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CETA Truck and EVA Restraint System

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Executive Summary

The Crew Equipment Translation Aid (*CETA*) experiment is an extra-vehicular activity (*EVA*) Space Transportation System (*STS*) based flight experiment which will explore various modes of transporting astronauts and light equipment for Space Station *Freedom* (*SSF* - Fig. 1). The basic elements of CETA are: (1) - Two 25 foot long sections of monorail, which will be EVA assembled in the STS cargo bay to become a single 50 ft. rail called the "track"; (2) - A wheeled baseplate called the "truck" which rolls along the track and can accept three cart concepts; (3) - The three carts (Figs. 2 and 3) are designated "manual", "electric", and "mechanical". The three carts serve as the astronaut restraint and locomotive interfaces with the track. The manual cart is powered by the astronaut grasping the track's handrail and pulling himself along. The electric cart is operated by an astronaut turning a generator which powers the electric motor and drives the cart. The mechanical cart is driven by a Bendix type transmission and is similar in concept to a man-propelled railroad cart. During launch and landing, the truck is attached to the deployable track by means of EVA removable "restraint bolts" and held in position by a system of retractable shims. These shims are positioned on the exterior of the rail for launch and landing (when the truck is bolted down) and rotate out of the way for the duration of the experiment. The shims are held in position by strips of Velcro nap, which rub against the sides of the shim and exert a tailored force. The amount of force required to rotate the shims was a major EVA concern, along with operational repeatability and extreme temperature effects. The restraint system has been tested in a thermal-vac and vibration environment and has been shown to meet all of the

initial design requirements. Using design inputs from the astronauts who will perform the EVA, CETA evolved through an iterative design process and represented a cooperative effort between two NASA centers and contractors.

CETA Flight Experiment Overview

The CETA concept grew from a SSF requirement for a small and quick transportation system to move astronauts along the length of the SSF 15M cubic erectable trusswork. Additionally, the requirement calls for a system concept that can be operated by a single astronaut, propelled at rates up to normal walking speeds (faster in the event of an emergency), and fitted to carry small hand tools and small replacement parts. The CETA would have the capability to travel in both directions along the length of the truss and to park anywhere along the track. The CETA is required to have an extended lifetime and be easily serviced or replaced on orbit.

A typical use of the CETA could involve a maintenance function for the photovoltaic arrays which are located at the extreme ends of the trusswork. The transporter would be used to carry the larger replacement units, tools and remote power supplies to the work site. However, as is common in any repair job, a tool or part could be left behind at the habitation module. It would be extremely time consuming for the transporter, designed for stability rather than speed, to inch its way back to pick up a tool. The CETA would allow an astronaut to quickly return to the habitation module, pick up the tool, and return to the work site using a minimum amount of valuable EVA time.

Another use of the CETA could be as an emergency return to the habitation module in the event of an injury or space suit malfunction. In this case the CETA would have to be powered by one astronaut and have the capability to carry a disabled crewman.

The CETA flight experiment was conceived to test the basic concept of a CETA system and three candidate carts. In addition, the CETA will gather data on operational loads, attainable velocities and flight temperature using sensors located on the truck.

A design team, with members from NASA's Langley Research Center (*LaRC*), Johnson Space Center (*JSC*), McDonnell Douglas, Lockheed Engineering and Science Co., Rockwell International, ILC Space Systems Corp. and others, was assembled at JSC in June of 1989 to design an experiment which could be built and flown the following summer (June 1990) with the Gamma Ray Observatory (*GRO*) experiment. This mission was chosen because once GRO is deployed the cargo bay will be clear for its entire length, allowing a sufficient run to test the candidate carts. Due to delays in the *Atlantis* STS-37 launch schedule, the GRO and CETA mission is set for April 1991. Astronauts Jerry Ross and Jay Apt, who were both very active in all phases of the CETA development, are the crewmen scheduled to perform the EVA.

The experiment is formed of three basic categories: (1) A track that could be stowed in two sections along the sidewall of the orbiter and assembled on orbit to form a continuous track approximately 50 feet in length, (2) a wheeled platform called the "truck" which would provide a standard interface to the carts and would ride along the track, (3) three concept carts to evaluate the most efficient way for an astronaut to propel a CETA for SSF. LaRC was responsible for the development of the tracks and the truck. McDonnell Douglas and Lockheed were responsible for the development of the manual cart, and JSC developed the mechanical and electrical carts. The ILC Corporation was responsible for the flight support equipment (*FSE*) that adapts the track to the STS.

The three cart concepts are the manual cart, the mechanical cart, the electrical cart (Figs. 2 and 3). The manual cart is powered solely by an astronaut pulling the CETA along the track by a handrail mounted to the track. The manual cart has a handbrake and parking brake integrated into the cart. The mechanical cart is similar to a man-powered railway cart. The astronaut will pump a handle which is connected to a Bendix type transmission. In order to stop the cart the handle is pushed past a certain set limit, which engages a brake internal to the transmission. The electric cart uses a hand cranked generator to supply electric current to a motor located at the base of the cart which propels the cart. Braking is accomplished by turning the generator backwards to develop back-EMF in the motor. The three carts will be interchangeable on the truck, which serves as the common interface.

The truck (Fig. 4) consists of five main sub-assemblies.

(1) Baseplate - a 20 inch square mounting surface and the main structural frame;

(2) Latches - mounted to the baseplate and secure the carts to the truck;

(3) Wheel Clusters - capture the rail and provide a rolling interface to the track. The wheel clusters are EVA removable, in the event of a jam or need to jettison the cart;

(4) Restraint System - secures the truck to the track for launch and landing;

(5) Arrestors - emergency stopping devices that impact a pair of aluminum honeycomb columns in the event of a brake failure during the experiment.

Truck Restraint System

The truck is restrained to the deployable track for launch and landing by means of the launch restraint system (Fig. 5) and consists of four main sub-assemblies;

(1.) Restraint Bracket

(2.) Restraint Bolt

(3.) Compression Spring

(4.) Shim

Adequate storage space is not available along the sidewall of the cargo bay to stow all three carts and the truck. Therefore it is required upon launch and landing that the truck, with the manual cart attached, be secured to the deployable track. An additional requirement is that during the experiment, the track surface must be free of protrusions to avoid the possibility of a crewmember being caught. This brought forward the concept of the truck restraint system which consists of track mounted retractable shims and EVA compatible restraint bolts which are captured in the truck. The shims hold the wheels away from the surface of the track so that launch and landing vibration will not overstress and damage the wheels. The restraint bolts screw into locking inserts in the track bulkheads, which secure the truck to the track. For the experiment, the restraint bolts are loosened (and held captured in the truck), the truck is moved away from the shims, and the shims are rotated into pockets within the track leaving the top surface of the track free from protrusions.

The shims are held in the pockets by strips of the nap side of Velcro tape. The truck is reinstalled on the shims for landing.

The truck launch restraint system posed a number of unique challenges for EVA design. The first was the development of the four (4) launch restraint bolts and brackets which are an integral part of the truck. The restraint bolts had to be retracted and captured during truck usage, meet EVA requirements, and be strong enough to restrain the truck (with the manual cart attached) during STS launch and landing. The four restraint bolts were designed to satisfy the 15g limit load factor that acts independently in three axis when the truck is restrained on the track during launch. The installation torque requirement of 25 ft-lbs came from astronaut inputs concerning the amount of torque they could exert on a bolt in the weightless environment. The restraint bolts have a 7/16 hex head, and the truck has 1.00 inch diameter tool clearance holes to satisfy EVA tool requirements.

A redundant method of retracting the restraint bolt has been incorporated in the restraint bolt design. A manual retract hole is located in the head of the restraint bolt with a hole drilled transversely through the head. The astronaut inserts a pip Pin in the hole and rotates it so that the handle aligns with the line on the head of the restraint bolt, locating the pip pin ball detents into the transverse hole. With the detents extended into the holes the astronaut can now pull up on the restraint bolt and allow the spring to secure it in the retracted position.

The bolts are captured by the restraint bracket and the truck as shown in Fig. 6. During truck usage, the compression spring forces the bolt up into the restraint bracket while the bottom surface of the truck acts as a stop. The spring was designed to exert enough force on the bolt to hold it in the retracted position during the experiment; yet without exerting so much force that the crewmember would have difficulty engaging the bolt for landing restraint. The spring design also has built in redundancy. If the spring were to break in the middle, either half would still have enough spring force to secure the bolt in the retracted position.

Another challenge for the shim design was the requirement that the top surface of the track remain free from protrusions during the experiment so that the astronaut could not inadvertently catch a gloved hand on anything. This required a shim that had to be removed from the surface of the track. The original concept was to have the removable shims placed on the track during launch and landing and during the experiment they would be removed and either stowed away or tethered nearby. This proved to be unacceptable because to tether the shims would introduce a safety problem. Stowing a removable shim would require space and time, both of which are in limited supply. A pivoting shim concept was therefore designed to be an integral part of the track itself. The shims rest on the surface of the track (Fig. 6) during launch and landing and rotate on a fixed pin into the track during the experiment.

When retracted, the shims must be held firmly in place so that they will not rotate out of position, yet the rotating force must be low enough so that an astronaut can easily manipulate the shim. The solution was to line the shim housing with the nap portion of Velcro strip. The advantage of this solution lies in its reliability and simplicity, and it works over a wide range of temperatures. During launch and landing,the shims are secured to the track by means of the truck and restraint bolts. During operation,it is necessary to ensure that the shims stay down below the track surface otherwise the truck would run into them. The Velcro acts as a brush that presses against the shim and thus holds it in place (Fig. 7). Testing determined the amount of Velcro needed to apply a particular force at a particular temperature. The astronauts rotated the shims and determined that a 12-15 lb force was optimum. For the projected flight environment low temperature of -80 degrees Fahrenheit, the corresponding surface area of Velcro required was installed in the track.

As the truck rolls along the track, it has the ability to "touch and go" at any wheel surface due to a 0.25 inch gap between the track and the horizontal wheels and a 0.125 inch gap between the track and the vertical wheels (Fig. 4). This tolerance, along with visual interference from the truck, make aligning the four bolt holes very difficult. The shims were therefore also designed to serve as an alignment ramp and stop for restowing the truck (Fig. 5), with the shims positioned on the track surface the astronaut simply pushes the truck until it slides up on the shims and is self-aligned. When the truck hits the stops at the ends of the shims, it is in position to secure the restraint bolts.

There exists a possibility of the shims bouncing off the track surface due to vibration while the astronaut pushes the truck into position for restraint. Once again, Velcro was used to eliminate this situation. A strip of Velcro nap (loop portion) was bonded to the track surface with a space grade epoxy and a strip of Velcro (hook portion) was bonded to a pocket in the shim (Fig. 7). The amount of Velcro used was a function of the force desired and the experiment's operational temperature.

LESSONS LEARNED

The Velcro method of retaining the shims in position was developed after the failure of a previous method. The original design incorporated the use of spring loaded ball detents located in the shims. Grooves were machined into the walls of the shim housings to retain the ball detents as the shim rotated into position. The force required to dislodge the shim from the grooves was easily controlled through the selection of ball detents with a specific spring force.

A problem in that design developed as the shims were repeatedly rotated back and forth between stowed position and launch/landing position. The harder stainless steel ball detents began to wear the softer anodized aluminum housing walls. Small pieces of aluminum became wedged in between the ball and the ball casing. The obstruction of aluminum became lodged between the casing and the ball bearing due to the inherent "self locking taper" in the design of the ball detent assembly. The shims therefore became stuck in either the stowed position or launch/landing position.

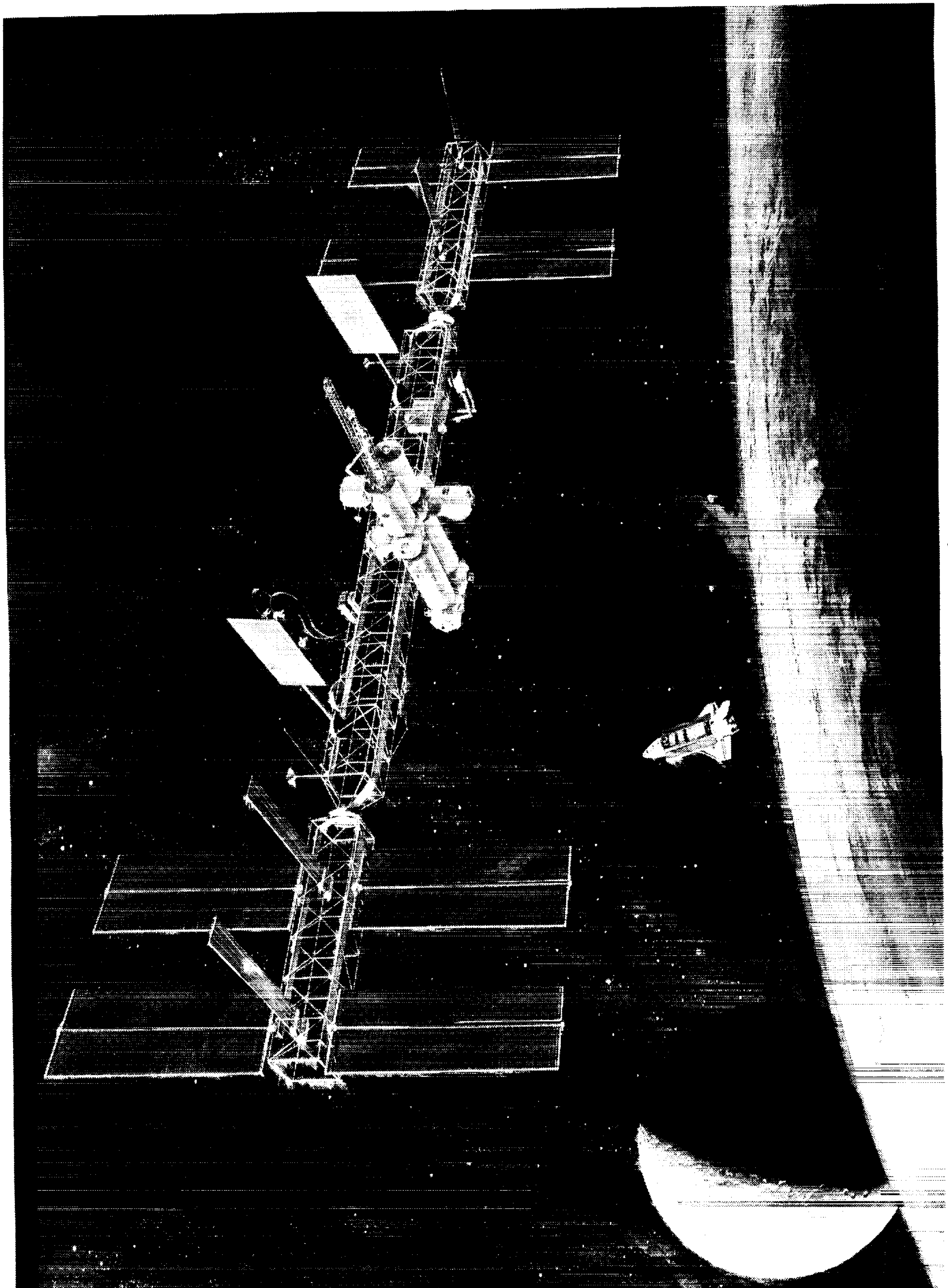

Fig. 1 Space Station Freedom

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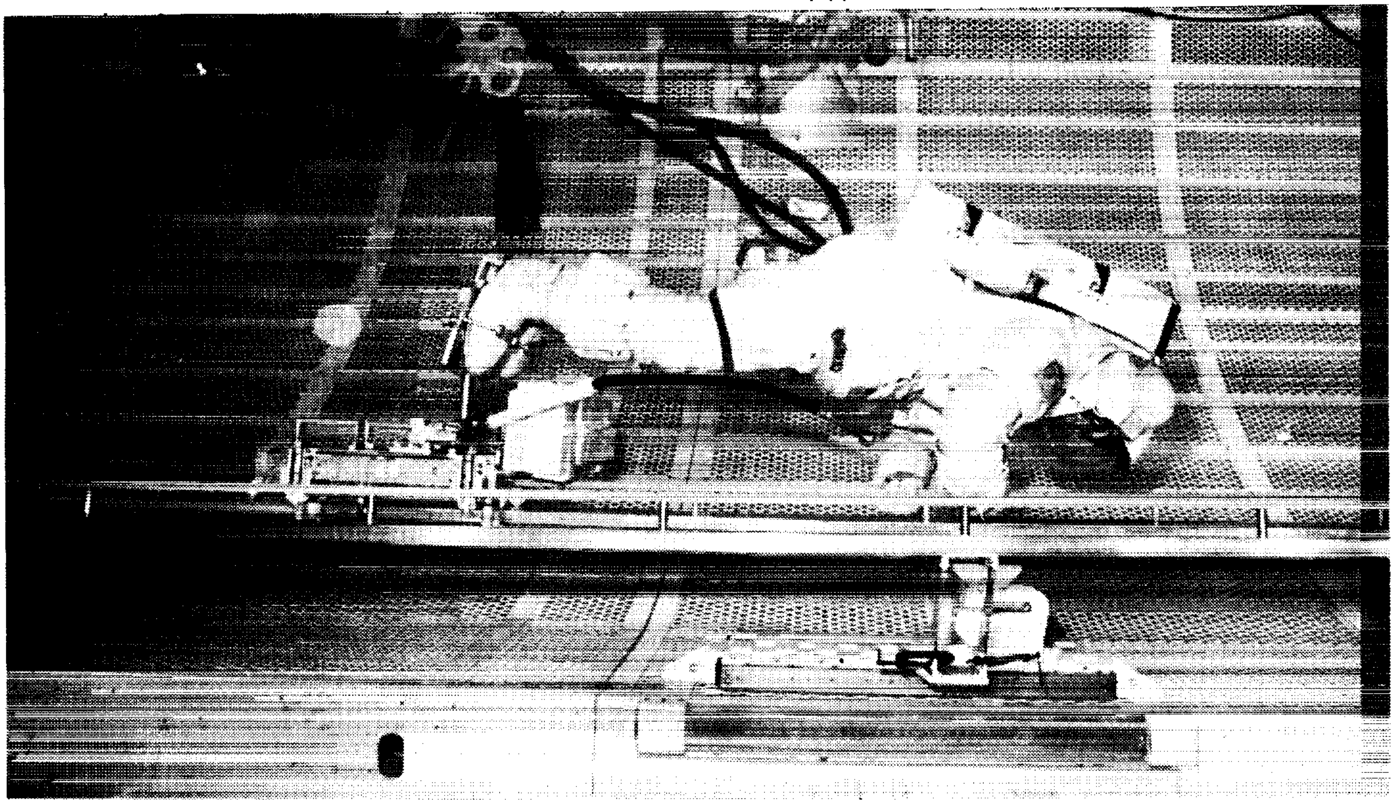
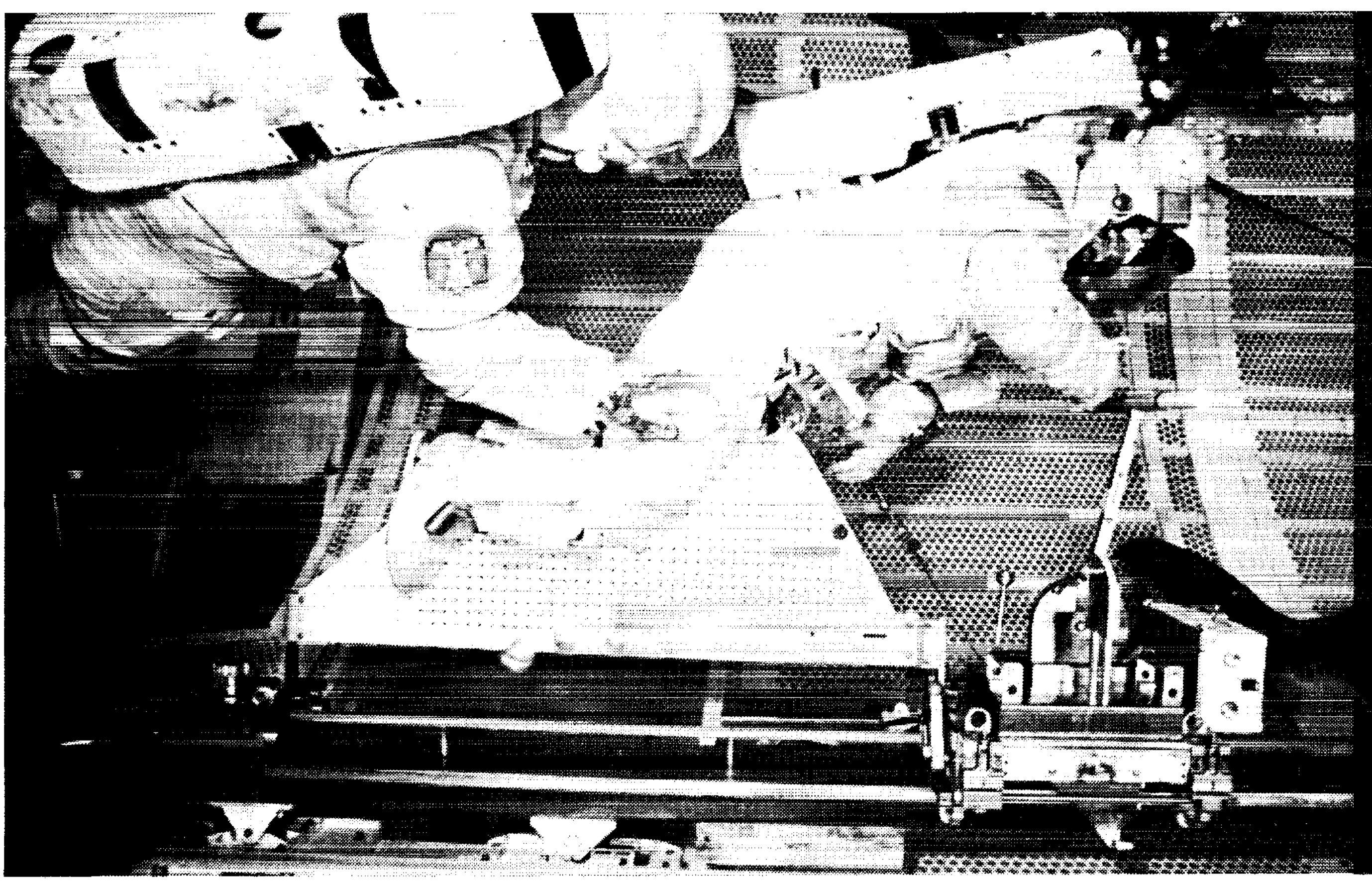


Manual Cart Mock-up in WETF Testing at JSC



Mechanical Cart Mock-up in WETF Testing at JSC

Fig. 2

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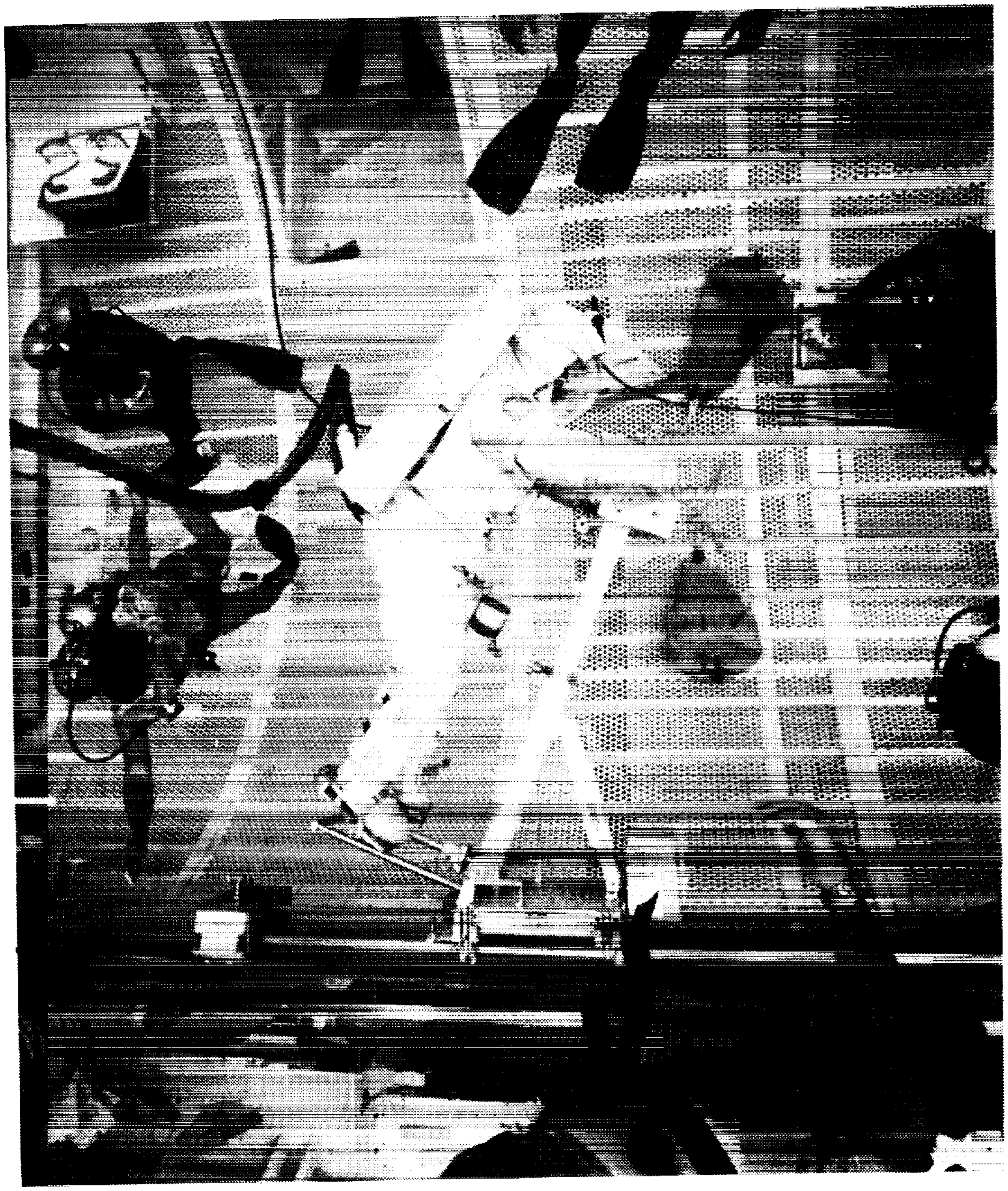


Electric Cart Mock up in WETF Testing at JSC

Fig. 3

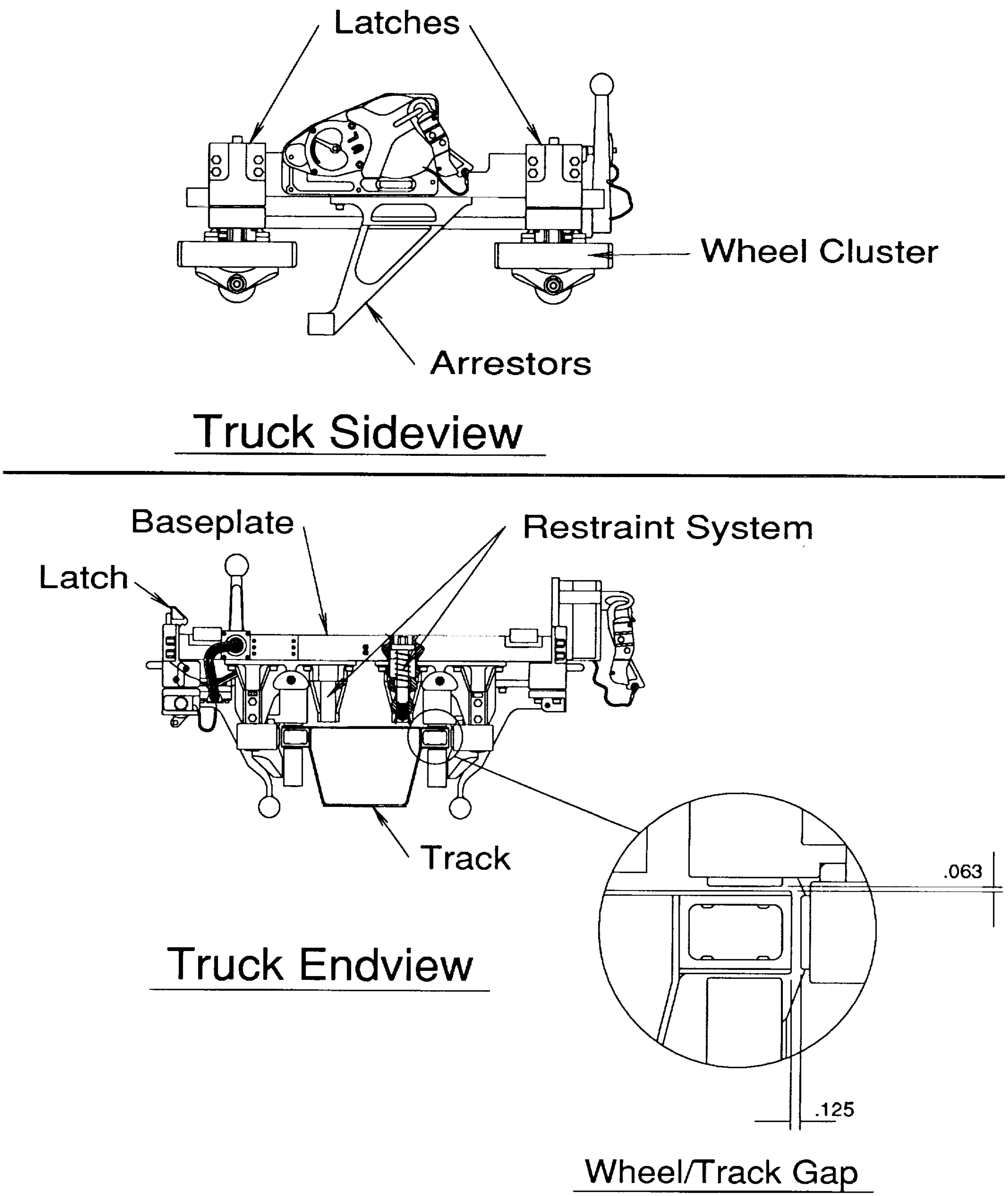
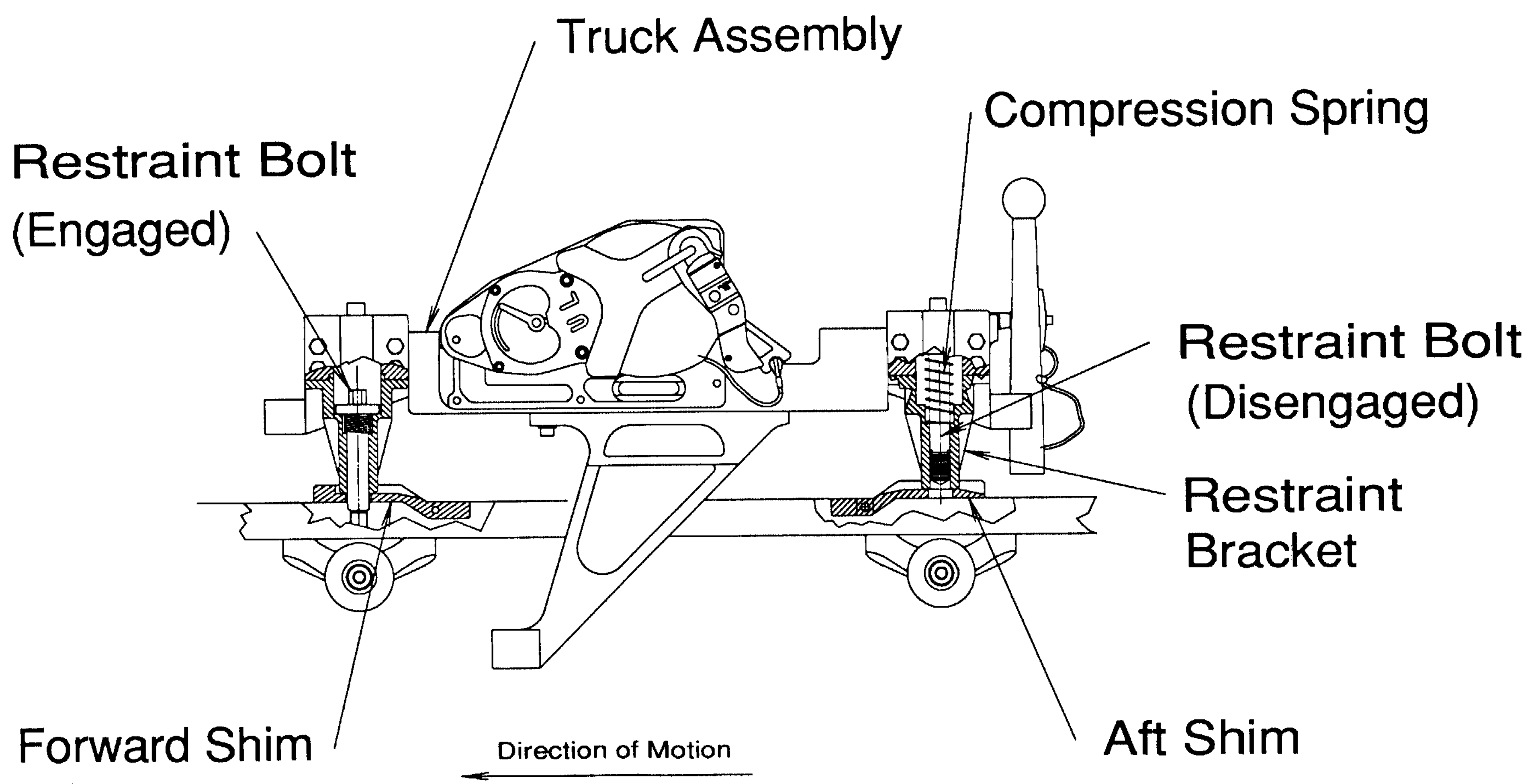
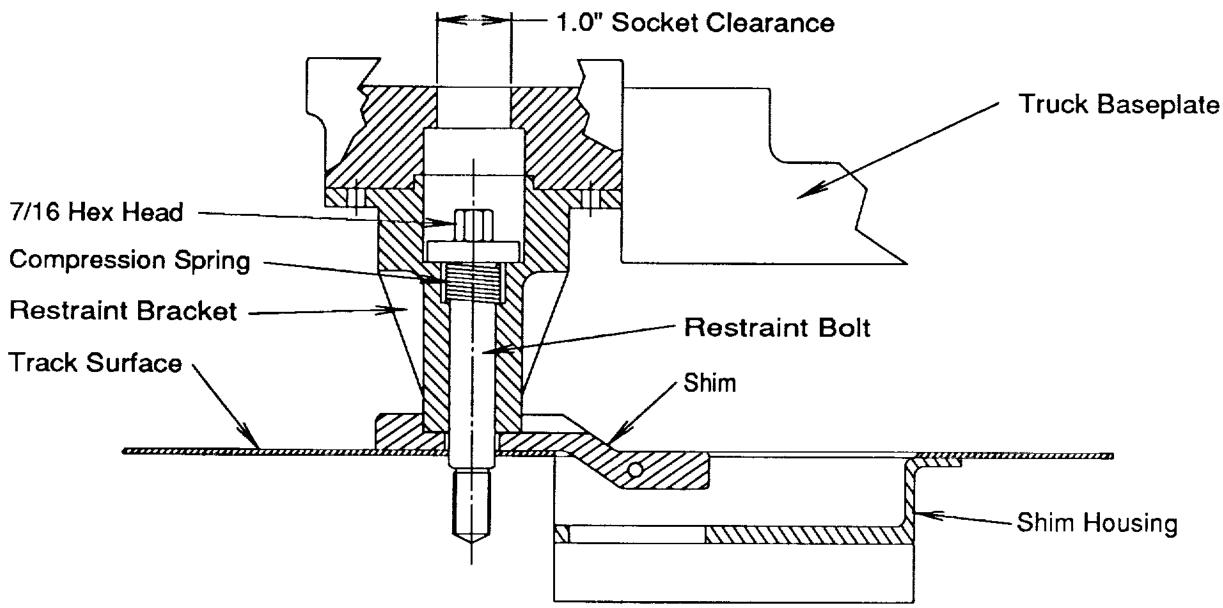

Latches
Wheel Cluster
Arrestors
Truck Sideview
Baseplate
Restraint System
Latch
Track
Truck Endview
.063
.125
Wheel/Track Gap

Fig. 4

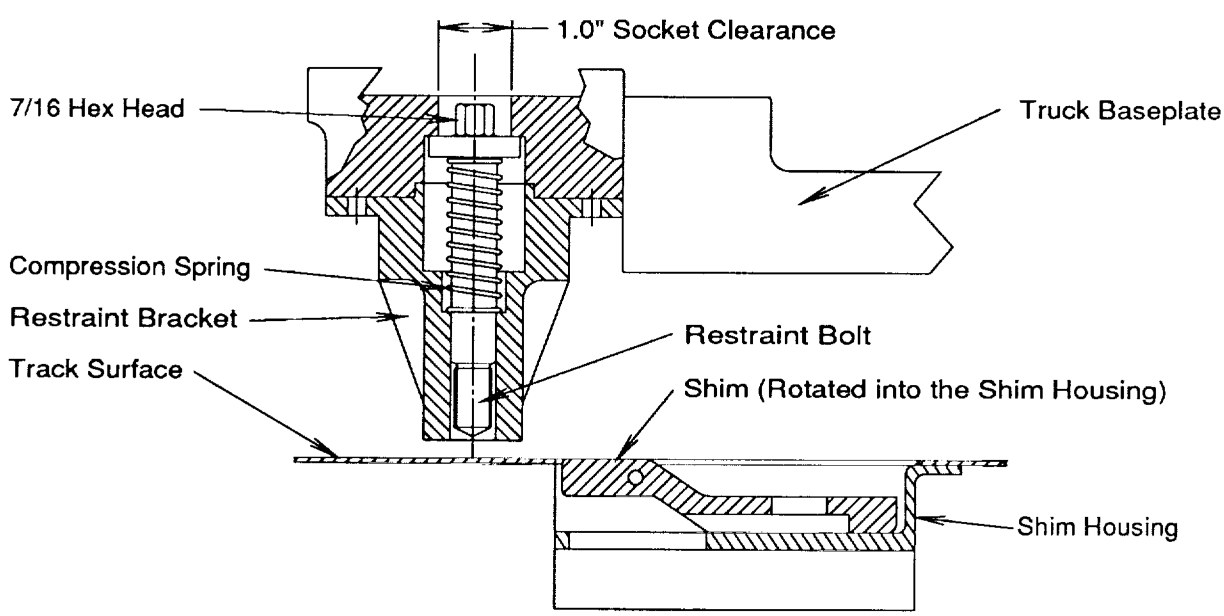


Truck In Launch/Landing Configuration

Fig. 5

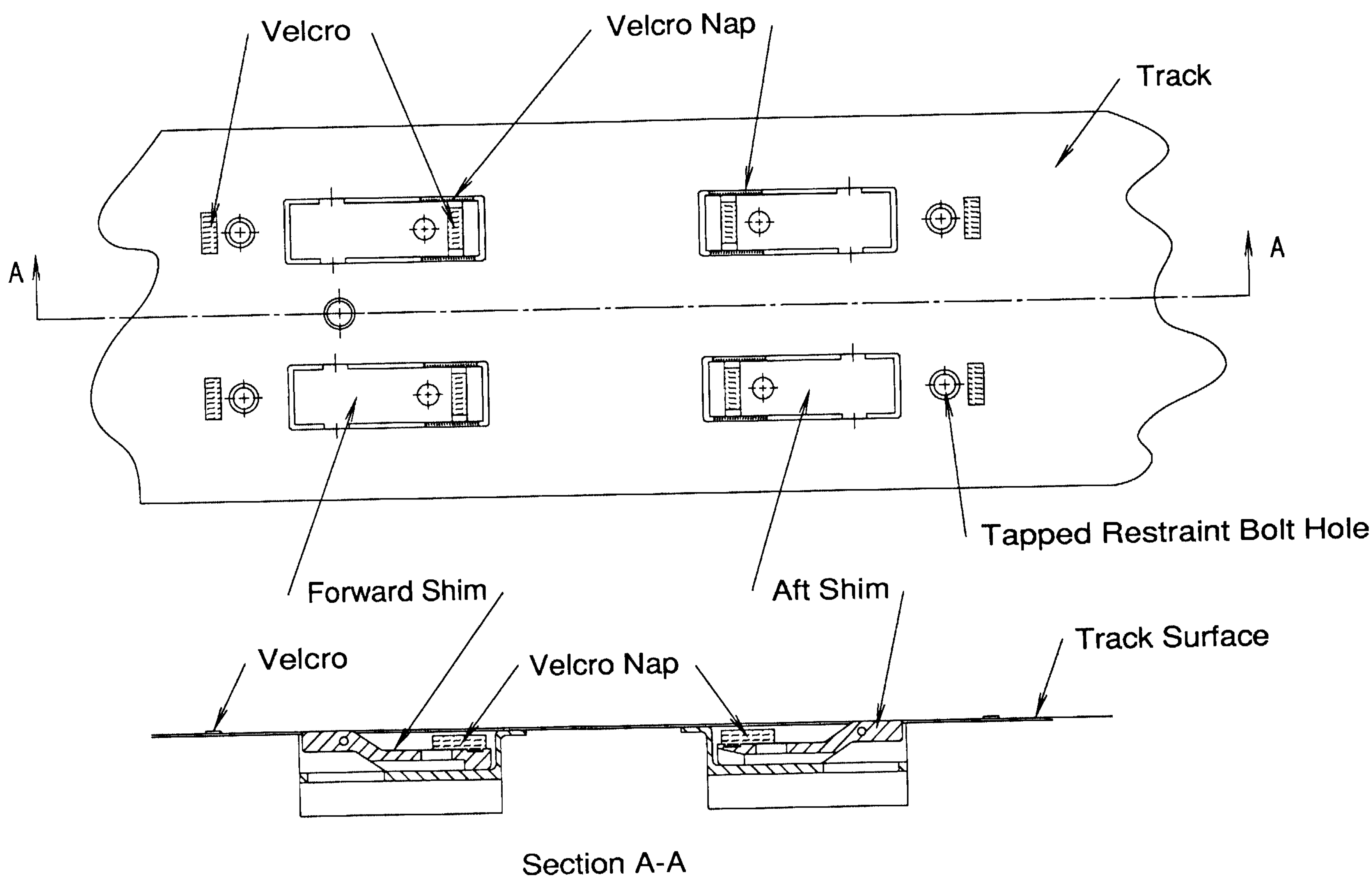


Truck Forward End
Restraint Engaged



Truck Forward End
Restraint Disengaged with the Shim stowed.

Fig. 6



Velcro
Velcro Nap
Track
A
A
Tapped Restraint Bolt Hole
Forward Shim
Aft Shim
Velcro
Velcro Nap
Track Surface
Section A-A

Fig. 7