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— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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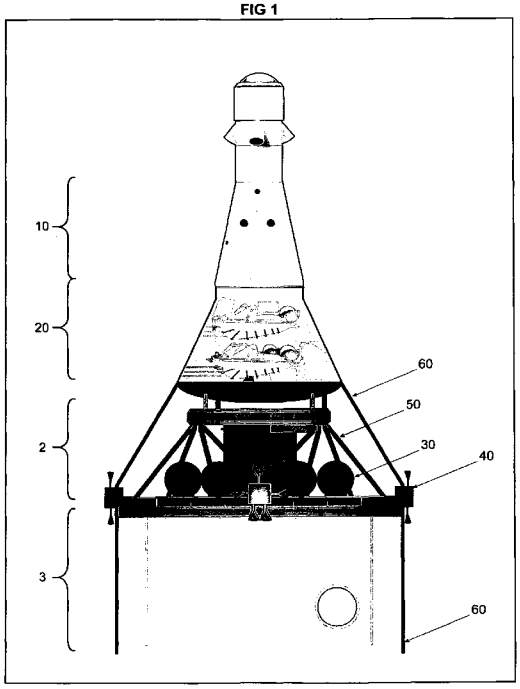
[Continued on next page]

(54) **Title**: CAPSULE SYSTEM, SERVICE MODULE, AND REUSEABLE REENTRY PAYLOAD AND DOCKING MODULE

FIG 1



(57) **Abstract**: A modular spacecraft comprising: a capsule module comprising a common bulkhead, and [0090] an additional spacecraft module comprising a common bulkhead, wherein said capsule module's common bulkhead is attached to said additional spacecraft module's common bulkhead.

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CAPSULE SYSTEM, SERVICE MODULE, AND REUSEABLE REENTRY PAYLOAD AND DOCKING MODULE

BACKGROUND

[001]The invention relates generally to spacecraft and more particularly to reusable modular vehicles capable of orbital boost, reentry, docking, and carrying payloads or passengers.

[002]The approaches described in this section are approaches that could be pursued, but not necessarily approaches that have been previously conceived or pursued. Therefore, unless otherwise indicated, it should not be assumed that any of the approaches described in this section qualify as prior art merely by virtue of their inclusion in this section.

BRIEF DESCRIPTION

[003]This invention pertains to the the structure and function of spacecraft. Specifically, this invention is in the field of spacecraft having a modular design. A spacecraft in accordance with an embodiment of the present invention provides capability for orbital boost to a higher altitude, rendezvous, docking and return of a capsule and a reusable payload module for use with a commercial space station facility. To allow for the spacecraft to be adaptable to multiple functional roles without the need for redesign and re-fabrication, the spacecraft architecture comprises independent modules each comprising a common bulkhead. These modules can be combined together in different combinations in order to give the spacecraft the hardware necessary to achieve these different functional roles presented by the mission at hand.

DRAWINGS

[004]These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with

reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[005]FIG. 1 shows a spacecraft comprising a capsule system, a service module, and a reusable reentry payload and docking module in accordance with an embodiment of the present invention.

[006]FIG. 2 shows a Service Module comprising a pressurized tunnel and unpressurized support structure in accordance with an embodiment of the present invention.

[007]FIG. 3 shows a Service Module comprising a pressurized tunnel and unpressurized support structure in accordance with an embodiment of the present invention.

[008]FIG. 4 shows a Service Module comprising a pressurized core element and unpressurized support structure in accordance with an embodiment of the present invention.

[009]FIG. 5 shows a Service Module comprising a pressurized core element and unpressurized support structure in accordance with an embodiment of the present invention.

[0010]FIG. 6 shows payload return capsule reentry diagram.

DETAILED DESCRIPTION

[0011] The modular aspect of spacecraft architecture in accordance with an embodiment of the present invention is based on a common bulkhead. This common bulkhead is a circular sheet of rigid material that is at least the interior diameter of the cargo modules. The common bulkhead can itself serve multiple purposes by having a hatch, a window, a cupola, or some other feature, usually at the center of the common bulkhead. The common bulkhead could also be solid rigid material with no penetrations. The majority of modules that can affix to the the spacecraft architecture

do so through either being affixed to another module being separated by the common bulkhead or attaching to a hatch located in the center of the common bulkhead.

[0012]Shown in FIG. 1 is a spacecraft comprising three major components in accordance with an embodiment of the present invention. The major components comprise a capsule system 1, a service module 2, and a reusable reentry payload and docking module 3. The combination provides unique capabilities for transport of crew and payloads to an orbiting commercial space station.

[0013]A spacecraft in accordance with an embodiment of the present invention can provide for: orbital boost to a higher altitude of a ground launched capsule 1; fine positioning, rendezvous and docking with a space station; and separation, de-orbit and reentry of both a reusable capsule 1 and reusable payload module 3.

[0014]A service module 2, as shown in FIGS. 2 and 3 in accordance with an embodiment of the present invention, can provide structure 50, tankage 30, plumbing, avionics, additional power, motors 40 for coarse and fine alignment and de-orbit, and a tunnel 70 for pressurized exchange of crew and payloads between the payload docking module 3 and the capsule 1. The payload docking module 3 is reusable and provides all the elements needed for docking; the pressurized environment for payload storage and crew direction of proximity operations, rendezvous and docking system control. The payload docking module 3 is derived from the basic capsule 1 modified to include the docking system and a modified parachute landing system.

[0015]The service module 2 provides the maneuverability for the capsule 1 and reusable reentry payload and docking module 3 to raise the combined vehicle altitude and allow for rendezvous and docking with a commercial space station. The reusable reentry payload and docking module 3 provides the docking system and payload capacity to support space station logistics. The combination of the crew capsule 1, service module 2 and reusable reentry payload and docking module 3, provides the integrated system for transport of crew and payloads to and from an orbiting space station.

[0016]The modularity of the design of the service module 2 allows for simple modification to support space stations located at higher or lower altitudes.

[0017]Certain components of a spacecraft in accordance with an embodiment of the present invention can be based on highly mature spaceflight hardware to provide the ability to reuse approximately 20-35 times multiple high cost elements of the reusable reentry payload and docking module 3. The combination of elements proposed can provide a very cost effective approach for routine travel to and from any compatible space station.

[0018]An embodiment wherein service module 2 is stacked at the bottom of the vehicle can perform a space tug function. Configuring an embodiment with the service module 2 on bottom adds some complexity but allows for reuse of service module 2. In a space tug embodiment, the service module 2 would function in same basic manner as other embodiments with the following exception: a Soyuz OM replaces Almaz capsule for reusable reentry payload and docking module 3 – trade the cost vs. benefit of development and reuse of Almaz reusable reentry payload and docking module 3 vs. modification and no reuse of the Soyuz OM. This embodiment also limits the capability for return of payloads to the Almaz capsule 1 reentry vehicle only.

[0019]Certain embodiments of the present invention comprise a service module 2 having payload return capability. Figures 4 and 5 show an embodiment comprising a pressurized service module 2 with required air resupply and propellant tanks 30, fine attitude thrusters 40 for rendezvous and docking and course thrusters 40 for major delta velocity addition along with two payload return vehicles 80. Payload return vehicles 80 could be based on an existing Russian design. A payload return vehicle 80 is shown in Figure 6.

[0020]A docking system could be located at the forward end of the system in this embodiment. A hatch for connecting a capsule 1 and a service module 2 could be

located at the aft of this vehicle. Two payload return canisters 80 are shown located at the aft end facing nadir and zenith.

[0021]FIG 6 shows payload return capsule reentry diagram. After ejection from the space craft it spins up by a small solid rocket motor. Then the main retro rocket fires and after burnout another small solid rocket fires to de-spin the capsule. The rocket motor pack is jettisoned before reentry. Before landing, a drogue chute pulls the capsule out of the heat shield. An airbag is inflated to cushion the landing.

[0022]An embodiment of the present invention could comprise a modular spacecraft comprising one or more modules using a common bulkhead. The modular spacecraft architecture preferably allows for compatibility with a plurality of existing launch vehicles so as to allow for maximum compatibility with minimal cost. The spacecraft architecture can be equipped with different combinations of varying modules in order to best be adapted for the requirements presented by differing mission scenarios.

[0023] Configurations:

[0024] ISS Crew Transport:

[0025] This embodiment of the present invention comprises a capsule module that provides the crew of the mission with a pressurized living space from which all of the spacecraft's systems are controllable, an escape tower module which allows for emergency separation of the manned capsule from the rest of the spacecraft in the event of an emergency, and an intermediate propulsion stage which allows for the maneuvering of the spacecraft while it is under the effects of microgravity.

[0026]Short Range Tourist:

[0027] This embodiment of the present invention comprises a capsule module which provides the crew of the mission with a pressurized living space from which all of the spacecraft's systems are controllable, an escape tower module which allows for emergency separation of the manned capsule from the rest of the spacecraft in the event of an emergency, an intermediate propulsion stage which allows for the maneuvering of the spacecraft while it is under the effects of microgravity, and a pressurized cargo module with either a copula or window set in the terminal common

bulkhead thus allowing the crew and tourist an extra pressurized living compartment which also allows a view outside of the spacecraft.

[0028]Short Range Tourist B:

[0029] This embodiment of the present invention comprises; a capsule module that provides the crew with a pressurized living space from which all of the spacecraft's systems are controllable, an escape tower module that allows for emergency separation of the manned capsule from the rest of the spacecraft in the event of an emergency, an intermediate propulsion stage that allows for the maneuvering of the spacecraft while it is under the effects of microgravity, and a D-shaped pressurized cargo module with either a copula or window set in the terminal common bulkhead, and another copula or window set in the flat portion of the D-shaped module, thus allowing the crew and tourist an extra pressurized living compartment that also allows a view outside of the spacecraft.

[0030]Pressurized Cargo Transport:

[0031] This embodiment of the present invention comprises; a capsule module that provides the crew of the mission with a pressurized living space from which all of the spacecraft's systems are controllable, an intermediate propulsion stage which allows for the maneuvering of the spacecraft while it is under the effects of microgravity, and a D-shaped pressurized cargo module with a passive common birthing mechanism outfitted on the flat side of the D-shaped pressurized cargo module so that the module can dock with the ISS or similar vessel and easily transfer cargo between the spacecraft and the ISS or similar vessel.

[0032]Pressurized Cargo Transport (Heavy):

[0033] This embodiment of the present invention comprises; a capsule module which provides the crew of the mission with a pressurized living space from which all of the spacecraft's systems are controllable, an intermediate propulsion stage which allows for the maneuvering of the spacecraft while it is under the effects of microgravity, a D-shaped pressurized cargo module with a passive common berthing mechanism outfitted on the flat side of the D-shaped pressurized cargo module so that the module can dock with a spacecraft, such as the ISS, and easily transfer cargo between the two spacecraft, and a pressurized cargo module that allows for increased pressurized volume for the pressurized transport of materials.

[0034]Pressurized and Unpressurized Cargo Transport:

[0035] This embodiment of the present invention comprises; a capsule module that provides the crew of the mission with a pressurized living space from which all of the spacecraft's systems are controllable, an intermediate propulsion stage which allows for the maneuvering of the spacecraft while it is under the effects of microgravity, a D-shaped pressurized cargo module with a passive common birthing mechanism outfitted on the flat side of the D-shaped pressurized cargo module so that the module can dock with a spacecraft such as the ISS and easily transfer cargo between the two spacecraft, and an unpressurized cargo module that allows for increased unpressurized volume for the unpressurized transport of materials.

[0036]Long Range Tourist:

[0037] This embodiment of the present invention comprises; a capsule module which provides the crew of the mission with a pressurized living space from which all of the spacecraft's systems are controllable, an escape tower module which allows for emergency separation of the manned capsule from the rest of the spacecraft in the event of an emergency, an intermediate propulsion stage that allows for the maneuvering of the spacecraft while it is under the effects of microgravity, a pressurized cargo module that provides extra pressurized volume for habitation by the crew and tourists, and a long range propulsion module that would provide more delta v such that the spacecraft may perform maneuvers at a longer range than would be possible with just the intermediate propulsion stage along.

[0038]Capsule:

[0039] A capsule module, according to the present invention, can be an Almaz, Orion, or any other manned or unmanned, pressurized or unpressurized capsule. If the capsule module is manned, then the capsule module will preferably be fixedly connected to the escape tower module so that the escape tower module can pull the manned capsule module away from the rest of the spacecraft in the case of life threatening emergency. The capsule module may also have a hatch that connects to the common bulkhead on the capsule's underside that allows the transfer of personnel or cargo to or from the capsule to any one of a plurality of other modules.

[0040]Escape tower module:

[0041] An escape tower module according to the present invention contains one or more rocket motors. The escape tower module is attached directly to the capsule module so that in the case of an emergency, the capsule module can be separated from the rest of the spacecraft and pulled away from the rest of the spacecraft by the firing of the escape tower module's rocket motors. Furthermore, in order to be able to perform this crucial separation and escape process at any time throughout the launch, deployment, and re-entry of the spacecraft the escape tower module cannot be confined within the fairing at the time of the spacecraft's launch.

[0042]Intermediate propulsion module:

[0043] According to the present invention, the intermediate propulsion module comprises; fuel storage tanks, and one or more rocket motors in fluid communication via piping to fuel storage tanks. The module further comprises a common bulkhead such that the intermediate propulsion module may be attached to another module on one or both sides.

[0044]Long range propulsion module:

[0045] Long range propulsion module could comprise a long range rocket propulsion module from the orion spacecraft system. Said long range propulsion module should be mounted to the bottommost common bulkhead interface on the modular spacecraft embodiment.

[0046]Pressurized cargo module:

[0047] A pressurized cargo module according to the present invention comprises an airtight cylindrical shell, said cylindrical shell being capped at either end by a common bulkhead. The common bulkheads at either end of the cylindrical shell can be equipped with any possible combination of common bulkhead additions. Being a pressurized vessel, this pressurized cargo module can be used either as a cargo compartment or as a living compartment connected to the capsule module via a hatch in one of the common bulkheads of the pressurized cargo module.

[0048]Unpressurized cargo module:

[0049] An unpressurized cargo module according to the present invention comprises a frame of rigid material that is not air tight. The module has a rigid cylindrical frame capped on both sides by common bulkheads so that the module has an interior volume. The unpressurized cargo module may be outfitted with a hatch

disposed in part of the cylindrical frame, so as to allow the ingress and egress of cargo without going through a hatch in one of the capping common bulkheads.

[0050]D-shaped Pressurized Cargo Compartment:

[0051] A D-shaped Pressurized Cargo Compartment module according to the present invention has a D-shaped cross-section instead of the cylindrical cross-section of the standard pressurized cargo compartment. Like the standard pressurized cargo compartment the D-shaped pressurized cargo compartment is capped at its ends by common bulkheads. Preferably, the flat portion of the D-shaped pressurized cargo compartment can be modularly fitted with a cupola, a hatch, or an extendable docking mechanism.

[0052]Fairing:

[0053] A fairing can be placed on top of/around the spacecraft modules for improved aerodynamics. A notable exception to the coverage of the fairing is when manned flights call for the utilization of an escape tower. If the spacecraft is configured for manned space missions the fairing would remain around the majority of the modules, however, the escape tower would protrude from the top of the fairing so that if necessary the rocket motors in the tower can fire and pull away the maned capsule module from the rest of the spacecraft without being encumbered or obstructed by the fairing.

[0054]Common bulkhead:

[0055]The common bulkhead comprises a rigid structure[] in the shape of a circle which prevents the flow of air. The common bulkhead may further comprise a window[], cupola[], docking adapter[], or pressurized tunnel[] set in the middle of rigid circular structure[].

[0056]

[0057]D-Shaped Pressurized Cargo Module:

[0058] In this module the circumference of common bulkhead[] is affixed to one of the open ends of D-shaped wall[]. The other open end of D-shaped wall[] is similarly affixed to the circumference of common bulkhead[]. Docking device[], extendible docking device[], window[], or cupola[] may be attached to flat surface[] of D-shaped wall[], otherwise the flat surface[] of D-shaped wall[] will be solid. The parts of this module are rigidly or movably affixed to one another in such a manner as to have the

interior volume of the module hermetically sealed from the exterior volume of the module.

[0059]

[0060]Pressurized Cargo Module:

[0061]In this module the circumference of common bulked[] is affixed to one of the open ends of cylindrical wall[]. The other open end of cylindrical wall[] is similarly affixed to the circumference of common bulkhead[]. Window[], docking adapter[], extendable docking adapter[], or cupola[] can be set into the surface of cylindrical wall[]. The parts of this module are rigidly or movably affixed to one another in such a manner as to have the interior volume of the module hermetically sealed from the exterior volume of the module.

[0062]

[0063]Unpressurized Cargo Module:

[0064]In this module the circumference of common bulked[] is affixed to one of the open ends of cylindrical cage[]. The other open end of cylindrical cage[] is similarly affixed to the circumference of common bulkhead[]. Docking adapter[], or extendable docking adapter[] may be set into the wall of cylindrical cage[]. The parts of this module need not be affixed to one another so as to form a hermetic seal.

[0065]

[0066]Long Range Propulsion Module:

[0067]This module comprises the propulsion module from an Orion capsule fixably attached to a common bulkhead[].

[0068]

[0069]Escape Tower Module:

[0070]This module comprises one or more rocket motors[], one or more fuel tanks[], piping[], one or more parachutes[], and an external fairing[]. In this module fuel tanks[], and parachutes[] are retained within the interior volume of external fairing[]. Rocket motors[] are connected to fuel tanks[] by piping[]. Rocket motors[] are fixedly or movably affixed to external fairing[] so that the nozzle end[] of said rockets[] are in fluid communication with external fairing[]'s exterior volume.

[0071]

[0072]Configurations

[0073]ISS Crew Transport:

[0074]In this configuration Escape Tower Module[90] is fixedly attached to nosecone[10] of Capsule Module[]. The bottom end[20] of Capsule Module[] is removably attached to the common bulkhead[160] portion of Intermediate Propulsion Module[2]. A Fairing[] may be positioned around the circumference of Intermediate Propulsion Module[2] for improved aerodynamics during launch.

[0075]

[0076]Short Range Tourist:

[0077]In this configuration Escape Tower Module[90] is fixedly attached to nosecone[10] of Capsule Module[1]. The bottom end[20] of Capsule Module[1] is removably attached to the common bulkhead[160] portion of Intermediate Propulsion Module[2]. Habitable Module [3], Pressurized Cargo Module[110], or D-shaped Pressurized Cargo Module[100] is fixedly attached to the aft end of Intermediate Propulsion Module[2]. The interior volume of Habitable Module [3], Pressurized Cargo Module[] or D-shaped Pressurized Cargo Module[100] may be in fluid communication with the interior volume of Capsule Module[1] through the use of a pressurized tunnel[] that runs through common bulkheads[160]. A Fairing[] may be positioned around the circumference of all modules in this configuration with the exception of the Escape Tower Module[] and Capsule Module[].

[0078]

[0079]Pressurized Cargo Transport:

[0080]In this configuration Capsule Module[] is fixedly attached to the common bulkhead[] portion of Intermediate Propulsion Module[2]. Either a Pressurized Cargo Module[110] or a D-shaped Pressurized Cargo Module[100] is fixedly attached by one of its common bulkheads[] to the other side of the Intermediate Propulsion Module[2]. Grapple fixtures [170] may or may not be attached to the Intermediate Propulsion Module[2], where the grapple fixtures [170] may be passive or have power and data capacities. More Habitable Modules [3],Pressurized Cargo Modules[110] or D-shaped Pressurized Cargo Modules[100] may, but do not have to, be connected (common bulkhead[] to common bulkhead[]) to the first Pressurized Cargo Module[110]. A Fairing[] may be positioned around the circumference of all modules in this configuration so as to improve the aerodynamic properties of the system. The

Pressurized Cargo Modules[110] or D-shaped Pressurized Cargo Modules[100] can optional include modular attachments such as a NASA Docking System (NDS) [130], an Androgynous Peripheral Attach System (APAS) [120], or a Passive Common Berthing Mechanism (PCBM) [140].

[0081]

[0082]Unpressurized Cargo Transport:

[0083]In this configuration Capsule Module[] is fixedly attached to the common bulkhead[] portion of Intermediate Propulsion Module[]. Either a Pressurized Cargo Module[] or a D-shaped Pressurized Cargo Module[] is fixedly attached by one of its common bulkheads[] to the other side of of the Intermediate Propulsion Module[]. Grapple fixtures [170] may or may not be attached to the Intermediate Propulsion Module[2], where the grapple fixtures [170] may be passive or have power and data capacities. One or more Unpressurized Cargo Modules[220] may, but do not have to, be connected (common bulkhead[] to common bulkhead[]) to the first Pressurized Cargo Module[]. A Fairing[] may be positioned around the circumference of all modules in this configuration so as to improve the aerodynamic properties of the system. The Pressurized Cargo Modules[110] or D-shaped Pressurized Cargo Modules[100] can optional include modular attachments such as a NASA Docking System (NDS) [130], an Androgynous Peripheral Attach System (APAS) [120], or a Passive Common Berthing Mechanism (PCBM) [140].

[0084]

[0085]Long Range Tourist:

[0086]In this configuration Escape Tower Module[] is fixedly attached to nosecone[] of Capsule Module[]. The bottom end[] of Capsule Module[] is removably attached to the common bulkhead[] portion of Intermediate Propulsion Module[]. Pressurized Cargo Module[], or D-shaped Pressurized Cargo Module[] is fixedly attached to the aft end[] of Intermediate Propulsion Module[]. Common bulkhead[] of Long Range Propulsion Module[] is fixably attached to the remaining common bulkhead[] of Pressurized Cargo Module[]. The interior volume of Pressurized Cargo Module[] or D-shaped Pressurized Cargo Module[] may be in fluid communication with the interior volume of Capsule Module[] through the use of a pressurized tunnel[] that runs through common bulkheads[]. A Fairing[] may be positioned around the

circumference of all modules in this configuration with the exception of the Escape Tower Module[] and Capsule Module[].

[0087]While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

CLAIMS:

1. A modular spacecraft comprising:

a capsule module comprising a common bulkhead, and

an additional spacecraft module comprising a common bulkhead, wherein said capsule module's common bulkhead is attached to said additional spacecraft module's common bulkhead.

3. A modular spacecraft according to claim 1 wherein:

said spacecraft module is selected from the list consisting of

a pressurized storage module,

an unpressurized storage module,

a short range propulsion module, and

a long range propulsion module.

3. A modular spacecraft comprising:

a capsule module comprising a common bulkhead,

a service module comprising a common bulkhead, and

a reusable reentry payload and docking module comprising a plurality of common bulkheads, wherein

one of the reusable reentry payload and docking module's common bulkheads is attached to the capsule module's common bulkhead, and

one of the reusable reentry payload and docking module's common bulkheads is attached to the service module's common bulkhead.

FIG 1

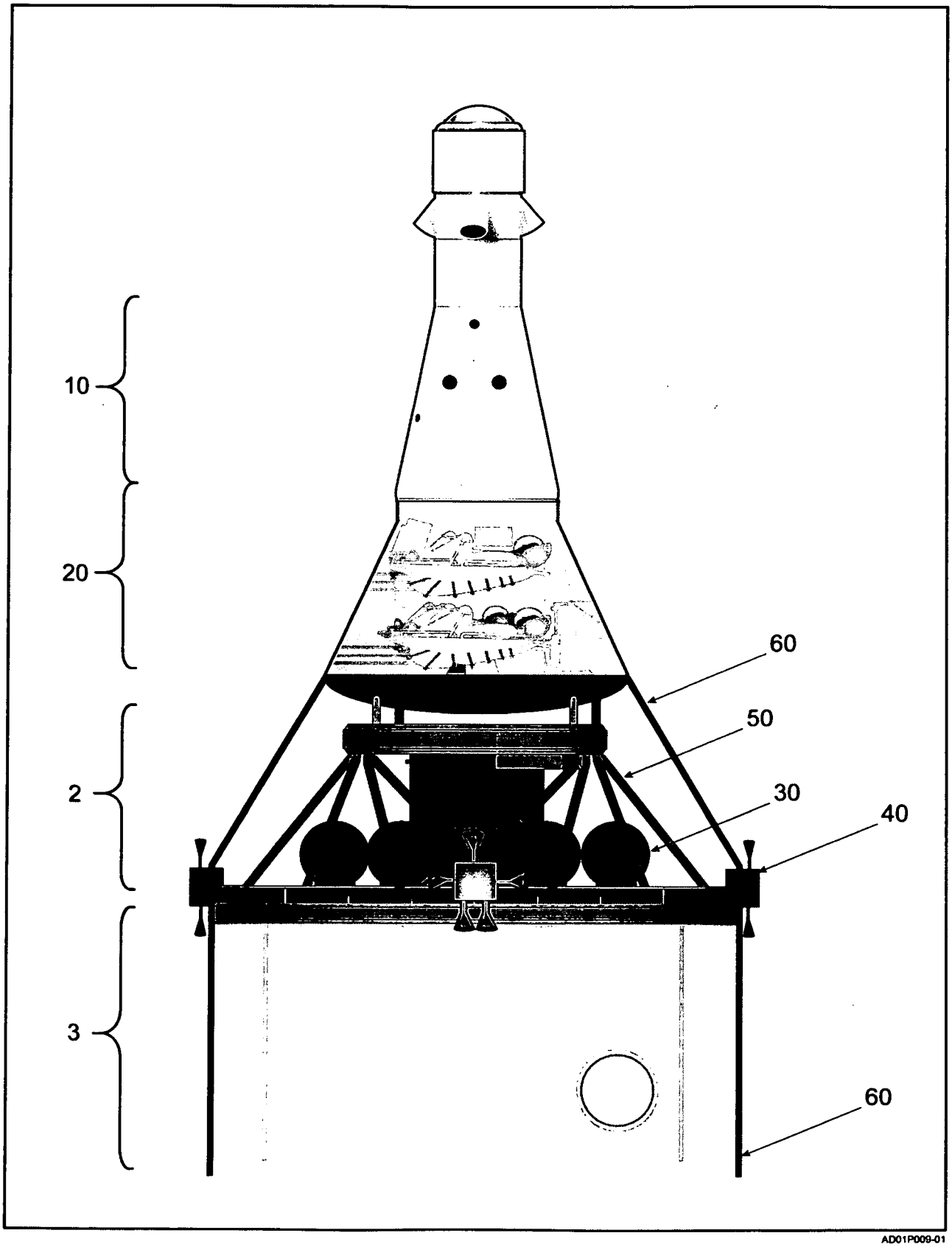

FIG 2

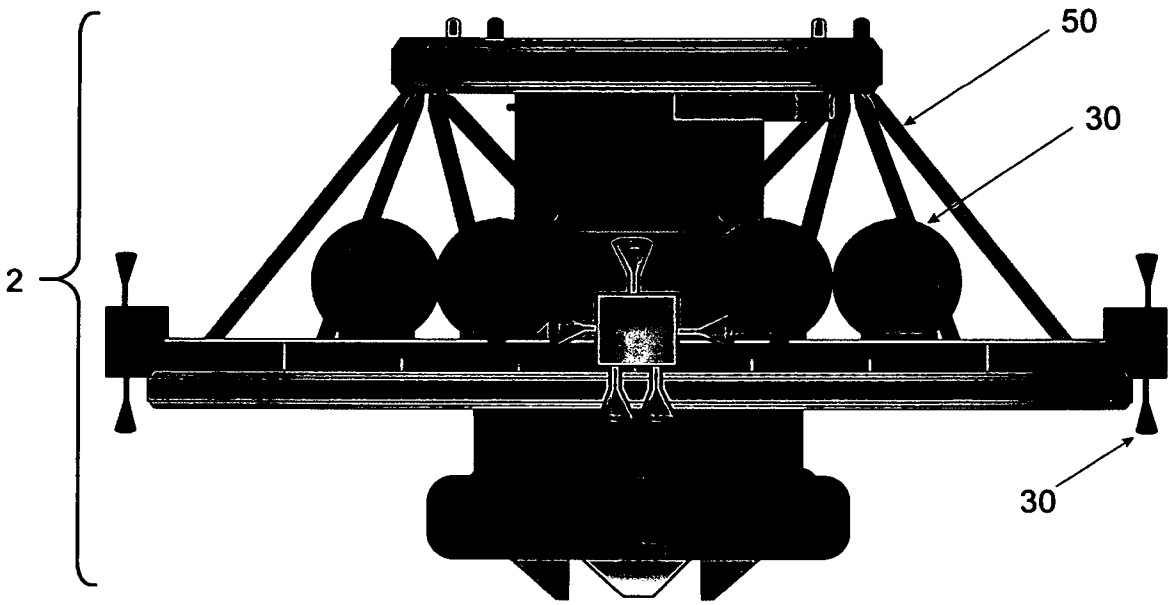

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FIG 3

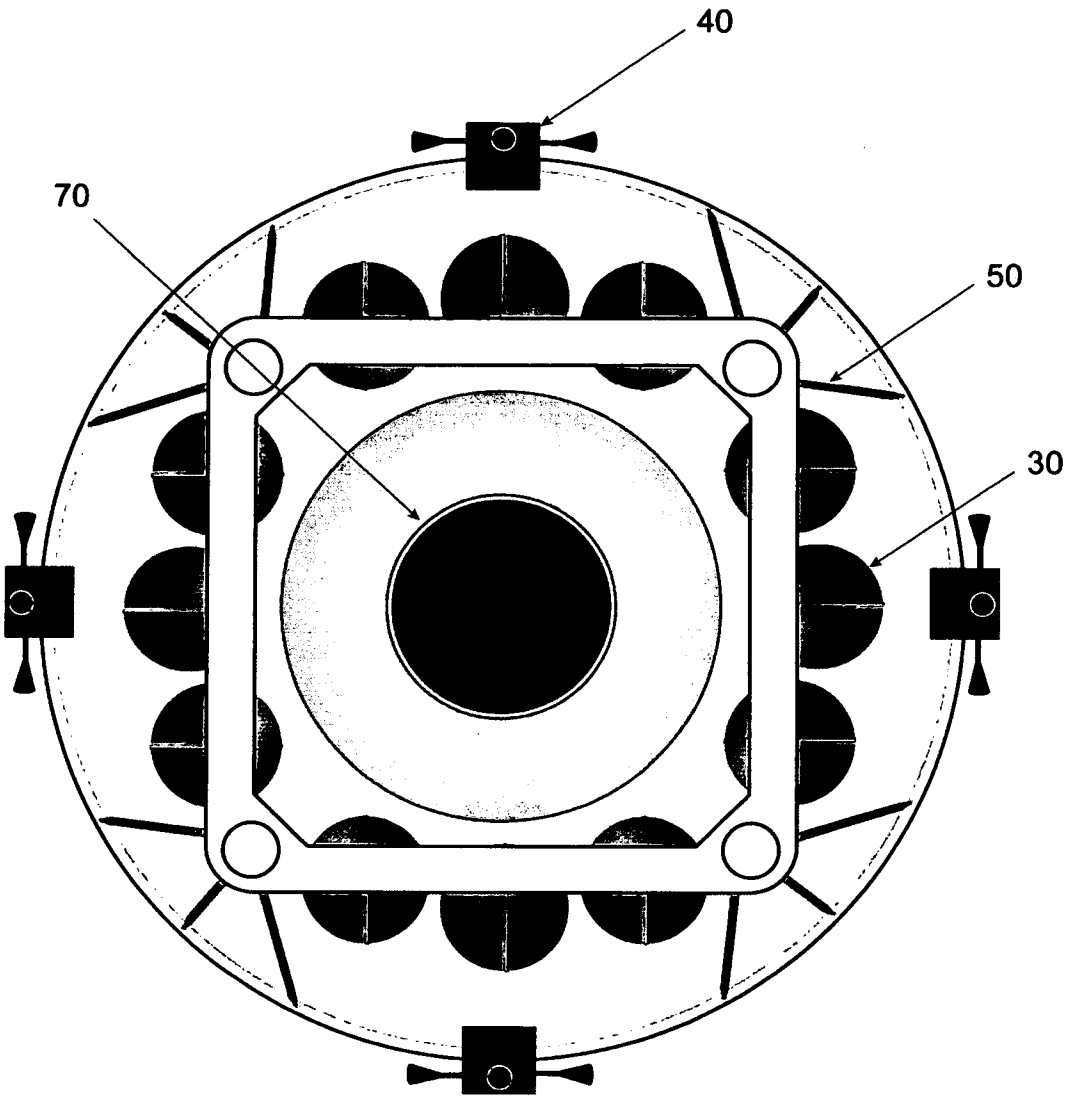

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FIG 4

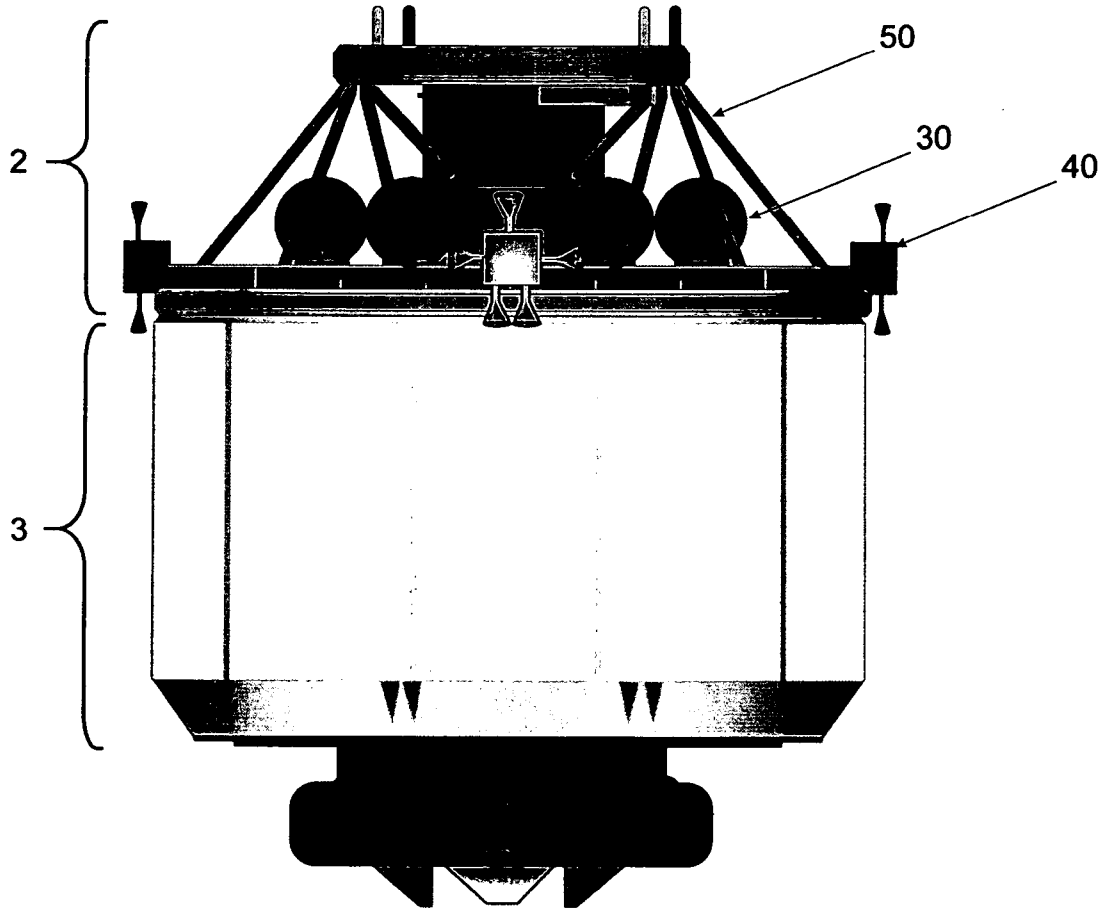

FIG 5

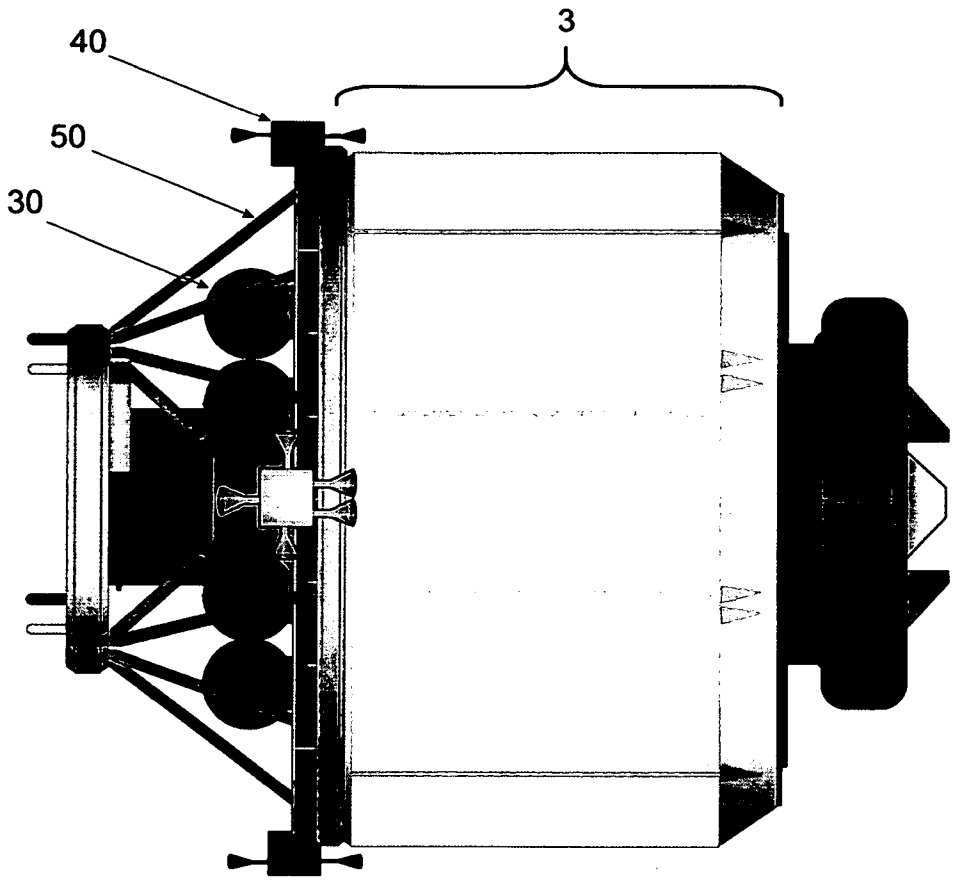

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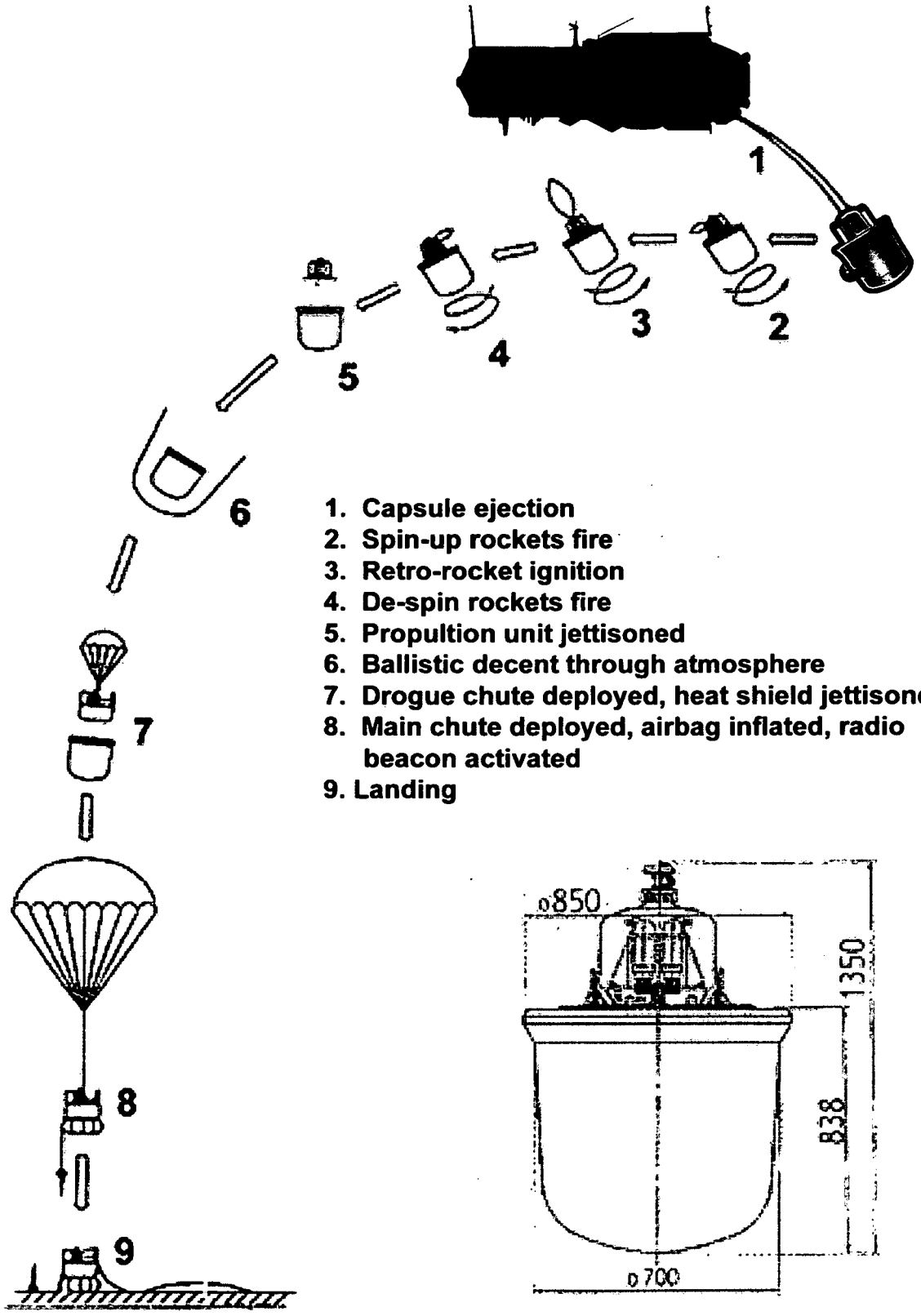
FIG 6


1
2
3
4
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6
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8
9
1. Capsule ejection
2. Spin-up rockets fire
3. Retro-rocket ignition
4. De-spin rockets fire
5. Propultion unit jettisoned
6. Ballistic decent through atmosphere
7. Drogue chute deployed, heat shield jettisoned
8. Main chute deployed, airbag inflated, radio beacon activated
9. Landing
ø850
1350
838
ø700
AD01P009-08

FIG 7

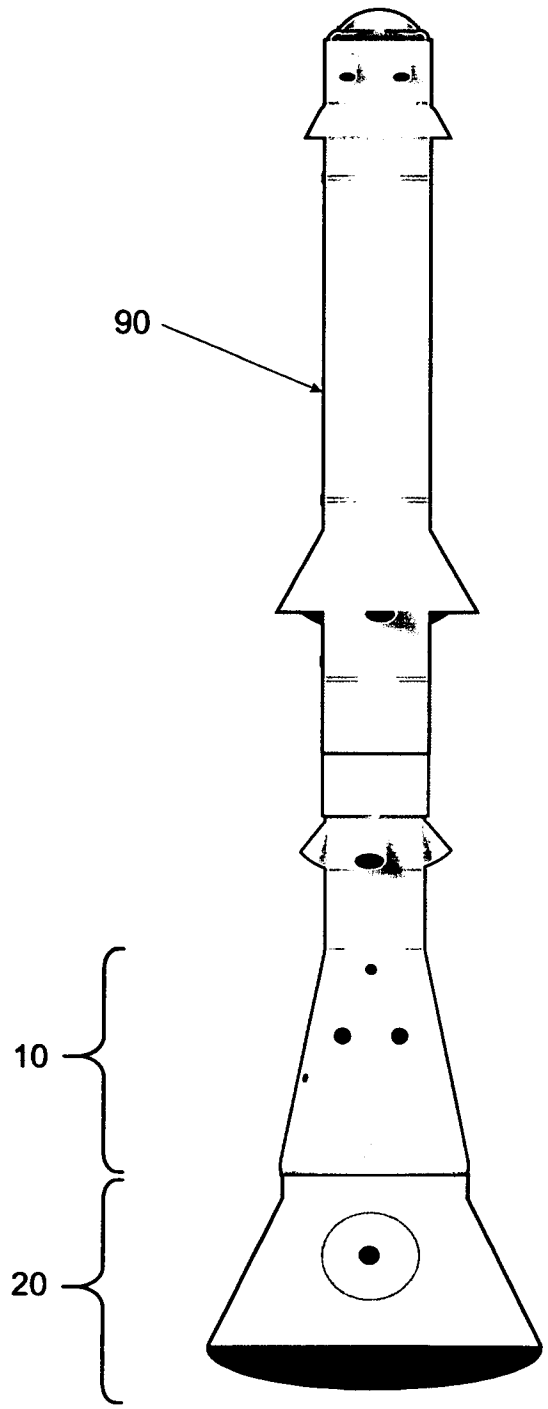

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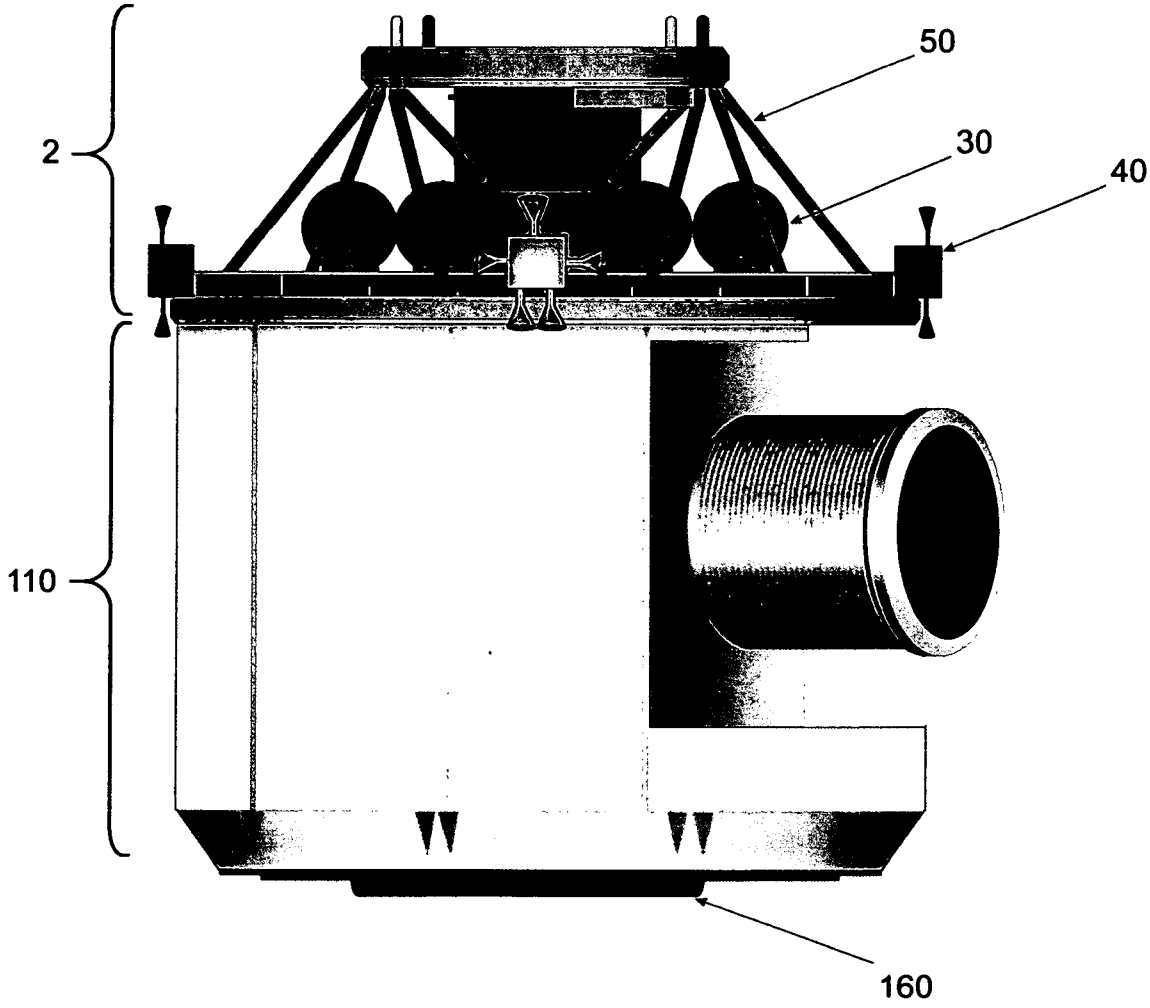
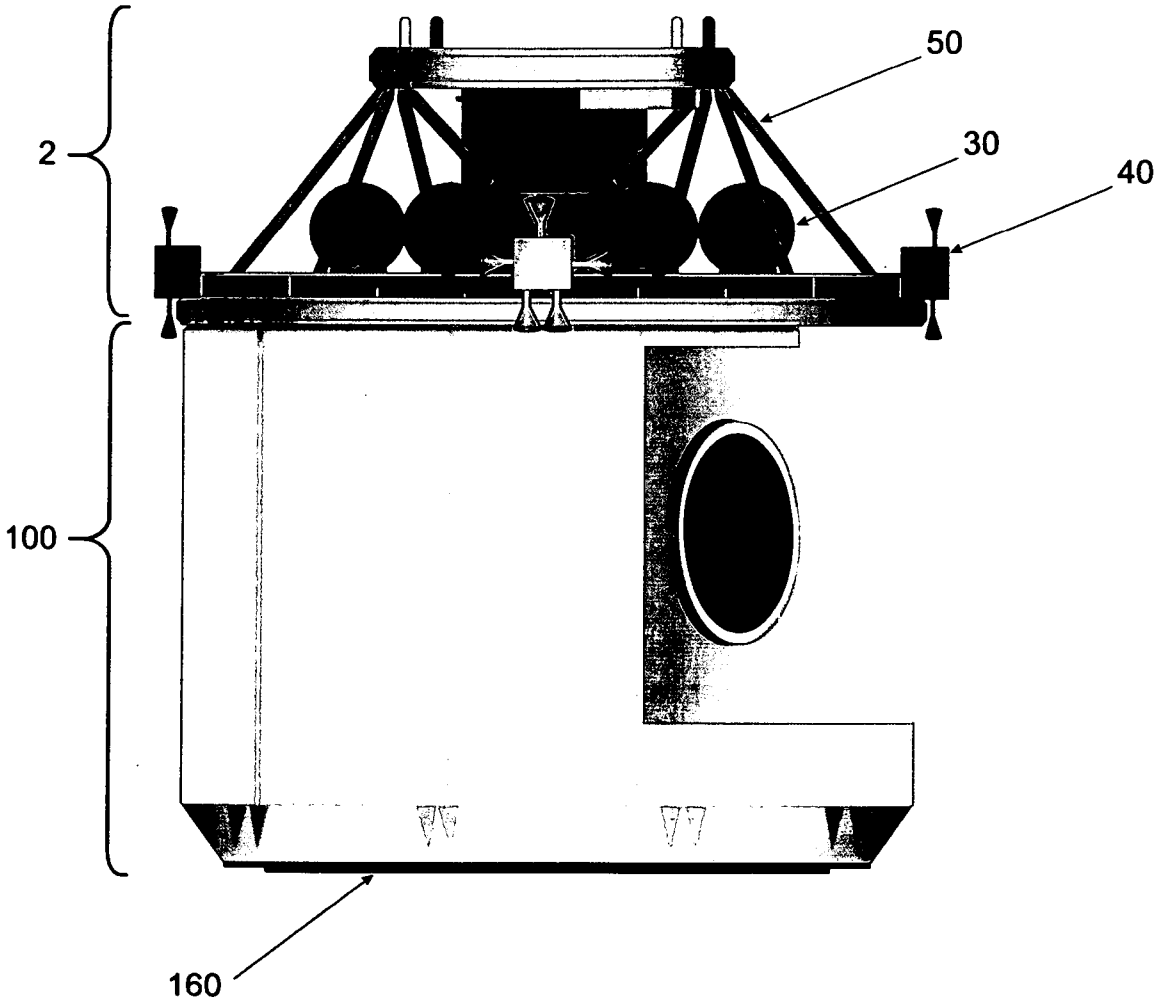
FIG 8



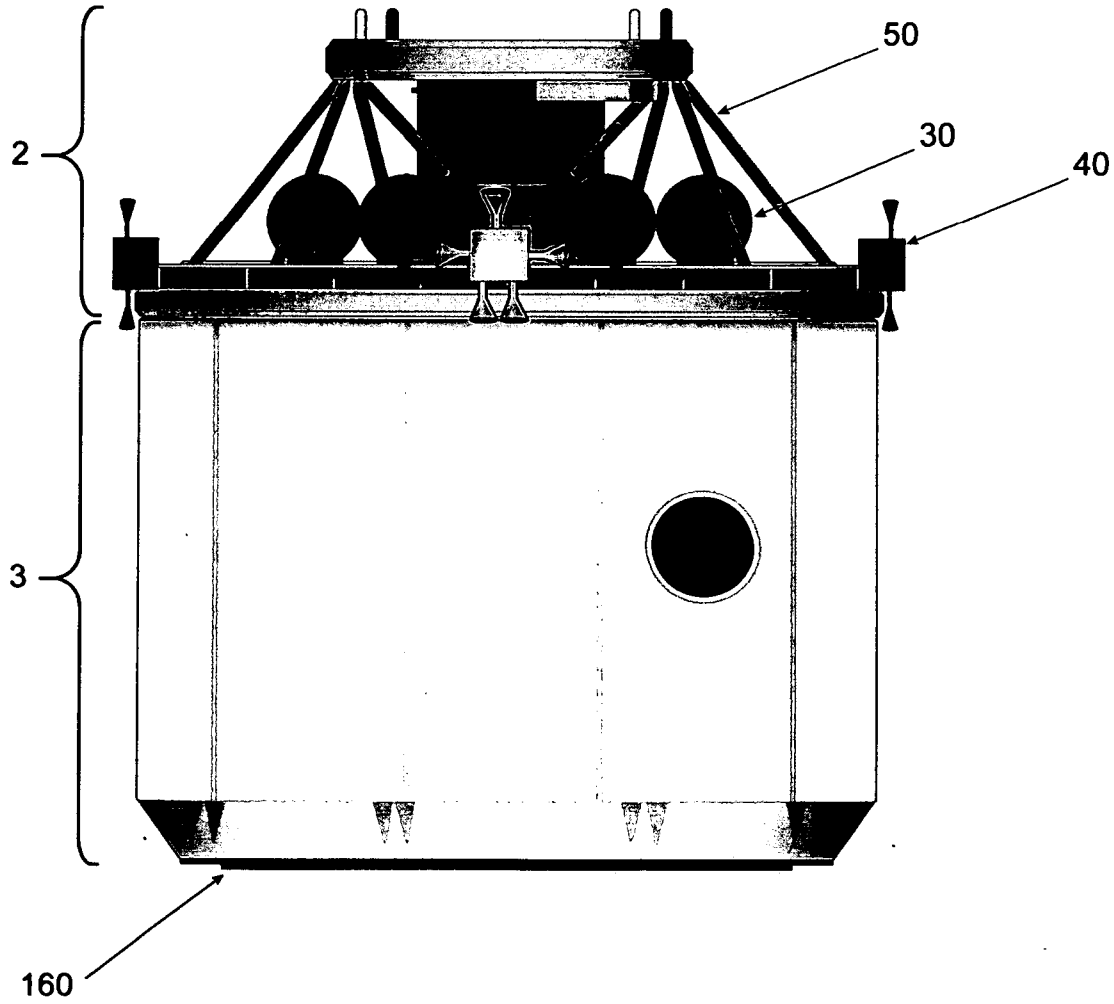
AD01P009-08

FIG 9



AD01P009-09

FIG 10



AD01P009-10

FIG 11 - Long Range Tourist Configuration

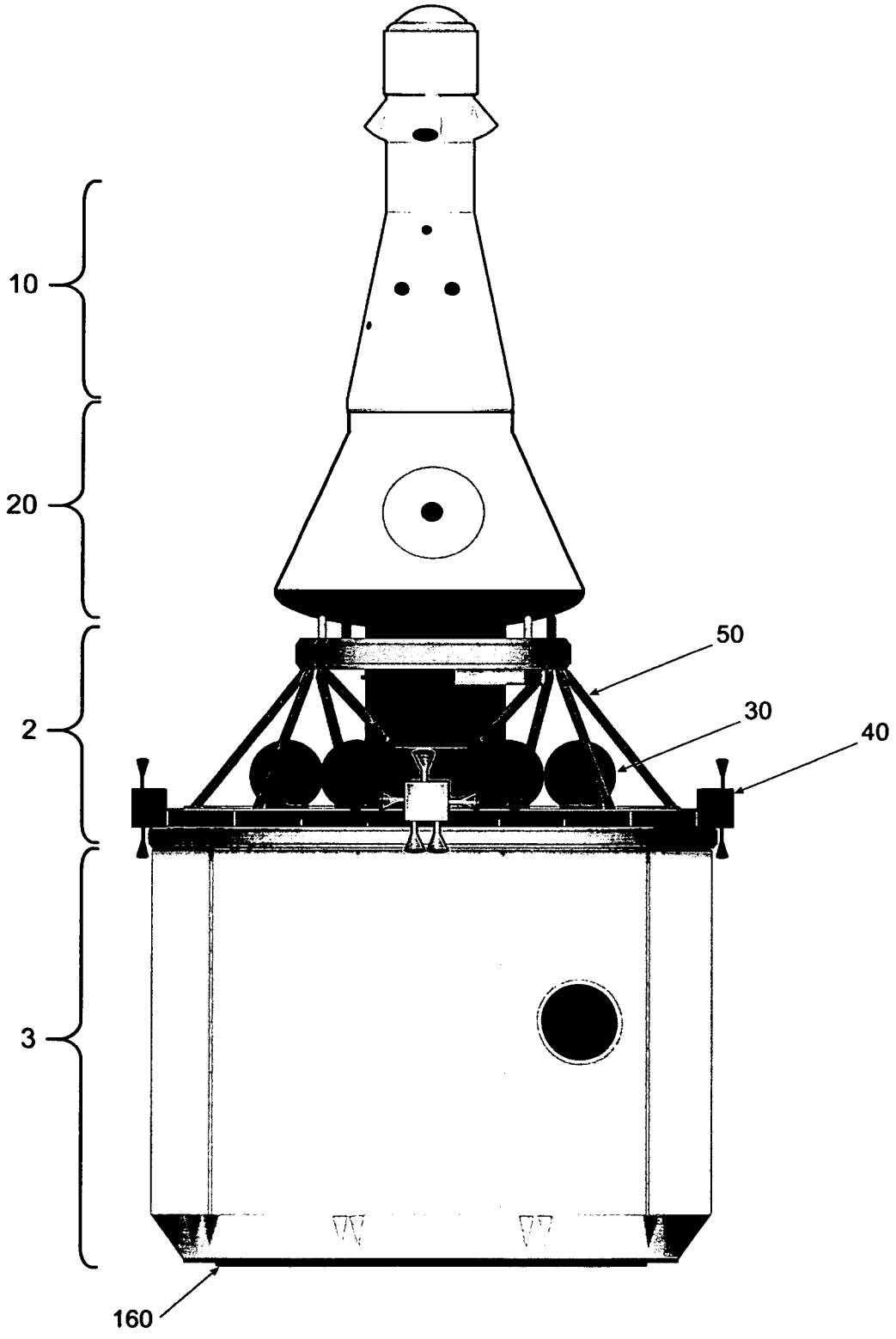


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FIG 12 - Pressurized Cargo Transport

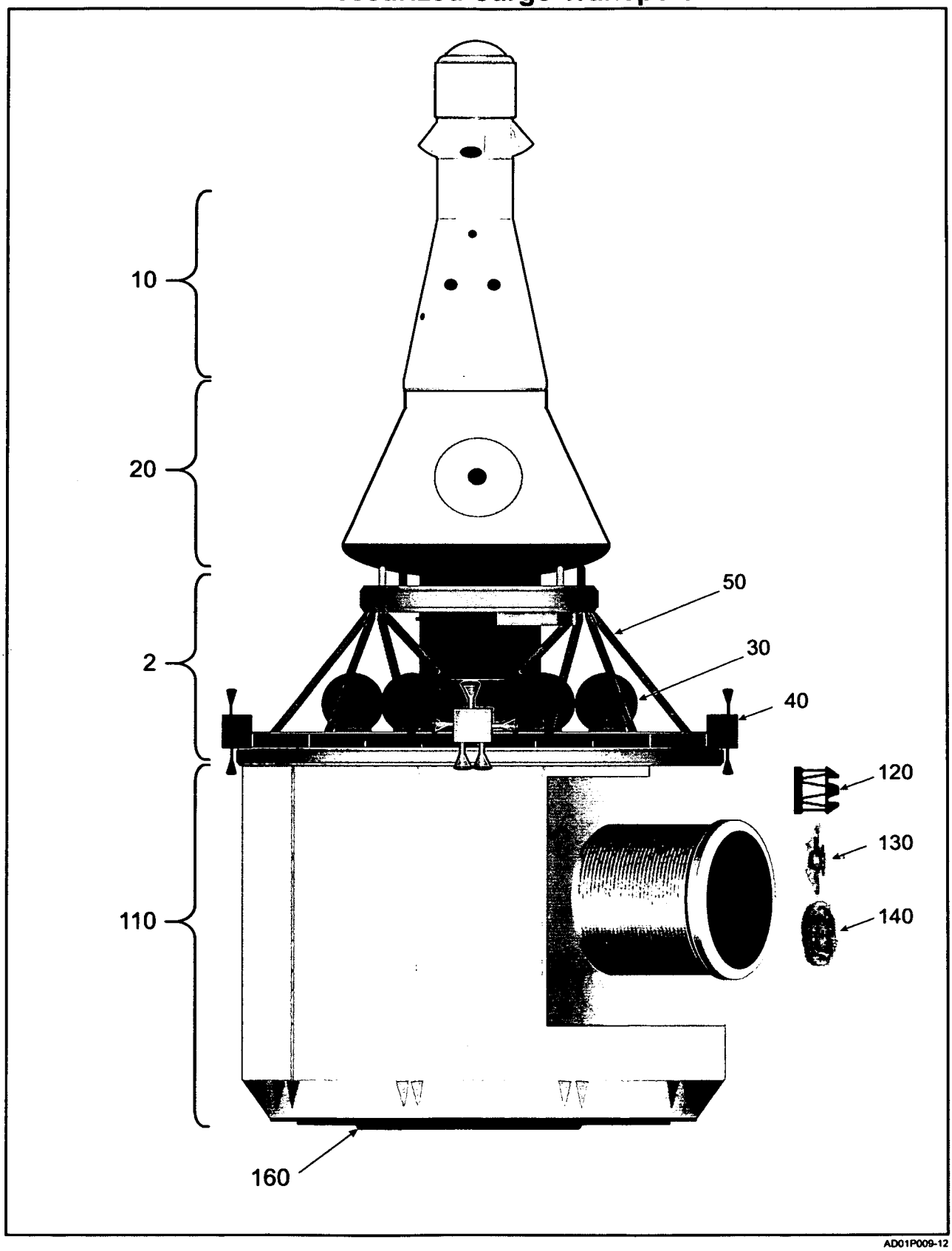
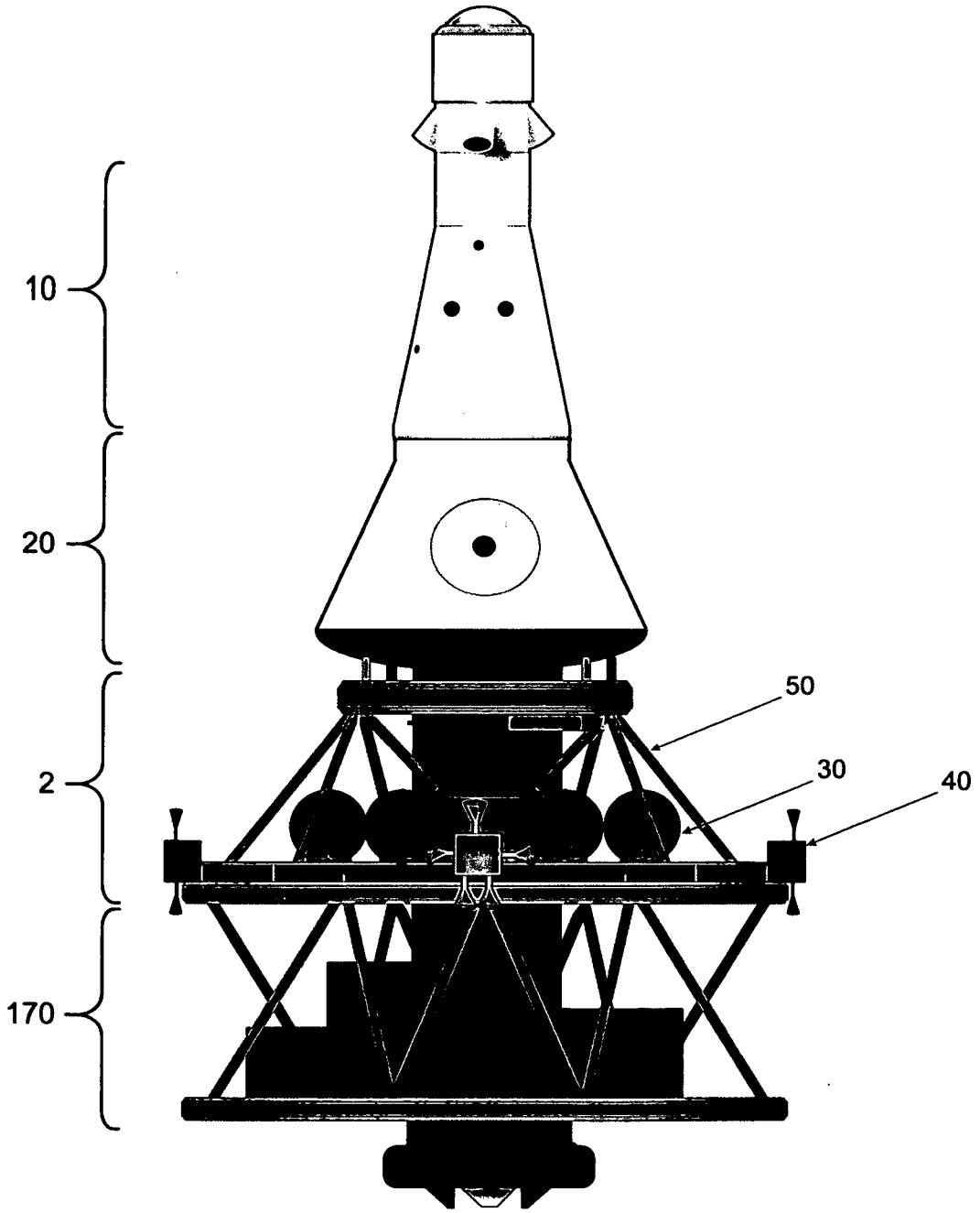


FIG 13 - Unpressurized Cargo Transport



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