

## CLEAN ACCESS PLATFORM FOR ORBITER

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## ABSTRACT

This report describes the design of the Clean Access Platform at the John F. Kennedy Space Center (KSC), beginning with the design requirements and tracing the effort throughout development and manufacturing. It also contains:

- a. A system description
- b. Testing requirements and conclusions
- c. Safety and reliability features
- d. Major problems experienced during the project
- e. Lessons learned, including features necessary for the effective design of mechanisms used in clean systems

## INTRODUCTION

Due to upcoming sensitive scientific payloads, cleanliness has become an increasingly visible issue at KSC. The capabilities of intricate and expensive payloads can be impeded severely by even the slightest particulate contaminant. Designated as Class 100,000, the Payload Changeout Room (PCR) Clean Room, the facility used to clean the Orbiter payload bay, is governed by stringent National Aeronautics and Space Administration (NASA) specifications that dictate standards of cleanliness measurable in 0.5-micron units.

In response to the stringent demands for cleanliness, KSC has established a Contamination Control Program. As part of this effort, the Orbiter Payload Bay is cleaned immediately prior to payload installation. Cleaning occurs with the Orbiter in a vertical position at the launch pad, and the PCR mated to the Orbiter. However, in order to access all areas of the payload bay for cleaning, a vertically moving platform is necessary.

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In the past, a Line Replaceable Unit (LRU) platform was used to access the payload bay. However, the platform was designed prior to the current emphasis for strict cleanliness standards. As a result, the platform contributed greatly to particle contamination in the room. Specifically, the system had eight wire ropes and four sheaves entering the PCR, and had numerous exposed rollers. Moreover, the platform itself was fabricated of carbon steel. Cleanliness aside, the hoisting system was unstable and required labor-intensive manipulation to coordinate the pneumatically and electrically operated hoists.

Because of these inadequacies, the platform was determined to be unacceptable, and a new design was called for: The new design is called the Clean Access Platform or CAP. The CAP is a new vertically moving platform with extensible fingers and side-rotating extensions to provide access to all areas of the payload bay. Wherever possible, this new platform has been designed to incorporate not only safety features, but also cleanliness features. See figure 1 for a view of the CAP assembly.

Installation of the CAP at Pad 39A was completed in October 1989, and operation was initiated with STS-32R on November 29, 1989. Full operational capability was achieved for STS-36 in February 1990.

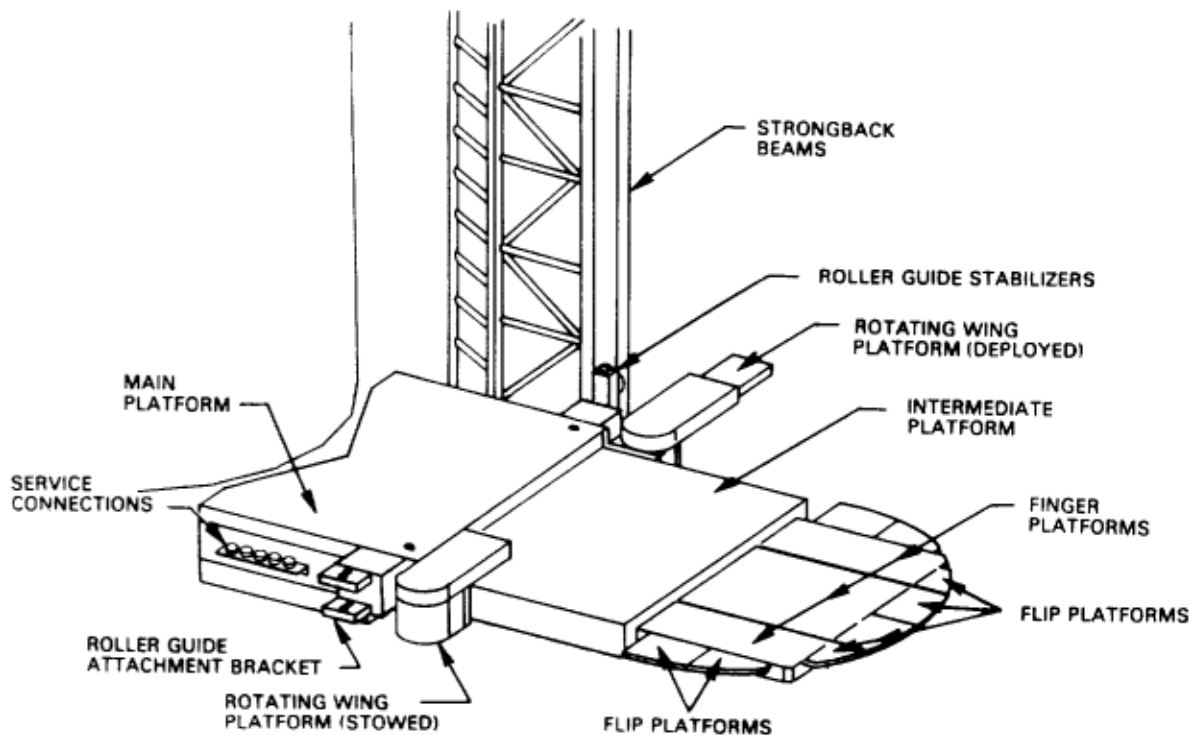


Figure 1. Clean Access Platform Assembly

## REQUIREMENTS

After the payload has been installed in the Payload Ground Handling Mechanism (PGHM) in the PCR, and the Orbiter has been moved to the launch pad, the Rotating Service Structure (RSS) and the PCR are rotated to the Orbiter mate position. The PCR doors and the Orbiter Payload Bay Doors are then opened, enabling final cleaning of the Orbiter Payload Bay.

Access is required to the Orbiter Payload Bay inner mold line and to the Payload Bay Door inner surfaces from the Orbiter Payload Bay forward bulkhead to the aft bulkhead. The Clean Access Platform is designed to provide this access. Figure 2 illustrates the CAP in the deployed position.

To provide access to the Orbiter Payload Bay, the CAP must meet the following requirements:

- a. The CAP must carry a live load of 680 kilograms (1500 pounds) (six technicians with tools).
- b. Access must be to within 30 centimeters (12 inches) of the Orbiter Payload Bay inner mold line, but no closer than 15 centimeters (6 inches).
- c. To meet time constraints, the CAP must be deployed and stowed in 2 hours maximum.

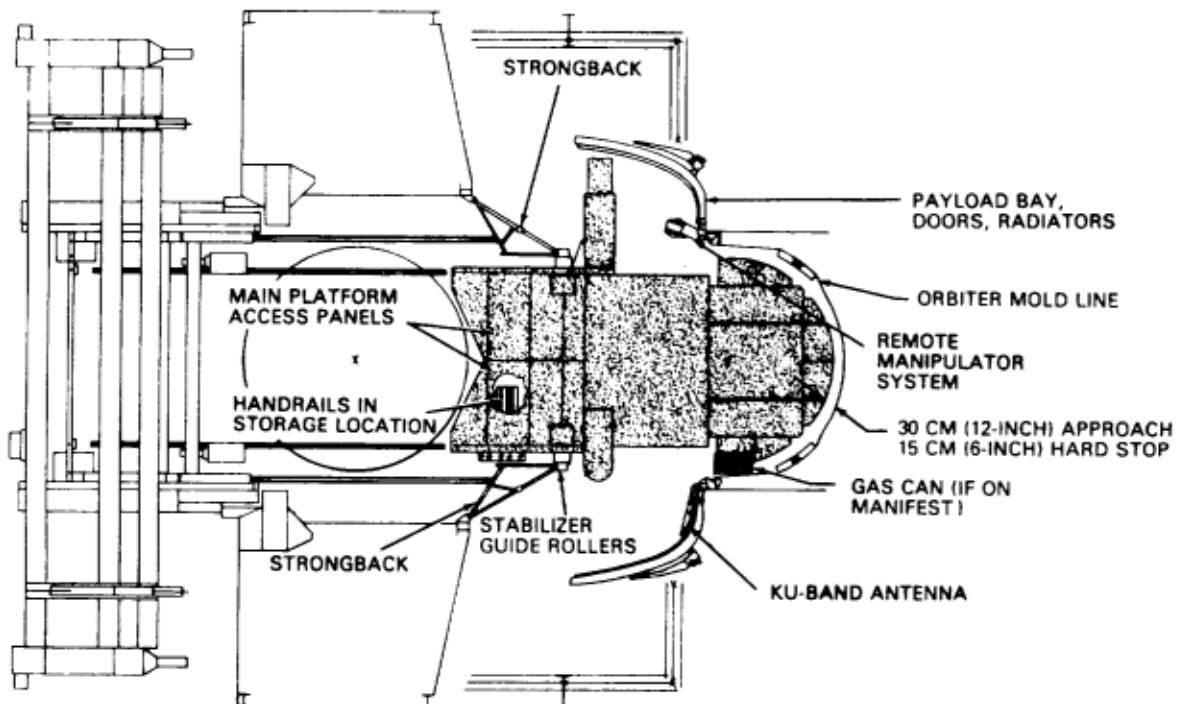


Figure 2. CAP (Deployed)

- d. In operation, the CAP must reach any location in the Orbiter Payload Bay within 10 minutes.
- e. Operation must be clean for both up-down movement and for extension-retraction of the platforms to ensure that the Class 100,000 Clean Room conditions in the PCR are not jeopardized.
- f. When stowed, the CAP must not interfere with normal payload operations in the PCR.
- g. The CAP Hoist System must meet NASA requirements for a man-rated platform so that technicians can ride on the main platform as the CAP is raised or lowered. Figure 3 illustrates the CAP and the safety features required.

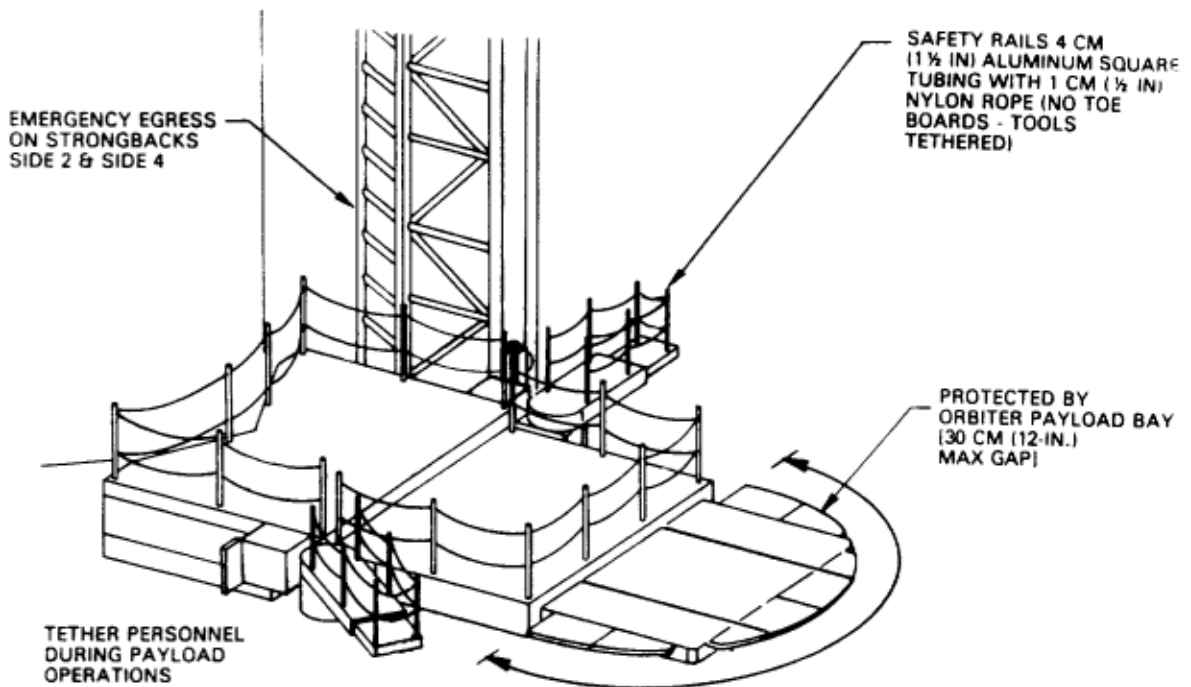


Figure 3. CAP Safety Features

- h. The Clean Access Platform must be available for contingency access to the payload after installation in the Orbiter Payload Bay.
- i. To accomplish contingency servicing, the CAP must be capable of handling the Line Replaceable Unit (LRU) Crane and other payload Ground Support Equipment (GSE).

## DESIGN CONCEPT

After studies of alternate concepts, the design of a new moving platform similar to the existing LRU platform was chosen. However, that basic design was upgraded to provide additional access to the Orbiter Payload Bay Door inner surfaces, to permit technicians to ride the platform, and to operate in the PCR Clean Room environment.

The Clean Access Platform and Hoist System was designed by the Lockheed Mechanisms Design Section with support from Structures, Pneumatics/GN2, and Electrical Design groups. Design was accomplished using the Autotrol Computer Aided Design (CAD) system.

The final design consists of a main platform with intermediate and secondary extension platforms and rotating and extensible wing platforms on either side.

## SYSTEM DESCRIPTION

The CAP consists of a hoist system, a control system, strongbacks and a stabilizer, rotating wing platforms, and extension platforms. All of these elements have unique functions and design characteristics.

### Hoisting System

The hoisting system consists of two independent, commercial, off-the-shelf, 9100-kilogram (10-ton) hoist units, and was designed in accordance with NSS/GO 1740.9 and ANSI A120.1. The use of off-the-shelf hoists provides proven reliability and eliminates new system development problems. Dual hoists were chosen for safety reasons. Moreover, a total failure of any one hoist will not cause the loss of the platform system. Due to this feature, the hoisting system is unique at KSC. Figure 4 is an overview of the CAP hoist system.

Because of the long procurement lead time involved, the hoists were sized and selected early in the design phase. At that time, a large portion of the platform was anticipated to be stainless steel, and therefore much heavier than the current design. Consequently, the safety factors on the hoist system are greater than the required 8 to 1.

The hoists have single-part reeving with single-layer, dual, 2-centimeter (3/4-inch) wire ropes on their drums. The ropes are routed through sheaves from a remote hoist equipment room into the PCR Clean Room. Four wire ropes, two from each hoist, enter the PCR and attach directly to each side of the platform, eliminating the use of sheaves within the PCR.

The number of wire ropes entering the PCR is held to a minimum. The previous access system had eight wire ropes and four sheaves that were suspected to be major contributors to the particle contamination in the PCR.

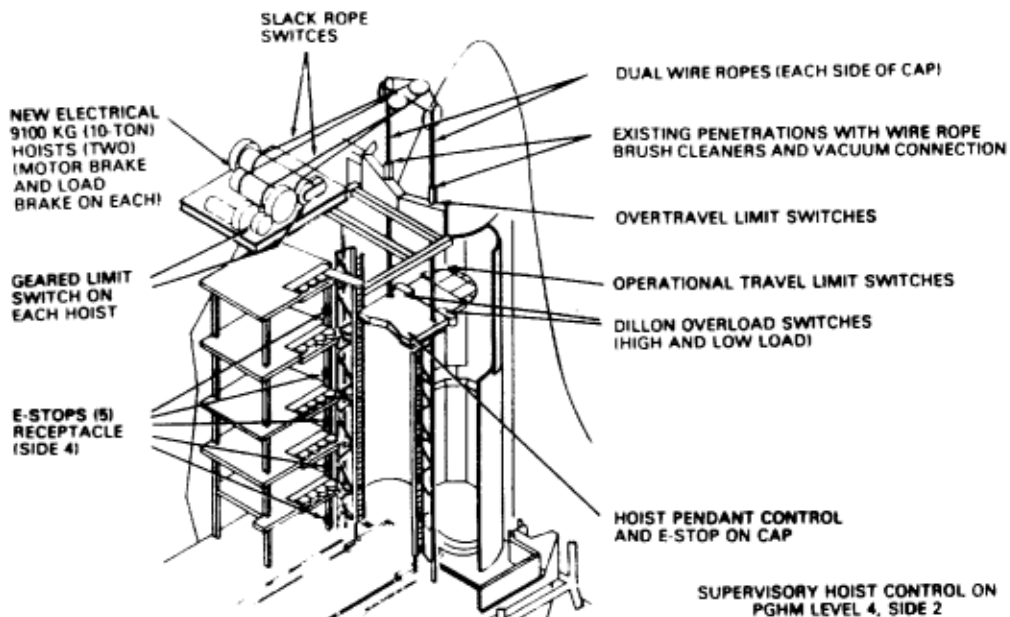


Figure 4. CAP Hoist System

Dual ropes are used to provide a rope to both sides of the platform from each hoist so that failure of a single hoist will not cause the platform to tilt. A single-layer grooved drum is used to limit the uneven rope take-up that is inherent in multi-layer rope drums. Single-part reeving minimizes the number of moving wire ropes in the Clean Room, thereby eliminating the requirement for wire rope sheaves at the platform.

### Control System

The control system is 120 volts alternating current with dual contactors operating both hoists. A portable operating station is situated on the platform, along with a remote, fixed supervisory station. Remote emergency stop stations are located at various vertical travel intervals. Additional safety features include overload/underload sensors at each hoist attach point, slack rope switches at the hoists, operational travel limit switches, and overtravel limit switches.

The supervisory station has override capability to take control of the system from the operator's station on the platform. The emergency stop controls also are manned, and can stop the motion of the platform at any time.

The overload/underload sensors, slack rope switch, and overtravel limit switch are wired to a shunt trip circuit breaker located in a locked cabinet. Trip out of this circuit breaker shuts down the system. Further, the circuit breaker cannot be reset by Operations personnel. This feature ensures that serious problems will be resolved before resuming platform operations.

The control circuit conductors are routed through an umbilical which must be connected and disconnected each time the platform is used. This

arrangement created a problem early in the platform's use. Specifically, the control switches were normally open to accommodate the connect and disconnect operations; thus, the operators were able to disconnect the safety sensors and operate the platform. As a result, a circuit was added to detect when the umbilical is disconnected.

### Strongbacks And Stabilizer

The 18-meter-long (60-foot-long) strongback is a truss structure fabricated from stainless steel with a structural rail guide assembly that guides the platform vertically and carries the overturning moments created when the platform is used. The strongback is foldable to meet clearance constraints, and to keep the guide rail as close as possible to the hoist attach point in order to limit hoist-induced moments.

The stabilizer is a roller assembly that rides in the strongback guide rail and has expandable latch pins to connect it to the platforms. Moment loads are transmitted from the platform, through the stabilizer rollers, and into the strongback.

### Rotating Wing Platforms

The rotating wing platforms are attached to the side of the platform. The platforms not only have an air-tool operated rotating drive (see figure 5), but they also have an extensible element operated by an air tool that provides the motive force for the drive mechanism.

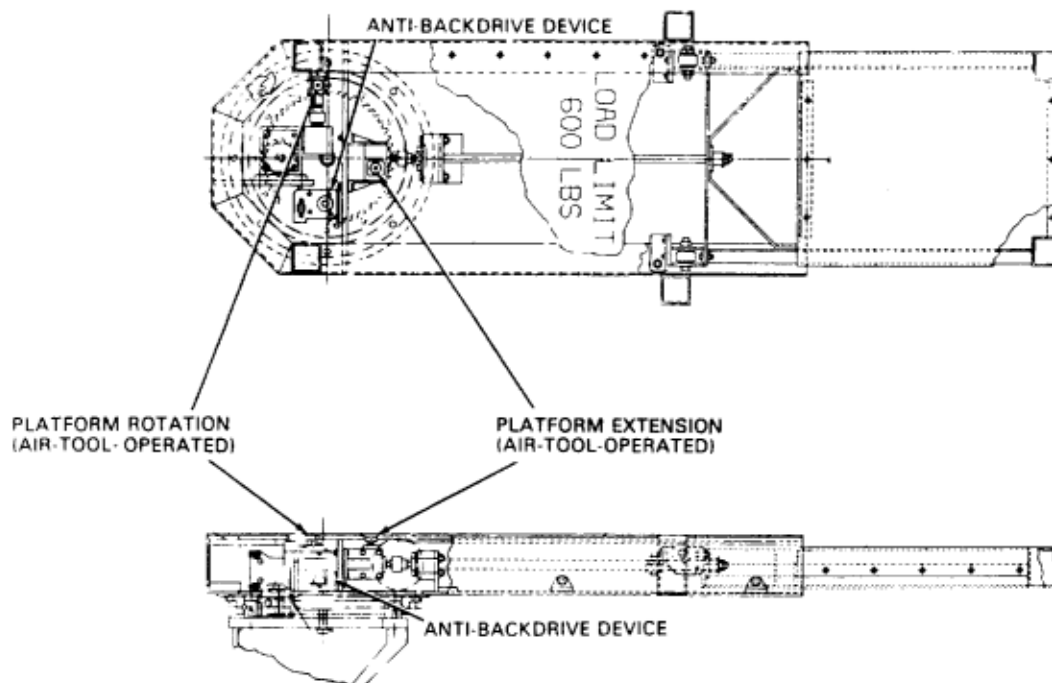


Figure 5. Rotating Wing Platform

A telescoping section was added within the rotating wing to provide clearance with the Remote Manipulator System (RMS). Both sections have hand-held, air-operated tools that provide the motive force.

One of the problems experienced with the platforms was backdriving of the rotating mechanism. Specifically, workers standing on the floor could push on the side of the wing with little effort and cause the platform to rotate. The drive mechanism gearbox was a 100-to-1 worm gear. Past experience with worm drives indicates that drives with ratios of greater than approximately 50 to 1 will not backdrive. Therefore, no problems were anticipated with backdriving. However, in actuality, the gearbox was a double-reduction worm gear with each reduction having a ratio of 10 to 1.

The problem was solved by installing a ratchet device on the wing ring gear to lock the wing in position when deployed. The ratchet device is independent of the drive mechanism.

### Extension Platforms

The extension platforms consist of an intermediate platform that extends horizontally from the main platform and carries three side-by-side finger platforms that extend from it. In turn, the ends of the finger platforms have hand-deployed flip platforms to ensure complete access to the empty payload bay of the Space Shuttle Orbiter.

The drive mechanisms (see figures 6 and 7) for the intermediate and finger platforms are of the same design and, like the rotating wing platforms, use a hand-held air motor to provide the motive force. The mechanism is sophisticated, primarily due to the need for it to be self-supporting and to accommodate the relatively large angular and linear deflections of the aluminum platforms.

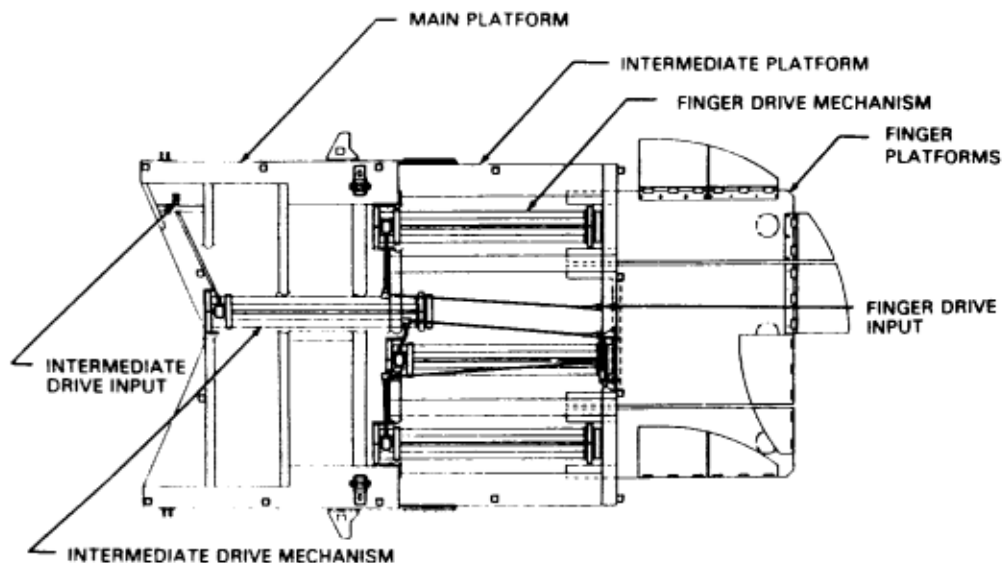


Figure 6. CAP Extension Drives



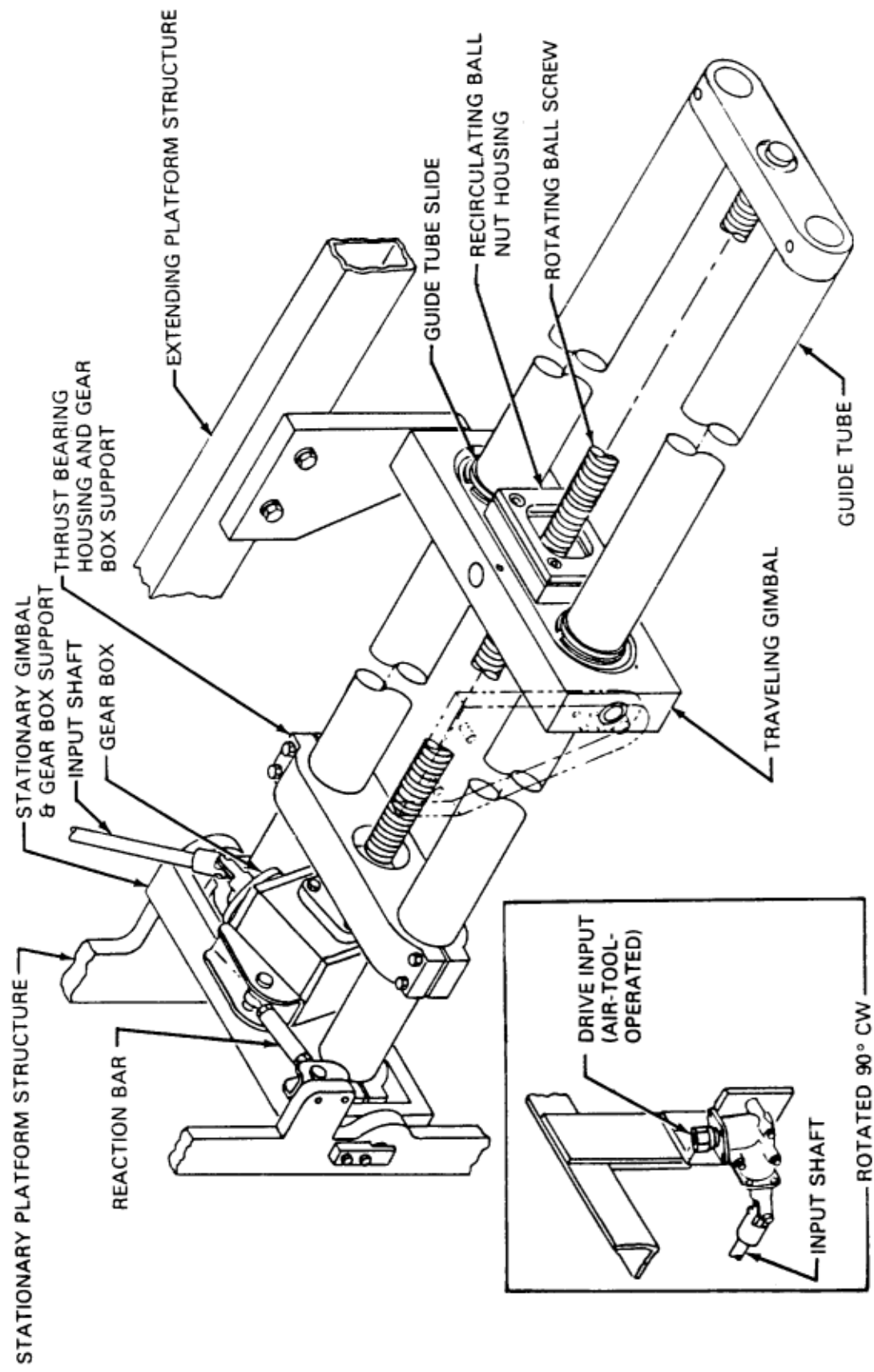


Figure 7. CAP Drive Assembly

The mechanism is a ball screw device with a traveling nut containing recirculating balls. The unit is gimballed on one end and free on the other, has a floating gearbox, and has independent thrust bearings for the rotating screw. The traveling ball nut is gimballed at its attach point on the extending platform, and slides on cantilevered guide tubes to provide support for the screw.

The ball screw is able to translate slightly in the guide tube fixture using thrust bearings configured to allow only tension loading of the screw. During platform extension, compressive loads in the drive are transferred to the guide tubes at the forward end of the screw. The elimination of column loading in the ball screw enabled the use of a significantly lighter screw, thereby reducing deflection at the end of the cantilever.

Slight backdriving problems also were encountered with the finger platform drive system, and were solved with a spring-actuated locking device that unlocks when depressed by the hand-held drive motor.

### TESTING

In-plant testing consisted of simulated hoisting, load tests, and testing of the extensible drive mechanism assemblies. Load tests and hoisting tests were conducted at the vendor's plant so that the vendor's facilities would be readily available in case of any major problems.

Hoist system testing, including function tests and proofloading, was performed at KSC, as was proofloading of the strongback assemblies. Special test fixtures were designed to perform the load tests with the hardware inside the PCR.

Full-up system testing was conducted after all components were installed, and included a static proofload equal to 150 percent of the safe working load of the platform. Additionally, dynamic testing at 100-percent load was conducted.

Testing revealed that the system has a tendency to oscillate at approximately 1 hertz while being raised in slow speed. The problem was less pronounced in high speed and appeared to occur when the stabilizer rollers contacted joints in the wear plates on the strongback guide rails. The problem was resolved by smoothing the wear plate joints and could also be eliminated by retracting the platforms while raising the unit.

### SAFETY AND RELIABILITY

In addition to a dual-hoist system with redundant load brakes, safety limit switches, and emergency stop stations, the CAP is equipped with removable handrails and emergency egress ladders. Associated operation instructions dictate that all tools on the platform be tethered, and that the number of passengers on the platform be limited to six. Moreover, CAP operators receive special training prior to certification.

A System Assurance Analysis (SAA) revealed a single failure point in the extensible platform drives, and corrective action has been taken.

## PROBLEMS

### Problem No. 1

The main problem encountered during the design phase of the project was due to startup complications associated with the use of the new CAD system. This project was the first one worked by the Mechanisms group that was accomplished exclusively with CAD. The original plan was to build 3D models and produce the drafted drawings from the models. However, the performance limitations of 3D soon became evident, and the plan was modified to use 2D layouts and drawings with 3D used only for envelope models of the structure and platform. File corruption due to new software was a major problem, and continued to plague efforts right up to the final drawing release.

### Problem No. 2

A major problem during fabrication concerned weld failures and distortion due to poor selection of welding sequences. The fabricator was constrained by a stringent schedule, and thus did not always use balanced welding techniques. Therefore, some weld fractures occurred due to locked-in stresses. To compensate for possible unreliable welds, mechanical bolt-on brackets were designed for critical locations.

### Problem No. 3

Major problems were experienced when deploying/stowing the CAP due to a minor misplacement [5 centimeters (2 inches)] of the strongbacks during installation. The CAP side attachment brackets were redesigned to correct this problem.

## LESSONS LEARNED

The following lessons were learned from this design effort:

- a. Cleanliness must be designed into clean systems. During the design phase, the following features should be incorporated wherever possible:
  - (1) Use closed sections (for example, tubes) rather than I-beams.
  - (2) Use rollers instead of slides.
  - (3) Eliminate as many moving parts as possible.
  - (4) If moving parts are unavoidable, enclose them if possible.

- (5) Use corrosion-resistant materials.
- (6) Use smooth surfaces for ease of cleaning.
- (7) Grind welds smooth and eliminate any gaps or crevices.
- b. When fabricating clean systems, cleanliness must be maintained starting with the fabrication process, and continuing throughout manufacturing.
- c. The CAD system greatly increased the capabilities of the design engineers to perform tolerance build-up and clearance studies, thereby eliminating manufacturing and fabrication problems before they occurred.
- d. The CAD system also allowed the design engineers to rapidly perform "what if" studies to deal with fabrication and installation errors.
- e. Start-up CAD projects should have the most enthusiastic and competent engineers and designers assigned.
- f. Major designer involvement is required in the fabrication testing and validation phases of a project to maintain high quality.
- g. Installation requirements and tolerances must be documented clearly, and a new survey of the area must be completed to ensure the proper location of critical elements.