of the selected RBUS include:

LH₂ CARRIER PLATE

LO₂ CARRIER PLATE

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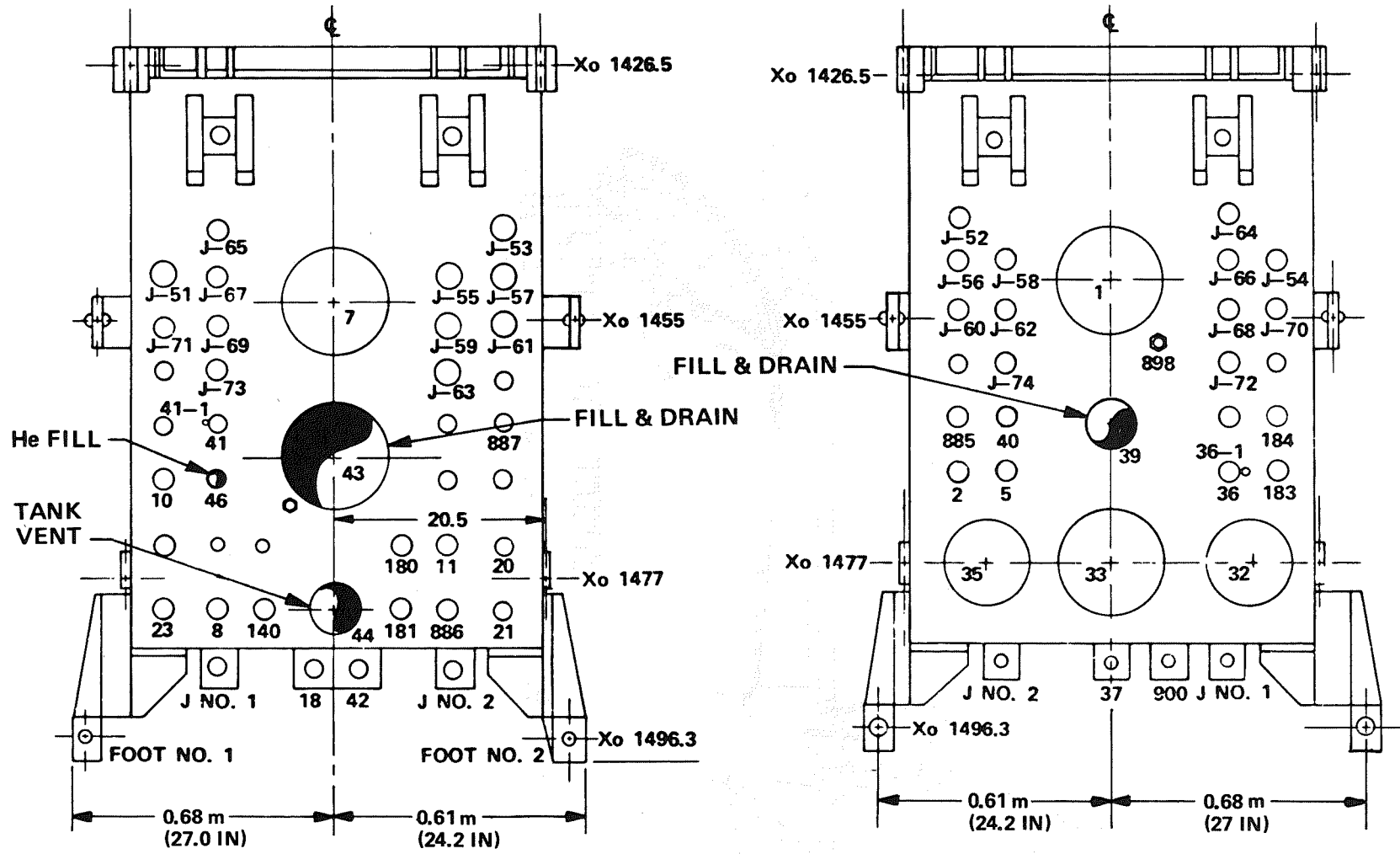


Figure 1. LH₂ and LO₂ Carrier Plates - TSI

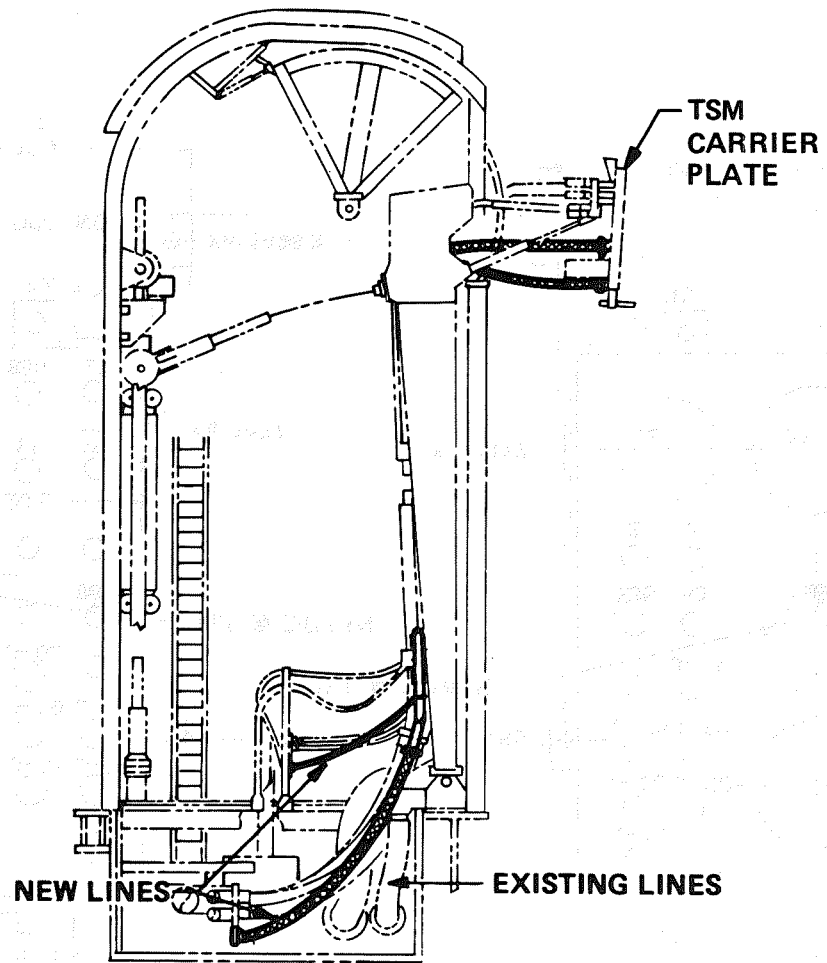


Figure 2. TSM With Centaur Service Added - LH₂

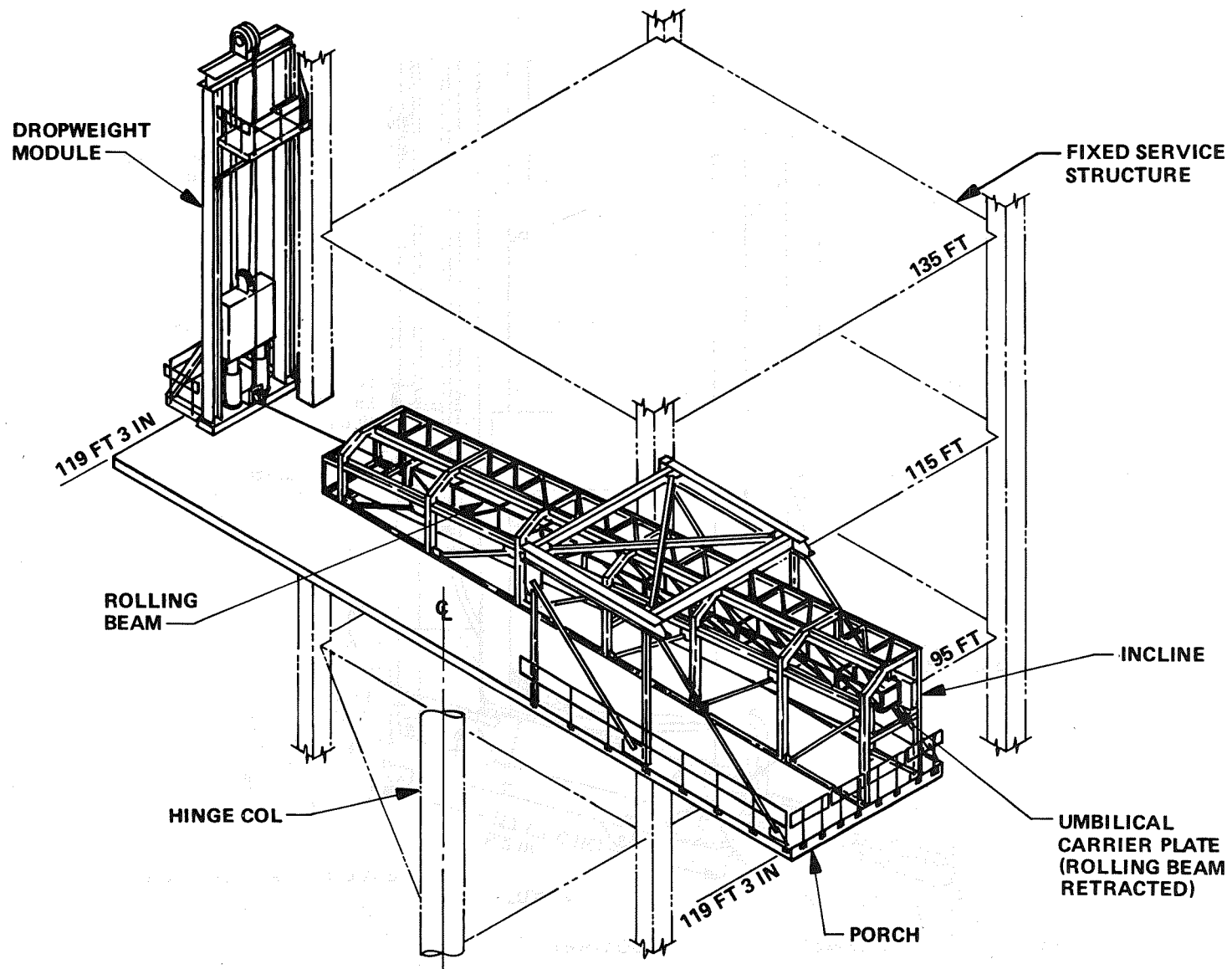


Figure 3. Centaur/STS Rolling Beam Umbilical System—Launch Pad 39A Installation

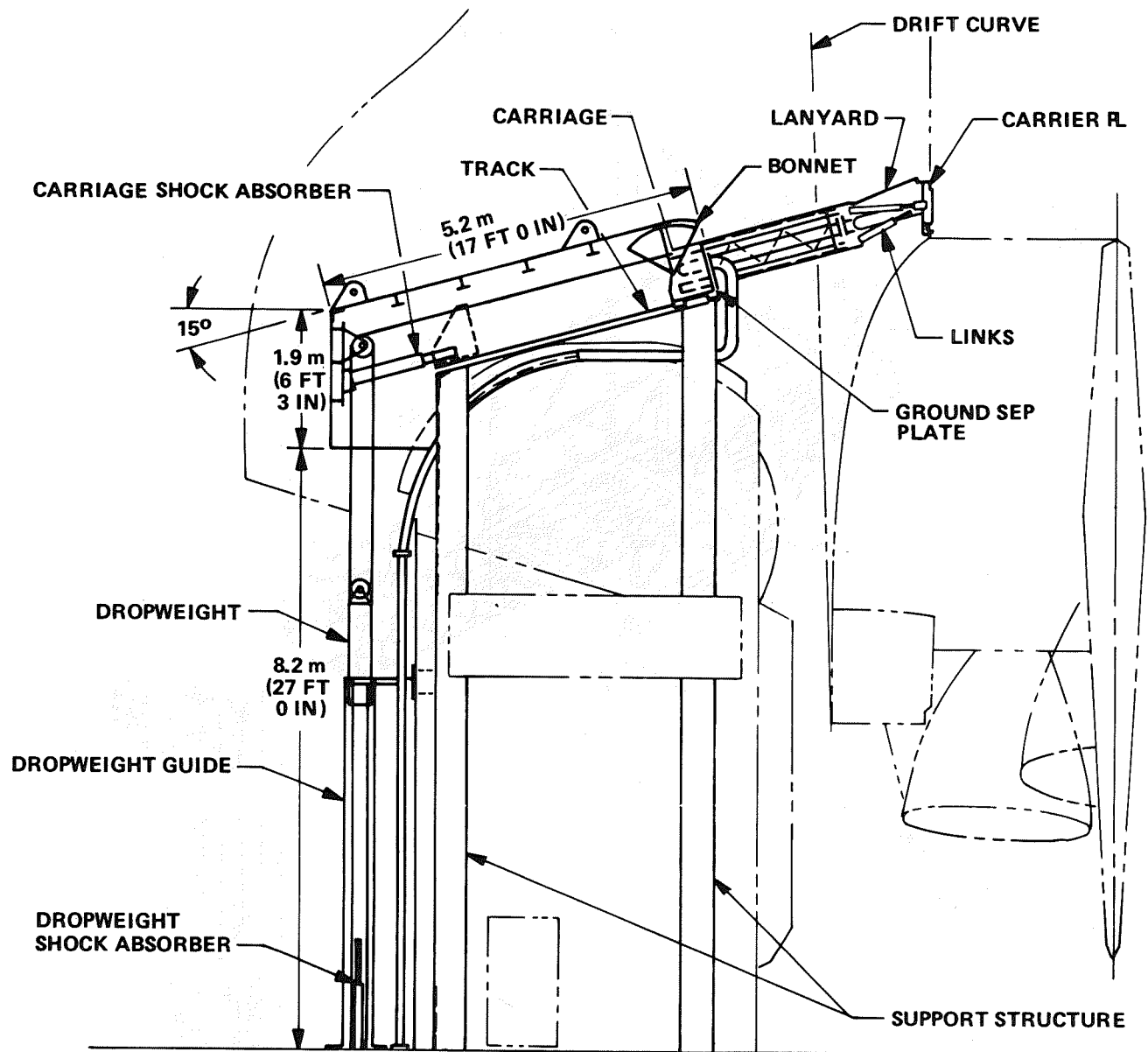


Figure 4. Payload Umbilical Mast – Reusable-Elevation View

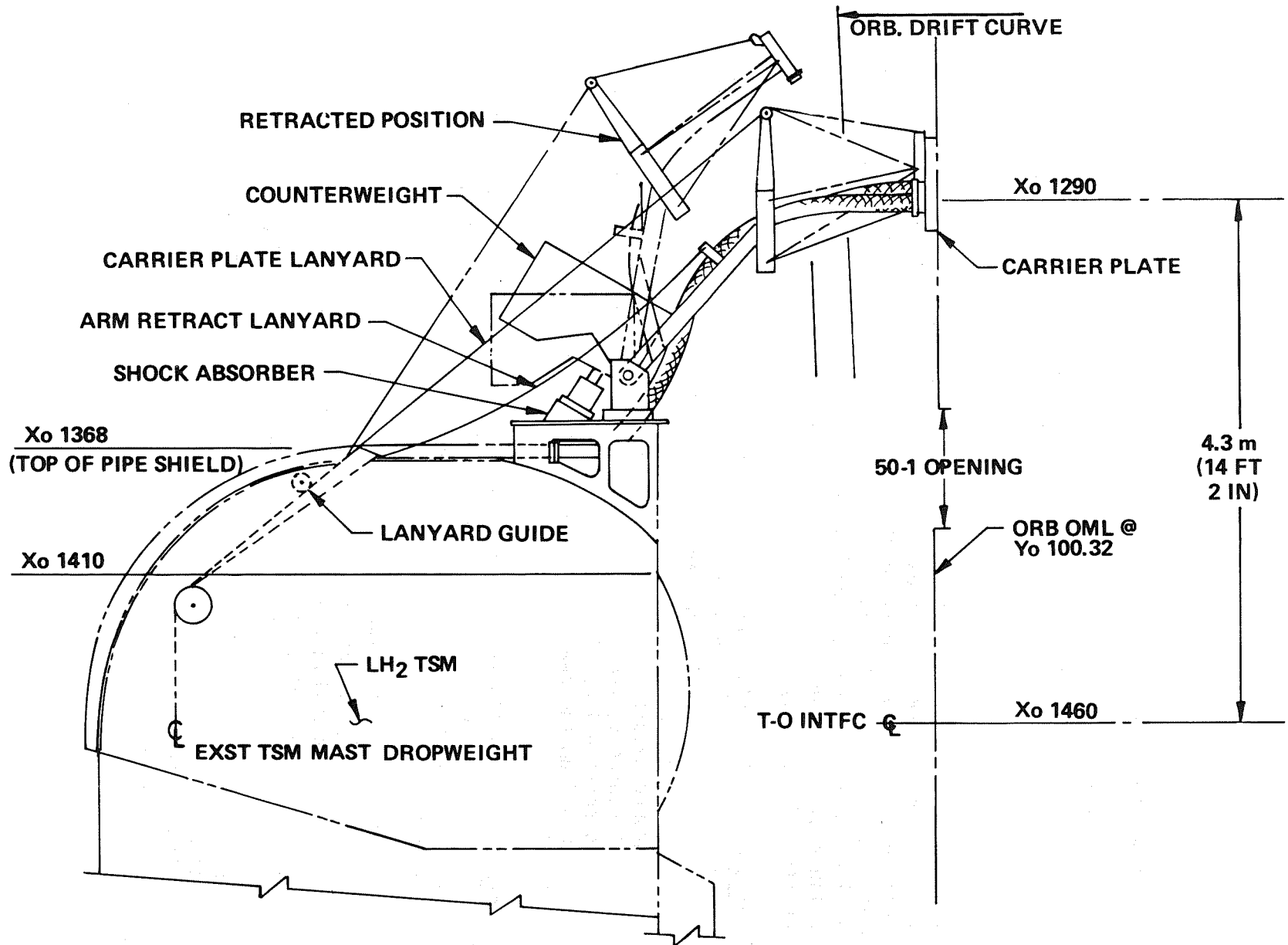


Figure 5. Payload Umbilical Mast – Expendable-Elevation View

- a. STS/Centaur rolling beam assembly (figure 6)
- b. Umbilical carrier plate assembly (figure 7)
- c. Dropweight tower assembly (figure 8)

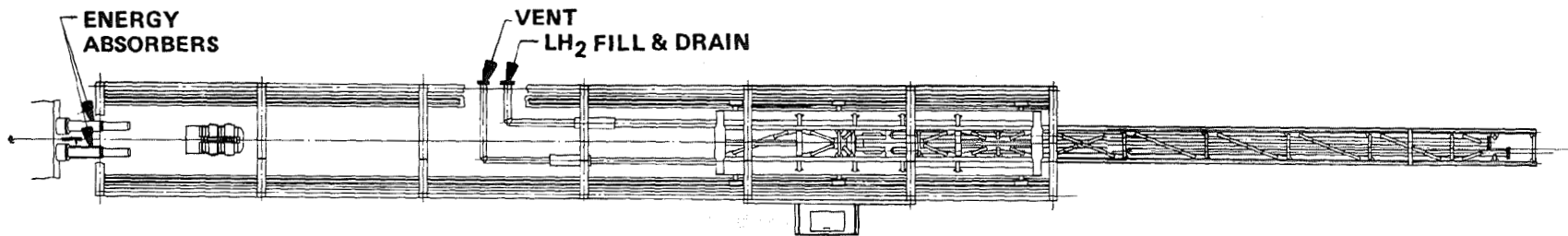
Installation of this equipment at the Launch Equipment Test Facility for test evaluation and development prior to delivery to Launch Complex 39A is shown in figure 9. A description of the cryogenic supply system is beyond the scope of this paper.

Umbilical Assembly. The umbilical assembly consists of the ground carrier plate (supplied by Rockwell International) supporting links, the LH₂ fill and drain vacuum-jacketed (VJ) flex line, and the LH₂ vent VJ flex line. The links will be equipped with ball joints to permit side-to-side motion as well as up and down. These links support the carrier plate after disconnect. The umbilical assembly includes the hockey stick disconnect lanyards and the static lanyards to prevent rotation of the ground carrier plate towards the Orbiter after disconnect.

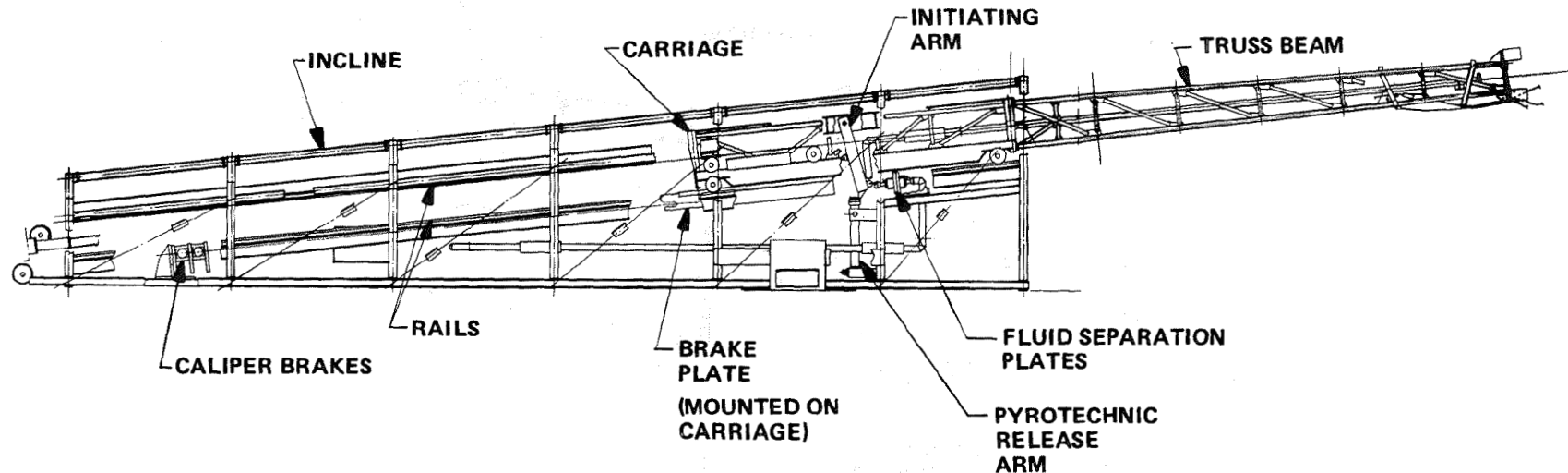
Rolling Beam Assembly. The rolling beam assembly consists of a tapered truss beam. One end of the beam supports the umbilical assembly. The other end of the beam is bolted to the carriage assembly. The carriage assembly contains wheels that capture the carriage to the rails. The carriage assembly contains a ground separation plate to support the carriage mounted cryogenic line quick disconnects, the carrier plate purge disconnect, and the various hazardous gas sensing line disconnects. The LH₂ fill and drain lines make a 180-degree turn from the beam to line up in the carriage with the ground separation plate.

Linear Brake. A linear brake acts on a friction plate mounted to the carriage to stop the rolling beam assembly. The brake system includes guide rollers in front of the brake. The brake consists of two spring-actuated caliper-disk-type units that are pneumatically retracted.

Incline Assembly. The incline assembly sets the rolling beam on a 6-degree angle necessary to interface with the Orbiter and provide stowage capability upon retract within the FSS. In addition to the linear brake described above, the incline contains final overrun stop energy absorbers designed for 11,340 kg (25,000 lb) over a distance of 0.472 m (18.6 in). The incline assembly supports the static half of the ground separation plate for the LH₂ fill and drain lines and the gaseous hydrogen vent line. A pneumatically powered winch provides the capability to lift the rolling beam up the incline. Upper guide rail and rollers limit carriage sway. Stairs and access platforms are provided on the incline, giving access to the rolling beam including umbilical and ground separation plates. Cooling water nozzles and piping will be mounted to the incline to protect the umbilical carrier plate.



PLAN



ELEVATION

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Figure 6. STS/Centaur Rolling Beam Assembly

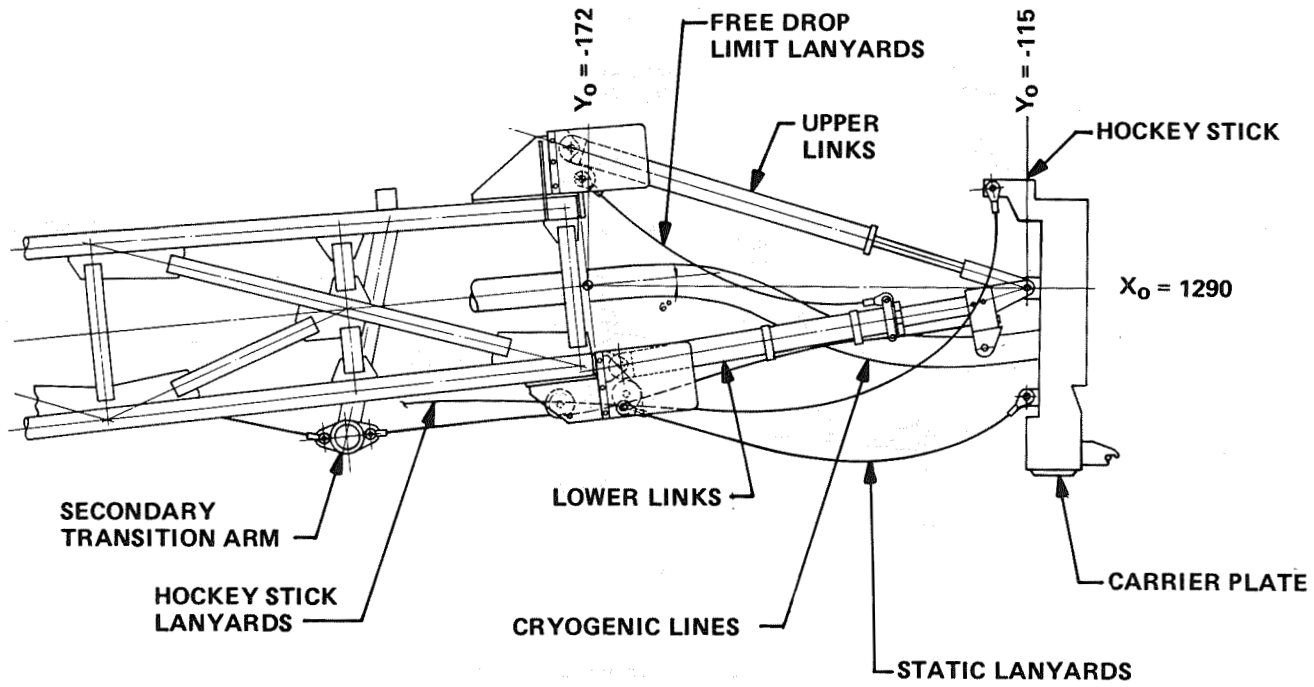


Figure 7. STS/Centaur Umbilical Carrier Plate Assembly

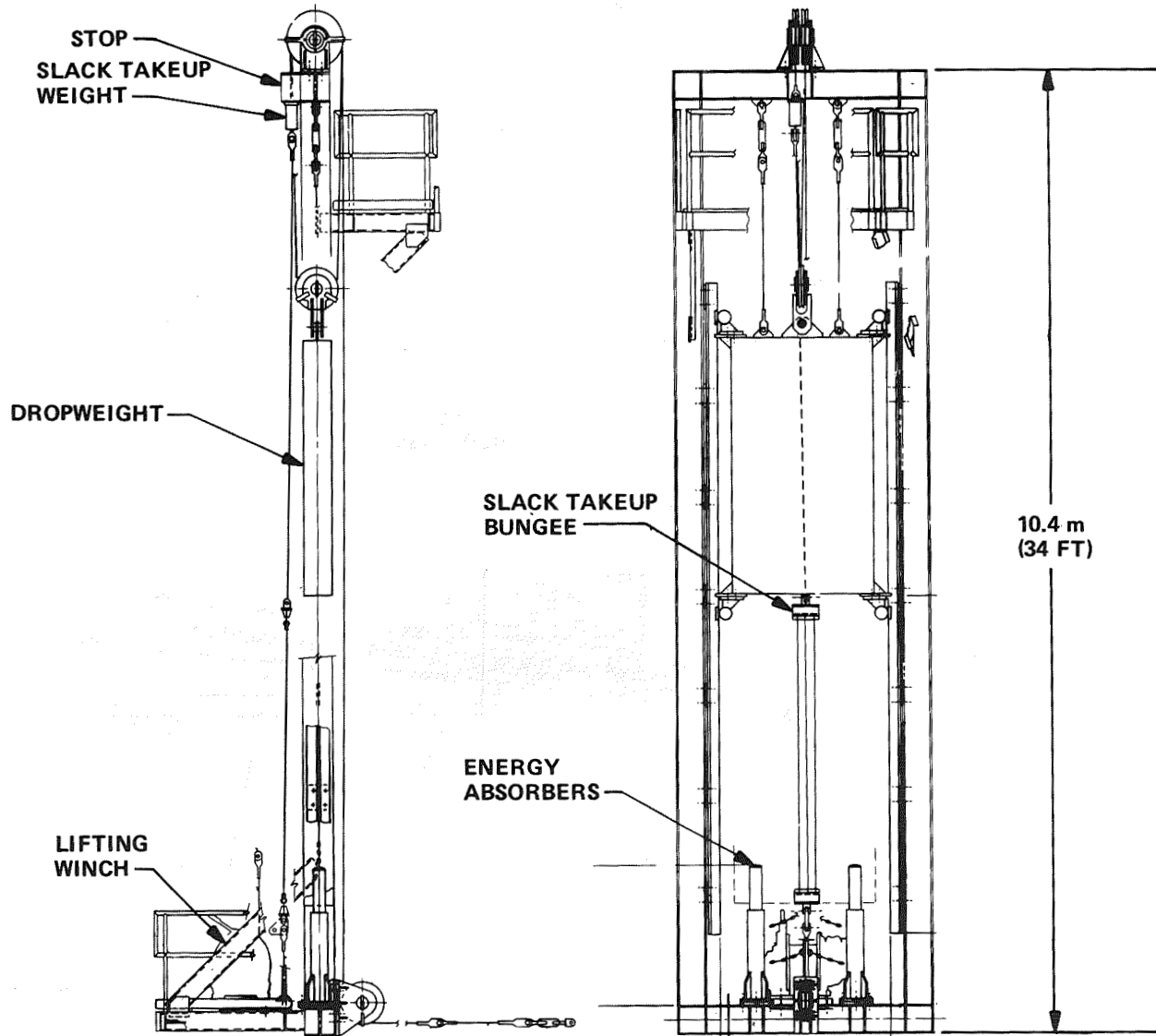


Figure 8. STS/Centaur Rolling Beam Dropweight Tower Assembly

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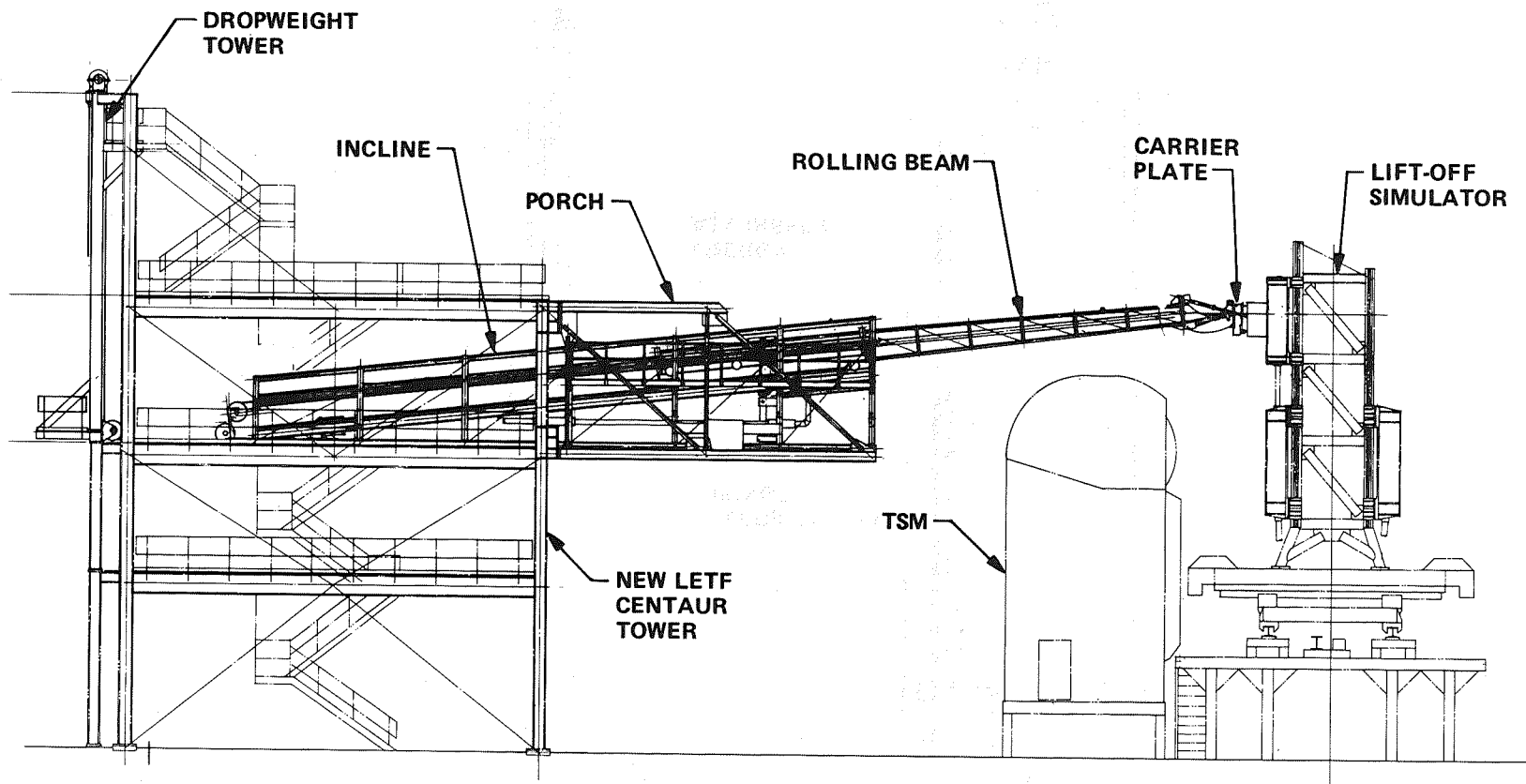


Figure 9. Launch Equipment Test Facility-STS/Centaur Rolling Beam Umbilical System Installation

Dropweight Tower. The dropweight tower contains the dropweight, dropweight lifting winch, energy absorbers, kinetic and static sheaves and cables, and cable slack takeup weight, bungee, and pulley. Cable length is adjusted at the attachment to the cable slack takeup weights and pulleys. The main dropweight cable is routed through sheaves to the carriage attach point on the initiating arm, which will be described later. To permit lifting the dropweight, the carriage end of the main cable is secured either to the carriage or to the incline structure attach point (for weight lifting only).

Porch Assembly. The porch assembly provides the necessary extension of the FSS to support the rolling beam assembly in position to service the Centaur payload in the Orbiter payload bay.

Disconnect Mechanisms. The disconnect mechanisms schematic is shown in figure 10. A latch mechanism holds the rolling beam in Orbiter mated position on the incline prior to launch with the dropweight applying static tension to the dropweight cable. The dropweight cable is attached to the initiating arm mounted in the carriage. This initiating arm first motion activates the hockey stick release lanyards and then transmits the accelerating force of the dropweight to the carriage. A redundant release mechanism triggers this action. Primary release is by a pyrotechnic bolt with dual charges. Either of these discharging will separate the pyrotechnic bolt and release the initiating arm. If the pyrotechnic bolt does not separate, an overcenter mechanism will be released by a lanyard that is activated by carrier plate lower lever extension, which takes place as the Space Shuttle vehicle lifts. The initial prototype rolling beam will incorporate a pyrotechnic bolt simulator that is released by a gaseous nitrogen pressure supply.

Initiating Arm. The initiating arm and its associated pyrotechnic release arm are the heart of the release mechanism, as they coordinate and control the functions of dropweight tension, pyrotechnic release, hockey stick activation, and mechanical secondary release. The trigger that mates with the pyrotechnic release arm is a bellcrank attached to the overcenter linkage. The lanyard action to break this linkage over center will release the trigger and permit rolling beam action to start in the event the redundant pyrotechnic bolt fails to discharge.

DESIGN CRITERIA

Pertinent design criteria for the RBUS are given in table 1. After serving the function of loading LH₂ onto the Centaur payload, the rolling beam must remain mated with the Orbiter until lift-off to provide for quick off-loading in the event of a launch abort requirement. The signal to start the retraction sequence of the rolling beam is initiated at solid rocket booster ignition. Within less than 3 s from the receipt of this signal, the rolling beam is to be retracted the necessary 11 m (36 ft) of incline distance and is stored within the incline structure where it is sprayed with cooling water to protect it for the next required launch.

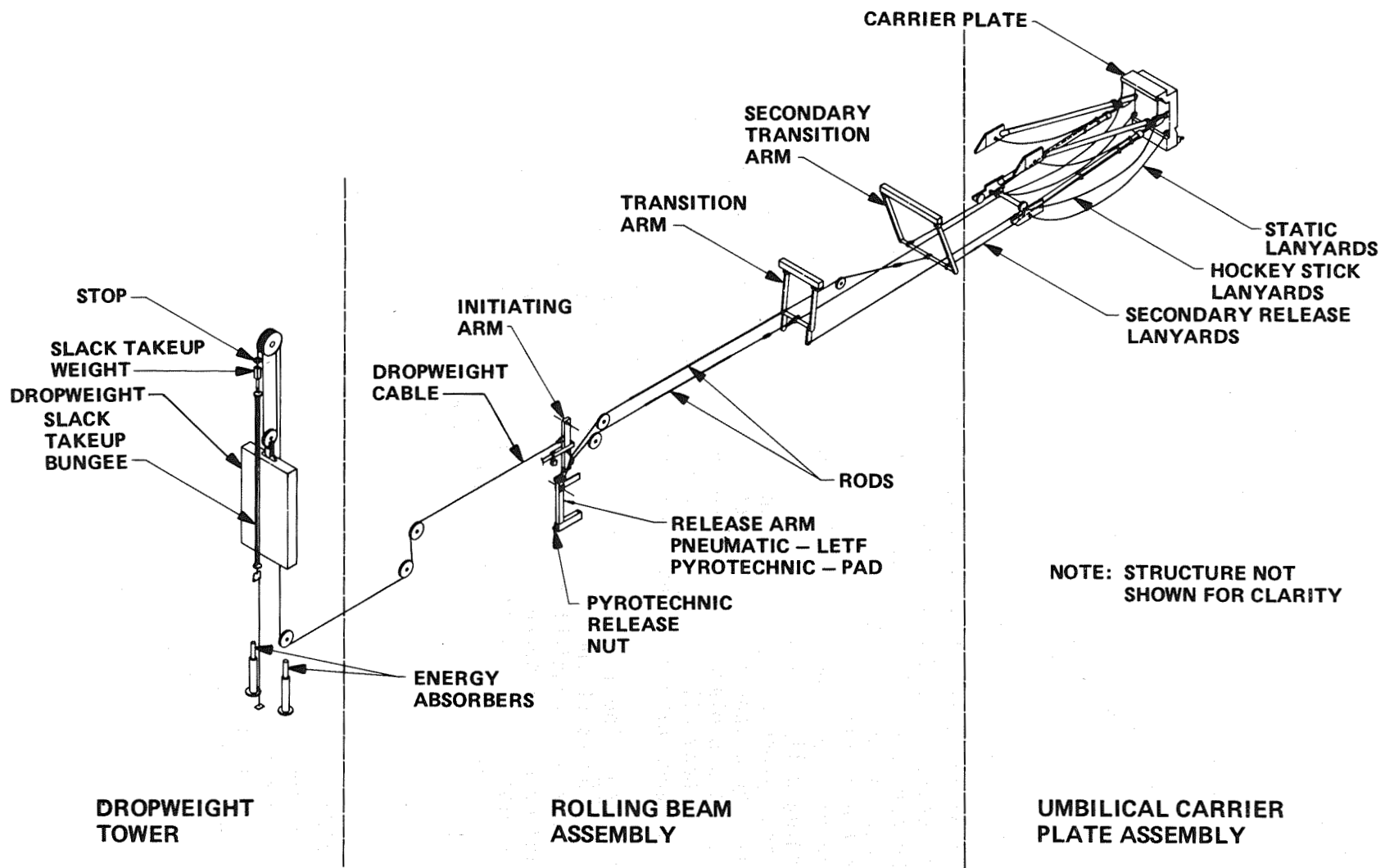


Figure 10. STS/Centaur Rolling Beam Umbilical System-Disconnect Mechanisms Schematic

Table 1. RBUS Design Criteria

Subject	Criteria
Beam retract distance	11.7 m (38.3 ft)
Acceleration distance	6.1 m (20.0 ft)
Coast distance	3.0 m (10.0 ft)
Deceleration distance	2.5 m (8.3 ft)
Overrun distance	0.46 m (1.5 ft)
Rolling beam weight	4,990 kg (11,000 lb)
Rolling beam material	ASTM A36
Factor of safety - dynamic members	2.0 minimum on yield
Factor of safety - static members	AISC criteria
Beam retract time	<3.0 s
Acceleration G's	<1.0
Deceleration G's (disk brakes only)	<2.5 (normal)
	<5.0 (abnormal)
Dropweight:	
Rolling beam/dropweight travel ratio	2 to 1
Dropweight travel	3 m (10 ft)
Dropweight energy absorption	2X(14,062 kg)X 0.41 m
Rolling beam module	90% status weight
Rolling beam including umbilical	4,990 kg (11,000 lb)
Incline	15,876 kg (35,000 lb)
Porch	8,618 kg (19,000 lb)
Total weight to be transported	29,484 kg (65,000 lb)
Brake type	Linear disk
Brake force	11,340 kg (<25,000 lb)
Normal coefficient of friction	0.30
Estimated coefficient of friction	0.25 to 0.30
variation	
Final stop overrun	Energy absorber
Final stop overrun force	2X(5,670 kg)
Incline angle	6.00 degrees
Umbilical type	TSM approach
Cooling provision (water)	1,782 l/min (500 gal/min)
Umbilical release - primary	Lanyard release
	Collet operation normal
Umbilical release - secondary	Hockey stick activates collet
	Lanyard release
Umbilical release - tertiary	Collet failed
	Hockey stick breaks collet shear pin
Rolling beam release - primary	Lanyard release
Rolling beam release - secondary	Hockey stick frozen
	Tension breaks collet shear pin
	Pyrotechnic bolt
	Lanyard release of mechanical trigger