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N84-22612

SPACE STATION ARCHITECTURE, MODULE, BERTHING HUB, SHELL ASSEMBY, BERTHING MECHANISM & UTILITY CONNECTION CHANNEL

AMES RESEARCH CENTER
MOFFETT FIELD, CA

1984

NASA CASE NO. ARC-11,505-1

PRINT FIG. 1

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S.N. 588,036
Filed 3-9-84.

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(NASA-Case-ARC-11505-1) SPACE STATION ARCHITECTURE, MODULE, BERTHING HUB, SHELL ASSEMBLY, BERTHING MECHANISM AND UTILITY CONNECTION CHANNEL Patent Application (NASA) 25 p HC A02/MF A01 CSCL 22B G3/18

N84-22612

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Serial No. 588,036

File Date: 3/9/84

NASA CASE NO. ARC-11505-1

SPACE STATION ARCHITECTURE, MODULE, BERTHING HUB, SHELL ASSEMBLY, BERTHING MECHANISM AND UTILITY CONNECTION CHANNEL

Invention Abstract

A space station 20 includes a plurality of modules 24 and berthing hubs 22, joined by interconnections 26 which are sideways connectable. The modules 24 and berthing hubs 2 are fastened together in a triangular configuration in two dimensions and a tetrahedral configuration in three dimensions. The interconnections 26 include a pair of opposed, axially aligned, flanged ports 50 and a clamp latch 52 formed from a plurality of sections 54, 56 and 58 hinged along their length and extending circumferentially around the flanged ports 50. A hermetic seal 63 is formed between the ports 50. The channel 68 has a shell with utilities connectors 74 movable between an extended position to mating connectors in the modules and a withdrawn position.

Prior art space station designs do not incorporate a triangular arrangement of modules in two dimensions or a triangular/tetrahedral structure in three dimensions or dedicated berthing hubs or sideways connectable connection ports. The triangular arrangement of modules allows shape symmetry axes and center of gravity to coincide and the tetrahedral structure provides a self-rigidizing, space filling assembly in three dimensions and allows a reverse angle cone of approach for space shuttle docking.

INVENTOR: Marc M. Cohen

EMPLOYER: NASA-Ames Research Center

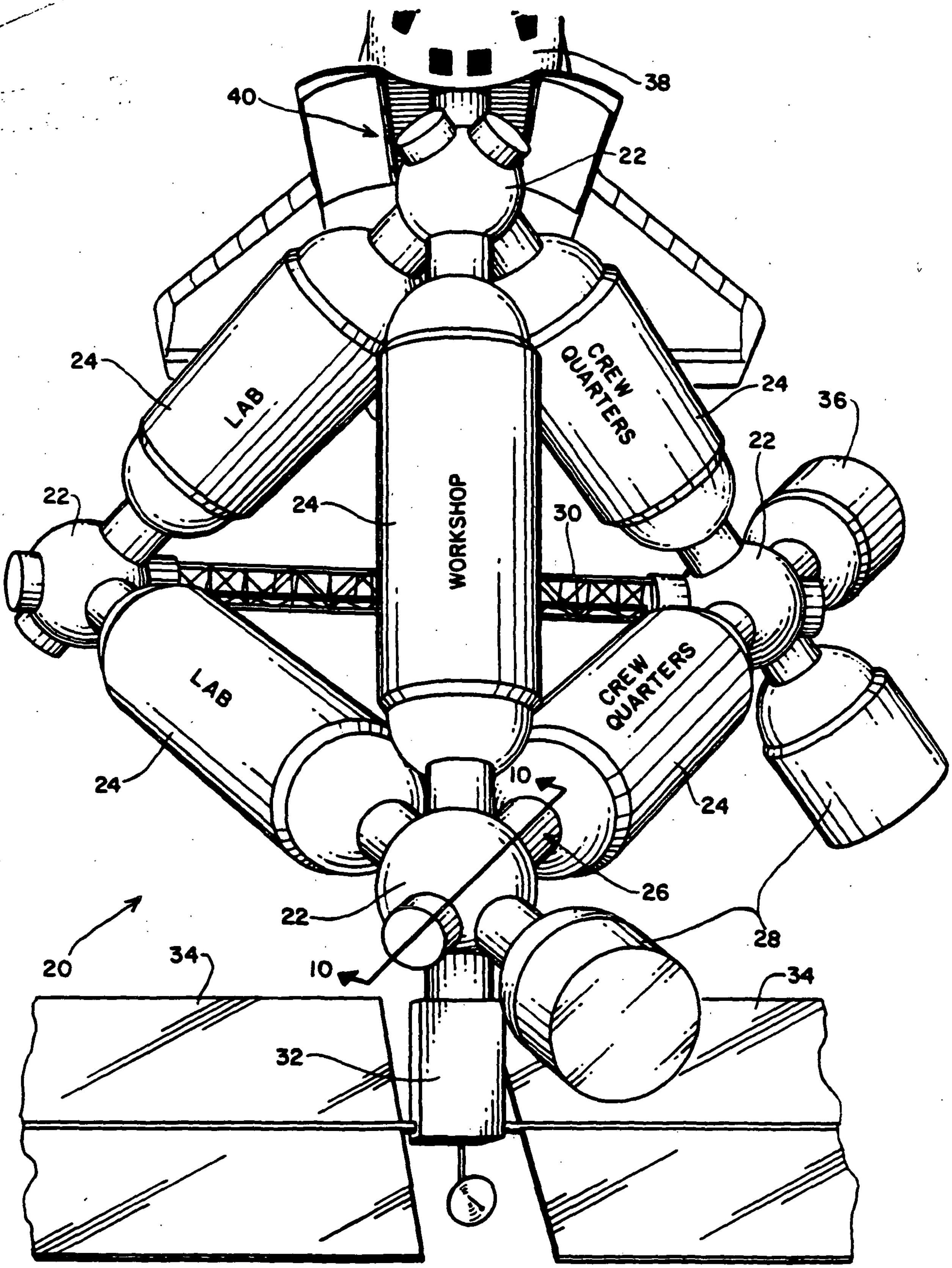

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FIG. 1

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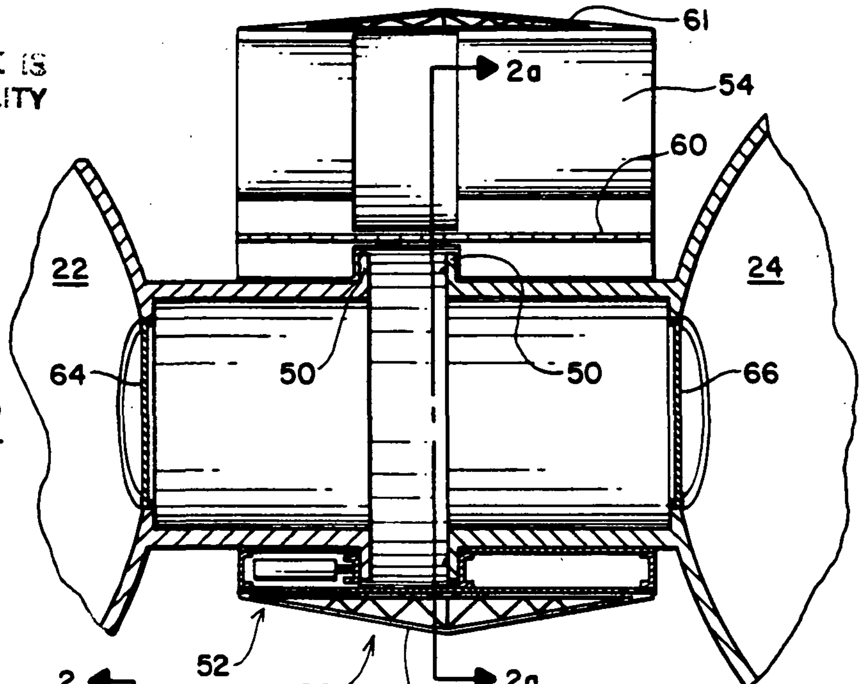


FIG. 2

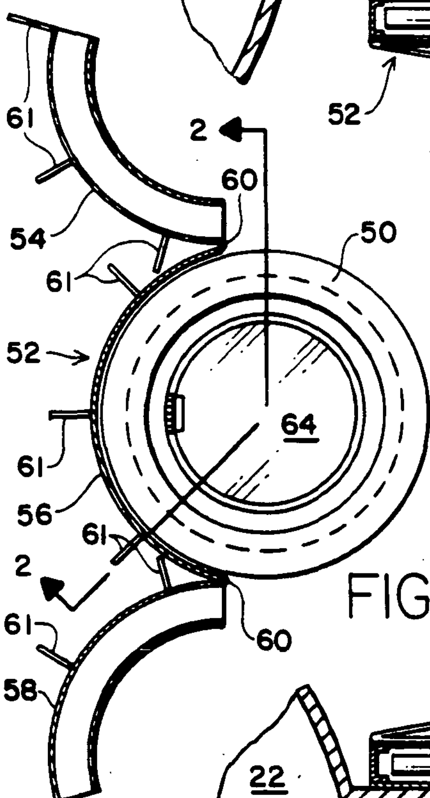


FIG. 2a

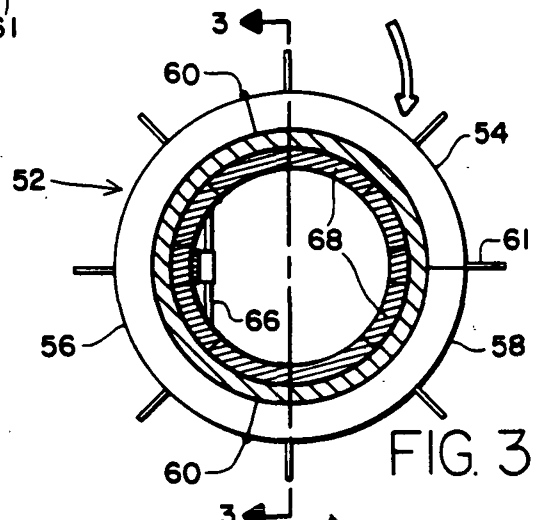


FIG. 3a

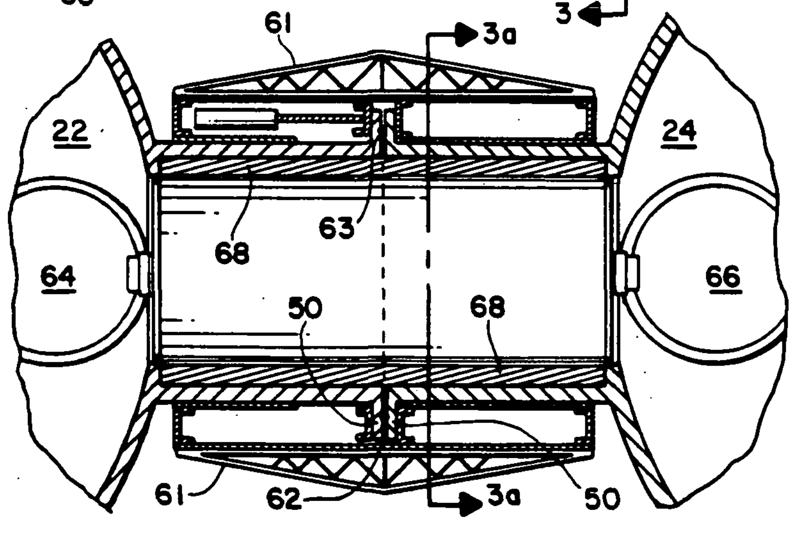
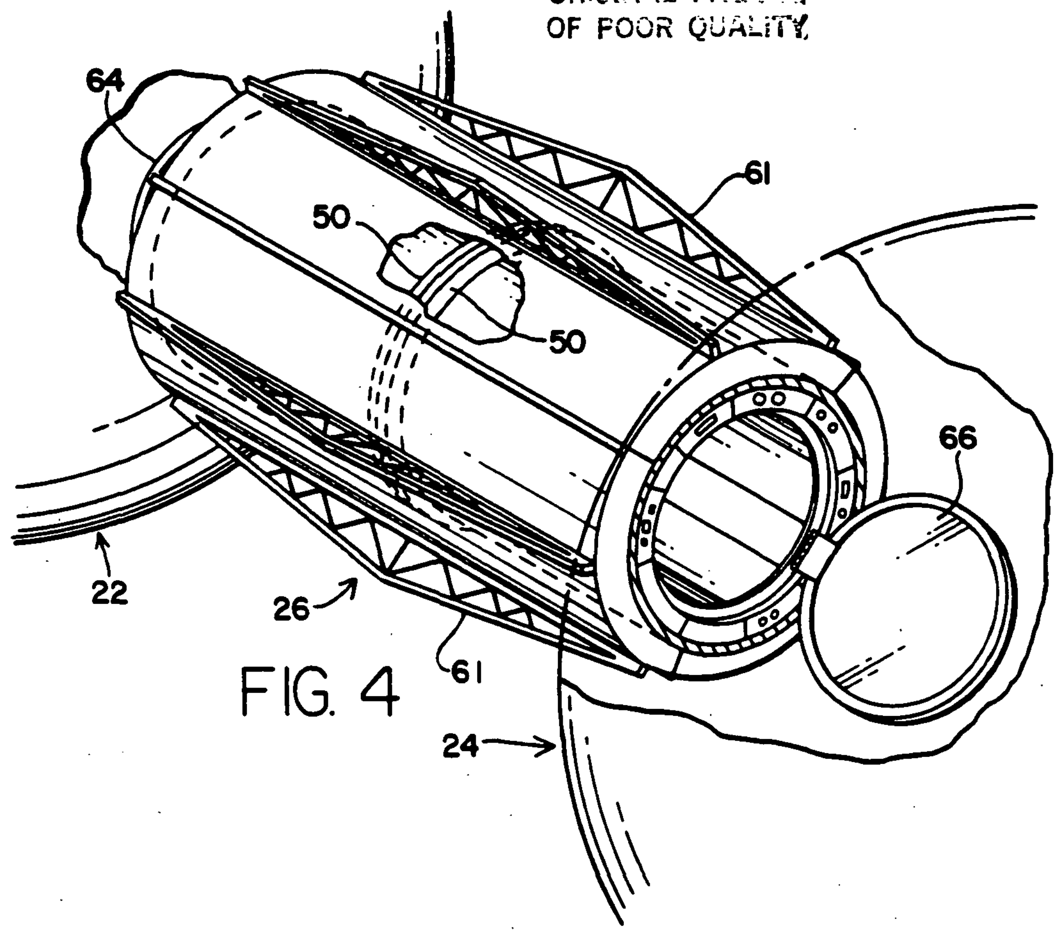


FIG. 3


64
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50
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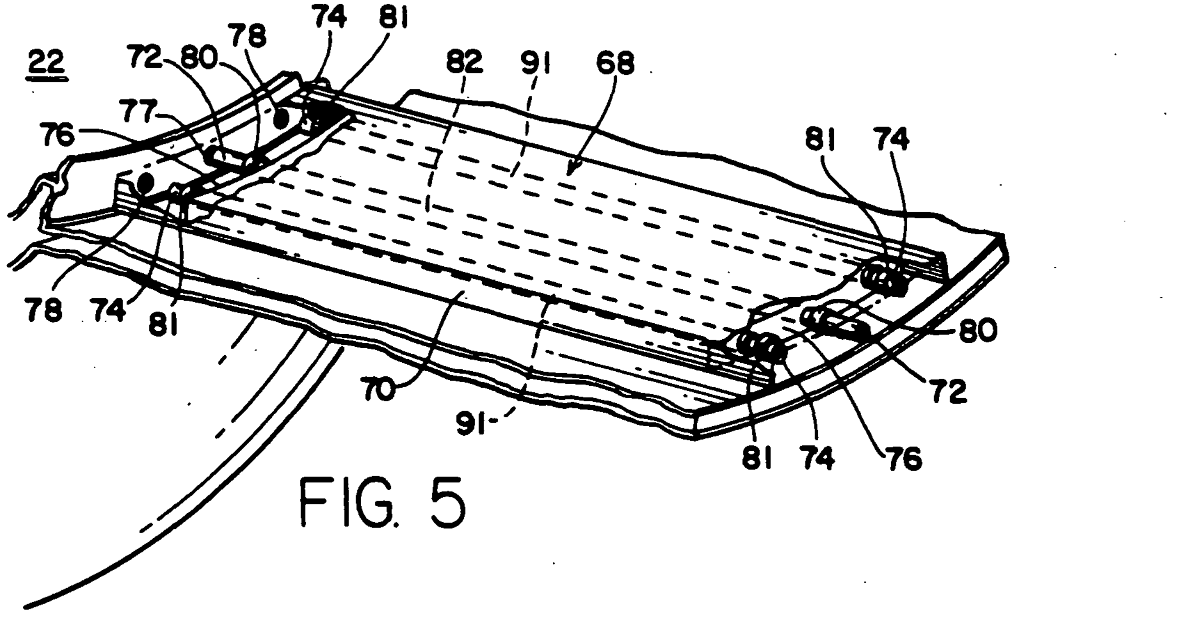
22
26
61
24

FIG. 4


22
72
80
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76
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FIG. 5

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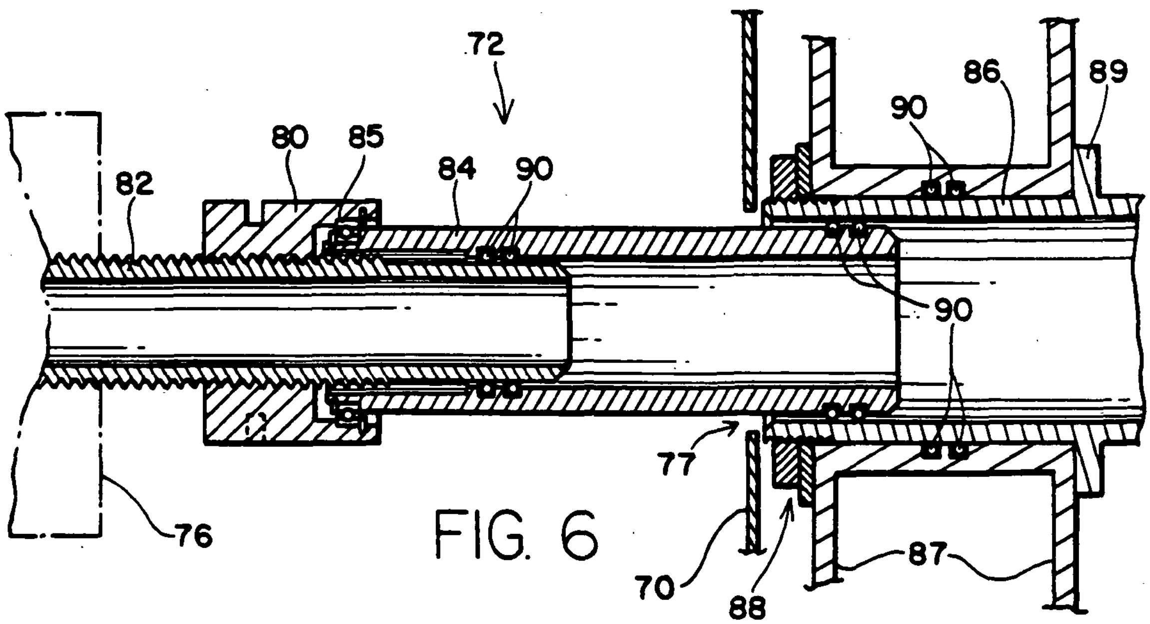


FIG. 6

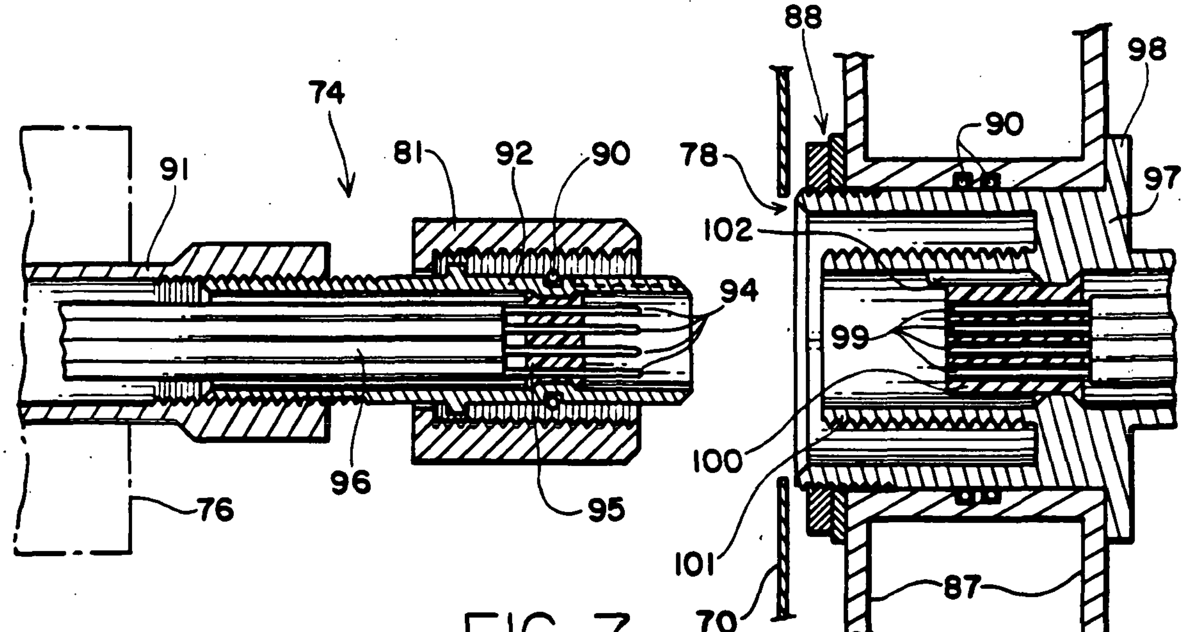
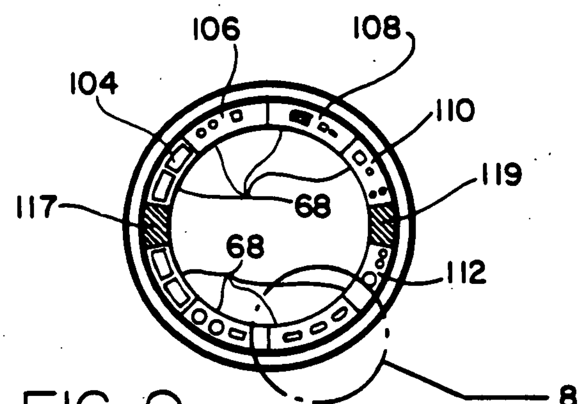


FIG. 7


106
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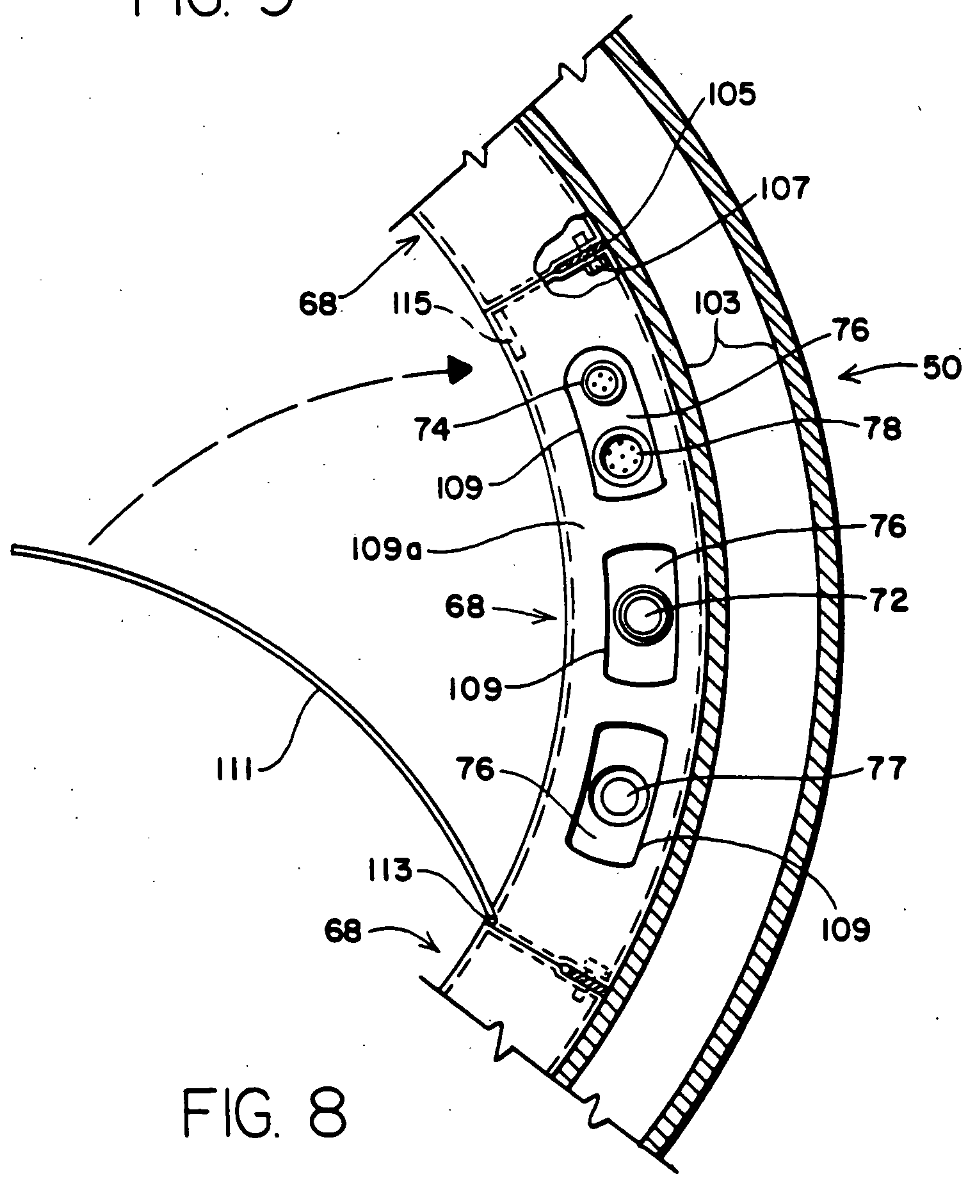
112
8

FIG. 9


105
107
68
115
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74
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109a
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68
109

FIG. 8

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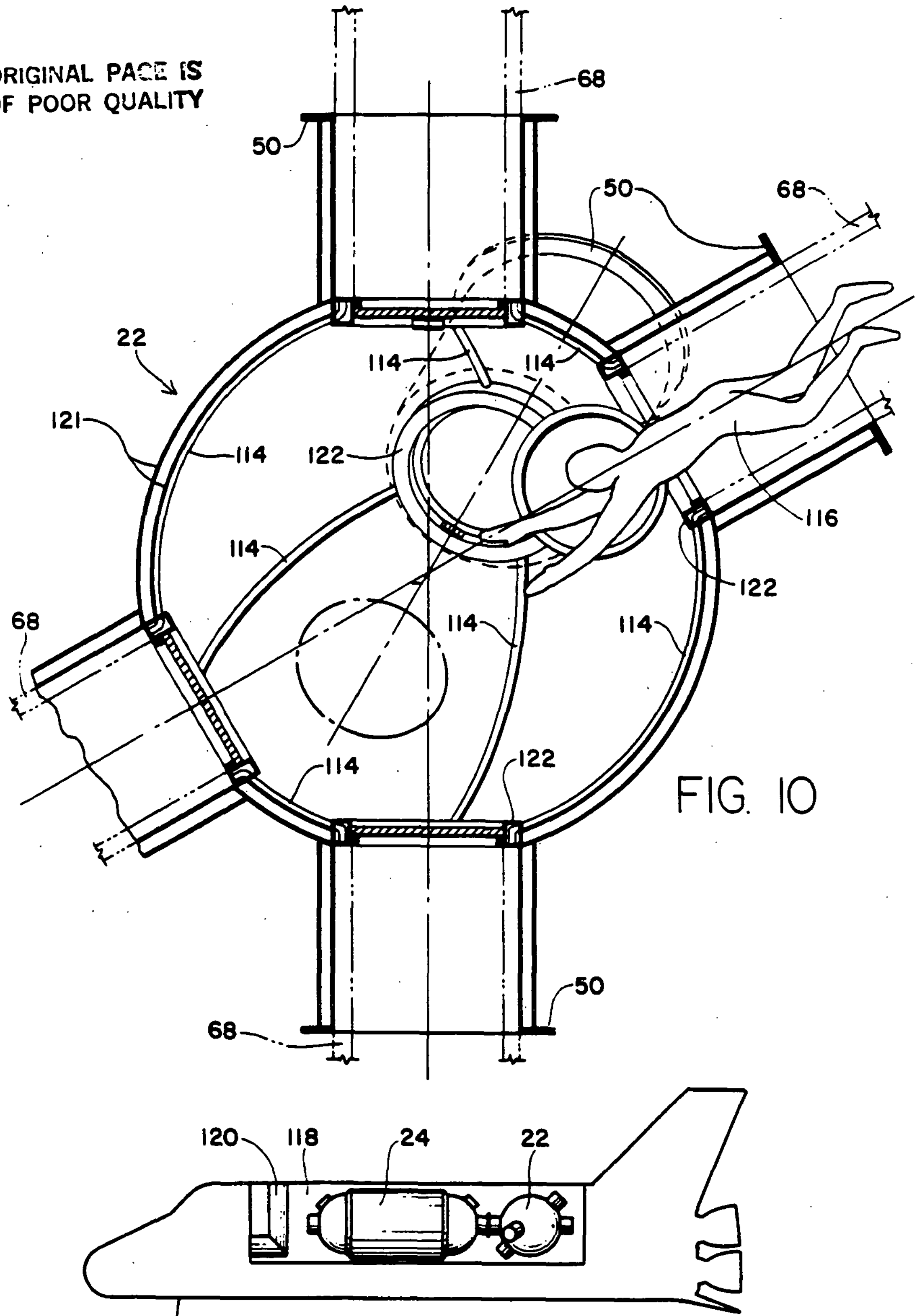


FIG. 10

FIG. 11

FIG. 12a

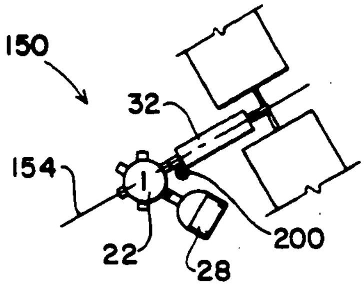
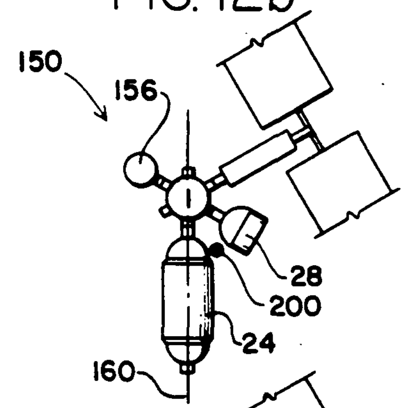


FIG. 12b



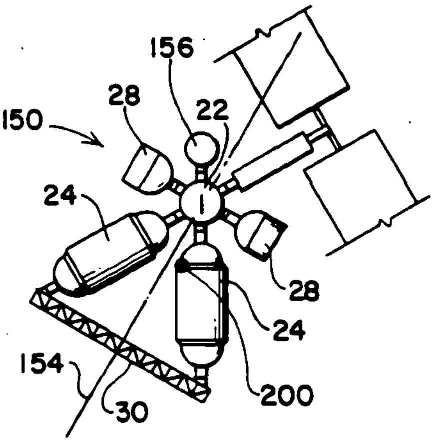


FIG. 12c

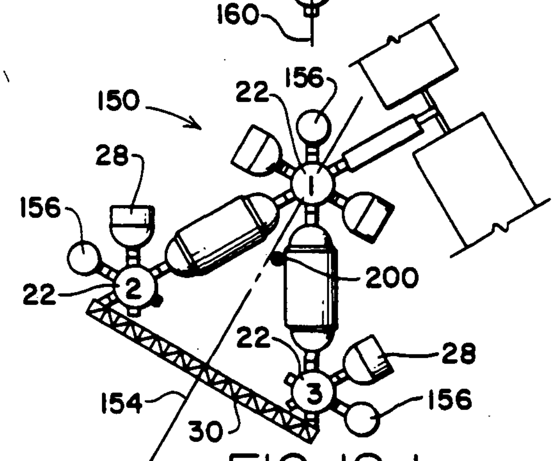


FIG. 12d

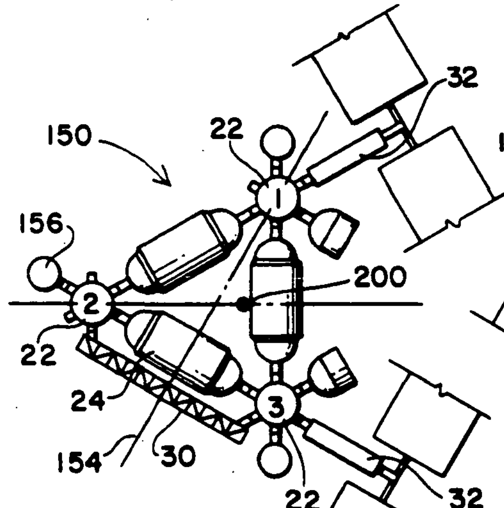


FIG. 12e

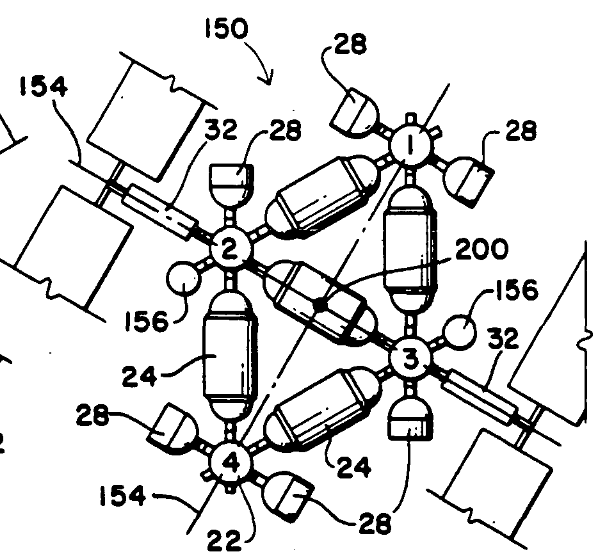


FIG. 12f

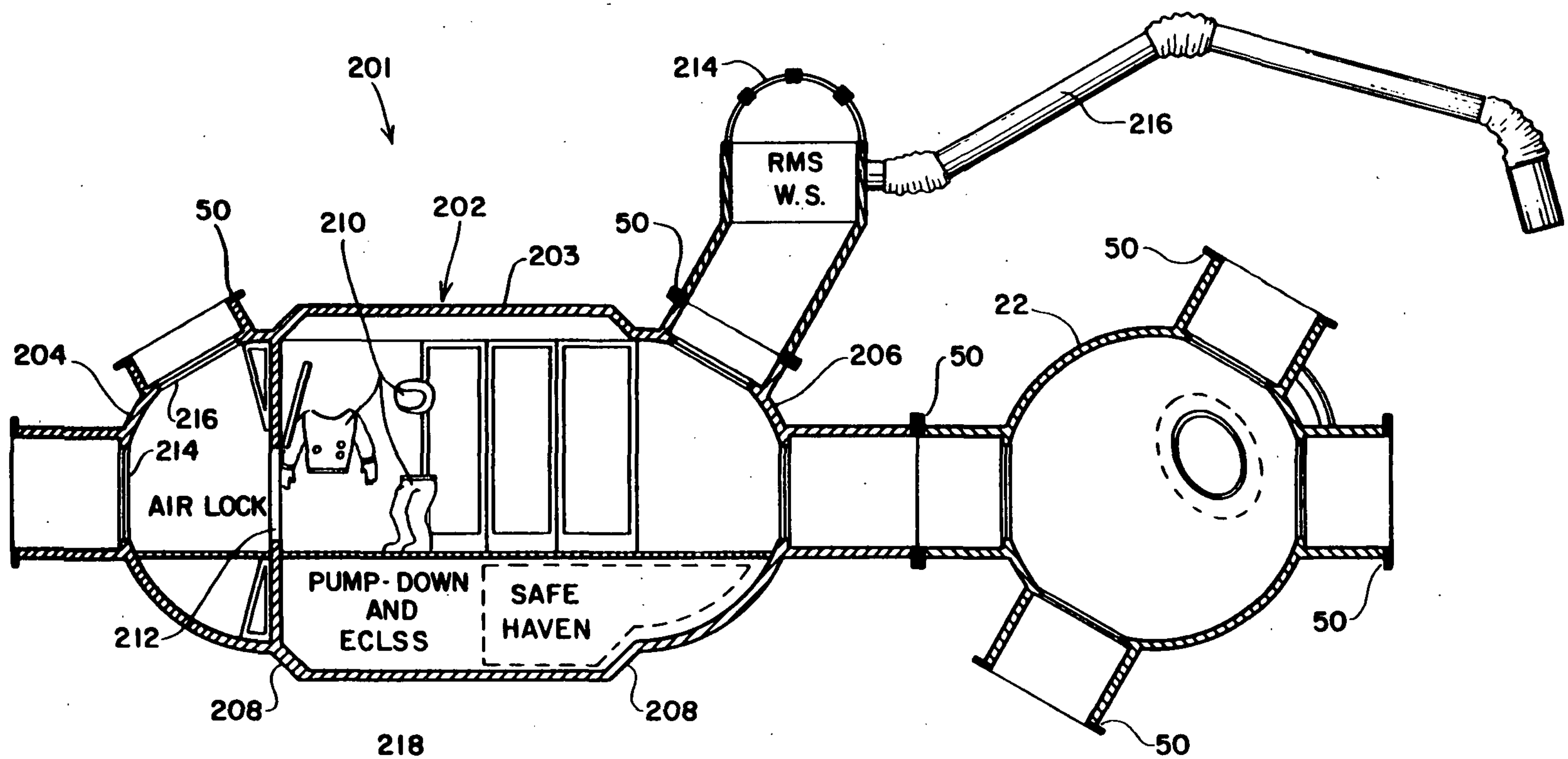


FIG. 13

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Serial No. 588,036
File Date: 3/9/84

NASA CASE NO. ARC-11505-1

SPACE STATION ARCHITECTURE, MODULE, BERTHING HUB, SHELL ASSEMBLY, BERTHING MECHANISM AND UTILITY CONNECTION CHANNEL

ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the U.S. Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

1. Field of the Invention. This application relates to a novel form of a space station. More particularly, it relates to a geometric form in which modules are interconnected and to the assemblies for connecting controlled atmosphere modules to form a structure connected together in an improved geometrical configuration using an improved interconnection assembly and utility channel connection.

2. Description of the Prior Art. A variety of space station configurations is known in the prior art. However, a characteristic which tends to prevail in prior art space station designs is that they tend to import gravity bound geometric conventions to a gravity free atmosphere. Examples of prior art space station designs are disclosed in the following U.S. Patents: 3,144,219, issued August 11, 1964 to Schnitzer; 3,169,725, issued February 16, 1965 to Berglund; 3,300,162, issued January 24, 1967 to Maynard et al.; 3,332,640, issued July 25, 1967 to Nesheim; 3,348,352, issued October 24, 1967 to Cummings; 3,478,986, issued November 18, 1969 to Fogarty; 3,744,739, issued July 10, 1973 to Weaver et al.; 4,057,207, issued November 8, 1977 to Hogan; 4,299,066, issued November 10, 1981 to Thompson; 4,308,699, issued January 5,1982 to Slysh; and 4,377,266,

issued March 22, 1983 to Belew et al. While these patents show that the art of space station construction is a well developed one, a need remains for further improvements in such construction, in order to improve safety, ease and versatility of handling and interconnection, and interconnection of utilities among modular units making up a space station or other controlled atmosphere environment.

SUMMARY OF THE INVENTION

Accordingly, it is an object of this invention to provide a space station that is deployable as space shuttle cargo in stages.

It is another object of the invention to provide a construction form for a space station or other controlled atmosphere environment which will provide a maximum efficiency connectivity and packing density of controlled atmosphere modules making up the space station or other environment.

It is a further object of the invention to provide a laterally approachable berthing mechanism for modular assembly of a space station.

It is yet another object of the invention to provide an improved form of utilities hookup for connecting modules in a modular controlled atmosphere construction.

It is another object of the invention to provide an omnidirectionally symmetrical space station berthing hub with a reverse angle cone of approach for docking or other interconnection.

It is a further object of the invention to provide a space station structure in which modules making up the space station have their center of gravity controllable in close proximity to their center of shape symmetry.

It is another object of the invention to provide a space station or other controlled atmosphere environment employing a standardized shell structure using hemispherical end caps for modules and to form spherical hubs.

It is yet another object of the invention to provide a modular space station assembly in which utilities connections can be made in a shirtsleeves environment that allows fine finger manipulation of utility connectors.

The attainment of the foregoing and related objects may be achieved through use of the novel space station architecture, interconnection assembly, berthing hub and utilities connection channel herein disclosed. A space station architecture in accordance with this invention has a controlled atmosphere environment with a plurality of interconnected modules having opposed connection ports with active mechanisms which are sideways connectable to a passive port of a berthing hub. The modules are desirably interconnected in a triangular configuration in two dimensions and a tetrahedral configuration in three dimensions. The result is a fully packed, symmetrical, self-rigidizing structure with a center of gravity in close proximity to its center of shape symmetry.

In another aspect of the invention, a spherical, polyhedral, or spherical derivative hub is used for docking and for module interconnection. The docking hub has a reverse angle cone of approach when employed for docking purposes. It also includes a maximum of 14 berthing ports all at 60 degrees face angles from each other.

In a further aspect of the invention, the hub incorporates a utilities connector channel which distributes gases, electric power communications, data links, control circuits, water and other fluids throughout the interconnected modules and docked transport ship in an improved manner through use of extendable opposing conduits adapted to interlock with mating sockets imbedded in the modules and hub pressure shells.

Because the triangulated structure is self-rigidizing, without requiring resistance to bending movements or torques at the hubs, the hubs need not be designed to resist bending or torques. This geometrical advantage will allow significant reduction in structural weight and depth. Because it is not necessary to resist bending and torques in this non-rectangular structure, it is possible to provide noise and vibration isolation between modules, which is very difficult, if not impossible in cartesian coordinate/rectangular configurations.

Further, the triangular/tetrahedral station has specific flight attitude and controllability properties. The triangular, two-dimensional planar station has advantages in terms of minimal atmospheric drag, equalized aerotorques with the center of pressure aligned with the center of gravity. It has the ability to fly in an earth-inertial, gravity gradient mode where the long axis through the center of the mass will point towards the center of the earth as a natural flight attitude. This flight attitude will allow the use of gravity gradient countertorques to counterbalance the aerotorques acting on solar arrays used to power the station.

The tetrahedral, three-dimensional station has other properties. Because it is self-rigidizing and omnidirectionally symmetrical, it can fly in an isotropic manner. That is, there is no natural preference for any orientation, so that the entire station can be rotated or otherwise maneuvered for orientation in any flight attitude, with minimum imbalance in its controllability. The atmospheric drag profile of the tetrahedral station is bigger than the triangular/planar station, but it can fly in generally symmetrical modes that will allow equalization and cancellation of aerotorques.

The connectors allow easy manual access for maintenance, repair, modification and replacement of utility systems in a shirtsleeves environment.

The attainment of the foregoing and related objects, advantages and features of the invention should be more readily apparent to those skilled in the art, after review of the following more detailed description of the invention, taken together with the drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of a tetrahedral space station in accordance with the invention.

Figure 2 is a longitudinal section view taken along the line 2-2 in Figure 2a of a berthing mechanism for assembling hubs and modules in accordance with the invention.

Figure 2a is a cross section view taken along the line 2a-2a in Figure 2.

Figure 3 is a longitudinal section view taken along the line 3-3 in Figure 3a of a portion of the assembly in Figure 2, but in another stage of assembly, with a structural clamp closed.

Figure 3a is a cross section view taken along the line 3a-3a in Figure 3.

Figure 4 is a perspective view of the assembly shown in Figure 3, but at the completion of assembly.

Figure 5 is a perspective view of a utility connection channel in accordance with the invention.

Figure 6 is a cross section view of a portion of the utility connection channel for fluid and gas utilities shown in Figure 5.

Figure 7 is a cross section view of another portion of the utility connection channel for electrical utilities shown in Figure 5.

Figure 8 is an end view of the utility connection channel of Figure 5.

Figure 9 is a cross section view taken along the line 8-8 in Figure 4 and showing utility connection channels as in Figure 5 in place in the assembly of Figure 4.

Figure 10 is a cross section view taken along the line 10-10 in Figure 1, showing details of a spherical berthing hub in accordance with the invention.

Figure 11 is a side and partial cross section view showing transport in a space shuttle cargo bay of space station components in accordance with the invention.

Figures 12a through 12f are plan views showing sequential assembly of a space station in accordance with the invention.

Figure 13 is a side section and elevation view of a typical module and hub pair of another embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Turning now to the drawings, more particularly to Figures 1-4, there is shown a space station assembly 20 with berthing hubs 22 in accordance with this invention. Modules 24 are assembled by the hubs 22 in a triangular configuration in two dimensions and a tetrahedral configuration in three dimensions, using a berthing mechanism 26, shown in Figures 2-4, to be described below. The cylindrical modules 24 may be outfitted in their interior to serve a variety of different uses in the space station, as indicated by the labels in Figure 1. Other equipment and modules may be attached to or incorporated into the space station 20, including logistics modules 28, a payload berthing or construction beam 30, a power resources module 32, including solar cell panels 34, and detachable experiment/laboratory module 36. As shown, one of the hubs 22 is employed for berthing space shuttle 38, using the same linkage assembly 26 used to attach modules 24 and the other components of the space station 20 together through the hubs 22, or the standard Apollo-Soyuz type single vector port (for shuttle only). Because the shuttle berthing hub 22 is located on an outside of an acute corner 40 of the tetrahedral configuration, the shuttle berthing hub 22 provides a "reverse" approach cone, making the berthing operation less difficult than with a more confining approach cone to a straight or planar surface.

The space station 20 of Figure 1 is shown in the configuration of a single tetrahedron. However, larger space stations made up of multiple tetrahedra comprised of hubs and modules assembled from modules 24 interconnected through hubs 22 and with berthing mechanisms 26 may be constructed. Significant advantages are obtained through use of such a tetrahedral form of construction arising from the self stabilizing or rigidizing, space filling, and equal interior and exterior angle properties of a tetrahedron. The space station 20, as well as larger space stations incorporating many tetrahedrons, are structurally stable and are omnidirectionally symmetric. In particular, the omnidirectional symmetry means that a close correlation can be maintained between a triangular or tetrahedral space station's shape symmetry and center of gravity. Such a close correlation is advantageous for orienting and moving the space station with thrusters and similar means of propulsion.

Figures 2-4 show details of the berthing mechanism 26 of the space station 20 in Figure 1 at various stages in the process of assembly. Module 24 and hub 22 each have flanged ports 50, which mate together to form the primary pressure seal 26. A clamp 52 consists of sections 54, 56 and 58, which are connected together by hinges 60 along their length. Radial stiffeners 61 are provided around the sections 54-58, for structural strength in the completed assembly. In the process of assembly, the module 24 and hub 22 are moved laterally together to the position shown in Figure 2, with the section 56 of the clamp 52 engaging both flanged ports 50. With the structural axes of the flanged ports 50 aligned in this manner, sections 54 and 58 of the clamp 52 are closed and latched loosely to allow rotation but not separation, to give the configuration shown in Figure 4. Module 24 is then rotated about the structural axis of its flanged port 50 as necessary to align utilities connections within the assembly 26, to be described below. The clamp 52 is then tightened and secured. A primary pressure seal 63 (Figure 3) is made at the mating flanges 62, and the assembly 26 is then pressurized. Hatches 64 and 66 in the hub 22 and the module 24 may now be opened by swinging or translating. Utilities channel connections 68 may now be inserted into the berthing assembly 26 in a "shirtsleeves" environment to complete the connection of module 24 and hub 22. This process of assembly is used to interconnect all of the modules and hubs of the space station 20, and may also be applied to docking with the space shuttle 38.

An example of a utilities connection channel 68 is shown in Figure 5. The connection channel 68 has a shell 70 with a radius of curvature configured to fit into the berthing assembly 26. Utility connector 72 and electrical connectors 74 are mounted inside channel housing 70. When the connection channel 68 is installed in the assembly 26, the utility connector 72 and the electrical connectors 74 are aligned opposite utility aperture 77 and electrical apertures 78, respectively. An actuator 80 on each end of the utility connector 72 is turned by an automated mechanism or by hand to extend the utility connector 72 into its corresponding utility aperture 77. Similar actuators 81 inside the channel housing on each end of the electrical connectors 74 are turned to extend the electrical connectors 74 into electrical apertures 78 in module 24 and hub 22.

Details of the gas or fluid utility connector 72 and the utility aperture 77 are shown in Figure 6. Tube 82 is fixedly mounted within the channel housing 70 at fixed mount 76. Actuator 80 is in the form of a drive nut which is threaded to the utility tube 82. End 84 of the utility connector 72 is connected to the actuator drive nut 80 by means of bearing 85, so that drive nut actuator 80 can rotate relative to the end 84. Fitting 86 into which the end 84 of connector 72 is extended by rotation of the drive nut actuator 80 is embedded in pressure shell wall 87 of the hub 22 by means of locknut and washer 88 and flange 89. Gaskets 90 ensure a hermetic seal among the tube 82, end 84, fitting 86 and wall 87. In use, the connection channel 68 is positioned so that end 84 is opposite aperture 77, and a spanner or similar wrench is manually or automatically used to drive nut 80 to advance the connector tip 84 into the utility aperture 77.

Details of the electrical connector 74 are shown in Figure 7. As in the case of the utility tube 82, the electrical cable 91 extends from the fixed mount 76 of the connection channel shell 70. A connector end 92 is threaded to the cable 91. Male connector pins 94 are mounted through block 95 and are attached to wires 96 within cable 91.

Also as in the utility connector 72, electrical apertures 78 are formed in an imbed fitting 97 extending through pressure walls 87 of the hub 22. Flange 98 and a locknut and washer 88 fix the imbed fitting 97 in place. Female connection pins 99 extend through block 100 within the imbed fitting 97. Threaded end 101 extends within the electrical aperture 78 surrounding the female connection pins 99, and is dimensioned to receive the connector end 92. A guide ridge 102 within the end 101 assures proper orientation of the end 92 within end 101 for mating of the male pins with the female pins 96. Nut tightener 81 advances the end 92 within the end 101. Gaskets 90 provide a hermetic seal among walls 87, imbed fitting 97 and ends 92 and 101.

Figure 8 shows additional details of the installation of the connection channels 68. Connection channels 68 are mounted to the inside surface of pressure shells 103 of the berthing ports 50 by means of index and anchoring support tabs 105 and bolts 107. Openings 109 in end wall 109a of the port 50 allow some flexibility in the location of male electrical connectors 74, female electrical apertures 78, male utility fluid or gas connectors 72 and female utility apertures 77, all of which are provided either in the mounts 76 of the connector channel 68 or in the hub 22 in mating relationship. Each connector channel 68 has a cover 111, hinged at 113 and latched at 115 to protect the utilities from adjacent through traffic and allow access to the interior of connection channel 68 for maintenance and installation. In practice, the connection channel 68 can be fabricated from light gauge aluminum or other sheet metal.

Figure 9 shows a layout of completed utilities connections in the berthing assembly 26. With the exception of the arc-segments of hatch hinge 117 and hatch latch 119, the connector channels 68 are installed in the entire circumference of the linkage assembly 26. The connector channels 68 can include a pneumatics channel 104, an intercom and video channel 106, a computer data link channel 108, a thermal coolant channel 110, and an electrical power channel 112. Duplicates of these channels 104-112 and other channels 68 are provided around the circumference of the assembly 26 as needed, in mirror image or inverted mirror image configuration.

Figure 10 shows further details of the hubs 22 in the space station 20. The flanged berthing ports 50 are spaced around the spherical or polyhedral interior of the hub 22. A total of six (in the figure) such ports 50 are provided in the hub 22, although a greater or lesser number of such ports can be provided for potential interconnections, with the limiting number of ports being determined by spacing required for the modules or other space station parts to be connected to the hub 22. Utilities lines 114 extend within the hub 22 and are fed into each port 50 for connection in a berthing assembly 26 incorporating the port 50. Utilities lines 114 extend between ports 50 in great circle arcs from inner collar 115 to inner collar 115. Person 116 passes through the ports 50 and the hub 22 while passing from one module 24 to another module 24 in the space station 20. Connection channels 68 extend between the flanged ports 50 of adjacent hubs 22 and modules 24. The hub 22 is formed from double walls 121.

Figure 11 shows how modules 24 and hubs 22 making up the space station 20 may be raised into orbit using the space shuttle 38. The placement of the denser hub at the stern/bottom of the cargo bay will conserve the critical location of the total shuttle cargo center of gravity envelope. A module 24 and a hub 22 may be interconnected on the ground and inserted in the cargo bay 118 of the shuttle 38. In this manner, a minimal configuration space station consisting of three modules 24, three hubs 22, and several smaller modules and other parts may be raised into orbit in four shuttle launches. Figure 10 also shows a docking and airlock port 120 for docking the shuttle 38 to the space station 20, in the same manner of interconnection assembly explained above for the space station 20 itself, or using existing Apollo-Soyuz type docking technology.

Figures 12a through 12f show an assembly sequence for a space station 150 based on a two dimensional triangle form of construction, which shows that a close correlation between axes of shape symmetry and centers of gravity may be maintained for the space station 150 as it grows. When the total mass of the space station is smaller, a more eccentrically located center of gravity can be allowed, but as the total mass increases, the center of gravity approaches closer to the symmetry of the station. In Figure 12a, a logistics module 28 and a power resources module 32 are interconnected by hub 22. Center of gravity 200 of this assembly is slightly to one side of axis of symmetry 154. In Figure 12b, a module 24 has been added to the assembly, along with a reboost module 156 for repositioning the space station 150 in its orbit. Center of gravity 200 of the space station 150 is slightly to one side of axis of symmetry 160 for the module 24. In Figure 12c, a second module 24 has been connected to the hub 22, a second logistics rack 28 has been added and the reboost module 156 in Figure 12b has been relocated and a beam 30 has been installed as a temporary construction brace for the modules 24. In this configuration, the center of gravity 200 and axis of shape symmetry 154 almost coincide. In Figure 12d, two more hubs 22 with logistics racks 28 and reboost modules 156 have been added. Beam 30 now connects the two additional hubs 22. The center of gravity 200 of this assembly remains almost on the axis of shape symmetry 154. In Figure 12e, a third module 24 is connected between the second and third hubs 22, a second power module 32 is installed on the third hub 22, and the beam 30 is stowed parallel to the third module 24. The center of gravity 200 of space station 150 is now slightly to one side of the axis 154. The Figure 12f, the first power module 32 has been relocated to the second hub 22, so that the two power modules 32 are at opposite ends of the station 150. A fourth and fifth module 24 have been added, to form a new triangle in the station 150. A fourth hub 22 has been added, and logistics racks 28 and reboost modules 156 are included and relocated as required. Center of gravity 200 and the cross-axes of shape symmetry 154 now coincide. This configuration allows ready reorientation and reboosting of the enlarged space station 150. In a similar manner, the space station 150 may be further enlarged in two or three dimensions by forming additional triangular assemblies of hubs 22 and modules 24.

Figure 13 shows a portion of another embodiment of a space station 201 in accordance with the invention; a typical module and berthing hub pair. The embodiment incorporates a berthing hub 22 as employed in the Figures 1-12 embodiments. Module 202 incorporates a cylinder 204 with hemispherical or hemi-polyhedral end caps 204 and 206. The hemispherical end caps 204 and 206 have flanged ports 50 of the same type as the flanged ports 50 of the spherical berthing hub 22. The module with its hemispherical end caps carries the active portion of the berthing mechanism, and the hub ports carry the passive portion. As shown, the hemispherical end caps 204 and 206 have a diameter somewhat less than the diameter of cylinder 203, for example, 12 feet for the end cap diameter and 14 feet for the cylinder diameter. In this embodiment, the diameter of end caps 204 and 206 is the same as the diameter of hub 22. A conical adapter section 208 at each end of the cylinder 203 joins the cylinder 203 to the hemispherical end caps 204 and 206. If desired, the end caps could have the same diameter as the cylinder 203 and be directly connected to it.

As shown, the hemispherical end cap 204 is configured as an air lock. If desired, the on axis flanged port 50 of the end cap 204 may be connected to another module, either directly, or through a berthing hub 22. The other flanged port 50 is used for access to space.

In use of the air lock formed by hemispherical end cap 204, an Extra Vehicular Activity (EVA) suit ("space suit") 210 is stored near hatch 212 connecting the end cap 204 and the cylinder 203. An astronaut or team of astronauts puts on the space suit 210, enters the hemispherical end cap 204, seals each hatch 212, 214 and 216, pumps down the end cap airlock 204, and then exits from the space station 200 through the hatch 216. This airlock can be sized to accommodate a larger team of astronauts going out EVA than the current shuttle airlock which accommodates only two.

A different use is shown for the hemispherical end cap 206. The end cap 206 serves to increase the available space in cylinder 203, as a connector to the berthing hub 22 through one flanged port 50, and as a connector through a second flanged port 50 to observation dome 214 for mechanical arm remote manipulator system (RMS) 216, used to manipulate equipment outside the space station 200 from within the station.

As indicated in Figure 13, the module 202 may be laid out to include a variety of functions, including a protected safe haven emergency supply package which, in the event of significant damage to the space station 200, will support life for the crew independently in that module for a period of time (such as 30 days) until repairs or rescue can be effected.

The hemispherical end caps 204 and 206 provide a number of advantages for the space station 200. Since the end caps 204 and 206 are based on the same form factor as the hubs 22, common tooling can be used. The end caps 204 and 206 can be used for a variety of purposes, thus increasing the options available in the assembly of the space station 200. Hatch 216 of the end cap 204 may be used as an alternative access to the cylinder 203 when the flanged port 50 of hatch 214 has already been blocked off in the space shuttle 38 prior to launch. Such an alternative access is highly convenient for last minute loading of, for example, life sciences experiments just prior to shuttle launch.

It should now be readily apparent to those skilled in the art that a novel space station, berthing mechanism assembly, berthing hubs and utility connection channels common module shell capable of achieving the stated objects of the invention has been provided. Through use of the triangular and tetrahedral space station architecture of this *invention, a space filling structure of modules may be* arranged with omnidirectional symmetry. The sideways approachable coupling assembly facilitates both assembly of the space station and docking. The connection channel provides a convenient utilities feed through as modules are added to the space station. Critical connection functions are separated by a vector both in time and in space. The component parts of a space station in accordance with this invention may be raised into orbit with a small number of space shuttle launches and assembled into the completed space station easily. Such a space station may grow into a large installation over time through the addition of additional modules and couplings.

It should further be apparent to those skilled in the art that various changes in form and detail of the invention as shown and described may be made. For example, the hub 22 and end caps 204 and 206 in Figure 13 could be polyhedral in configuration. It is intended that such changes be included within the spirit and scope of the claims appended hereto.

ABSTRACT OF THE DISCLOSURE

A space station (20) includes a plurality of modules (24) and berthing hubs (22), joined by interconnections (26) which are sideways connectable. The modules (24) and hubs (22) are fastened together in a triangular configuration in three dimensions. The interconnections (26) include a pair of opposed, axially aligned, flanged ports (50) and a clamp latch (52) formed from a plurality of sections (54, 56 and 58) hinged along their length and extending circumferentially around the flanged ports (50). A hermetic seal (63) is formed between the ports (50). A utilities connection channel (68) extends between the ports (50). The channel (68) has a shell (70) with utilities connectors (74) movable between an extended position to mating connectors in the modules (24) and a withdrawn position. Assembly sequence and common module shell structure is detailed.