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CONSTRUCTION CONCEPT FOR ERECTING AN OFFSET-FED ANTENNA

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Introduction

A number of future space missions are directed toward applications that involve the use of large offset-fed antennas (refs. 1-4). Antennas of this type are of interest because the configuration eliminates the effects of feed and feed support blockage. Although construction of the antenna is not covered in detail in the references, they suggest that the antenna structure would be deployed (unfolded from the packaged configuration) from a free flying satellite. Reference 1 identifies a number of technology needs including confidence in structural deployment that must be satisfied before these large antennas can be flown.

Alternative concepts for constructing large space structures are currently being investigated. In reference 5, a concept for erecting a space station using astronauts was developed and discussed. In reference 5 scenarios were also discussed which demonstrated how the erection concept proposed for the space station construction could be applied to assembling other large space structures including an application involving accurate surfaces such as a submillimeter astronomical observatory. The construction concept of reference 5 is based on the application of machine-assisted astronaut assembly. The machine which is identified as an assembly and transport vehicle (ATV) is a platform that moves along standoffs attached to the joints of a truss structure. The ATV is capable of translating in orthogonal directions over the surface of the assembled structure.

The purpose of the current report is to expand the range of application of the ATV concept by demonstrating how it can be used to construct an offset-fed antenna. This construction concept would eliminate the potential problems associated with confidence in deployment (see ref. 6) such as deployment dynamics, surface management, and joint lockup. A conceptual scenario showing the assembly of a generic offset-fed antenna with the aid of the ATV is described and discussed. Assembly is based on state-of-the-art type hardware with the exception of the ATV which is conceptually a simple low risk mobile platform that can be evaluated independently of this application.

Figure 1

Artist Sketch of A Large Offset-Fed Antenna

An artist sketch from reference 1 of a large offset-fed antenna which could be used for monitoring Earth's geophysical parameters is shown in figure 1. The antenna described in reference 1 is a typical configuration and considerable analysis has been performed to develop the preliminary design. A number of the structural and geometric design features taken from the reference are described below.

This antenna has a spherically/parabolically contoured mesh reflective surface which is attached to a truss substructure. The surface is spherical in the long dimension and parabolic in the short dimension. The reflective surface is a tricot-knitted monofilament wire material that is radio frequency reflective. The mesh is attached to the substructure by standoff members which are columns attached to the nodes (joints). A scheme proposed to deploy the truss substructure is shown in the next figure.

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ARTIST SKETCH OF A LARGE OFFSET FED ANTENNA

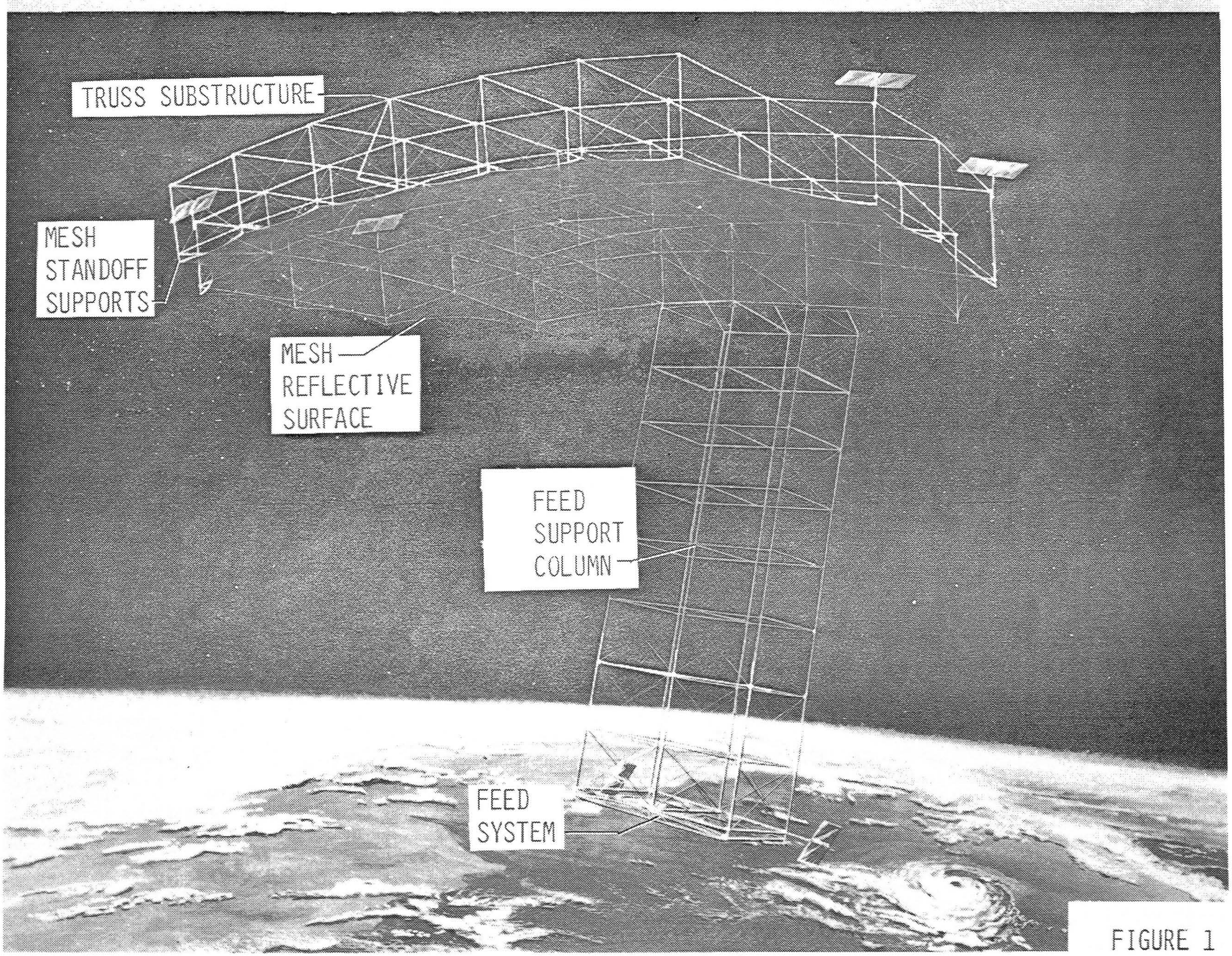

FIGURE 1

Figure 2

Deployable Concept for Offset-Fed Antenna

A concept for deploying an offset-fed antenna as a free flying satellite has been developed and is discussed in reference 4. Several sketches from reference 4 are shown in figure 2. The substructure is a deployable frame that unfolds in a sequential manner as depicted to form the general contour of the surface. The mesh surface is attached to, and deployed with, the substructure to form the desired surface. The shape of each section is controlled by the length of diagonal tension members. The peripheral members of most sections are of equal length which provides a very desirable commonality of parts. However, to achieve the proper contour, the diagonal members are each of different length and must be set individually. Attached to each column is a number of cables which tension the mesh and draw it to the desired contour (ref. 1). This cable system is relatively complex and each cable must be individually preadjusted to form the desired surface contour. The accuracy of the contour required for antenna operation is discussed in reference 1. The reference indicates that a typical Earth observation application will require an rms accuracy of 0.051 cm. For a structure that is fabricated and assembled on Earth, packaged for launch into space where it is deployed for long term (up to 10 years) autonomous operation, these design features and contour accuracy requirements provide a challenging assignment. An alternative approach using the assembly and transport vehicle (ATV) is outlined in subsequent figures.

DEPLOYABLE CONCEPT FOR OFFSET-FED ANTENNA

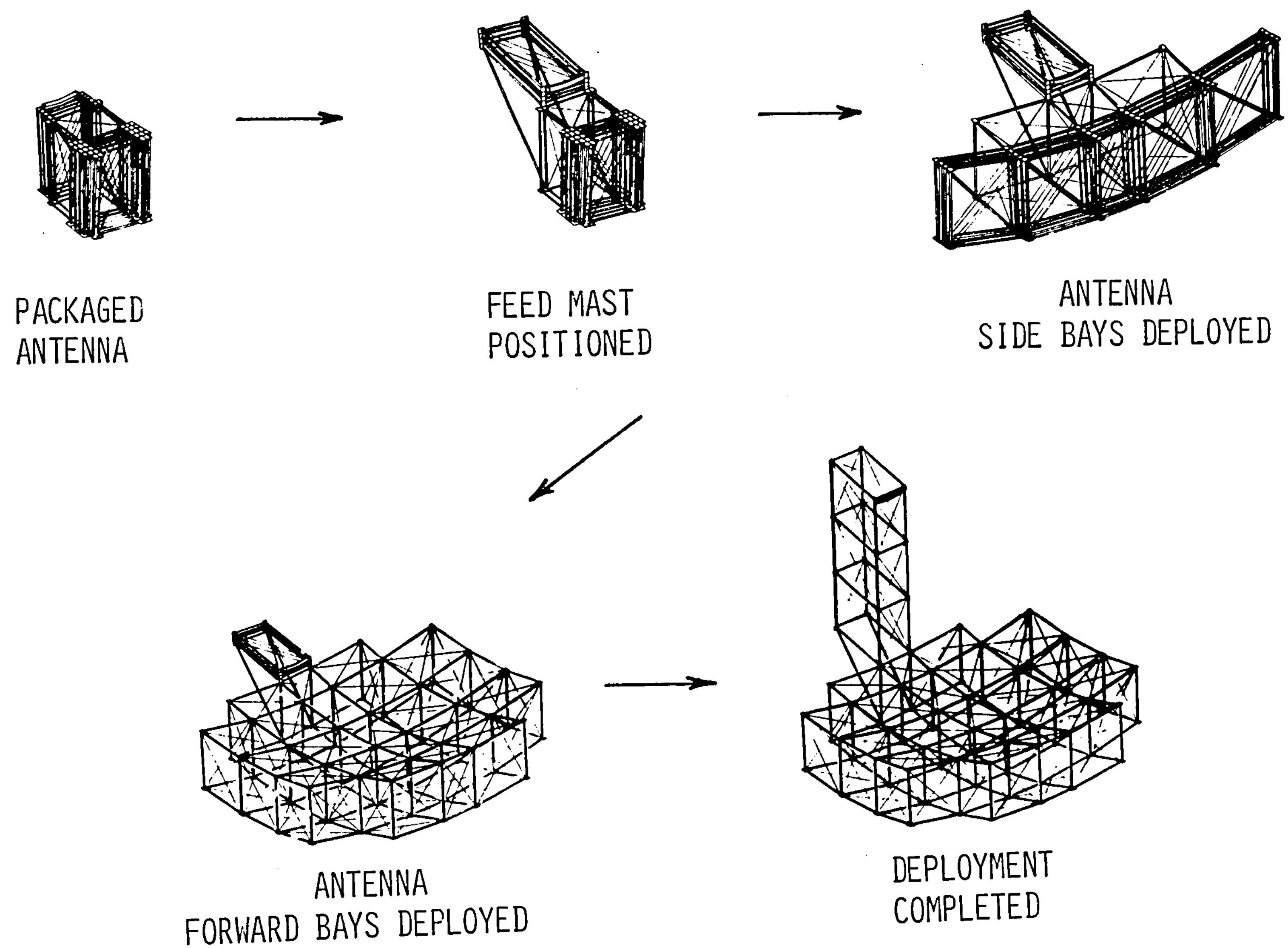

FIGURE 2

Figure 3

Assembly and Transport Vehicle

The Assembly and Transport Vehicle (ATV) is a major component of a manned-machine construction concept presented in reference 5 and is shown schematically in figure 3. The ATV is a movable work and assembly platform powered by a drive mechanism which operates in a reciprocating manner to push the platform along the truss one bay (strut length) at a time. The platform spans one bay of width and two bays along the length of the square truss grid and is supported by pegs located at each joint as shown in the figure. The same pegs on adjacent nodes serve as reaction points when the pin latch connector located on the end of the drive rail is attached to them. As the drive mechanism is moved, the platform is pushed along the truss structure. The platform is designed to pivot around a center support point and by using a rotating switch in each guide rail can move orthogonally along a two dimensional grid system. Pressure suited astronauts attached to a small mobile platform by foot restraints are postioned by special devices within their work envelope. The astronauts assemble tubular struts with snap lock joints, similar to those described in reference 7, using the guide rails as an assembly fixture. The platform may also have a "space crane" attached for positioning payloads. The surface of the platform would be used to transport construction material along the structure. The ATV system is conceived as an assemblage of conventional state-of-the-art space rated components such as redundant drive electric motors, a rack and pinion drive system, and simple solenoid actuated clamping and positioning devices.

ASSEMBLY AND TRANSPORT VEHICLE

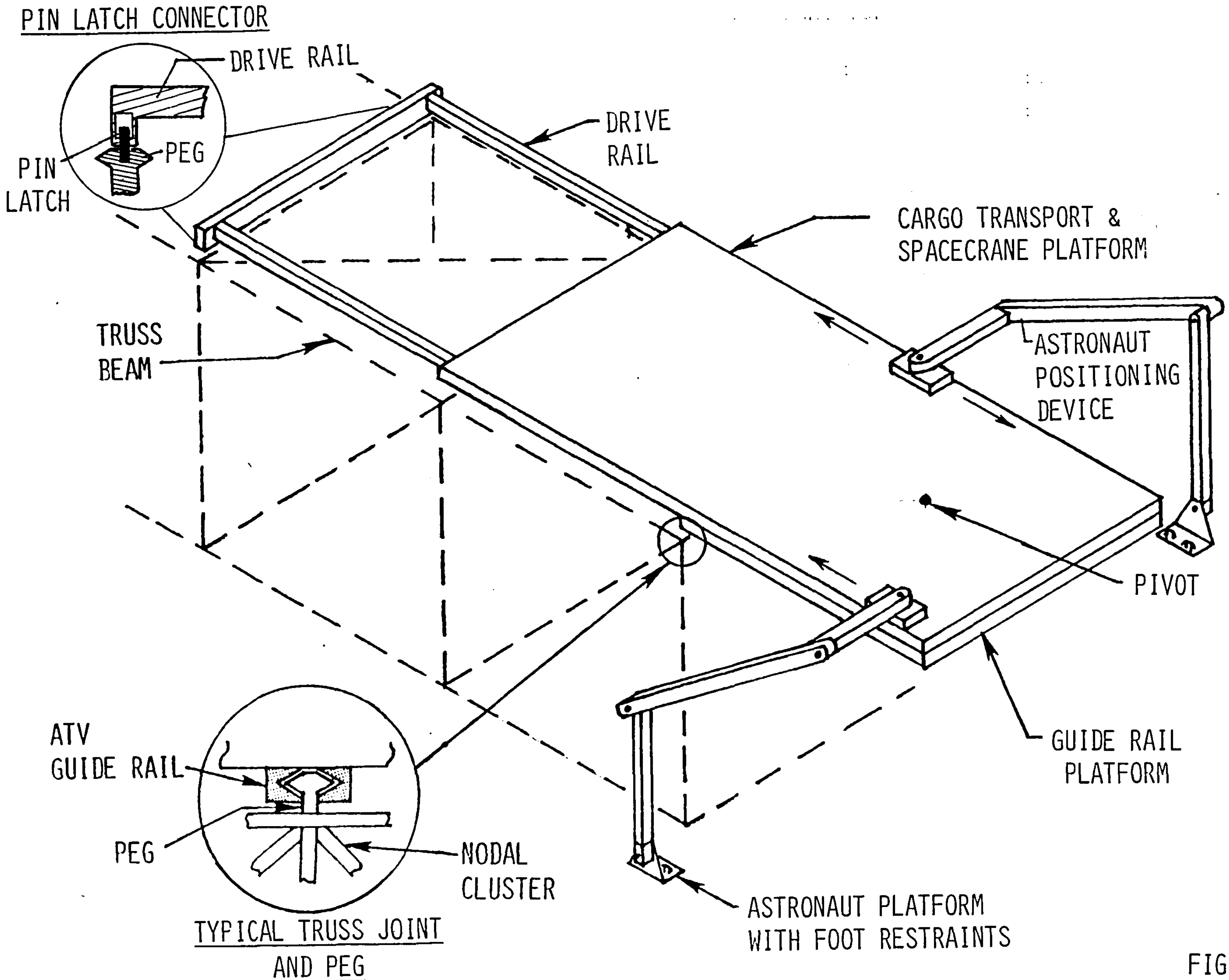

FIGURE 3

Figure 4

Support Column Assembly From Shuttle Cargo Bay

The construction concept for erecting an offset-fed antenna using the ATV is shown in figure 4 and the several subsequent figures. The ATV is berthed to a cargo bay pallet, and the antenna components are packaged in the cargo bay during launch. In orbit, astronauts in pressure suits attached to the ATV by foot restraints, initiate the assembly of the structure. Figure 4 shows assembly of a construction support column with one end fixed to the pallet. The function of the support column is to keep the assembled structure attached to the cargo bay during construction. The support column would also permit all antenna assembly operations to be performed away from the orbiter and not interfere with the cargo bay doors or other orbiter components and systems. The support column is assembled from members that are of uniform size. All members are of only two different lengths. The length of each member can be accurately set prior to launch and does not require adjustment during assembly. The longitudinal and batten members are all of one length and the diagonal members are all of the second length. All joints in each bay are alike.

As a bay is completed, the ATV is advanced to start assembly of the next. Although not shown it is assumed that all the structural members and joint would be transported in supply containers on the platform well within the envelope of the astronaut positioning device.

SUPPORT COLUMN ASSEMBLY FROM SHUTTLE CARGO BAY

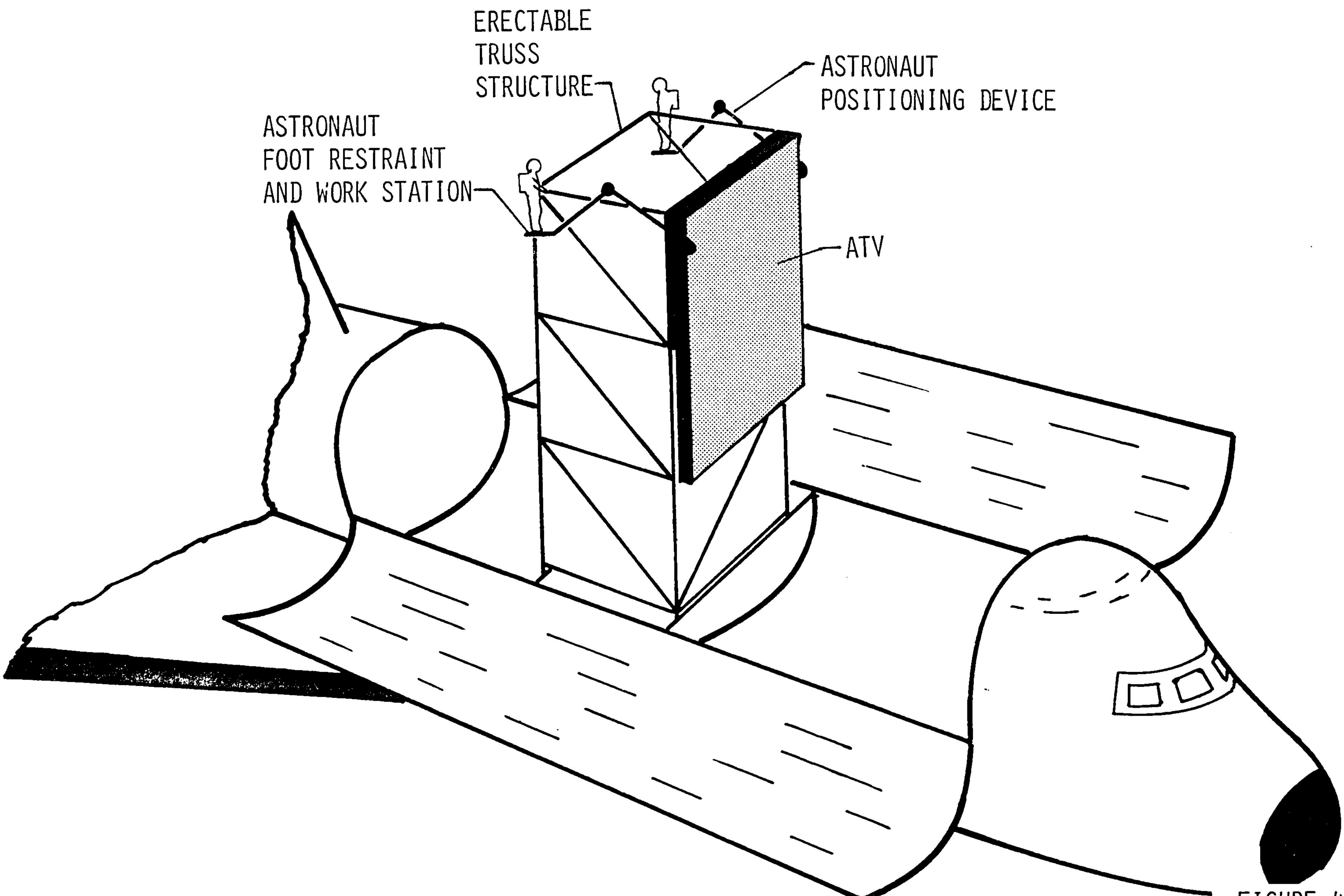

FIGURE 4

Figure 5

Reflector Substructure Assembly

The reflector substructure nearing completion is illustrated in figure 5 with only one corner of the antenna platform remaining to be assembled. For this concept, the support column and reflector substructure are assembled from similar components. The 25 bay reflector substructure shown represents a 20 meter by 20 meter platform. The total assembly including the support column has approximately 330 members of which approximately 60 percent are for the side and batten members and the remaining longer members are diagonals. Eighty-eight identical nodal cluster joints would be required with four additional pivot joints (to be discussed later) at the reflector-support column intersection.

It is anticipated that the completed antenna would be a free flying satellite and may be transferred to a different orbit than the one in which it was assembled. Therefore, small jets and control system components would also be installed during the substructure assembly. These components would use snap-lock connections and be attached to the nodes using the same (or similar) design and operation as those proposed for the structural members (e.g., see ref. 7).

REFLECTOR SUBSTRUCTURE ASSEMBLY

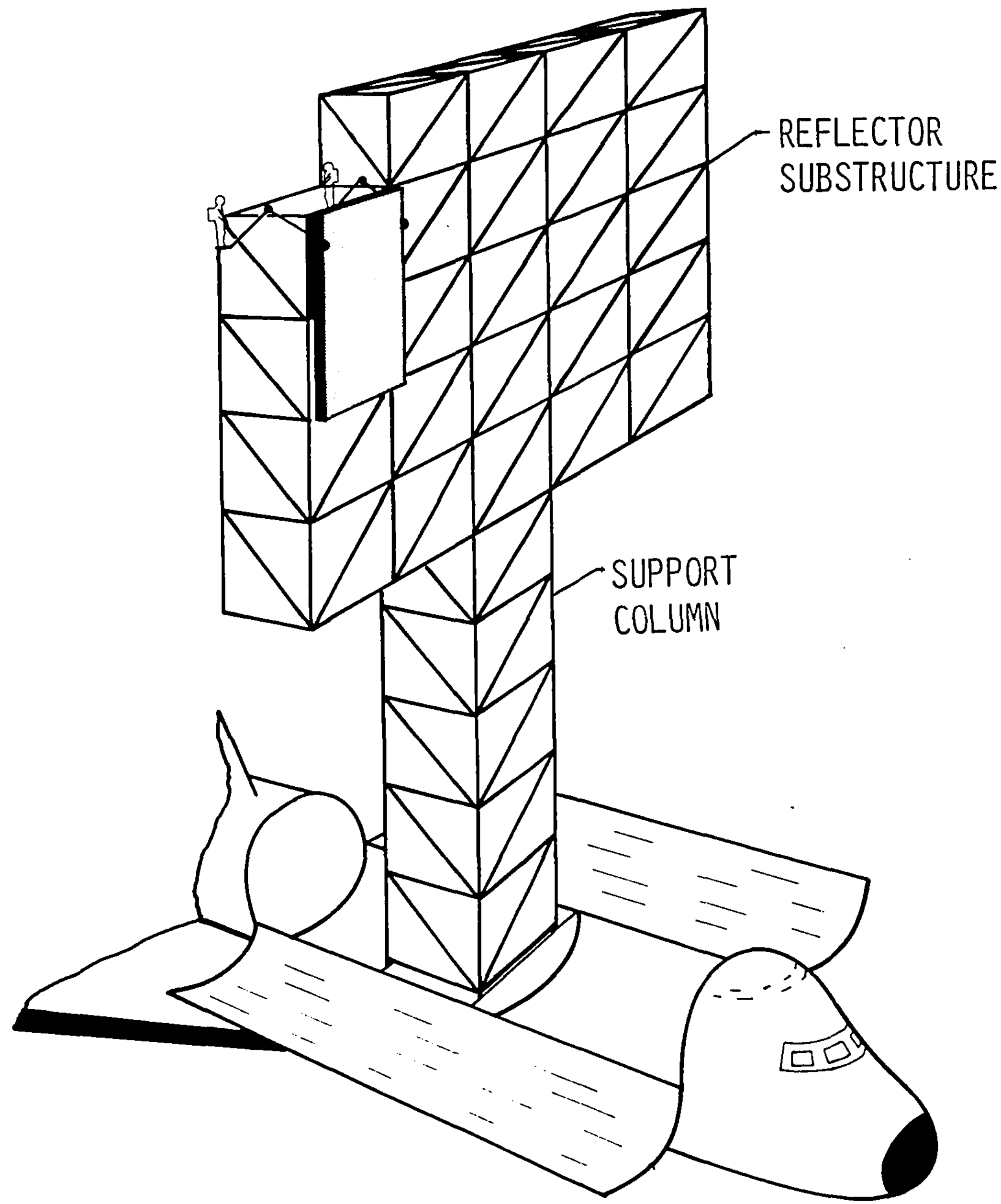

FIGURE 5

Figure 6

Installation of Antenna Reflector Panels

Upon completion of the antenna substructure assembly, the astronauts would install short structural members denoted as standoffs at each face node. The length of the standoff would be predetermined and a special length would be required for each node. If the length of the standoff member is on the order of the length of the substructural members, additional diagonal ties between standoffs would probably be desirable. However, since the substructure is a stiff platform to which the antenna reflective structure is attached, a diagonal at each standoff member would probably not be required.

As the standoff members are installed on each bay, the antenna mesh reflective surface would be mounted to them. The method of mesh attachment and support has not been defined but it could be accomplished in a number of ways. One way may involve the stretching of the mesh between stiff bay perimeter members. A number of studies have been conducted to define the surface contour accuracy of stretched membranes and mesh materials and some results are reported in references 4 and 8-10. An additional concept is to attach the mesh directly to a stiff panel that has been preformed to the desired parabolic contour. Such panels may involve the use of a light-weight composite lattice structure as defined in reference 11. The reflective surface would be installed on the truss bays on both sides of the center section before installation of the center section. This will permit the ATV to return to the cargo bay via the support column. Installation of the reflector mesh panels would complete the assembly of the reflective surface for this antenna.

INSTALLATION OF ANTENNA REFLECTOR PANELS

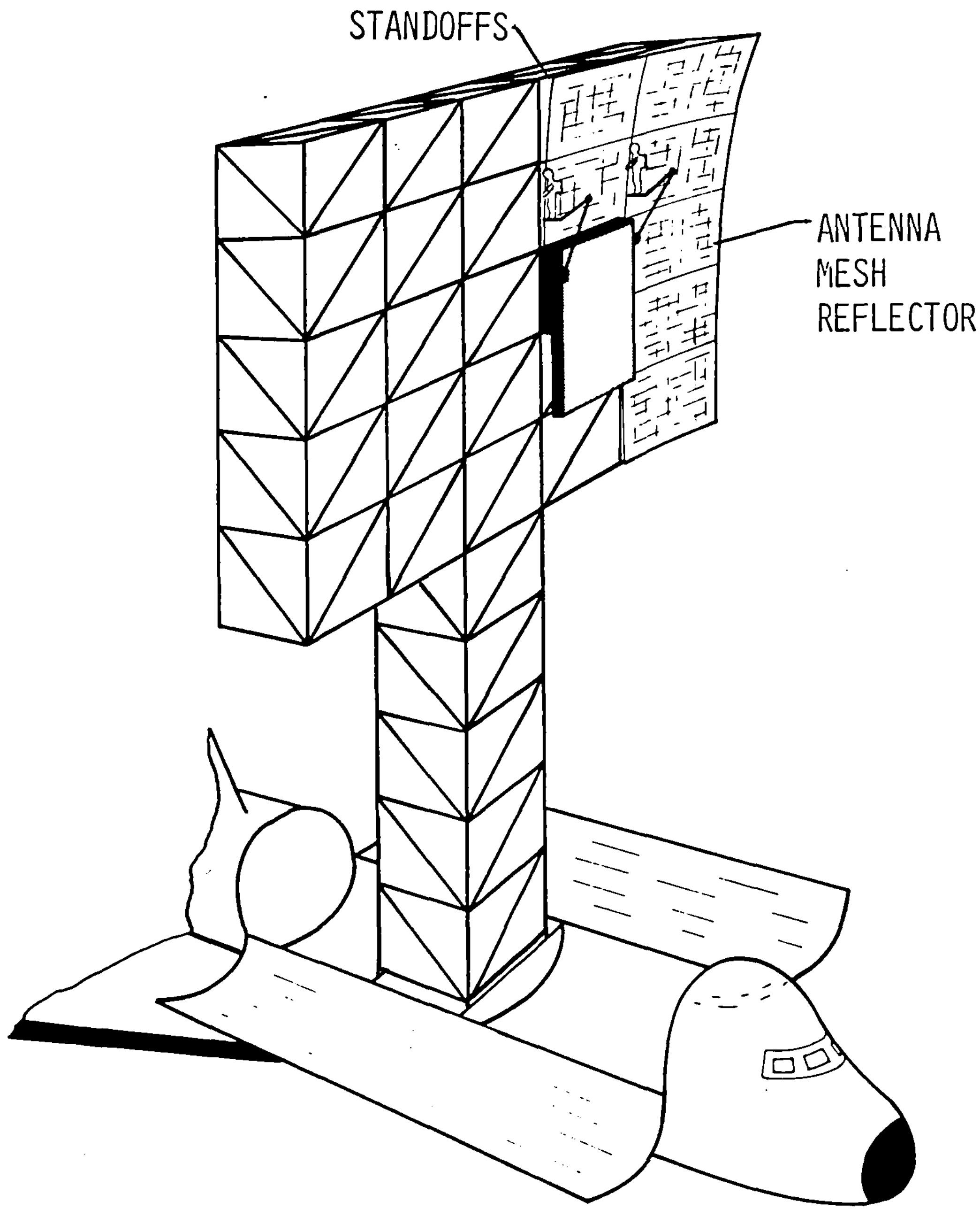

FIGURE 6

Figure 7

Rotation of Reflector into Operating Position

Upon completion of the antenna reflective surface a feed support mast that lies approximately 90^{o} to the plane of the reflector substructure must be assembled to complete the antenna structure. The support column can be made to serve this function by rotating the completed antenna platform about the special pivot joint (mentioned in the figure 5 narrative) at the support column/reflector interface. The ATV is positioned at the top of the support column upon completion of the installation of the reflector mesh. Therefore, the rotation could be accomplished using the proposed space crane mounted on the ATV or by a activation device in the structural assembly. The astronauts can then remove and/or install the required additional members as noted by the insert in figure 7 as they return along the support column. The incorporation of the construction support column into a feed mast support means that no structure other than that required for the antenna mission is necessary and little, if any, would have to be disassembled upon completion of the antenna.

ROTATION OF REFLECTOR INTO OPERATING POSITION

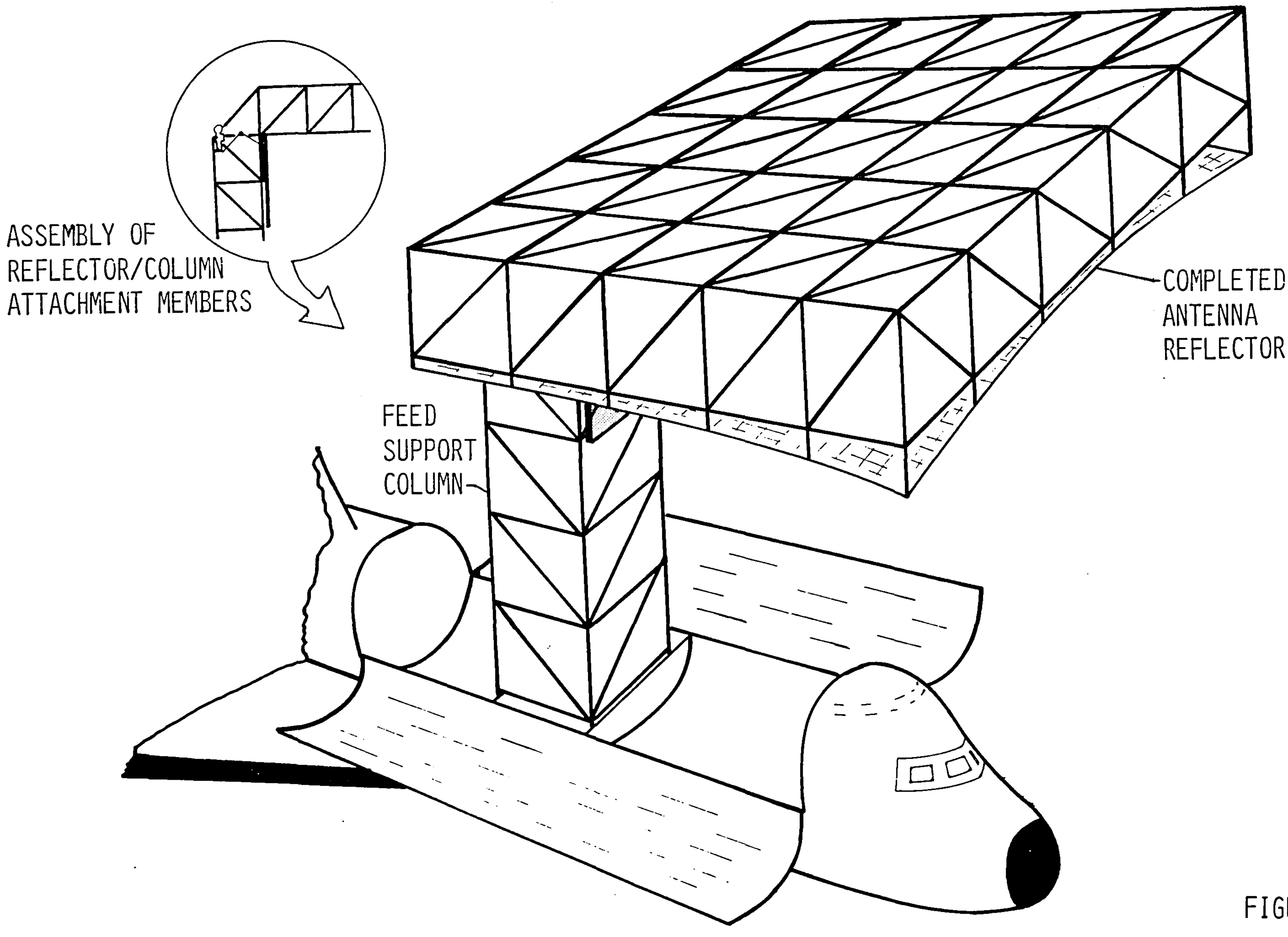

FIGURE 7

Figure 8

Completed Offset-Fed Antenna

After positioning and locking the feed support column to the antenna platform substructure the astronauts attach the antenna feed system. Also, the astronauts would install any support systems such as solar array panels or transmission antennas that may be attached to the feed support column. Although the support systems are shown attached to the column in figure 8 they could be attached to the sides or back of the platform substructure prior to installation of the reflective mesh. When all systems are installed and integrated they can be checked and the completed antenna operationally evaluated before being released from the shuttle as shown in the figure. The figure also indicates that the ATV is resecured in the cargo bay for return with the shuttle and it would thereby be available for use in other construction projects. Also, many large spacecraft including antenna and observatories will require refurbishment after a number of years of orbital operation. The ATV would be available and would be a natural part of any refurbishment activity.

The time required to assemble and checkout any large antenna system using the construction technique proposed herein depends upon many factors. Examples of these factors include: how components are stored for transport on the ATV, the number of trips to the cargo bay required for the complete operation, the amount of actual working time astronauts have during each EVA operation, and the manner in which the various operational systems are integrated with the antenna structure. However, tests have been conducted to determine the time required to assemble structural components using 5.5m long members with the snap-lock type joints and the results are reported in reference 7. Based on these tests it seems reasonable that the complete antenna with its approximately 330 substructure members could be assembled in a normal shuttle flight without extended mission capability.

Construction of large structures in space is a challenging assignment. Other construction scenarios have been proposed, however, they generally require sophisticated deployment schemes which must be controlled and synchronized. Many of these schemes are unproven and cannot be reliably evaluated by ground tests. Therefore, the deployment schemes require considerable developmental testing including orbital evaluation. The assembly construction technique proposed herein is within the current state of technology and could be reliably implemented. Construction could be conducted from a space station platform as proposed in reference 5 as well as from the shuttle cargo bay as discussed herein. These options illustrate the versatility of ATV assisted construction and is only one of its many potential applications.

COMPLETED OFFSET FED ANTENNA

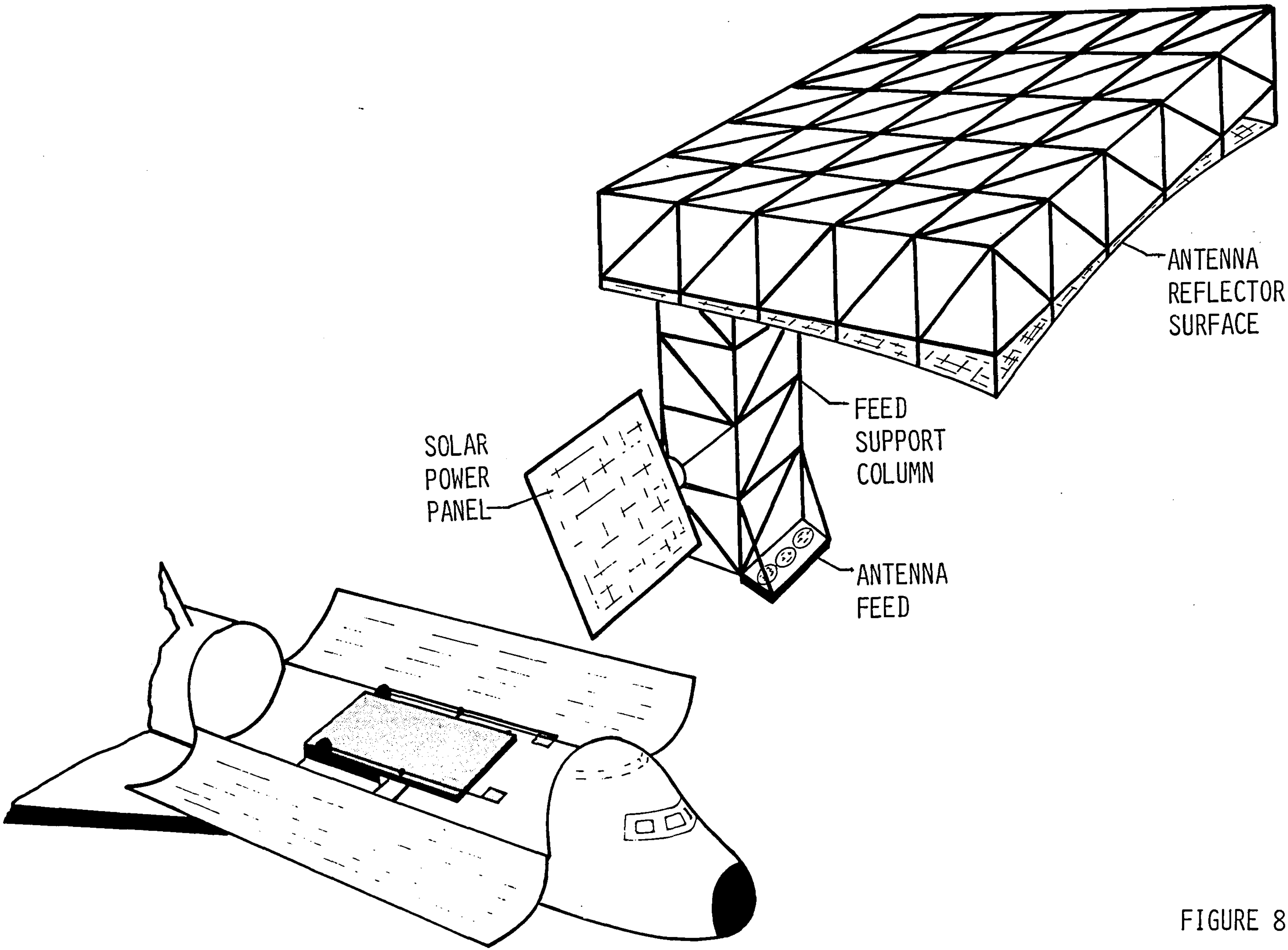

FIGURE 8

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15. Supplementary Notes

16. Abstract

A design concept for the construction of an offset-fed antenna is developed and discussed. Antennas of this type are of interest for many space applications because the configuration eliminates the effects of feed and feed-support blockage. The proposed construction concept is developed around the assembly of a stiff truss substructure by pressure-suited astronauts operating in extravehicular activity (EVA) assisted by a mobile platform that moves along the structure to position the astronauts at joint locations where they can latch members in place. Construction can be accomplished from the shuttle cargo bay in the course of a normal flight or from a space station platform. The concept demonstrates the versatility of machine assisted manned assembly and is only one of many potential applications.

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