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GENERAL DESCRIPTION OF NESTABLE COLUMN  
STRUCTURAL AND ASSEMBLY TECHNOLOGY

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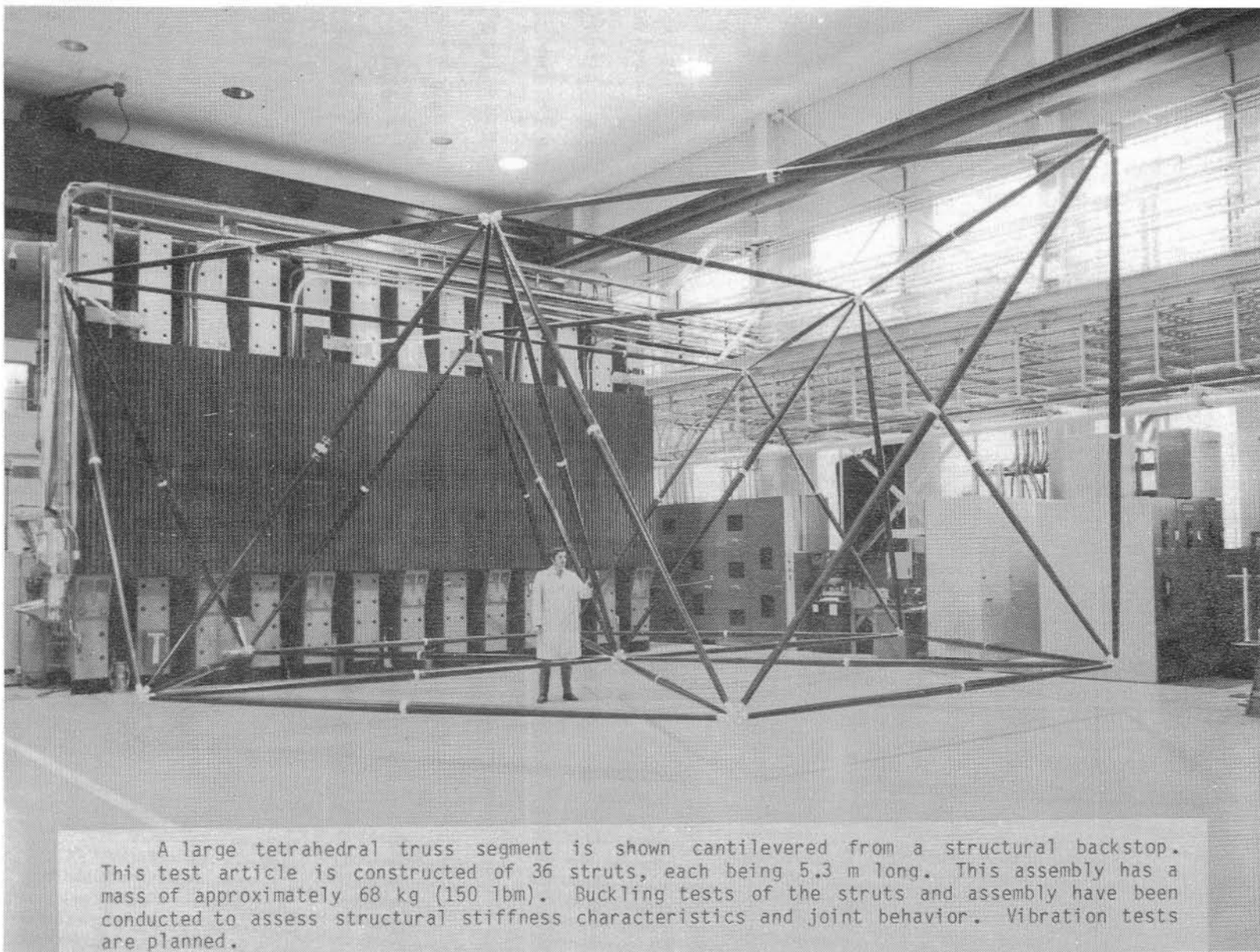
## GENERAL DESCRIPTION OF NESTABLE COLUMN STRUCTURAL AND ASSEMBLY TECHNOLOGY

### INTRODUCTION

Since the mid-1970's, the aerospace community has considered ways to take advantage of the Space Transportation System's mass-lift and cargo bay volume capabilities to perform missions requiring large spacecraft in earth orbit. These capabilities represent a substantial increase over those of existing expendable launch vehicles. Missions requiring platform or antenna structure packages which exceed expendable launch vehicle capabilities are possible with the Shuttle and have been studied. Early studies determined that even with the payload capability of Shuttle, it is inefficient to transport large pre-assembled spacecraft which are folded for packaging in the cargo bay.

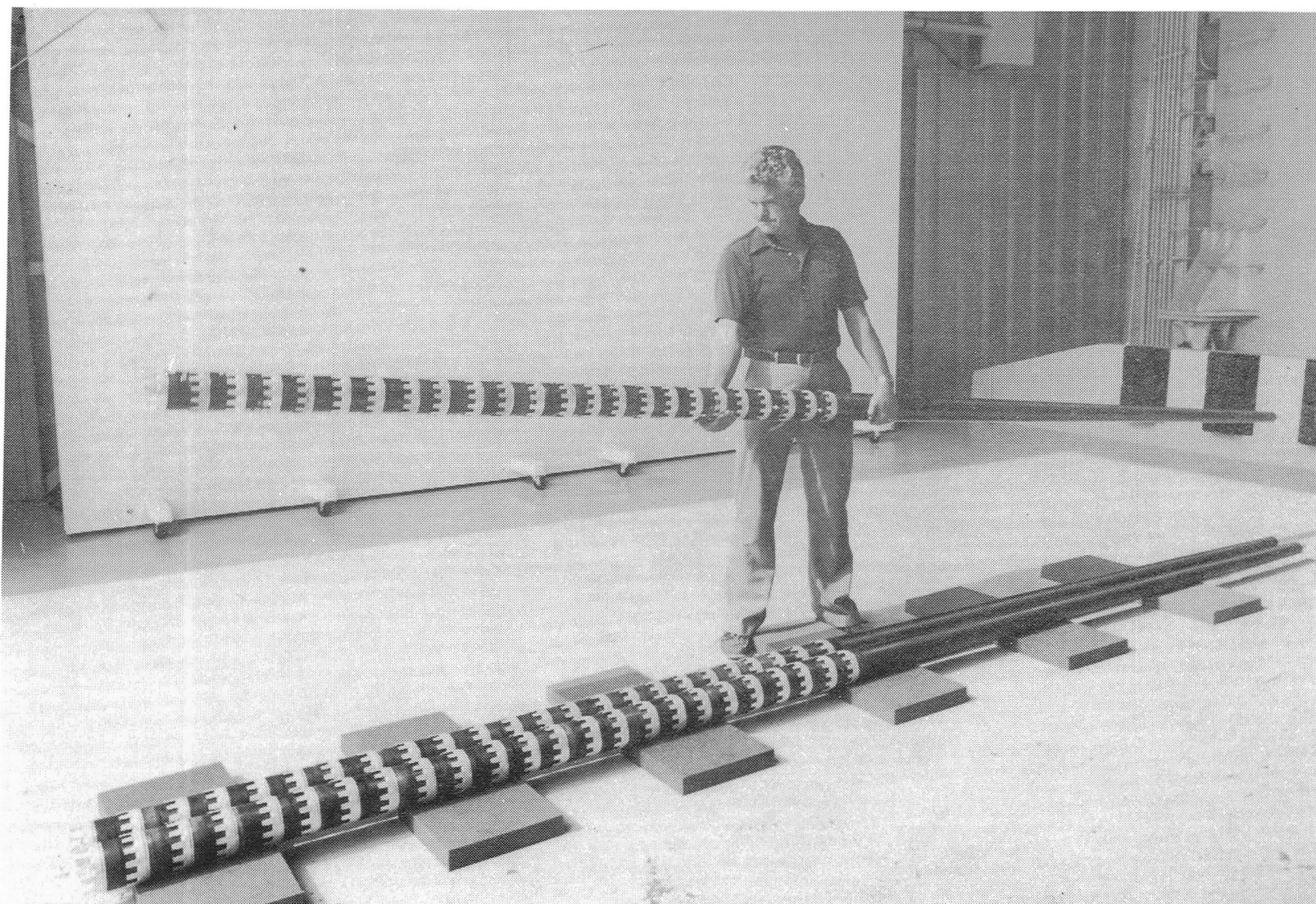
An alternative structural concept, the nestable column, has been developed as a basic building block from which desired structural truss configurations can be erected. The superior packaging characteristics of nestable column structural elements make this concept attractive for application to missions requiring large and/or high stiffness, or complex structures. The major unknown concerning use of the nestable column elements has been lack of information about assembly methodology. Considerable effort has been expended investigating various assembly techniques and developing basic timelines to permit informed decisions when considering future missions.

This report presents a general, pictorial description of investigations which have been pursued to date relative to defining structural and assembly technology using nestable column structural elements.

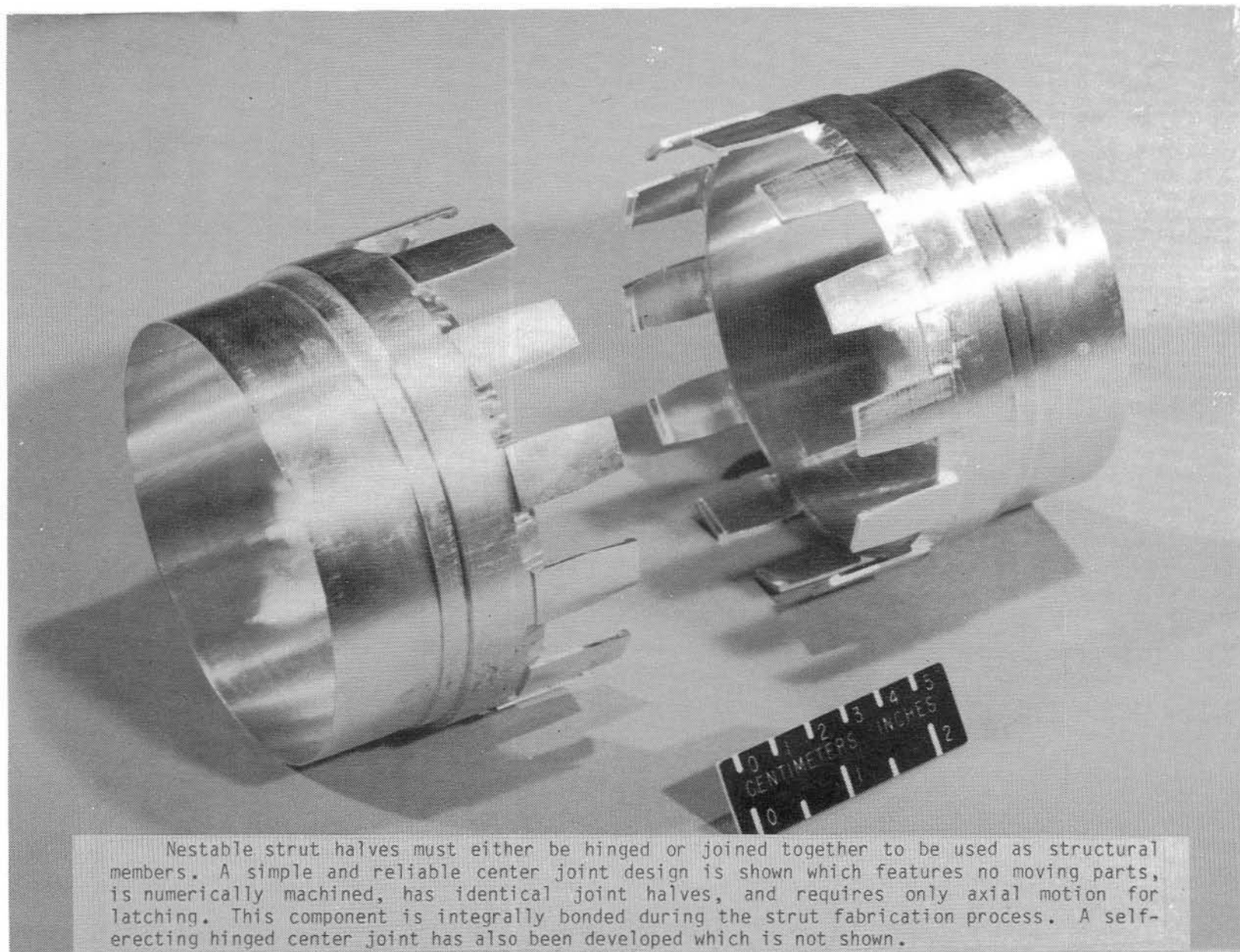


A large tetrahedral truss segment is shown cantilevered from a structural backstop. This test article is constructed of 36 struts, each being 5.3 m long. This assembly has a mass of approximately 68 kg (150 lbm). Buckling tests of the struts and assembly have been conducted to assess structural stiffness characteristics and joint behavior. Vibration tests are planned.





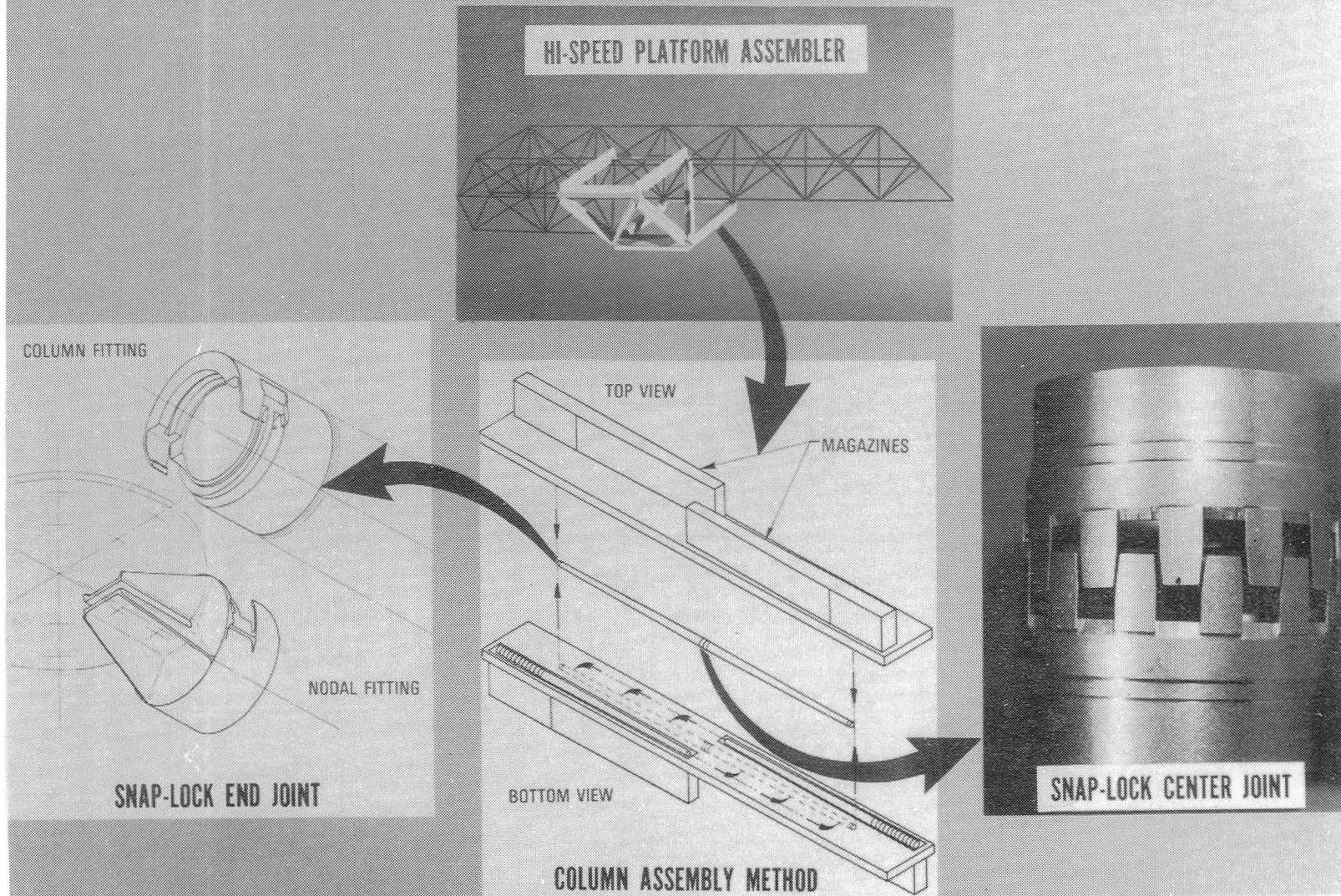
The compact packaging features of the nestable column (strut) halves are shown in the figure. The columns shown were integrally molded with a Langley developed metallic center joint which is used to form a complete, doubly tapered compression column using strut halves withdrawn from a stack. The columns shown above are the exact number required to construct the truss segment in the previous figure.



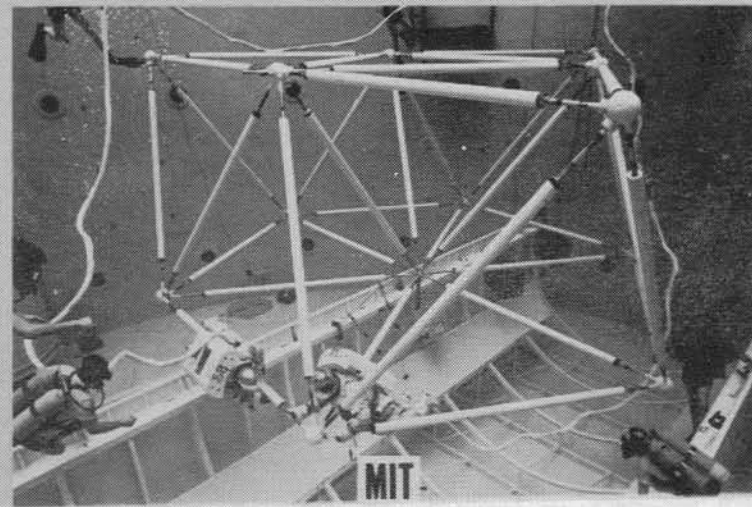
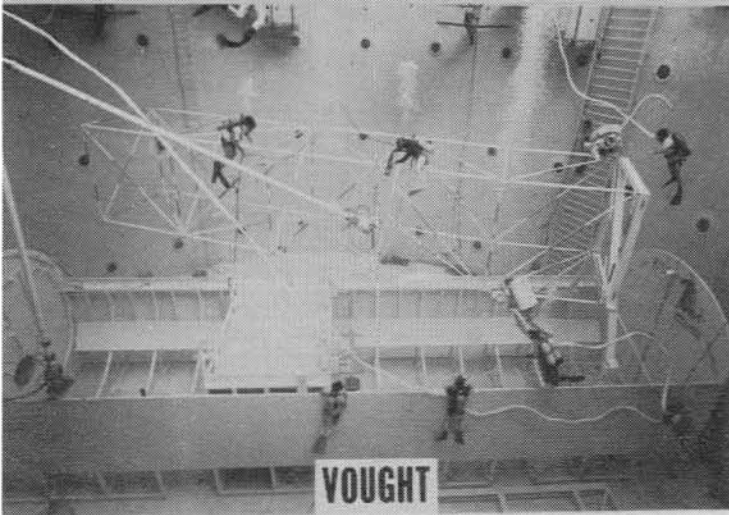
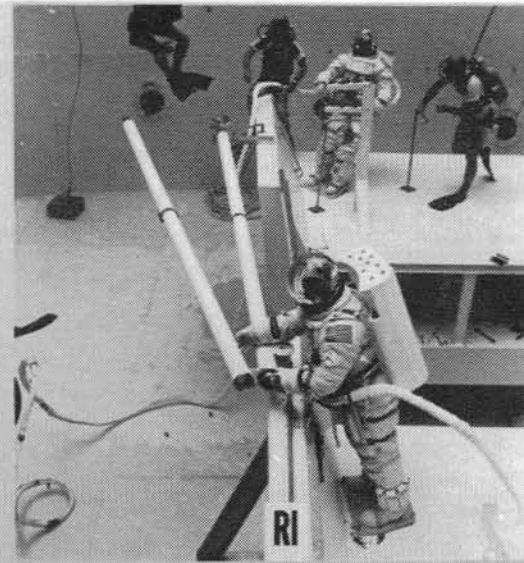
Nestable strut halves must either be hinged or joined together to be used as structural members. A simple and reliable center joint design is shown which features no moving parts, is numerically machined, has identical joint halves, and requires only axial motion for latching. This component is integrally bonded during the strut fabrication process. A self-erecting hinged center joint has also been developed which is not shown.



## SPACE STRUCTURE ASSEMBLY AIDS

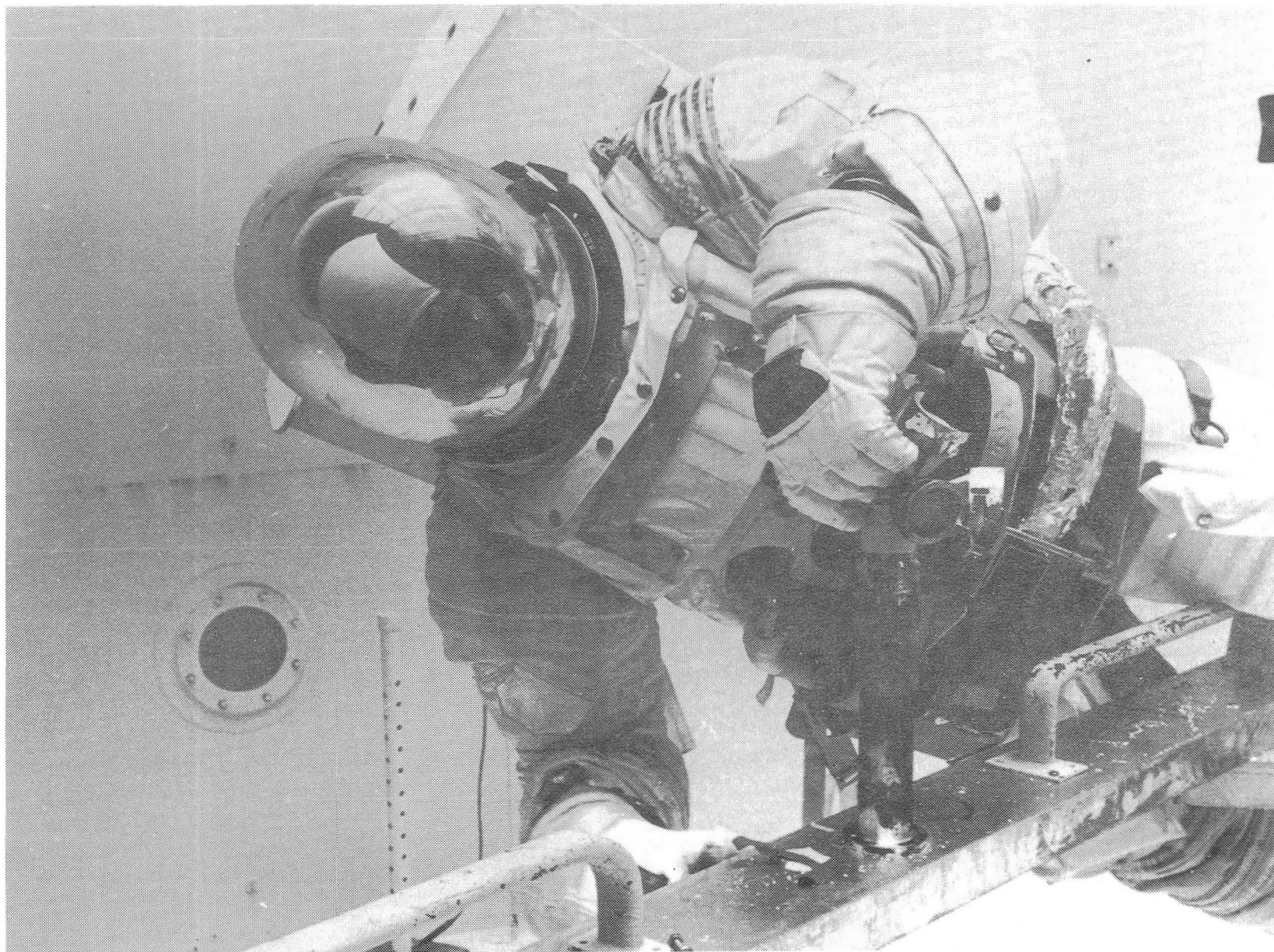


Erectable structures technology has been keyed, to date, on the nestable strut concept. Various aspects of the assembly process have been examined and several aids which enhance the assembly process are shown. A conceptual design for a high speed automated assembler has been developed which includes the column (strut) storage magazines and dispensing device. The column assembly method incorporates the center joint design shown and the rapid installation of struts is accomplished using the quick assembly side entry end joint system shown.

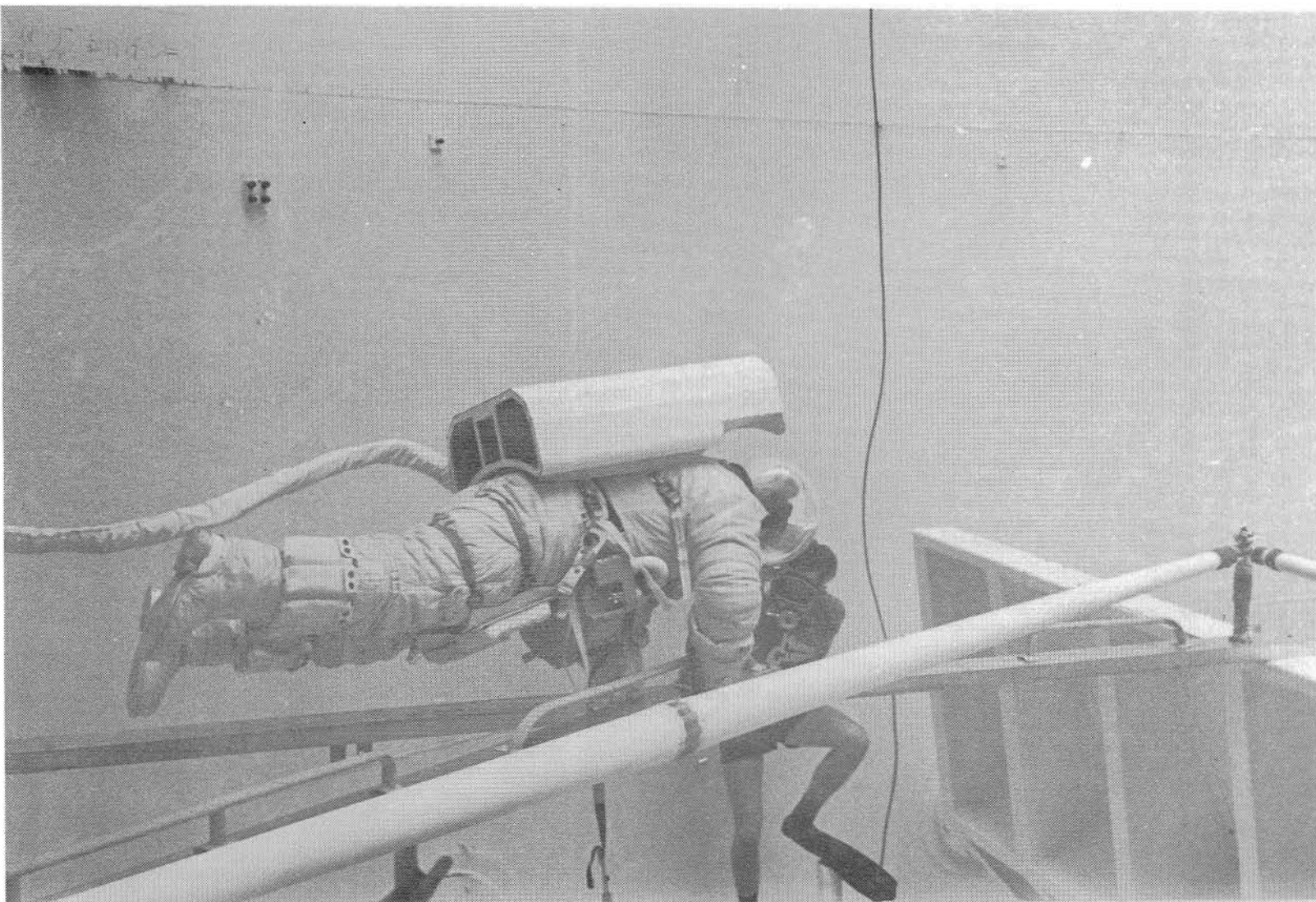


Space assembly of various types of structures has been simulated in the Marshall Space Flight Center Neutral Buoyancy Facility. Some of the activities are illustrated in the figure and include space suited (extra-vehicular activity) assembly of a tetrahedral cell using LaRC Nestable Struts, deployment of a folding strut by Rockwell International, assembly of deployable platform frame modules by Vought and assembly of a small 36 strut tetrahedral truss segment by Massachusetts Institute of Technology students.



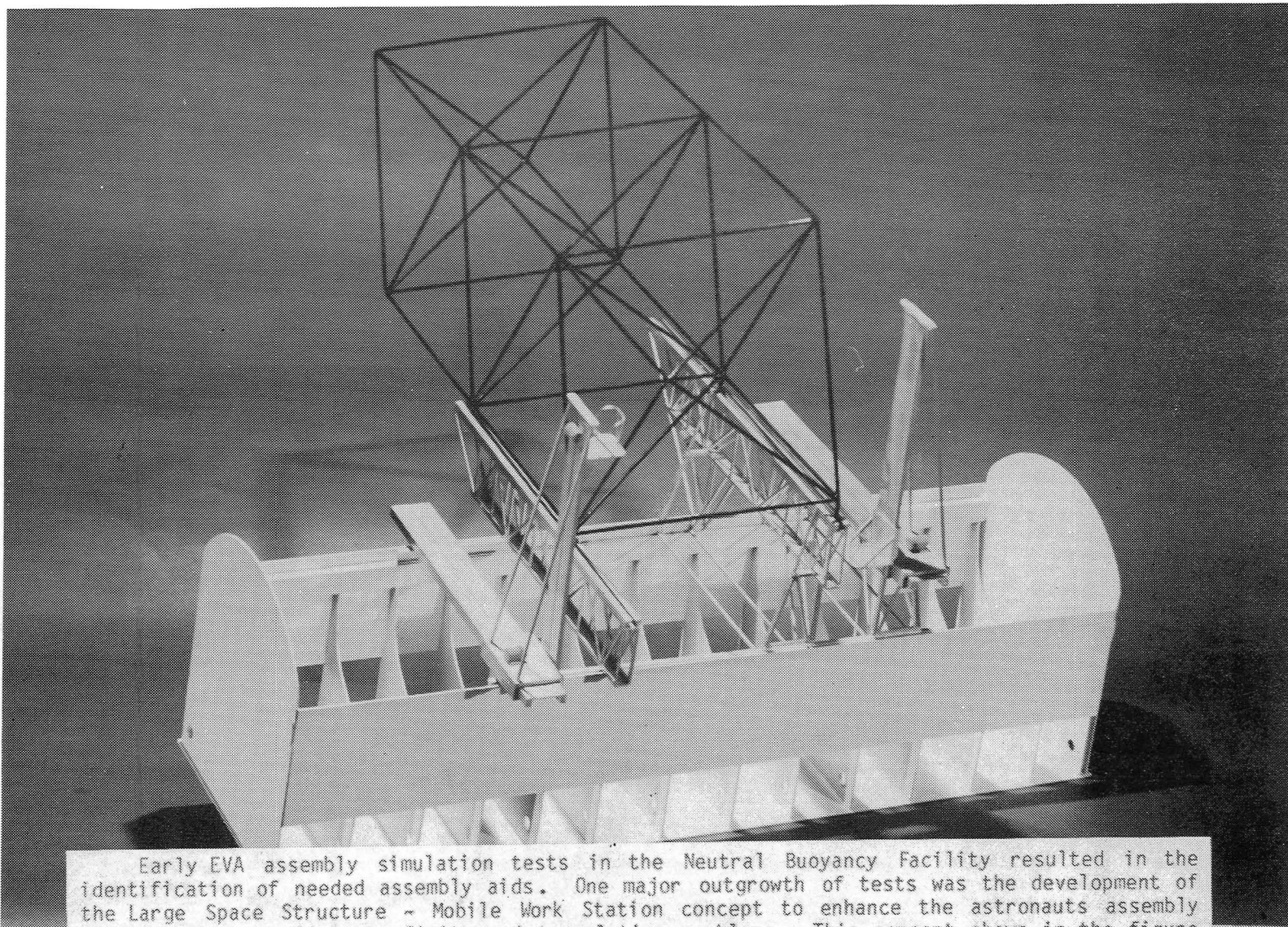


Space-suited EVA assembly simulation tests in the Neutral Buoyancy Facility re-emphasized the need for providing astronaut "fixity" at a work site. The figure shows an "astronaut" hanging on to adjacent structural fixturing as the installation of a nodal cluster joint is attempted. Astronaut maneuvers to provide themselves "fixity" greatly increase the risks of damage to the article being assembled or personal injury and should be avoided.

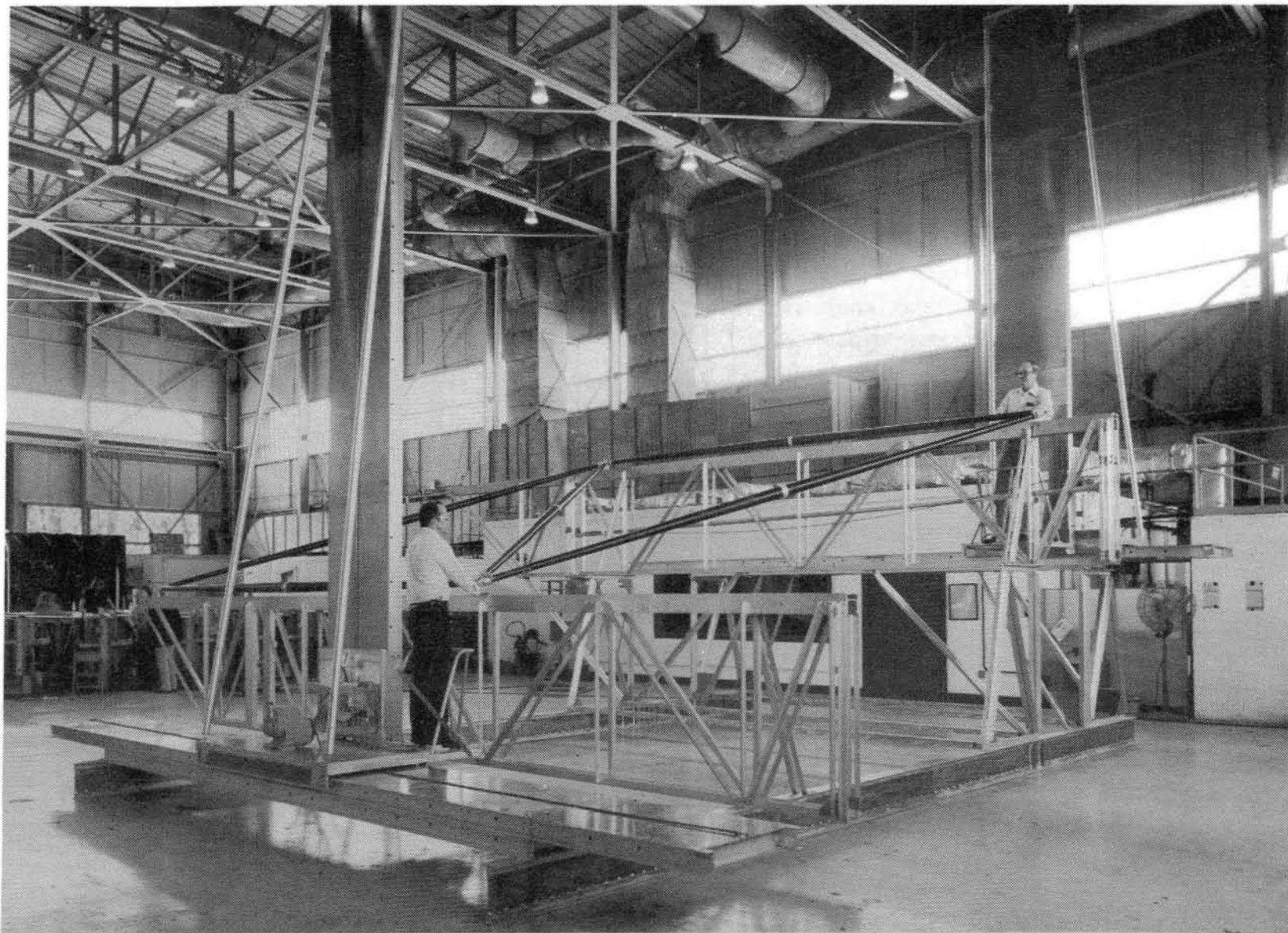


The Neutral Buoyancy Facility assembly simulation test identified astronaut translation as a time consuming and fatiguing activity. While astronauts were able to seek "minimum" energy methods of moving about to reduce fatigue, use of the structures to effect translation (where handrails do not exist), increases the risk of damage to the object being assembled.



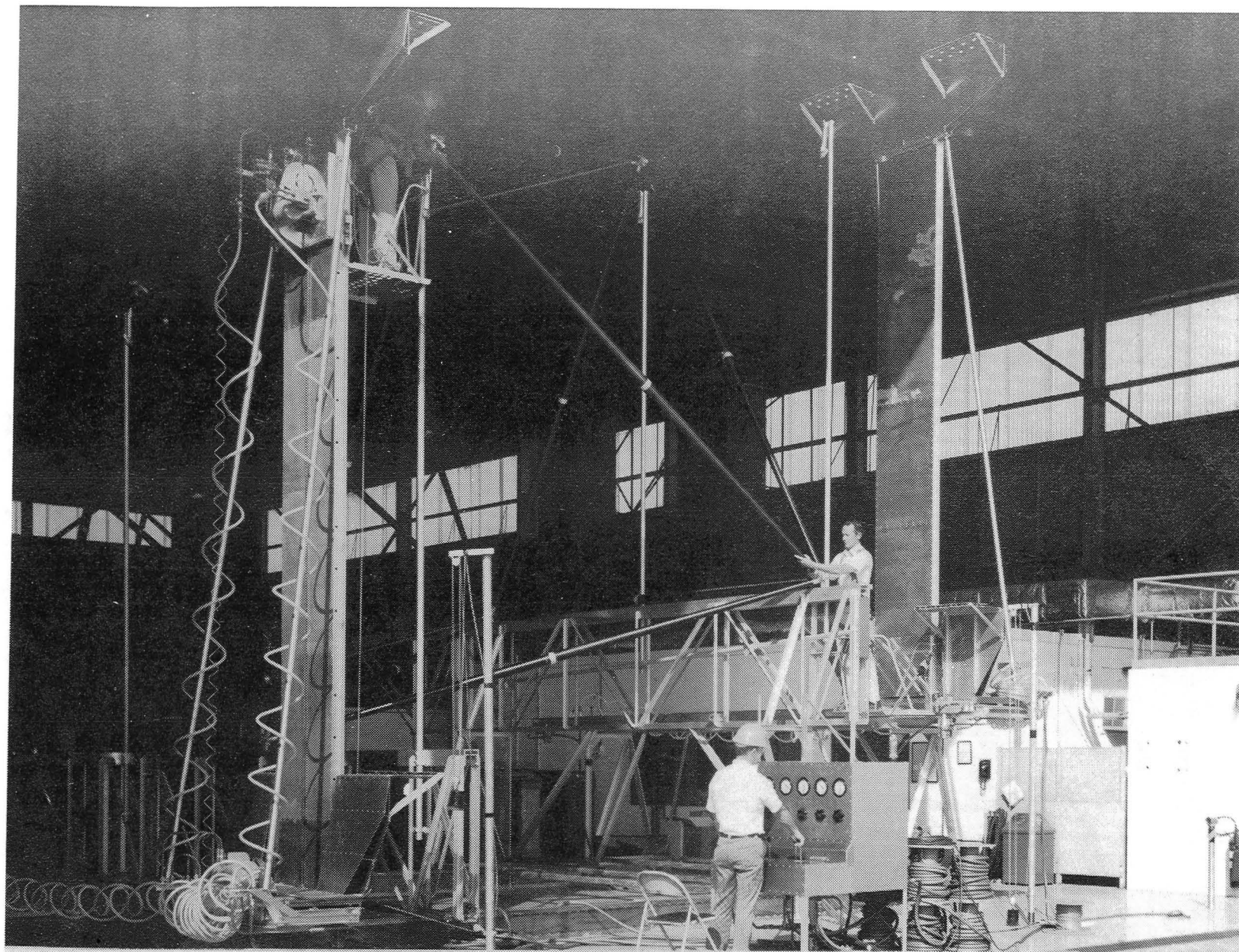


Early EVA assembly simulation tests in the Neutral Buoyancy Facility resulted in the identification of needed assembly aids. One major outgrowth of tests was the development of the Large Space Structure - Mobile Work Station concept to enhance the astronaut's assembly productivity and eliminate fixity and translation problems. This concept shown in the figure consists of an assembly line to which the structural elements are attached. Astronauts are fixed via foot restraints onto work platforms, one on each "face" of a structural segment. Each astronaut is moved within a prescribed plane, or work envelope and performs manual assembly tasks as required. Struts probably would be stored in racks which move with the astronaut for maximum efficiency. When a truss segment is completed, the assembly line moves the structure, permitting additional elements and/or equipment to be added as needed. This concept is applicable to the construction of linear or areal structures, either planar or curved. It could be Shuttle mounted in several positions for space use, free-flown with a control capability, or attached to a space operations center.

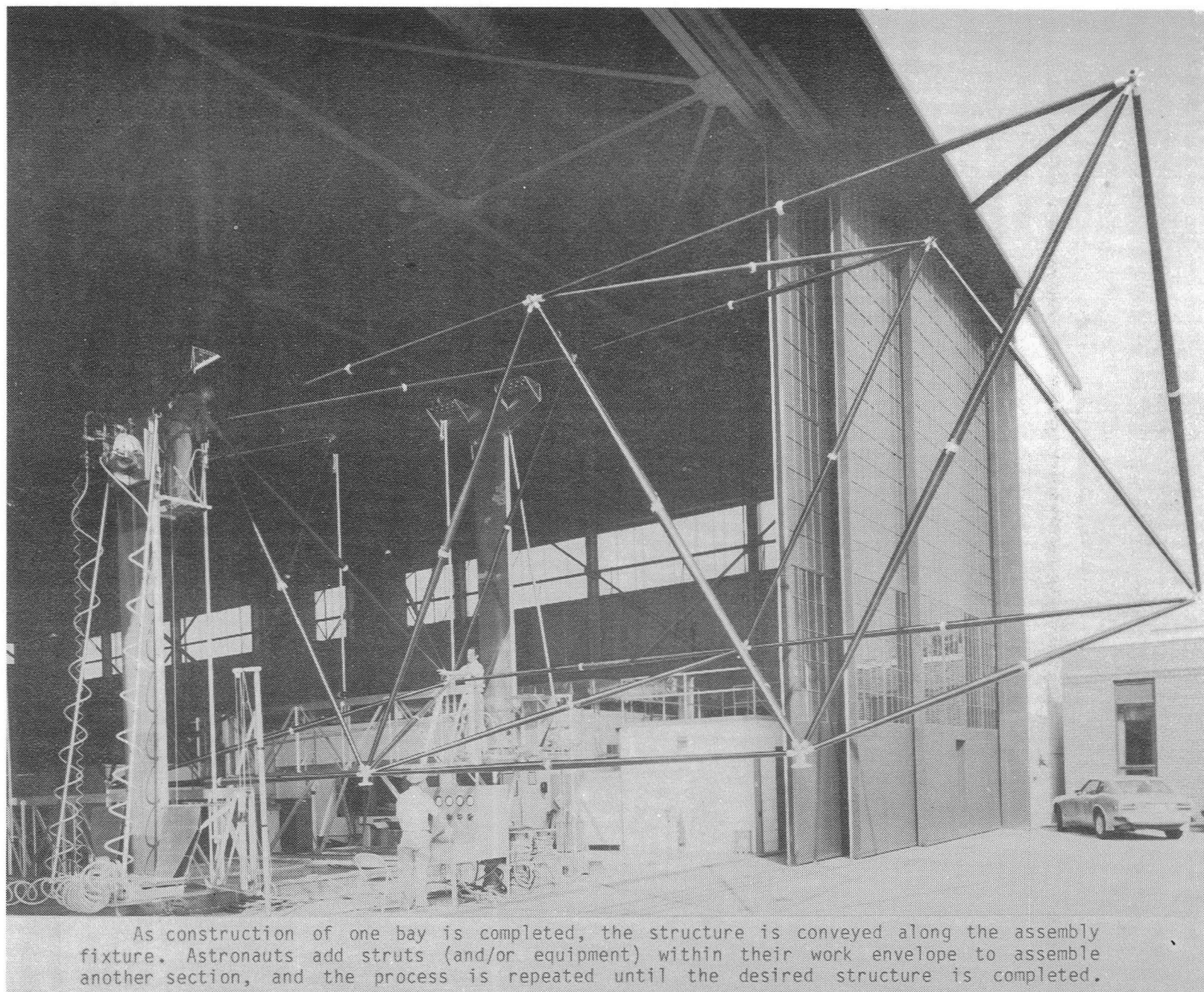


An experimental version of the Large Space Structure Mobile Work Station has been constructed to permit evaluation of this space assembly method. The figure shows the basic components-i.e., the horizontal and vertical tracks for each work station and the structure conveyor with a planar assembly of struts installed. Pneumatic lines and strut stowage racks are not shown. The 30' long mounting rails (on the floor) are spaced, in this version, 15' apart to fit a space shuttle cargo bay mockup.



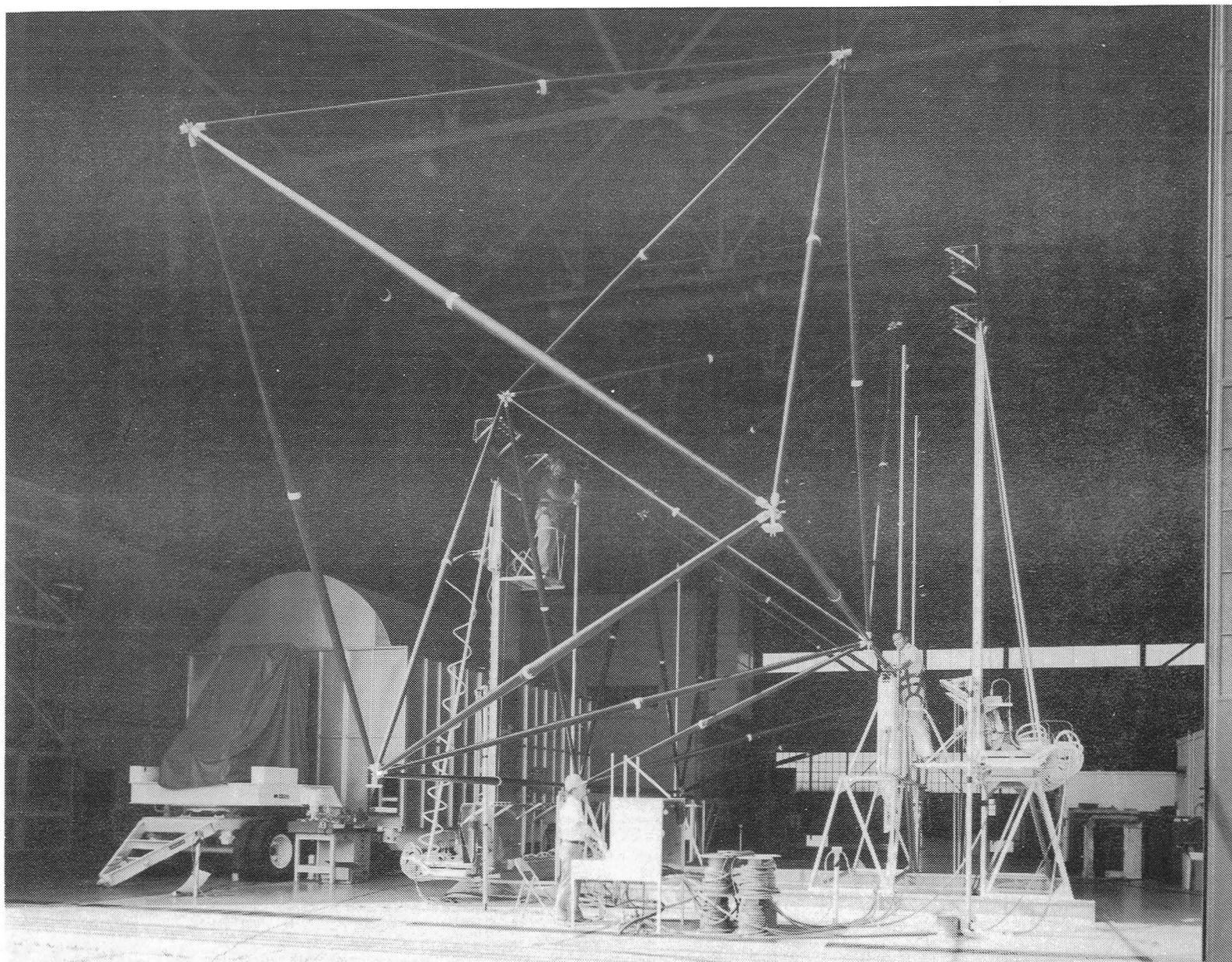


An assembly sequence for the linear beam under construction has been evolved during ground testing activities. Movement of the work stations within a prescribed envelope is controlled from the console leaving the work station occupants hand free to perform assembly tasks. Pneumatic lines (not required in space) and strut stowage racks are shown in the figure.

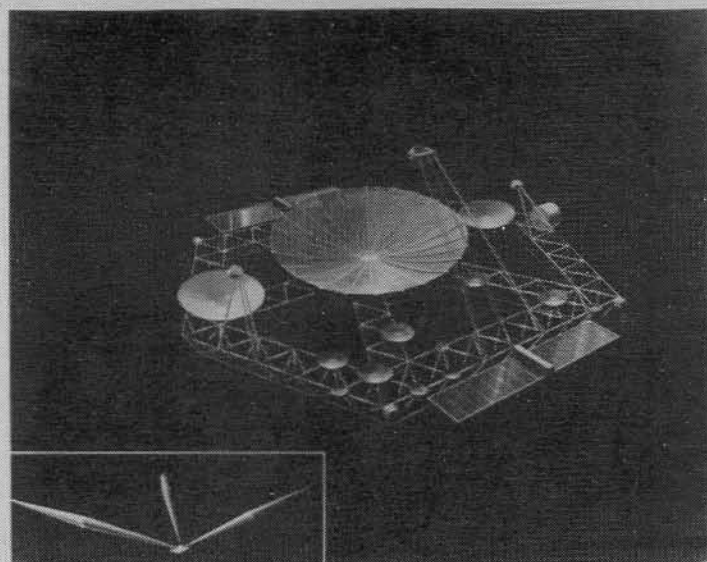
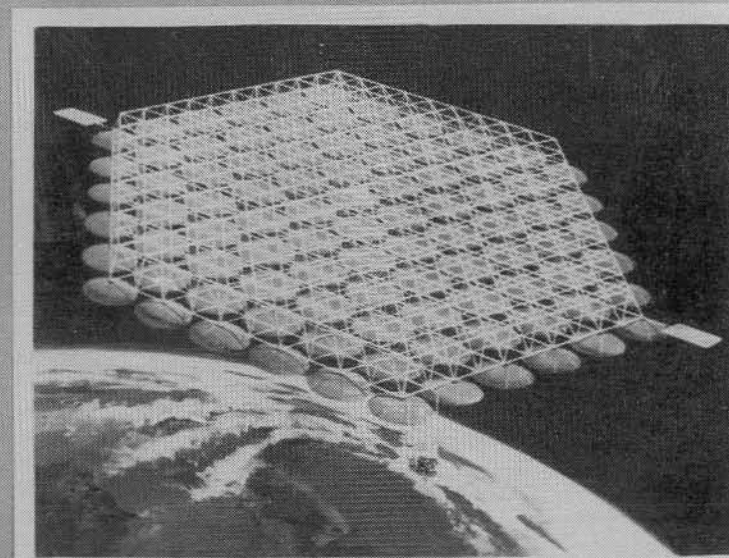


As construction of one bay is completed, the structure is conveyed along the assembly fixture. Astronauts add struts (and/or equipment) within their work envelope to assemble another section, and the process is repeated until the desired structure is completed.





An assembly sequence has been developed for the 38-strut linear tetrahedral beam shown in the figure. Atmospheric tests yielded assembly times of less than 15 minutes for the 38 elements. Neutral Buoyancy Facility tests are planned at MSFC to examine the effects of weightlessness and the space suit constraints. Atmospheric and NFB tank test results will be analyzed and combined to yield projected timelines for space assembly.



Current activities in nestable strut assembly via the Mobile Work Station are centered around a linear beam arrangement. Appropriately modified, various configurations of platforms or reflectors could be easily assembled.

Assembling a 100 meter platform from the 5.3 meter struts used in the ground tests would require about 2500 struts and only 20 hours of assembly time. Assembling a 300 m platform from the 5.3 m struts used in the ground tests would require nearly 22,000 struts and 180 hrs. of assembly time. However, increasing the strut length to 10 m would reduce these numbers by about a factor of 4.

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