N90-22092

The Connector Space Reduction Mechanism

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INTRODUCTION:

In the summer of 1987 the Telerobotic Engineering Office initiated an effort to review the current Space Station Work Package 3 hardware concepts and fabricate mockups for the Robotics laboratory (NASA/GSFC Building 11). The particular hardware selected for the mockup effort was the Station Interface Adapter (SIA), Payload Interface Adapter (PIA), Deck Carrier (DC) and the box-type Orbital Replacement Unit (ORU) (see figure 1). At that time only a rough design concept existed for the hardware, allowing the opportunity to fill in vague areas in the design as necessary to allow the mockups to function. A decision was made to generate and select concepts that were reasonable for upgrade to space flight.

One vague area was the utility connection at the PIA/SIA interface. The PIA/SIA interface consists of two devices with three legs. Each leg includes provision for coarse alignment, fine alignment and a utility connection (see figure 2). The utility connection consists of electrical data, electrical power, fibre optics and fluid couplings. The interface is held together with a single mechanism. The mechanism has the capability to pull the interface together, preload the interface and eject the interface halves. Only one electromechanical device is required to mate the system.

BACKGROUND:

A review of current NASA and industry concepts was initiated. The concepts fell into two general categories, connector mating orthogonal to the PIA/SIA interface and connector mating parallel to the PIA/SIA interface (see figure 3). In each category some concepts use the mechanical power of the single structural attachment mechanism while others have independent motors. A decision was made to use a concept that did not require a dedicated electrical motor. This would reduce the interface total number of electromechanical devices from four to one. This is a tremendous reduction in system complexity, providing schedule and cost savings with no affect on the function of the utility connections.

The next choice was the direction of connector motion with respect to the PIA/SIA interface desired to mate connectors. The connectors can be mated parallel or orthogonal to the PIA/SIA interface (see figure 3). The motorless parallel concepts require provisions to ensure that the interface is structurally together prior to connector mating. This adds complexity to the system levers, pivots, etc. This also introduces the possibility of the utility connection mechanism preventing structural attachment of the payload. The motorless orthogonal concepts are the simplest. A decision was made to pursue the motorless orthogonal concept where the connectors are mated as the structural mating of the PIA/SIA occurs. This is the simplest possible approach using only the mechanical power of the structural mating mechanism for the utility connection.

The next step was to plot the mating trajectory of the PIA/SIA alignment system and select suitable connectors. The mating trajectory is determined by the fine and coarse alignment provisions in the system. The system has trajectory plots for each degree of freedom but only the most critical translation plots are shown. To make a trajectory plot of the PIA/SIA system, one must plot the worst-case misalignment vs. the interface height. Misalignment is the linear or angular measure from perfect alignment at the location in the system where the connectors are located (see figure 4). Then one simply compares these plots with connector-required trajectory plots from the manufacturer's drawings and specifications.

THE PROBLEM:

The connector evaluated for our application was the G & H Technologies shell #1 type connector. These have many desirable features and have flight history on the Modular Multimission Spacecraft ORUs. The housings are tough and have forgiving geometry; it is unlikely pins will be bent during operation. The connector-required trajectory plot was compared with the system plot and it was found that in the worst case connectors could not be mated (see figure 5).

THE SOLUTION:

To resolve this problem two avenues exist. The interface alignment system can be changed or the connectors can be modified. Improving the alignment system must be done with care since fine alignment over long interface heights will cause system binding (see figure 6). This is a problem on the PIA/SIA interface with its central attachment mechanism. When mating or demating the interface, the alignment pins and cones will not separate or mate in unison. This problem forced modifications to the mockup hardware to eliminate binding. With this in mind a decision was made to leave the mating system as it is and modify the connector trajectories instead.

The connector translational and rotational requirements can be relieved with the addition of guides and gimbals, but these do not change the travel required. The guides must be long and protrude above the interface. This could be a safety hazard. The problem could be eliminated with the addition of an alignment cusp with a feature that when depressed an amount the connector halves move together twice that amount. This device eliminates the requirement for tight tolerances over large distances for the connectors. If the device is designed carefully, blind mate connectors of all types could be used. The only problem with the system is with the 1-to-2 motion ratio, the force to mate connectors doubles. The structural mating mechanism has ample force margins to overcome this problem. G & H Technologies has been working on connectors that require significantly lower mating force. Other companies have successfully accomplished this with different styles of connectors. This imminent marriage of connector technology will eliminate the mating force problem. Several design concepts were generated, ranging from a mechanism using levers and cams to one with racks and gears. The latter was chosen for the first cut since it appeared more robust.

The device has some design features that are essential and others that are arbitrary. The device has two halves an active half and a passive half (see figure 7). The active half contains the mechanism that provides the mating motion. Both halves can rotate about an axis and translate along that axis. When mounted into position, these axis are orthogonal to one another. This allows for misalignment of mating interfaces in rotation and translation about two axis. The halves can gimbal about only one axis each or binding and pin bending will occur upon demating of connectors.

The sequence of operation is as follows(see figure 8):

1. and 2. The PIA and SIA are brought into close proximity in the worst-case alignment situation.

3. The interface height is reduced until the cusp makes contact. Each half of the mechanism is gimbaled until each half is parallel.

4. and 5. As the interface height is reduced, the connector moves twice as fast, cutting the distance or space with the fine alignment requirement by 50%. For this reason the device is called the Connector Space Reduction Mechanism (CSRM).

The amounts of translation and rotation can be chosen to match the application. For our application and geometry, +/- 0.635 cm (0.25") translation and +/- 6 degrees rotation were allowed on the passive half and +/- 0.635 cm (0.25") translation and +/- 1.5 degrees rotation for the active half. These values allow ample margins for our specific application. Translational and rotational misalignments about the axis orthogonal to the PIA/SIA interface are handled by the proven means of giving one connector half a compliant mounting.

A requirement is that malfunctioning or damaged connectors must not interfere with structural attachment. This is simply achieved by mounting one connector half on springs with a preload exceeding the normal connector force by 50%. If the connector is damaged, the connectors will simply push out of the way, allowing structural mating (see figure 9).

THE HARDWARE:

The prototype CSRM was designed for G & H Technologies shell #1 blind-mate connector. An adapter plate was fabricated for operation with 3 AMP, blind-mate connectors. The CSRM was designed for a 3109-N (700-pound) worst-case mating force. The mounting includes material that encloses the PIA and SIA 5.08-cm (4") square tube with through bolts. The motion of the device is provided by dual racks and pinion. These require good alignment and this is provided with four IKO linear roller bearings. The bearings provide smooth, precise motion between the cusp and the connector mounting plate. The device is made predominantly of aluminum with an anodized coating. The device has brass gimbal bushings that provide translation as well as rotation. The CSRM halves are held in neutral position in translation and rotation by compression and tension springs. The device consists primarily of milled-out pieces. This provided the strongest final product (see figure 10).

ASSEMBLY AND TEST:

The device was assembled and installed on the PIA/SIA mockup in the GSFC Telerobotics laboratory. The device halves were placed loosely on the PIA/SIA structure. Both halves were adjusted until, when perfectly aligned, both halves were in the neutral position with respect to translation and rotation. Then matching holes were drilled through the SIA and PIA square tube for permanent mounting.

The device was tested several cycles with the PIA/SIA mating normally. No problems were encountered. Then several mating cycles were accomplished with the PIA imbalanced to force the worst-case misalignments to the system. The CSRM performed flawlessly. The CSRM has operated several cycles weekly since 3-24-89 without a single malfunction. The prototype CSRM has exceeded the number of life cycles for a flight unit by a factor of ten. The testing was accomplished with G & H connector shells and repeated with AMP blind-mate connectors on an adapter plate. The AMP connectors are excellent for the laboratory since they are low cost and readily available. AMP connectors are much more fragile than G & H connectors, and the CSRM has yet to damage a shell or bend a pin.

IMPROVEMENTS AND FUTURE WORK:

Since this was a prototype device, two areas for potential improvement came up. The first area is that one of the telescoping shells on the active half of the device can be eliminated (see figure 11). This would offer decreased weight and complexity. The second improvement would be to reduce the weight of the device. The prototype passive half weighs 14.5 kg (32 pound) and the active half weighs 25.8 kg (57 pounds). The weights are to high due to limited stress analysis and compound factors of safety. The device could be reduced in weight by 30% and possibly 50%.

CONCLUSION:

The CSRM is a simple device that can reduce the number of electromechanical devices on the PIA/SIA from 4 to 1. The device uses simplicity to attack the heart of the connector mating problem for large interfaces. The CSRM allows blind-mate connector mating with minimal alignment required over short distances. This eliminates potential interface binding problems and connector damage. The CSRM is compatible with G & H connectors and Moog Rotary Shutoff fluid couplings. The CSRM can be used also with less forgiving connectors, and this has been demonstrated in the laboratory. The CSRM is a NASA/GSFC exclusive design with patent applied for. The CSRM is the correct mechanism for the PIA/SIA interface as well as other similar berthing interfaces.

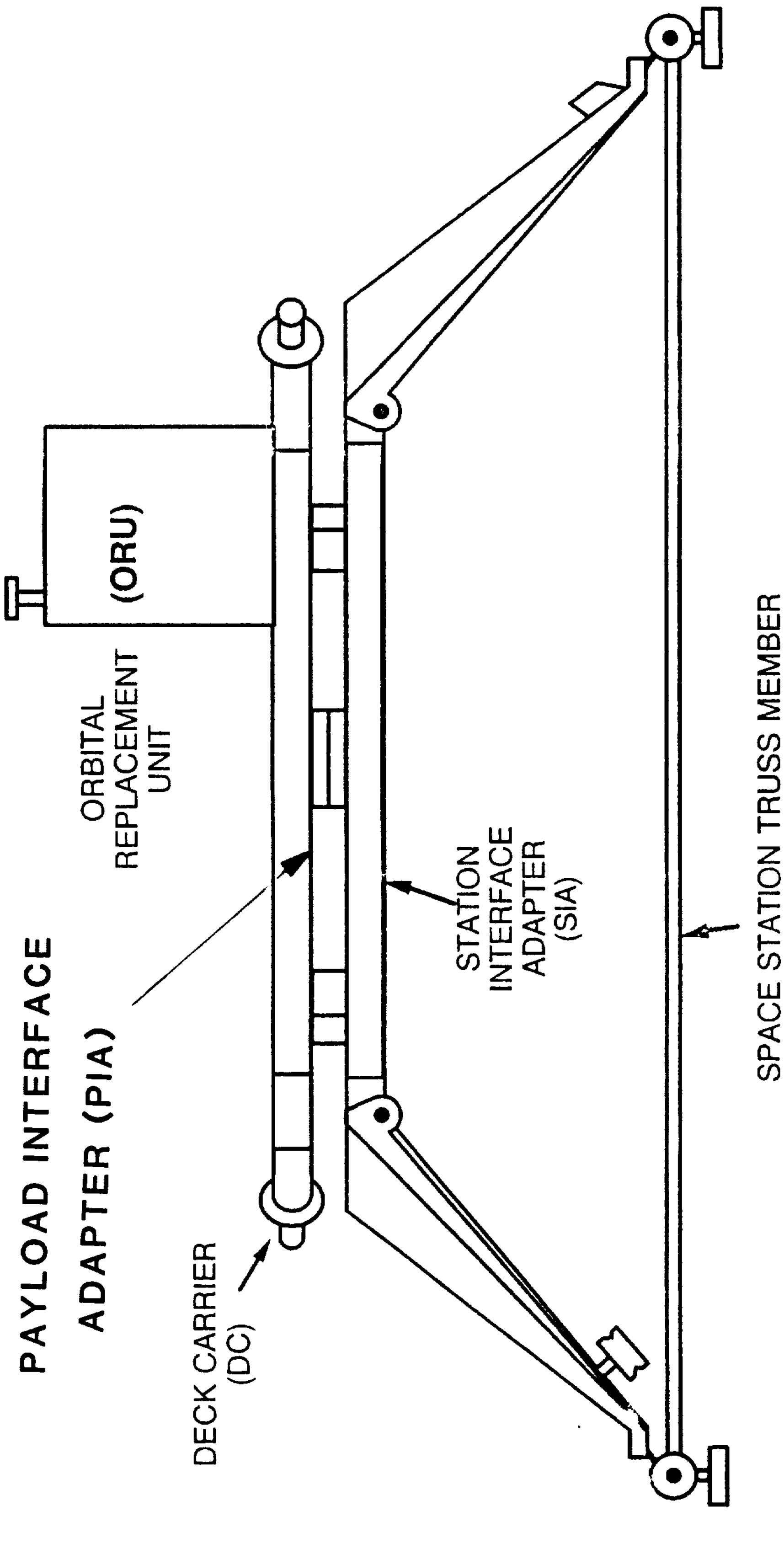
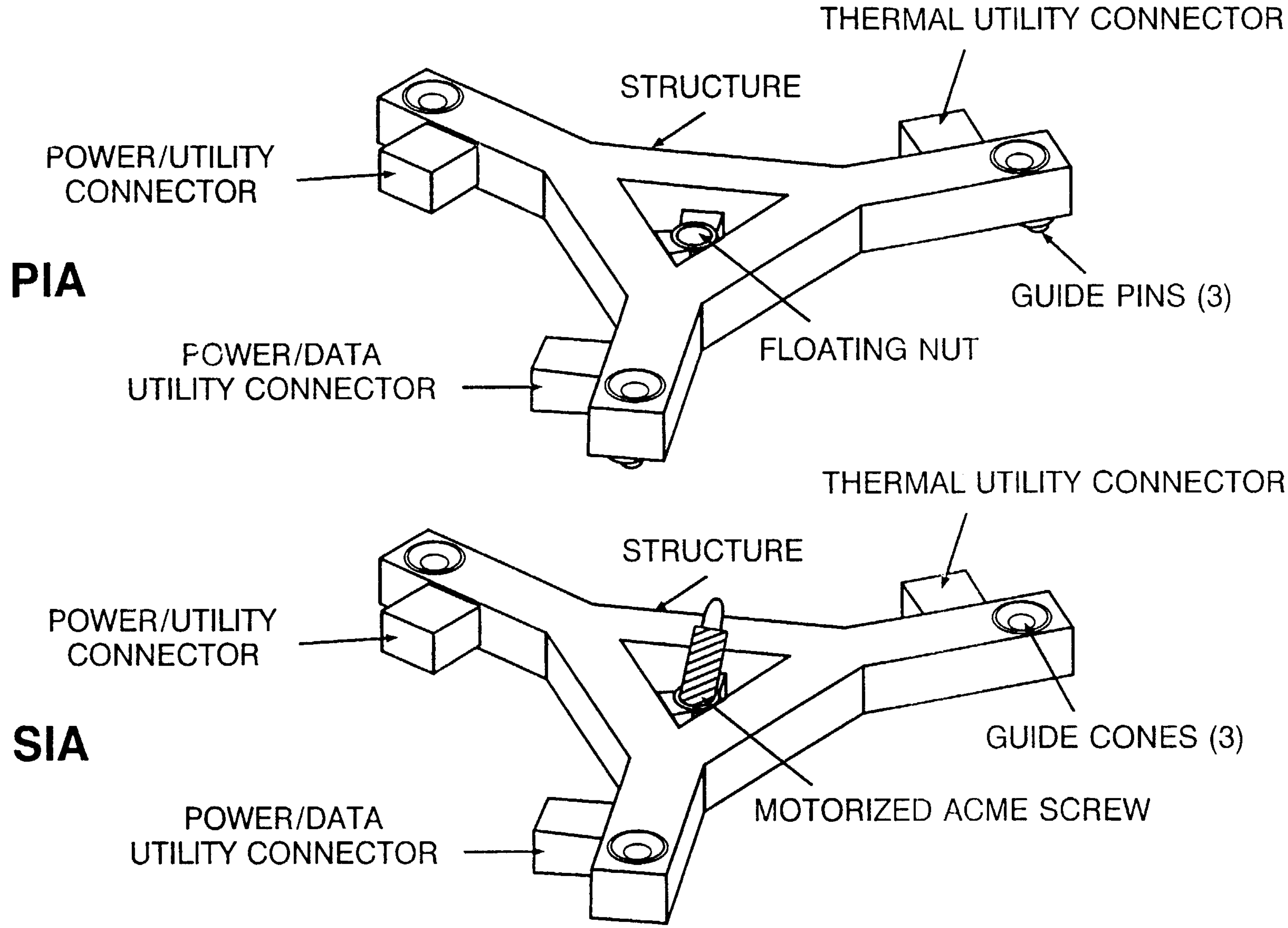


FIGURE 1

A365.005



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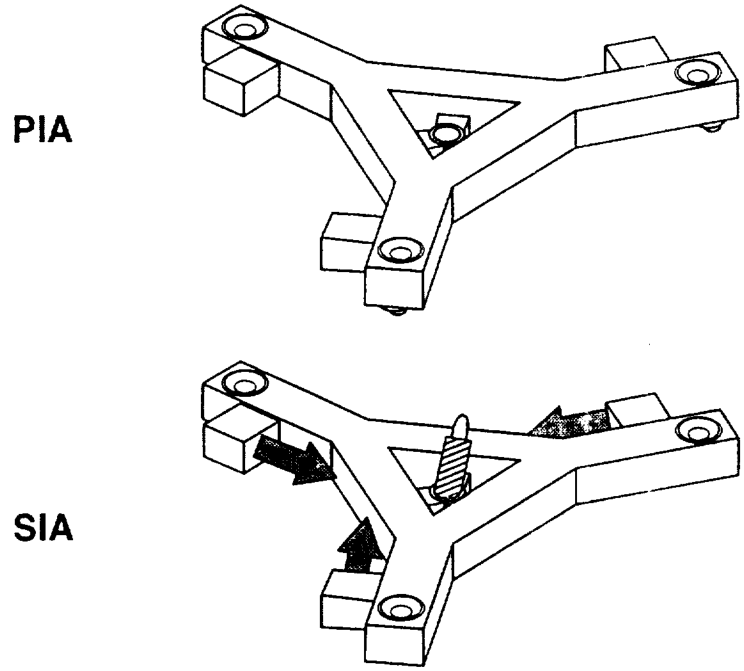
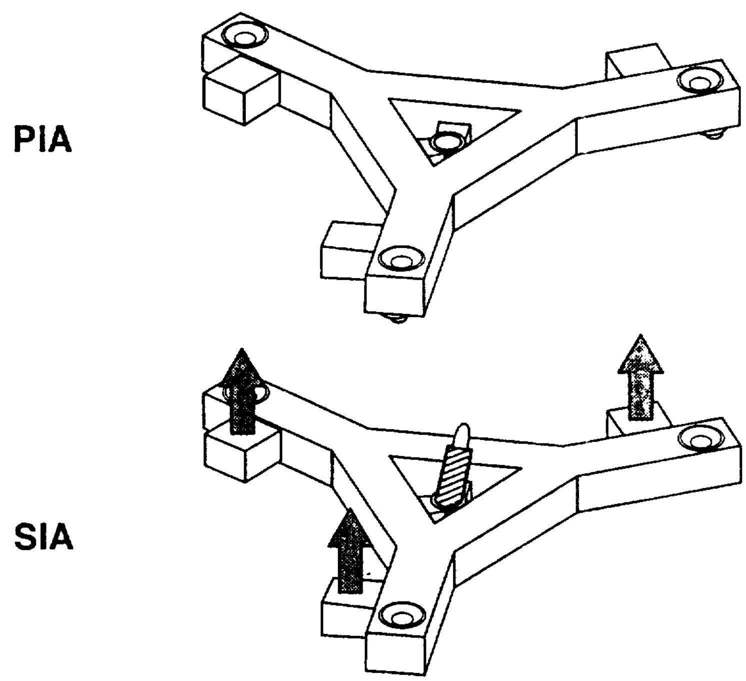
PIA/SIA INTERFACE

FIGURE 2

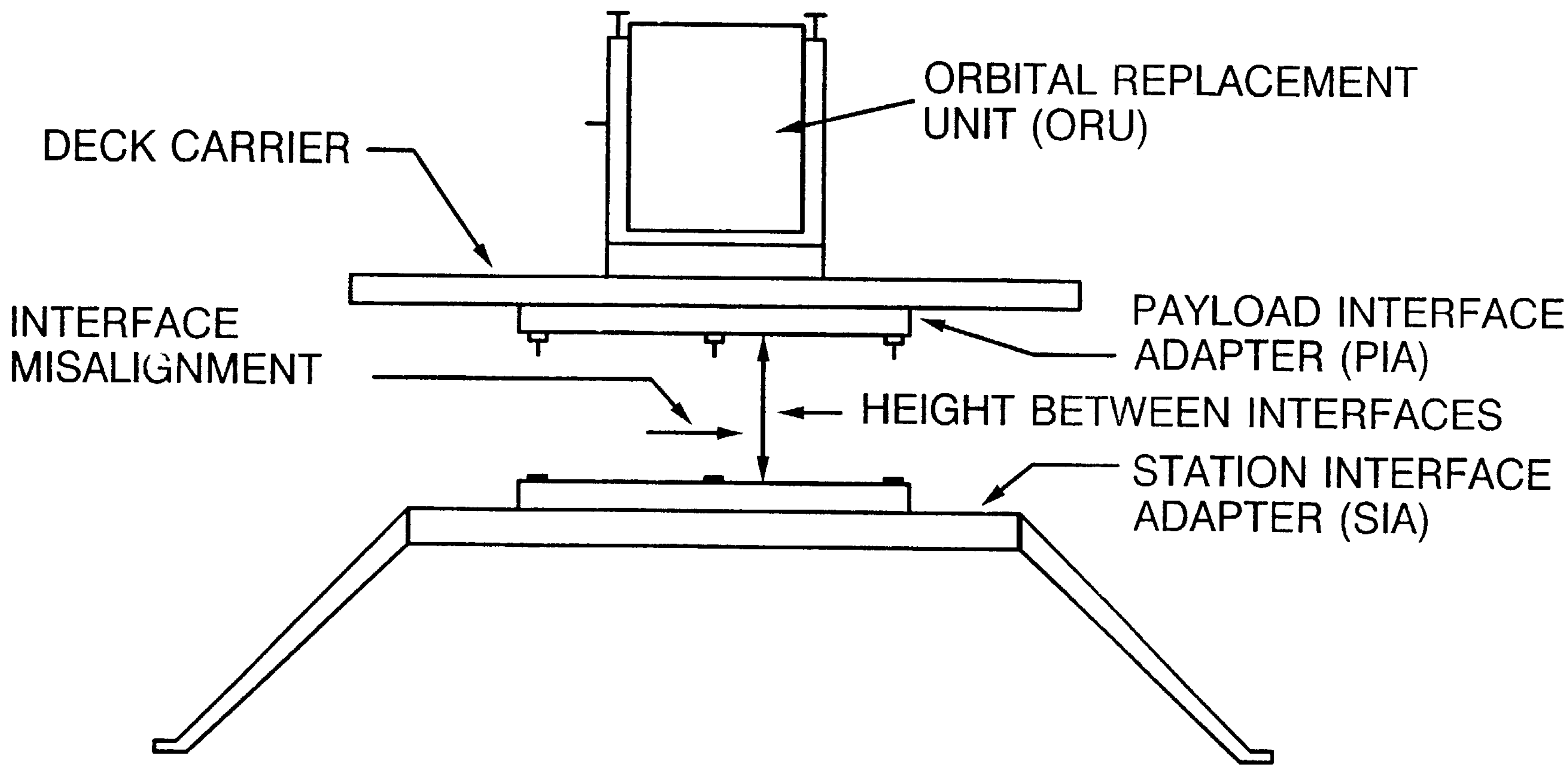


A365.008 CONNECTOR MATING PARALLEL TO PIA/SIA INTERFACE



A365.009 CONNECTOR MATING ORTHOGONAL TO PIA/SIA INTERFACE

FIGURE 3



MATING TRAJECTORY PLOT

FIGURE 4

A365.006

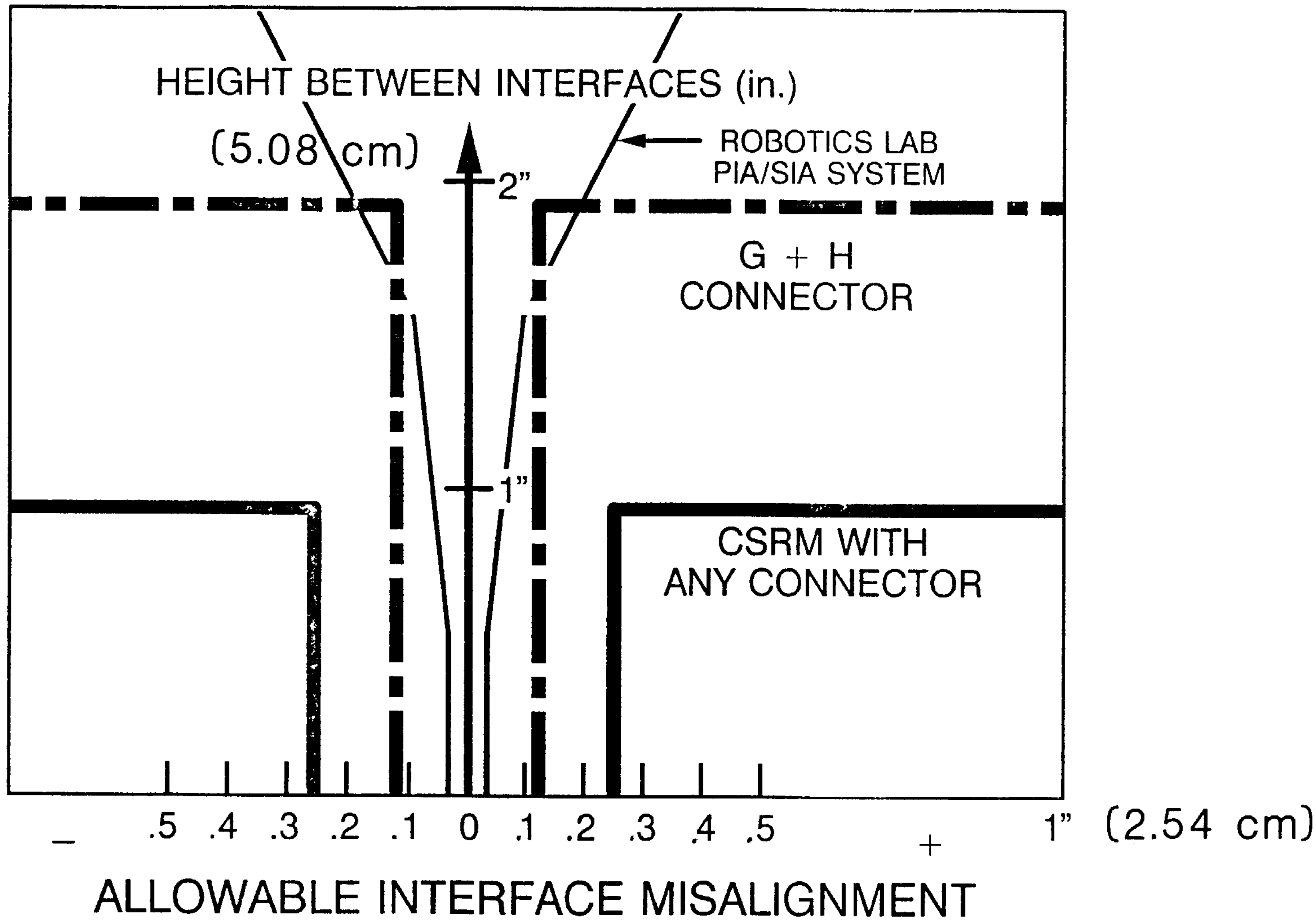


FIGURE 5

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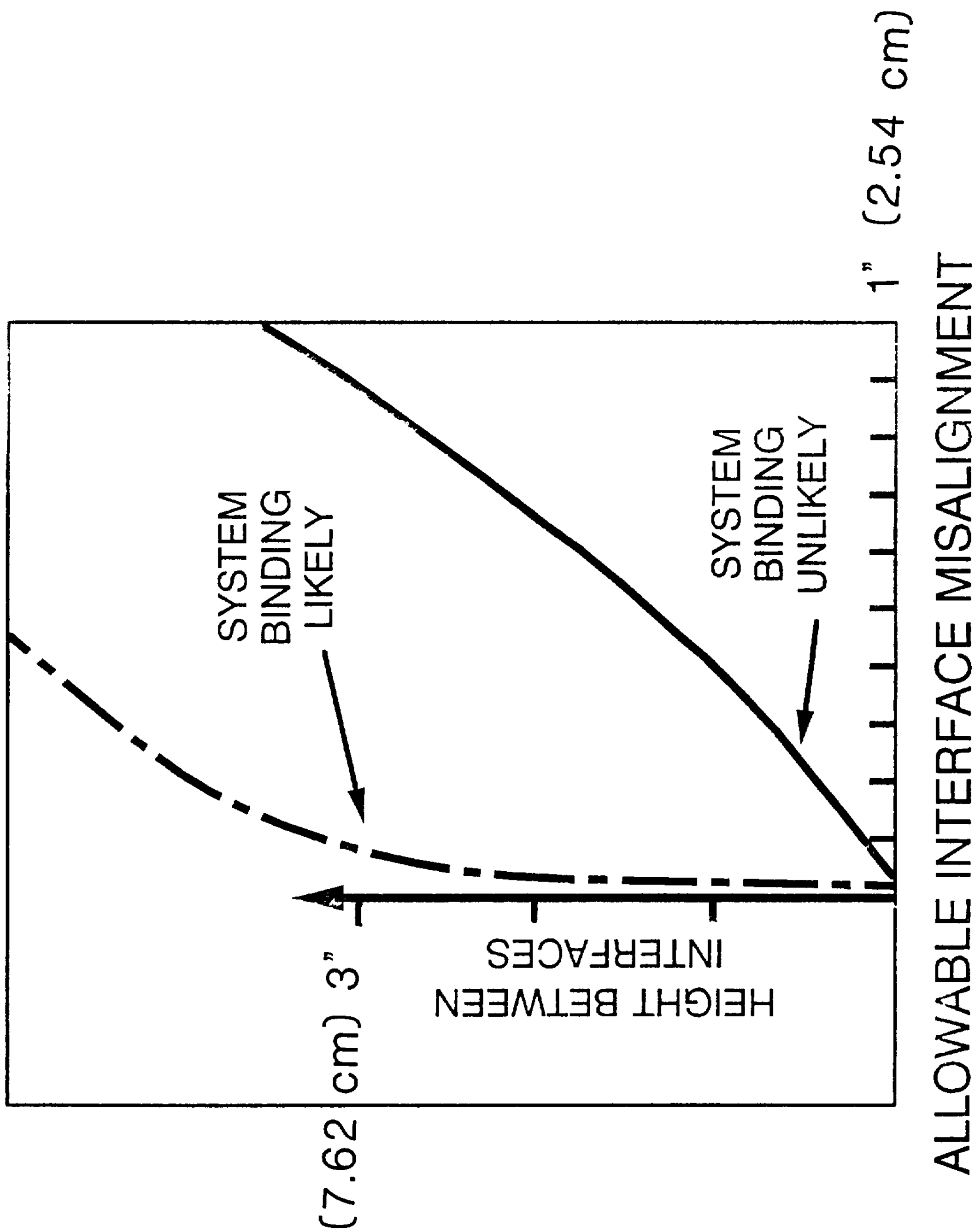
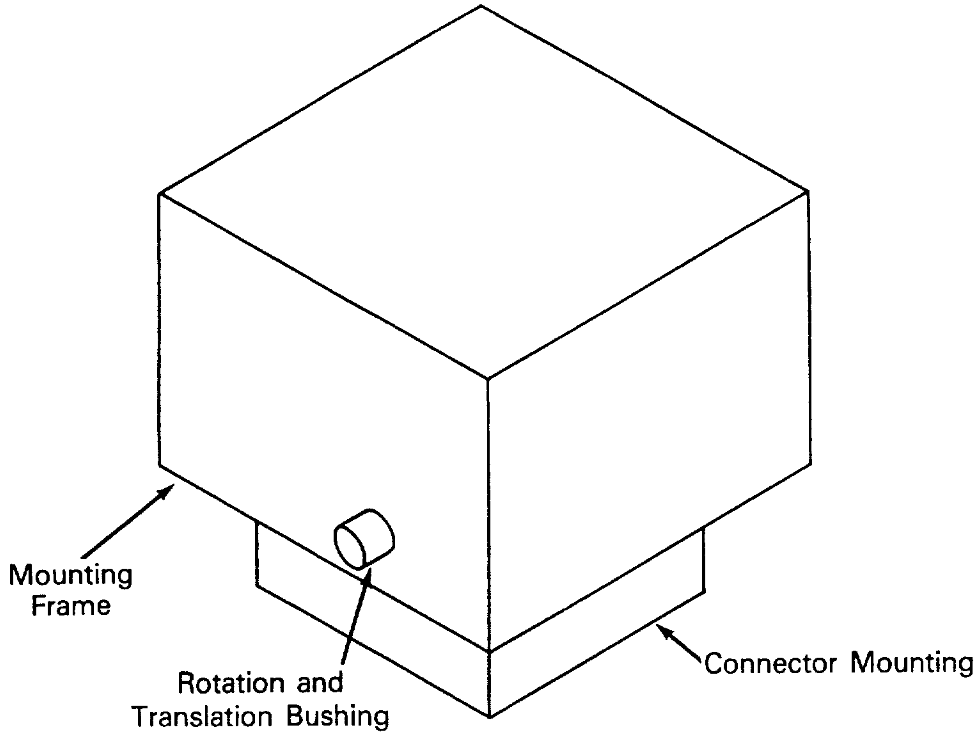
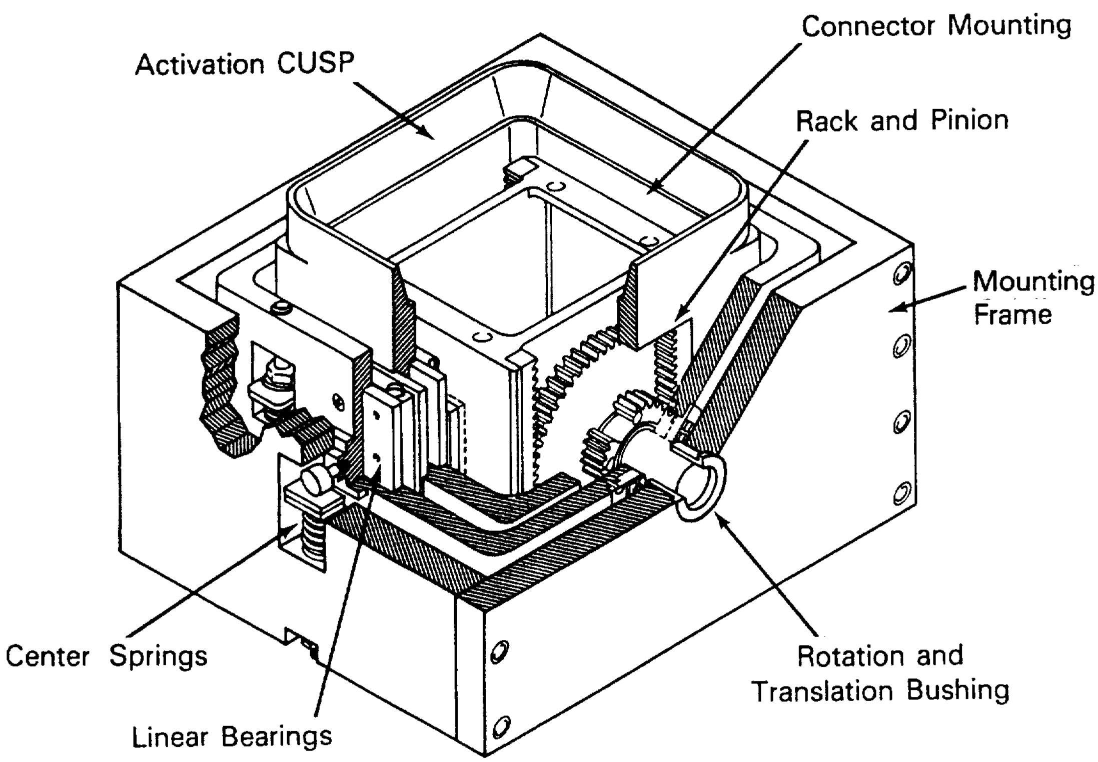


FIGURE 6

A365.001

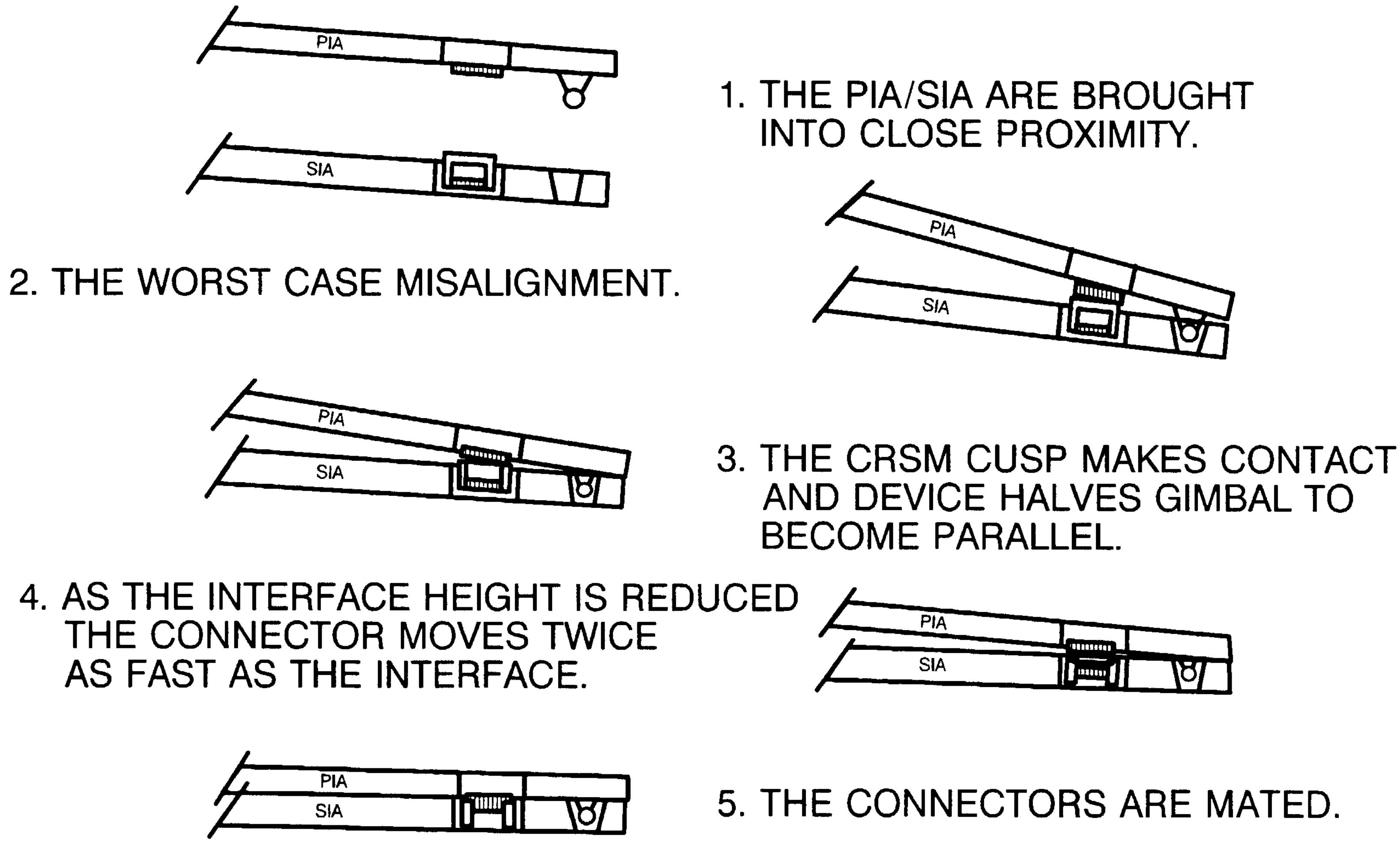


CSRM Passive Half



CSRM Active Half

FIGURE 7



CSRM SEQUENCE OF OPERATION

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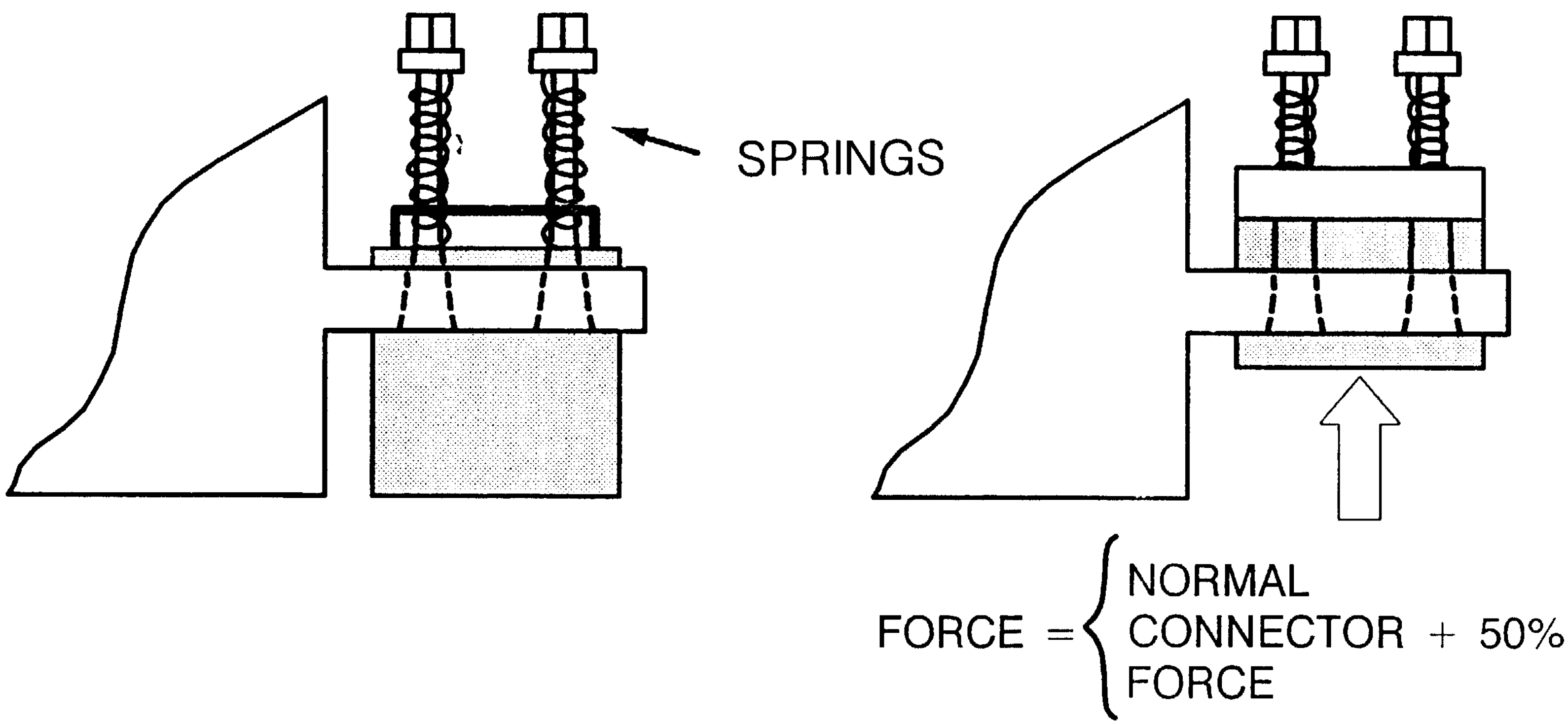
FIGURE 8



CONNECTOR MOUNTING

FIGURE 9

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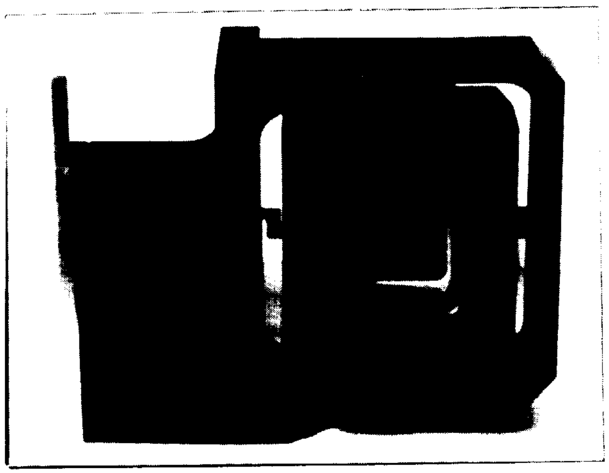
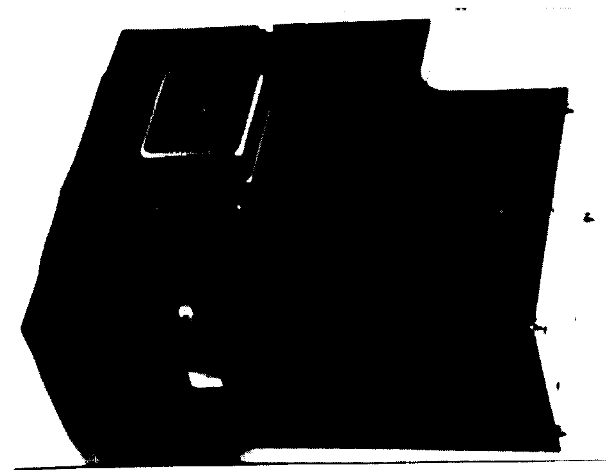


PAYLOAD HALF



STATION HALF

The CSRM is a NASA/GSFC exclusive design

FIGURE 10

CSRM HARDWARE

IMPROVED CSRM
"ONE TELESCOPING CYLINDER ELIMINATED"

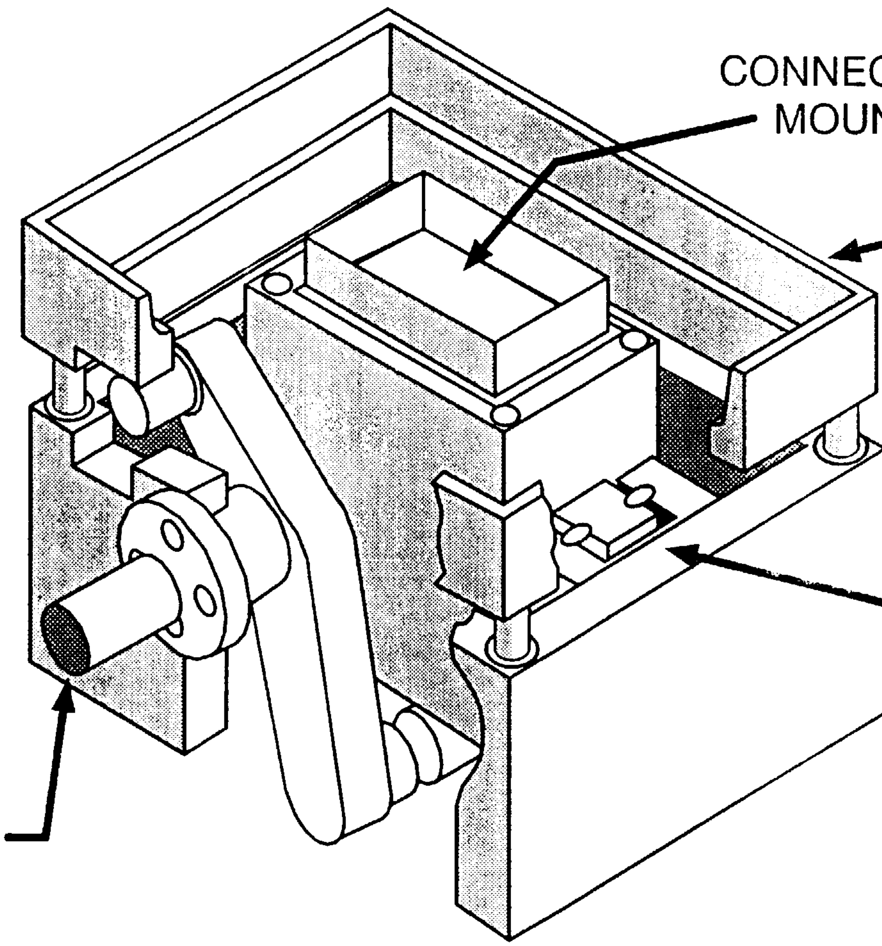


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FIGURE 11