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A MECHANICAL ADAPTER FOR INSTALLING MISSION EQUIPMENT ON LARGE SPACE STRUCTURES

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ABSTRACT

In the construction of large space systems, the installation of mission equipment and payloads on structural platforms poses a serious challenge to space construction operations. For such operations, attachment mechanisms are required that promote simple and quick mate and demate capabilities and provide a rigid connection during mission operations. While under contract to the National Aeronautics and Space Administration (NASA), Rockwell International has designed, constructed, and tested such a mechanical attachment adapter in NASA's Neutral Buoyancy Simulator (NBS) at Marshall Space Flight Center, Huntsville, Alabama. The adapter was included in a simulation program that investigated techniques for assembling erectable structures under simulated zero-g conditions by pressure-suited subjects in a simulated EVA mode. The adapter was utilized as an interface attachment between a simulated equipment module (SEM) and one node point of a tetrahedral structural cell. The mating performance of the adapter, a self-energized mechanism, was easily and quickly demonstrated and required little effort on the part of the test subjects.

INTRODUCTION

In the study of large space systems, initial emphasis has been placed on beams and joining concepts for various structural configurations. Since equipment installations are considered basic and routine operations even on the earliest of missions utilizing large space structures, interface concepts must be generated to promote "easy" mate and demate capabilities with positive verification in the orbital environment.

An operational concept for installing mission equipment on a large space platform was investigated by Rockwell International during a study of Erectable Large Space Systems for Langley Research Center. A subsequent effort by Rockwell while under contract to Langley Research Center and Marshall Space Flight Center concerned, among other objectives, the design of a self-energized mechanical adapter that could function as the interface between mission equipment and structure.

This paper discusses the fundamental requirements of such mechanical interfaces and presents two concepts considered during the study. One of the concepts underwent a proof-of-concept design, and a prototype unit was fabricated and tested. The design will be described, along with the test and its results.

FUNDAMENTAL REQUIREMENTS

The main function of the adapter is to provide a structurally sound interface between any two assemblies. For illustration, let us assume the assemblies of interest are a large space truss platform structure and mission equipment made up of individualized modules, as shown in figure 1. The adapter is the structural connection that couples each module to the platform. In that function, the adapter must be rigid and capable of supporting loads imposed on it throughout the life of the mission. These include impact loads during construction, orbit transfer loads, and operational loads caused by dynamic modules.

The adapter must also satisfy several important operational requirements and features. A simple and easy engagement mechanism on the adapter is essential to facilitate its attachment manually or remotely. The initial insertion must be forgiving in terms of alignment and orientation, but once engaged, the attachment must be rigid and provide a specific orientation (clocking) in all three axes. The adapter must also provide a positive indication of engagement, and a disengagement capability for contingency and maintenance operations.

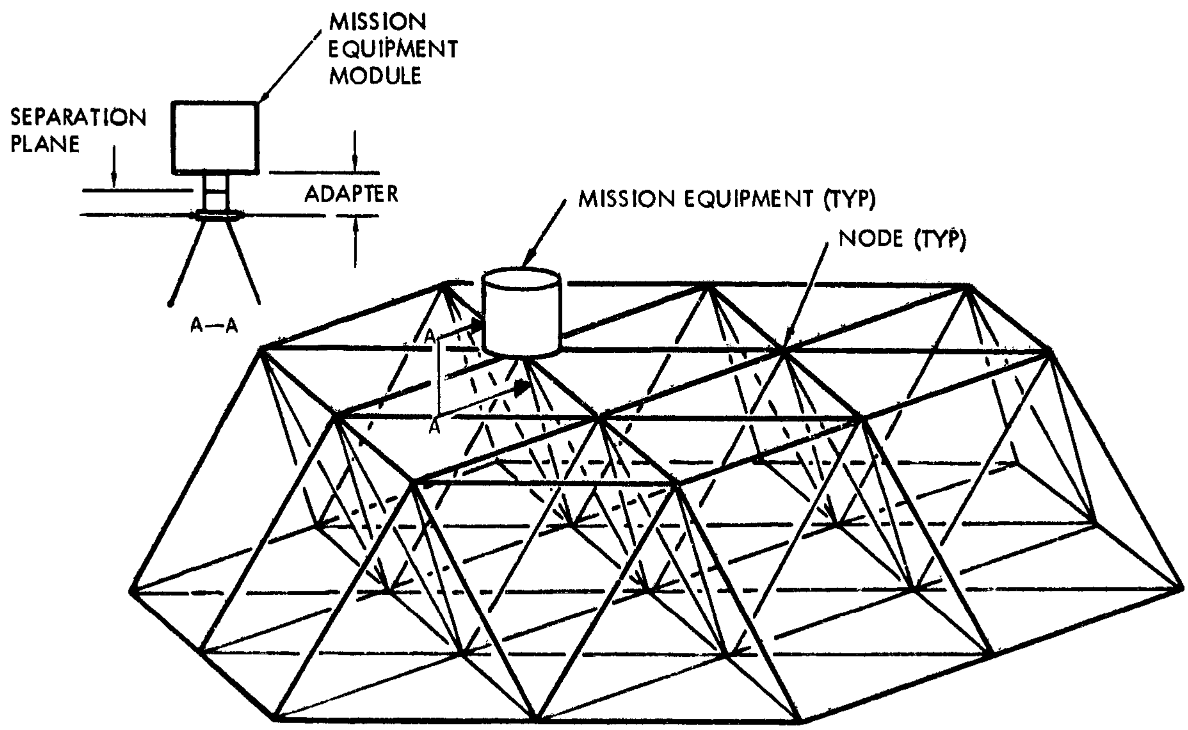

Figure 1. Representative Structure

DESIGN CONCEPTS

To satisfy the fundamental requirements, two adapter concepts were generated during the design of the test hardware. The concepts, a ball-socket adapter and a self-energized screw adapter, were subjectively evaluated, and the latter emerged as the best candidate for further detail design. Both concepts are described in this section, along with discussions of their operational features that had a bearing on the final selection. It should be emphasized that, although the following discussions and illustrations show the female half of the adapter as part of an erectable structure node union, its application is by no means limited to a node point or to the erectable structure.

Ball Socket Adapter

The first adapter concept to be considered for the test is based on a ball socket joint design developed for the joining of structural elements during space construction (reference 1). The main advantage of the ball socket joint was its operational ease which was verified during ground simulations involving both remote and EVA assembly techniques (references 2 and 3). The ball socket adapter, illustrated in figure 2, is essentially a probe drogue coupling where the probe is part of the module and the drogue is incorporated within the cavity of the node union.

The probe is engaged in a two-step latching procedure. First, as the module is positioned "over" the node union and slowly "lowered" into posi-

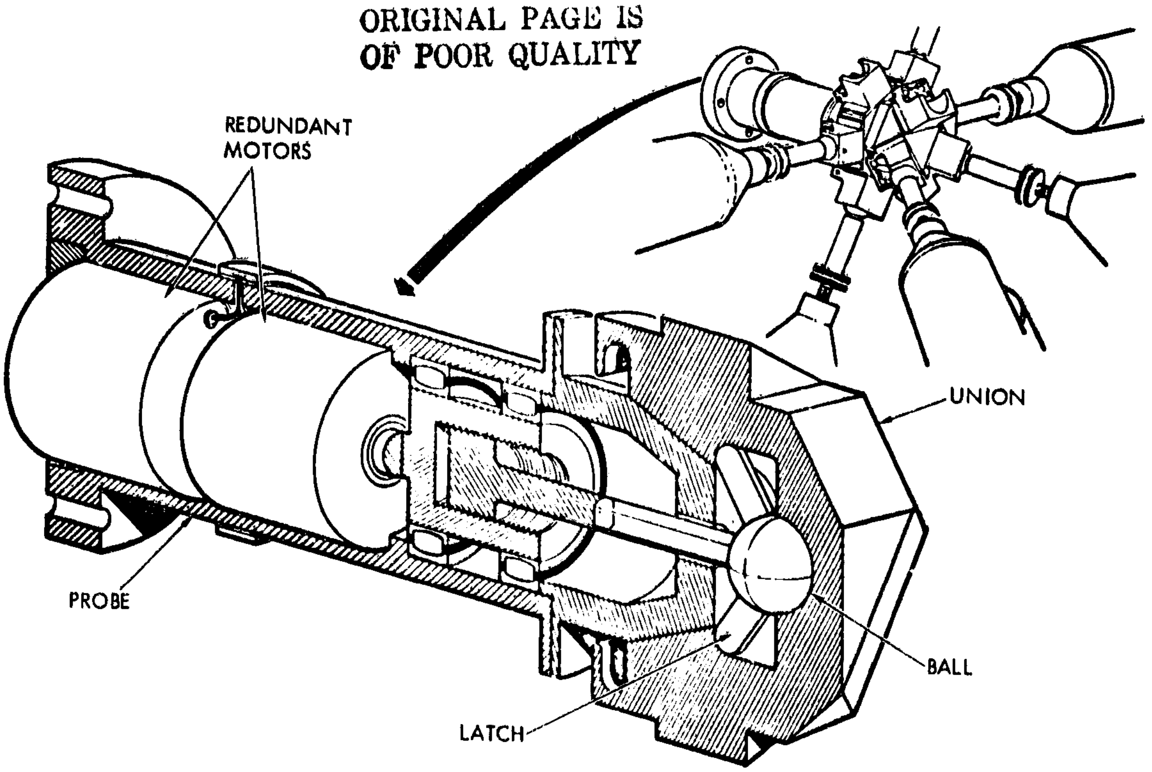

Figure 2. Ball Socket Adapter

tion, the ball end of the probe engages the drogue and its latches. In the second step, the drogue's redundant motors are activated to drive the tapered shell of the probe into the cavity of the union and effect a rigid interface. The motors could be torque-limited and reversible so that disengagement would be effected, if warranted. Power for the motors could be supplied by the manipulator or by EVA astronauts through hand tools, depending on which module installation method is employed.

The two-step engagement operation of the ball socket adapter is an advantage. However, it requires external power which is not easily supplied by either the manipulator or EVA astronauts. While disengagement of the tapered shell can be achieved, the ball disengagement is a more difficult task because of its inaccessibility.

Self-Energized Mechanical Adapter

This adapter is a self-energized coupling that promotes the quick attachment of relatively large modules on the surface of a large space platform. The active half of the coupling, which drives an Acme threaded screw, forms a part of the module. The other half incorporates a receiving nut into a structural union which represents a node point on the surface of a truss-configured space platform. As depicted in figure 3, the energy source for the adapter is a set

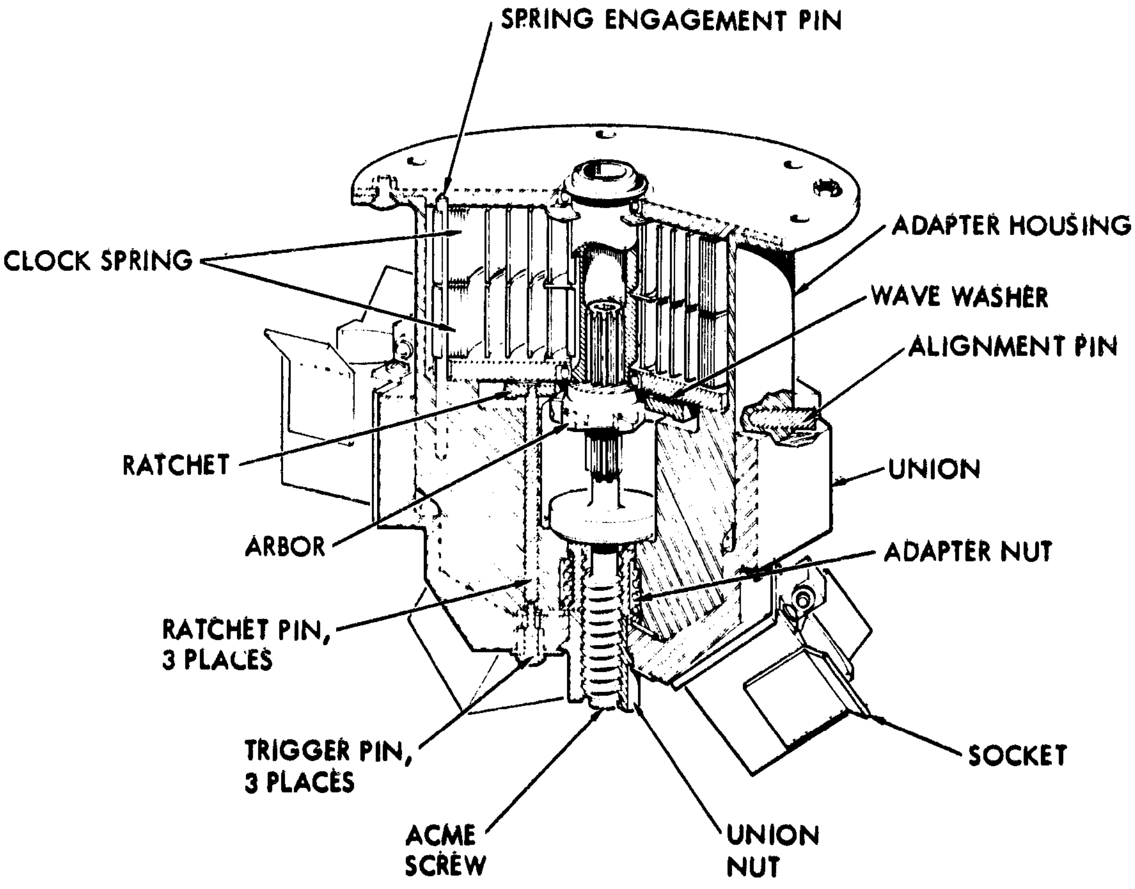

Figure 3. Self-Energized Adapter

of two clock springs that drive the Acme threaded screw into the receiving nut on the mating union. The screw is held in the energized position by a ratchet until triggered by the insertion of the adapter into its union and the application of a slight compressive force on it.

To disengage the adapter, a square-nosed speed wrench can be inserted into a socket at either end of the screw shaft to rewind the screw; this disengages the adapter and reenergizes it at the same time.

This concept fulfills most of the requirements that are expected in such a device. Therefore, it was selected for inclusion in the test. A detailed design and operational description of the adapter is presented in the next section.

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DESIGN AND OPERATION

The module half of the adapter is a probe that houses all the active components to energize and drive the probe into a rigid attachment with the structural platform. A photograph of the adapter probe and the module is shown in figure 4. The major active components of the probe are:

Figure 4. Simulated Equipment Module (SEM)

- Two clock springs which provide the energy for the adapter. The outside lips of both springs are anchored to a single engagement pin. Internally, both springs interface with a rotating arbor.

- An arbor that rotates freely on Teflon journals. Externally, it incorporates a groove for capturing the internal lips of the two clock springs. On one end, there are six teeth for engaging the ratchet. Internally, it contains a spline to couple with the screw shaft in torsion only. The screw shaft is free to slide axially.

- A ratchet that retains the arbor in the energized position until triggered. It accepts the arbor teeth and prevents the arbor from rotating in the clockwise direction only. Three pins are attached to the ratchet which protrude to the leading end of the adapter. The ratchet pins form a part of the trigger mechanism.

- An Acme screw which is partially engaged in an adapter nut. It features a central flange to control its travel by bearing against an adapter housing internal shoulder, and a splined end that couples, torsionally only, with the arbor spline.

The platform half of the adapter is a union that accepts the probe half. The union features a slot to accept the adapter housing alignment pin, three trigger pins that align with the ratchet pins and a captive floating nut to accept the screw when triggered.

Operationally, a module with an energized adapter attached is brought to the node point and "lowered" into it. As the adapter guide pin rides over the lip of the union, the module is rotated until the pin "drops" into its slot and, in the process, the trigger pins are aligned with the ratchet pins. A slight compressive force on the module causes the trigger pins to depress the ratchet pins which disengage the ratchet from the arbor. At that point, the stored energy in the clock springs is released by rotating the arbor and, in turn, the screw. Since the screw is already partially engaged in the adapter nut, it drives itself through to the captive union nut until the flange on the screw shaft seats itself inside the adapter. At that position, sufficient residual energy remains in the springs to assure a positive engagement at all times.

TEST METHOD

The mechanical adapter was tested in the Neutral Buoyancy Simulator (NBS) at Marshall Space Flight Center, Huntsville, Alabama, as a portion of the Large Space Systems Erectable Structures Assembly Simulations in which an entire truss cell was constructed under simulated zero-g conditions. As a final task of the construction, a simulated equipment module (SEM) was installed at the node of the truss cell. The SEM was attached by the self-energized mechanical adapter described herein. Two pressure-suited test subjects in a simulated EVA mode manipulated the SEM into position, oriented it, and inserted it to the point where installation was effected. The assembled test article is shown in figure 5.

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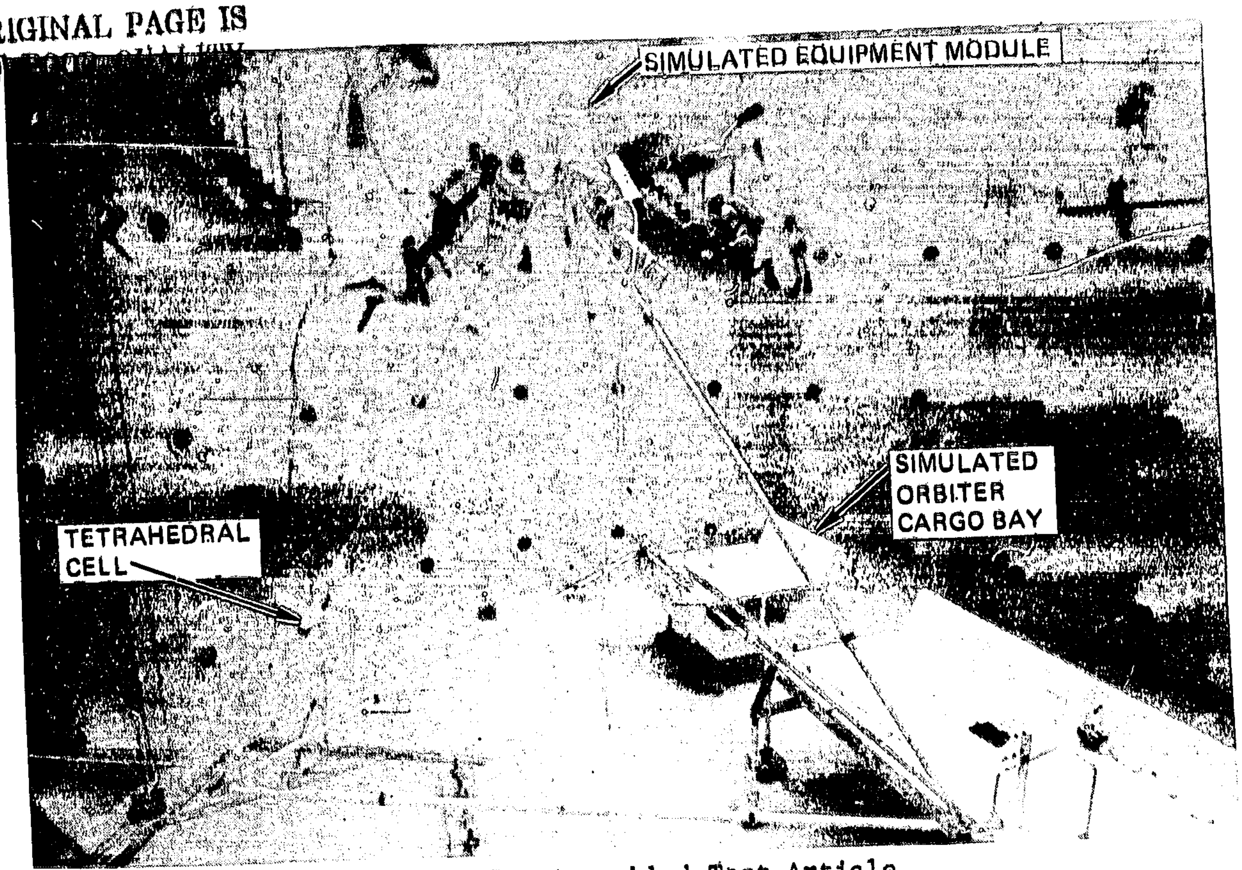

Figure 5. Assembled Test Article

RESULTS

In the initial series of tests, operational and design difficulties surfaced which resulted in unsatisfactory performance of the adapter. After modification, the adapter operated satisfactorily, and repeated tests showed that the attachment of equipment to a structural platform could be performed by EVA subjects in less than 35 seconds. The relatively easy attachment was rigid and permanent, and imposed no undue loads on the structure.

The first difficulty was encountered in attempting to orient and level the SEM relative to its mating union. In performing that task, the actions of the test subjects seem uncoordinated. Figure 6 illustrates the leveling difficulty, which was eliminated in subsequent tests by adding a work station adjacent to the node of the truss cell.

Once leveling was achieved, the test subjects were unable to trigger the adapter. When repeated attempts resulted in partial engagements at best, the adapter was modified to the configuration shown in figure 7. The major corrective actions included the following:

1. The interfacing surfaces of the union and the adapter were reconfigured to a conical shape to eliminate a suspected binding of the original stepped cylindrical surfaces.

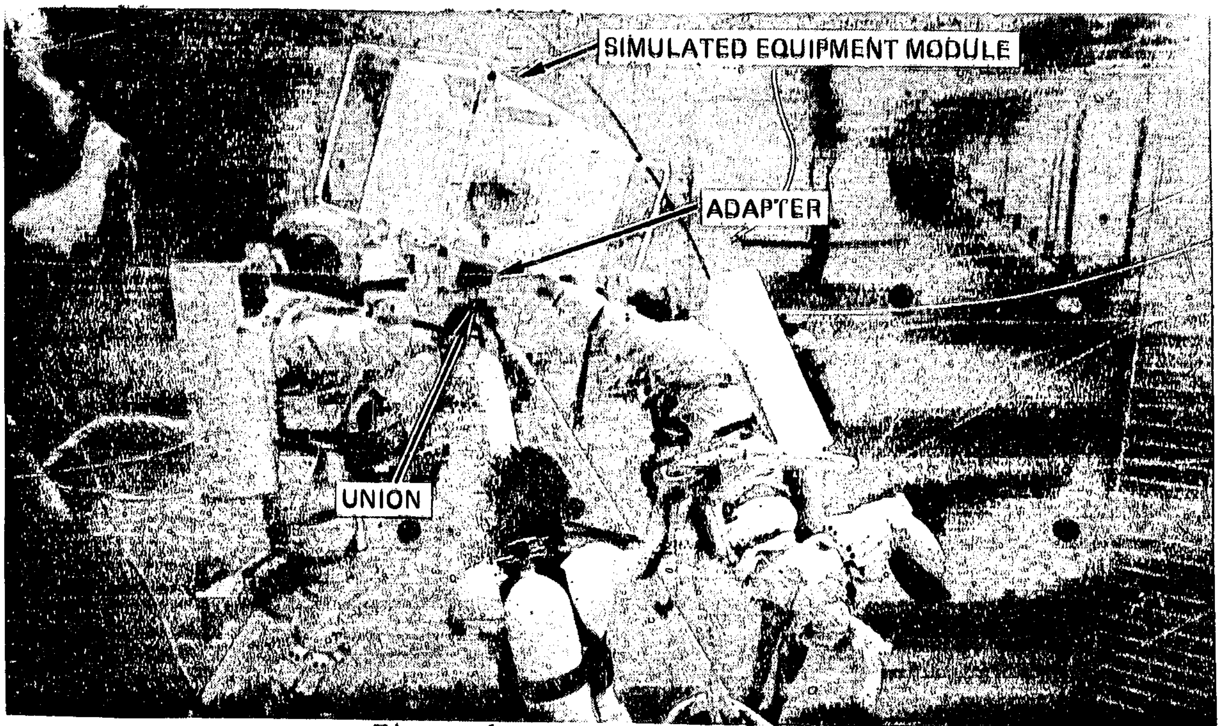

Figure 6. SEM Installation

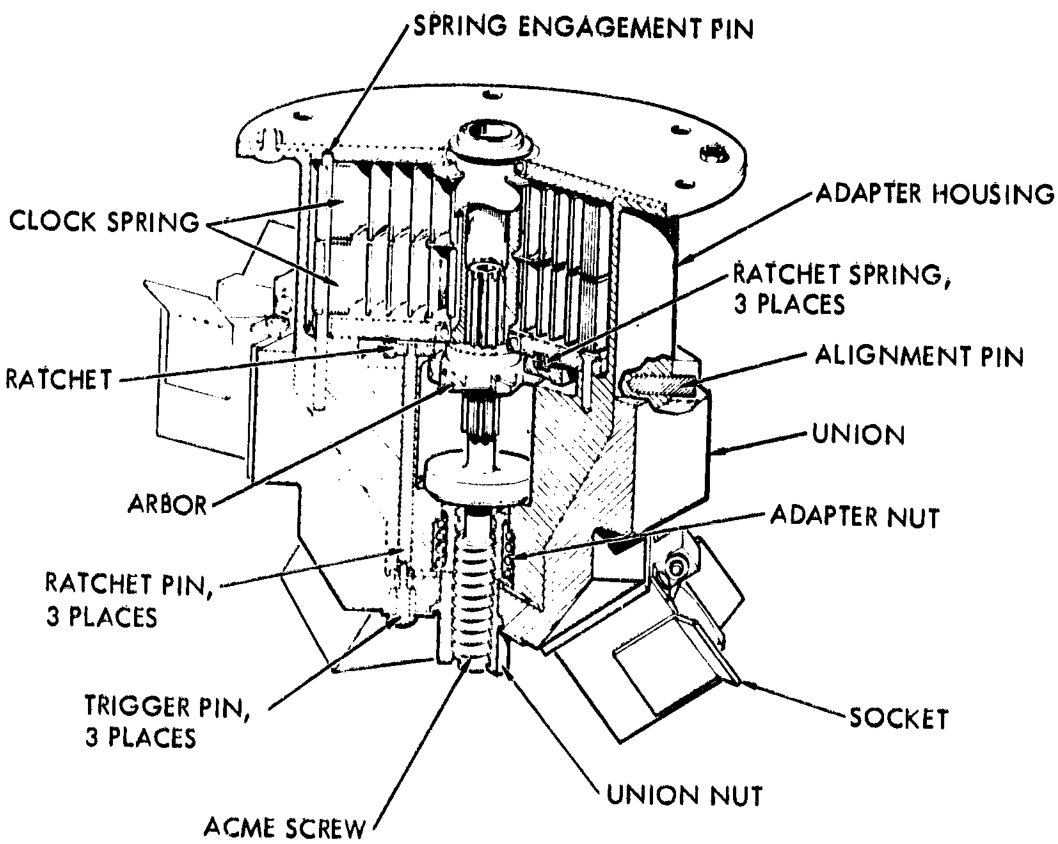

Figure 7. Modified Self-Energized Adapter

2. The captive receiving nut was slightly countersunk to accept misalignment of the screw, and shortened slightly to allow the screw to protrude through it for visual verification of engagement.

3. The ratchet wave washer was replaced by three softer compression springs to bring the triggering force from 178N (40 lb) down to 124N (11 lb).

After modification, another series of tests was conducted in which the module was satisfactorily and reliably attached with relative ease.

Disengagement of the adapter by EVA subjects was another objective of the tests. The task required one subject to insert a square nose speed wrench into a socket at the end of the screw and rewind it until the probe disengaged. The initial attempt indicated that the subjects were unable to reach the adapter from outside the cell, and consequently, could not disengage it.

CONCLUSIONS

The self-energized mechanical adapter is a feasible concept for the structural attachment of mission equipment or subsystems to a large platform. However, improvements in its disengagement features will be required before the adapter can be productively used.

Another important finding is that equipment to be operated in the foreign environment of space must be tested and refined under simulated space conditions to verify the equipment configuration.

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