

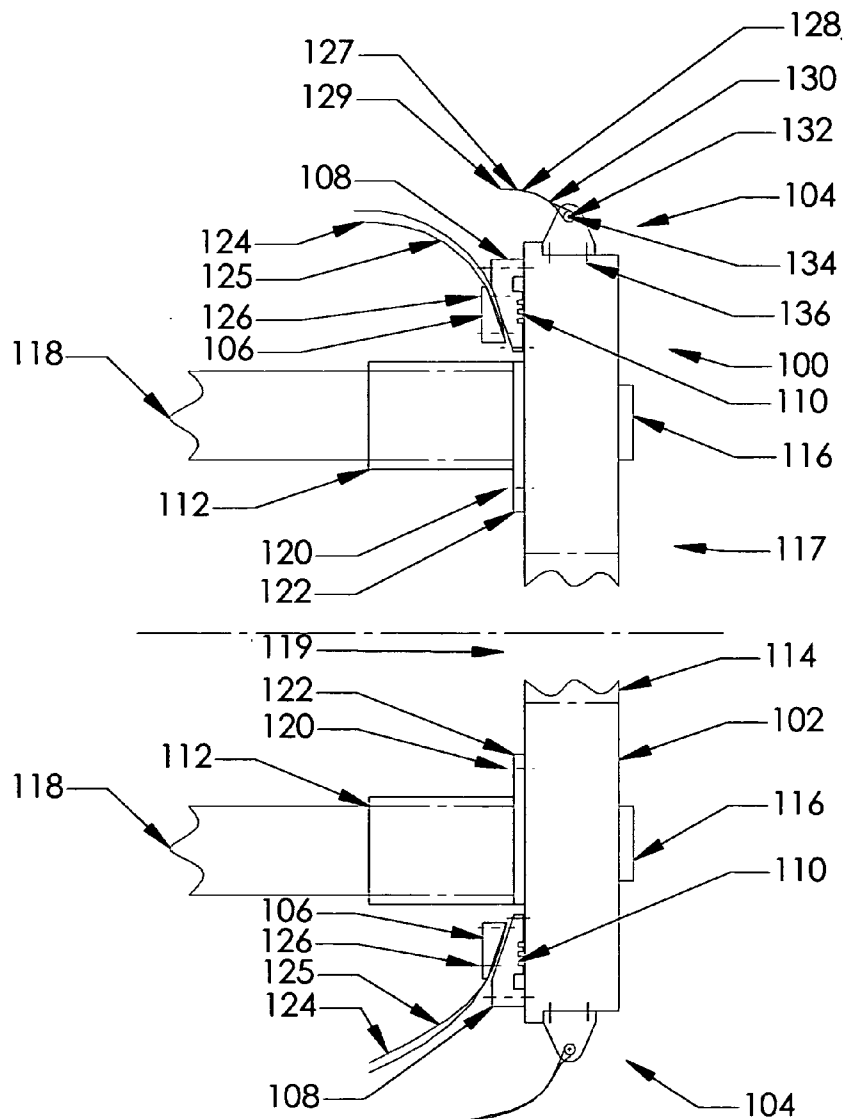
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(57) **ABSTRACT**

A bulkhead assembly for use with an inflatable modular structure is claimed. The assembly is comprised of a plate, at least one longeron sleeve for receiving and securing the longeron in place, a first and second bladder flange and bladder seals for use in securing an one end of an inflatable bladder to the plate, a number of longitudinal restraint fittings disposed on the plate for securing the loops of a restraint layer such hat the restraint layer substantially encompasses the inflatable bladder.

(51) **Int. Cl.⁷** **E04G 11/04**



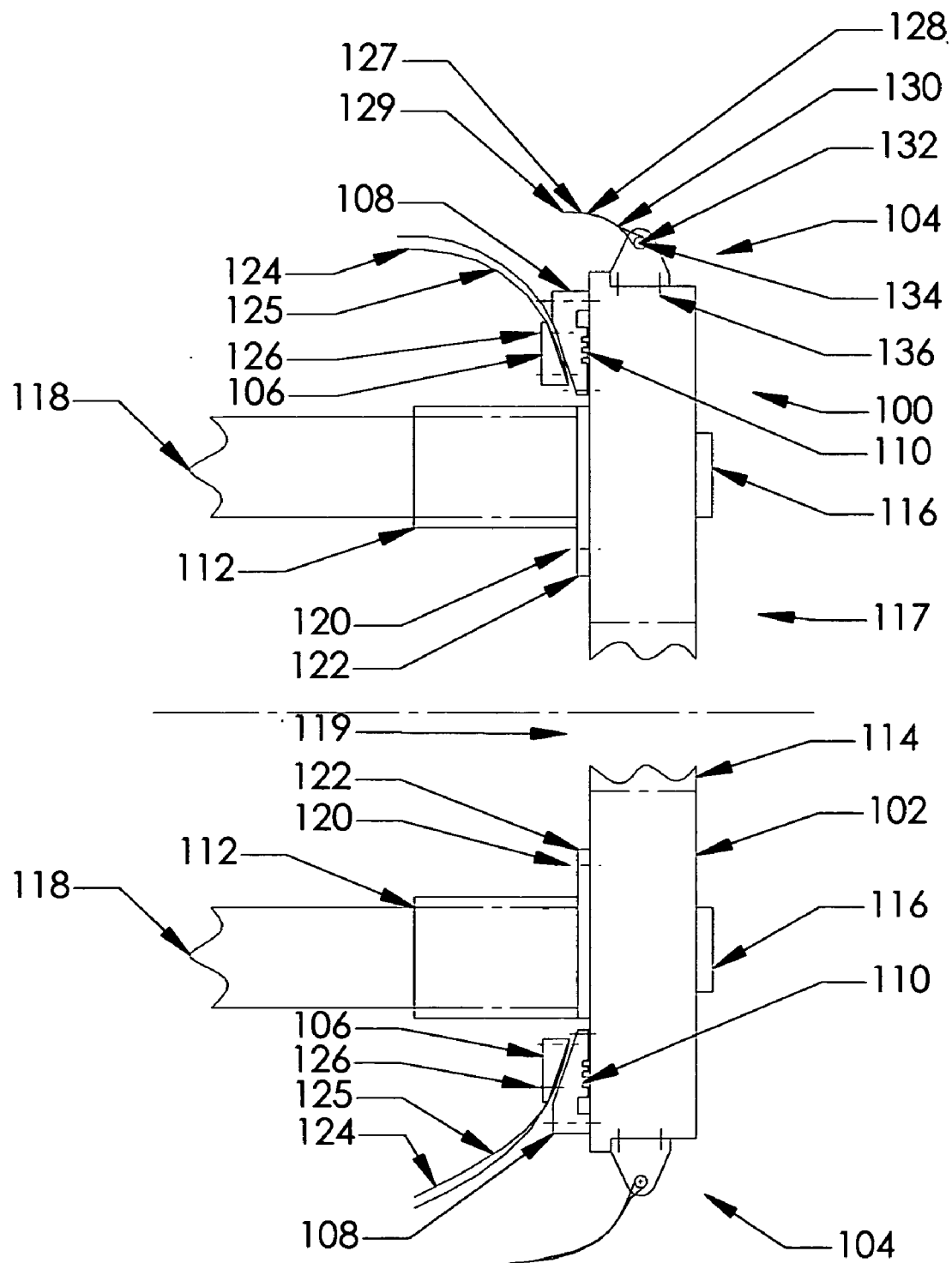


Fig. 1

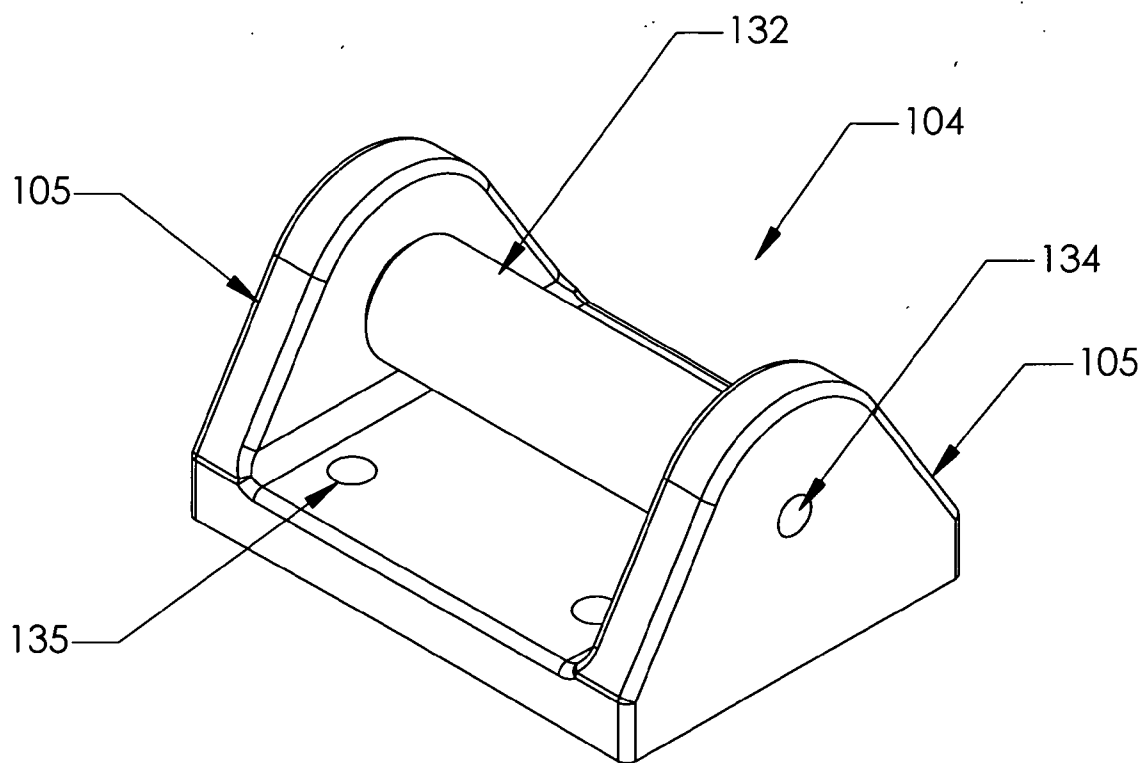


Fig. 2

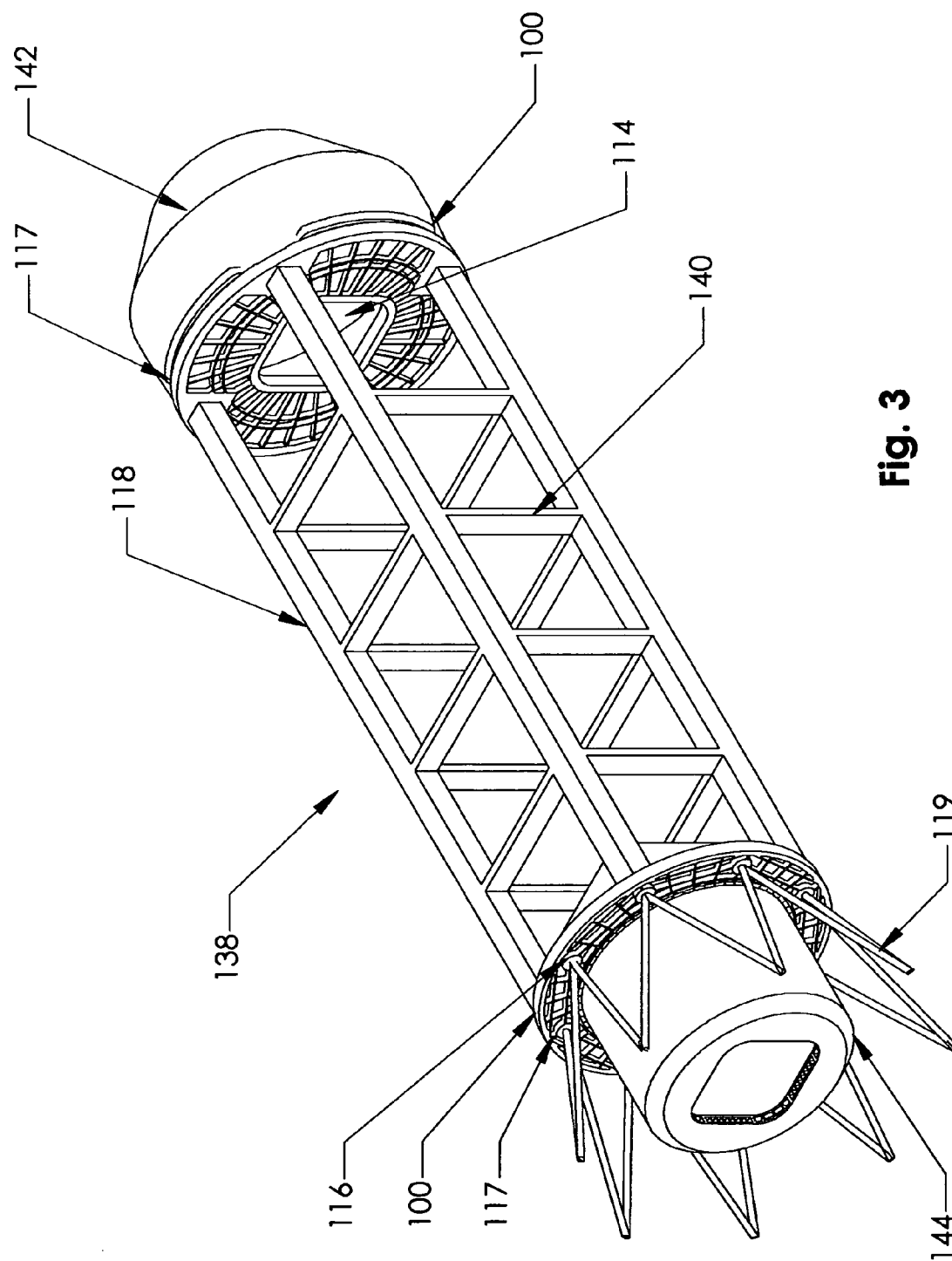


Fig. 3

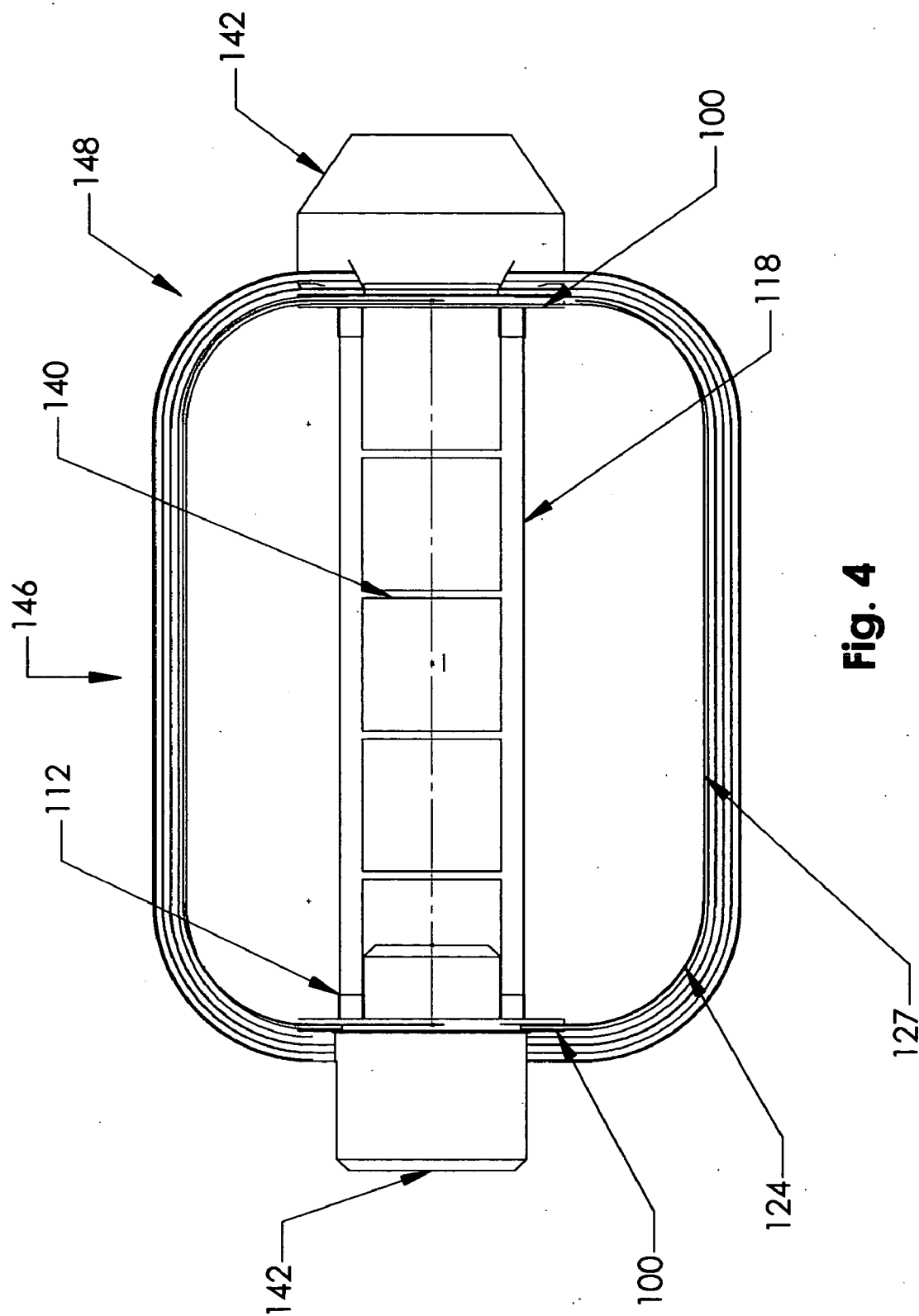


Fig. 4

BULKHEAD ASSEMBLY

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] This invention relates to a bulkhead assembly and in particular a bulkhead assembly used with an inflatable modular structure. The inflatable modular structure can be used as a spaced based platform or a habitat for use on a planet or other extraterrestrial body.

[0003] 2. Description of the Prior Art

[0004] Bulkheads are used commonly in aircraft, ships, and boats as partitions to separate compartments on such craft. In this application, the bulkheads typically are walls that may or may not have doors or passageways.

[0005] Bulkheads have also been suggested for use with inflatable modular structures such as those structures identified by U.S. Pat. No. 6,547,189 to Raboin, et al. When used with inflatable modular structures, a bulkhead serves a number of functions besides the traditional task of partitioning areas of a vessel.

[0006] An inflatable modular structure is a unique approach at providing a cost effective, large volume, habitable working environment for use in space and on extraterrestrial bodies. This approach is distinct due to the characteristic structure of the module.

[0007] The inflatable structure has a truss arrangement predominately surrounded by an inflatable flexible multi-layered shell. This allows for minimizing the volume of the module at launch and maximizing the volume when deployed.

[0008] In the pre-deployed configuration, the shell is folded about the truss and secured in such a way that the module can be fitted into the payload section of a conventional launch vehicle. When the payload is launched brought to a desired location, the module is transformed into a deployed configuration.

[0009] In this configuration, the flexible shell is released and the module is inflated with a gas; usually air. As the volume within the module increases, the shell unfolds and expands. When fully inflated the shell encompasses a volume that is far greater than the comparable volume in a solid hulled craft of the same launch dimensions.

[0010] The availability of a module that has a deployed internal volume that is not confined to the volume of a hard-shelled vehicle opens the way for a new paradigm impacting numerous areas in the space sciences. For example, to date the design of equipment for use on a space module has been restricted by the size of a craft's launch payload volume. Furthermore, a great deal of equipment is usually secured in a permanent location within the space vehicle. In some cases, so secured that it cannot be removed once deployed. By virtue of an inflatable modules' larger deployed volume, the module not only reduces this restrictive parameter for equipment design, it allows for movement of the equipment from one location to another within the larger volume in a variety of ways.

[0011] Another way the prototypical approach to creating a space module is changed is in the area of cost. Presently, most modules rely upon a solid shell. The shell is a specialty

item that must be intensely scrutinized as any flaws in the structure could result in a loss of air from the module and a potentially catastrophic failure; especially if a leak occurs behind a secured piece of equipment. To address this scenario a great deal of testing and inspection must be done on the hull. Further, the hull must be composed of a material that can withstand a certain level of debris impact, insure reliability, and yet be light enough for launch. These are factors that drive up the cost of a hard-shelled module.

[0012] The inflatable module utilizes reliable flexible materials with proven characteristics. Coupled with this advantage, the module has multiple layers of a flexible debris shield. The use of such a shield on a rigid hulled craft would still require the volume in the craft to be reduced to accommodate the shield. While this is a serious impediment to the internal volume of the rigid craft, it is not such a serious impact to the more voluminous flexible shelled vessel.

[0013] Even though testing and inspection is still important for a flexible module, inspection and testing of the flexible materials is typically less expensive than for a solid shelled craft. Furthermore, since the deployed volume of the flexible craft is larger than the deployed volume of a rigid shelled craft having a comparable launch payload volume, the launch cost per cubic foot of the deployed inflatable module is expected to be far less than for the hard shelled module.

[0014] The aforementioned advantages of the inflatable module depend from the combination of an inflatable malleable shell and a rigid, or semi-rigid truss. The truss performs the function of a skeletal backbone to the module and is integral in defining the shape of the module and insuring that the module retains a relatively constant longitudinal dimension. This is accomplished through an interaction of a variety of structural members including the longerons and braces in a truss, airlocks, and the use of bulkhead assemblies.

[0015] A bulkhead in an inflatable module should serve several functions to reduce the need for other structural elements thereby reducing cost and weight. To begin, it would be the element that receives the ends of the longerons and connects to the airlocks. Furthermore, the bulkhead would provide the support for the inflatable shell. Typical elements of an inflatable shell include a inflatable bladder, flexible restraint layer, and a meteoroid/debris shield. Each of these elements requires connection points to assist in keeping the shell in place.

[0016] The Raboin patent identifies, but does not specifically claim, the use of a bulkhead in an inflatable structure. Rather, a pass through frame is claimed. However, there is no suggestion as to how any longerons are connected to the identified bulkhead or claimed pass through frame. Furthermore, the elements securing the restraint layer and bladder are depicted in the figures as being offset at a substantial distance from the bulkhead. This is not necessarily the optimum positioning as extending these elements away from the frame can weaken the elements as they experience forces along a moment arm. Finally, there is no mention of bulkhead load pads for distributing the forces associated with a launch.

[0017] What is needed is a bulkhead that receives one of the ends of a longeron, secures the flexible restraint layer

and bladder in place without a large offset, and allows for the attachment of an airlock. Furthermore, the bulkhead, when situated within a launch payload and facing the booster, should have bulkhead load pads for the dispersing the load experienced during the launch of the module into space.

SUMMARY OF THE INVENTION

[0018] This invention is directed to a bulkhead assembly for use with an inflatable module. The inflatable module has at least two longerons, an inflatable bladder having an opening on opposing ends, and a flexible restraint layer having an opening on opposing ends and a plurality of attachment loops on each end. The bulkhead has a plate with an inner surface, a number of longitudinal restraint fittings, a first bladder flange, a second bladder flange, a number of flange seals, and at least two longeron sleeves.

[0019] Each longeron sleeve is fixedly secured to the inner surface of the plate and each sleeve is adapted to fixedly receive a longeron. One end of the inflatable bladder is secured between the first and second bladder flanges. The second bladder flange is secured to the inner surface of the plate and the flange seals are secured between the inner surface of the plate and the second bladder flange.

[0020] The longitudinal restraint fittings are secured to the plate and each fitting receives a loop from one end of the flexible restraint layer. Thus, the bulkhead assembly provides a structure that secures the ends of the inflatable bladder, flexible restraint layer, and longerons.

[0021] As dictated by the circumstances of a particular situation, the bulkhead can have an access opening and a number of bulkhead load pads.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] FIG. 1 is a cross-sectional view of a bulkhead assembly;

[0023] FIG. 2 is an isometric view of the top of a longitudinal restraint fitting;

[0024] FIG. 3 is an isometric view of a truss with opposing distal ends;

[0025] FIG. 4 is a cross-sectional view of an inflatable module; and

[0026] FIG. 5 is a cross-sectional view of an inflatable module with longerons partial isometric view of a cover on two longerons.

DETAILED DESCRIPTION OF THE DRAWINGS

[0027] The present invention may best be understood by reference to the following description taken in conjunction with the accompanying drawings. FIG. 1 is a cross-sectional view of a bulkhead assembly 100. Displayed are the elements of the bulkhead assembly 100, including the plate 102, two of the plurality of longitudinal restraint fittings 104, the first bladder flange 106, the second bladder flange 108, the flange seals 110, and two of the longeron sleeves 112. Also present are the access opening 114 and the bulkhead load pads 116. The bulkhead load pads 116 are used for transferring force from the launch vehicle through the bulkhead plate 102 to the longerons 118 during launch. Thus, in the preferred embodiment, the load pads 116 are on the bulkhead assembly

that is adjacent to the propulsion section of a launch vehicle. Also shown is an outer surface 117 for securing a structure to the plate 102 and an inner surface 119.

[0028] The longeron sleeves 112 are secured to the inner surface 119 of the plate 102 by any number of conventional means. In the preferred embodiment, this is accomplished by using a number of bolts 120 extending through a plate 122, which is part of the longeron sleeve 112, and into the bulkhead plate 102. Each sleeve receives a longeron 118. Again, the longerons 118 are fixedly secured in place by conventional means. In the preferred embodiment, a series of bolts 124 extend through the sleeve 112 and into the longeron 118. However securing means can also include welding, pressure fittings, adhesives, nuts and bolts, or a combination of any of the aforementioned means.

[0029] A bladder 124 is secured between the first bladder flange 106 and the second bladder flange 108. The bladder serves to retain the atmosphere of a deployed space module. The bladder has openings on opposing ends 125. In the preferred embodiment, a sealing material is placed on the bladder 124 around the edges of the opposing ends 125 to assist in creating a seal between the bladder flanges 106, 108 and the bladder 124. A number of flange seals 110 are positioned between the second bladder flange 108 and the plate 102. The bladder flanges 106, 108, bladder 124 and flange seals 110 are fixedly secured to the plate 102 as a unit by known means. In the preferred embodiment, the means includes utilizing a number of screws 126 extend from the first bladder flange 106 through to the plate 102. As indicated in the figure, the bladder flanges 106, 108 abut the bladder 124 along a length of the bladder 124. In this way, the bladder is secured in place without requiring that the flanges 106, 108 extend far above the plate 102. Thus, the flanges 106, 108 are not extensively offset and do not react to torque as significantly as would a longer element.

[0030] A restraint layer 127 comprised of a number of straps 128 is used to provide support for the inflated bladder 124. The restraint layer 127 has opposing ends 129 where there are a number of loops 130. When the bladder 124 is inflated, force is transferred from the bladder 124 to the restraint layer straps 126. In this way, the straps not only restrain the dimensions of the inflated bladder, but also act to reduce the stress on the bladder.

[0031] Each strap ends in a loop 130. Each loop 130 extends about a roller 132 that is secured by a pin 134 to a longitudinal restraint fitting 104. The restraint fitting 104 is secured to the plate 102 by known means. In the preferred embodiment, a number of bolts 136 extend through the fitting 104 and into the plate 102. By having a loop 130 fit around a roller 132 that is secured to the plate 102, this is a means for securing the loop 130 to the bulkhead assembly. In the preferred embodiment, each fitting is secured to the plate, then a roller is placed within each loop, then the roller is secured in place to the fitting with the pin.

[0032] As indicated by the figure, the restraint layer 127 fits over the bladder 124. In this way, the restraint layer 127 is said to substantially encompass the bladder 124. Also, as shown in the figure, longitudinal restraint fitting 104 does not extend very far above the plate 102. This assists in preventing torque as could be experienced by an extended moment arm from the plate. Furthermore, the fittings 104 are generally in a position adjacent to the flanges 106, 108.

[0033] The bulkhead assembly **100** provides the base for the ends of the bladder and the restraint layer as well as a structure to secure the ends of the longerons. **FIG. 1** shows a single bulkhead assembly. It is anticipated that a module will have such an assembly at opposing ends of a structure.

[0034] Turning now to **FIG. 2**, the longitudinal restraint fitting **104** is substantially “U” shaped. There are opposing posts **105** that support the pin **134** that in turn supports the roller **132**. Also shown are holes **135** where bolts can be inserted to secure the fitting **104** to the plate **102**.

[0035] **FIG. 3** shows how a bulkhead assembly **100** is disposed on the ends of a truss **138** comprised of a number of longerons **118** and support beams **140**. An access opening **114** is also shown that leads into a distal end assembly **142**. This assembly **142** can take the form of an airlock or storage area.

[0036] Opposite to the end **142** is another distal assembly **144**. This assembly **144** can also be an airlock or storage area. Note that the end **144** is of a different shape than the distal end **142**. This is to allow for a launch structure that would interface with the bulkhead load pads **116** to facilitate transferring forces experienced during launch to the longerons **118**. An example of a launching structure **119** is shown attached to the pads.

[0037] Both ends **142**, **144** are secured to the outer surface **117** of the bulkhead assembly. Both distal ends **142**, **144** are secured to the bulkhead assembly **100** by conventional means. In the preferred embodiment, the ends **142**, **144** are welded to the plate **102**.

[0038] Turning now to **FIG. 4**, a cross-section of an inflatable modular structure **146** is shown. There are opposing distal ends **142**, that can be airlocks, fixedly connected to the bulkhead assemblies **100**. The longerons **118** are secured to the longeron sleeves **112** and the sleeves **112** in turn are secured to the plate **102**. The bladder **124** is secured to the assembly **100** and is substantially covered by the restraint layer **127**. It is important to note that while the figure displays an inflated module, the restraint layer **127** also substantially encompasses the bladder **124** when the module is not inflated. At the furthest layer, a debris shield **148** covers the restraint layer **127**.

[0039] Addressing **FIG. 5**, two bulkheads are assembled into the module **146**. There is a first bulkhead assembly **150** at the fore end of the longerons **152** and a second bulkhead assembly **154** at the aft end of the longerons **156**. Both assemblies **150**, **154** have access opening **114**. This is the preferred embodiment. However, it is not necessary that both assemblies have an access opening. Thus, in an alternative embodiment, the first bulkhead assembly **150** would not have an access opening.

[0040] The fore ends of the longerons **152** are received in the longeron sleeves **112** of the first bulkhead assembly. The aft ends of the longerons **156** are secured in the same manner to the longeron sleeves **112** of the second bulkhead assembly **154**. The fore and aft ends are secured in the same manner as described supra for attaching a longeron to a longeron sleeve as described in reference to **FIG. 1**. Returning to **FIG. 5**, the bladder is attached to the bulkheads in the same manner as described in reference to **FIG. 1**, supra. Again referring to **FIG. 5**, the restraint layer is attached to the bulkheads as in same manner as described in reference to **FIG. 1**.

[0041] There has thus been described a novel bulkhead assembly for use with an inflatable modular structure. It is important to note that many configurations can be constructed from the ideas presented. The foregoing disclosure and description of the invention is illustrative and explanatory thereof and thus, nothing in the specification should be imported to limit the scope of the claims. Also, the scope of the invention is not intended to be limited to those embodiments described and includes equivalents thereto. It would be recognized by one skilled in the art the following claims would encompass a number of embodiments of the invention disclosed and claimed herein.

1. A bulkhead assembly for use with an inflatable modular structure, the inflatable modular structure having at least two longerons, an inflatable bladder having an opening on opposing ends, and a flexible restraint layer having an opening on opposing ends and a plurality of attachment loops on each end, the bulkhead assembly comprising:

- a plate having an inner surface;
- a plurality of longitudinal restraint fittings;
- a first bladder flange;
- a second bladder flange;
- a plurality of flange seals;
- at least two longeron sleeves;

each longeron sleeve being fixedly secured to the inner surface of the plate and adapted to securely receive a longeron;

the first and second bladder flanges being adapted to securely receive one of the opposing ends of the inflatable bladder therebetween;

the second bladder flange being secured to the inner surface of the plate with the plurality of flange seals secured between the plate and second bladder flange; and

the plurality of longitudinal restraint fittings being secured to the plate and each of the longitudinal restraint fittings adapted to receive an attachment loop from one of the opposing ends of the flexible restraint layer such that the restraint layer substantially encompasses the inflatable bladder.

2. The bulkhead assembly of claim 1 wherein each longitudinal restraint fitting is substantially “U” shaped defining opposing posts and each longitudinal restraint fitting further comprises a roller being secured between the opposing posts and adapted to receive an attachment loop around the roller.

3. The bulkhead assembly of claim 1 wherein the plate has an access opening.

4. The bulkhead assembly of claim 1 wherein the plate further comprises an outer surface, the outer surface being adapted to receive an airlock assembly.

5. The bulkhead assembly of claim 1 wherein the plate further comprises an outer surface, the outer surface being adapted to receive a distal end assembly.

6. The bulkhead assembly of claim 1 wherein the plate further comprises an outer surface, said outer surface and inner surface having a plurality of bulkhead load pads.

7. The bulkhead assembly of claim 1 wherein the longitudinal restraint fittings are adjacent to the second bladder flange.

8. A bulkhead assembly for use with an inflatable modular structure, the inflatable modular structure having at least two longerons, an inflatable bladder having an opening on opposing ends, and a flexible restraint layer having an opening on opposing ends and a plurality of attachment loops on each end, the bulkhead assembly comprising:

a plate;

means for securing the longerons to the plate;

means for securing one of the opposing ends of the inflatable bladder to the plate; and

means for securing the attachment loops on one of the opposing ends of the flexible restraint layer to the plate.

9. A method for attaching a bulkhead assembly to an inflatable modular structure, the inflatable modular structure having at least two longerons, an inflatable bladder having an opening on opposing ends, and a flexible restraint layer having an opening on opposing ends and a plurality of attachment loops on each end, the method of attaching the bulkhead assembly comprising the steps of:

securing the longerons to the bulkhead assembly;

securing one opposing end of the inflatable bladder to the bulkhead assembly; and

securing the attachment loops on one of the opposing ends of the flexible restraint layer to the bulkhead assembly.

10. The method for attaching a bulkhead assembly to an inflatable modular structure in claim 9 using the bulkhead assembly of claim 3.

11. A method for attaching a bulkhead assembly to an inflatable modular structure, the inflatable modular structure having at least two longerons, an inflatable bladder having an opening on opposing ends, and a flexible restraint layer having an opening on opposing ends and a plurality of attachment loops on each end, the method of attaching the bulkhead assembly comprising the steps of:

securing the longerons to the bulkhead assembly of claim 1;

securing one opposing end of the inflatable bladder to the bulkhead assembly of claim 1; and

securing the attachment loops to the bulkhead assembly of claim 1.

12. A method for attaching a bulkhead assembly to an inflatable modular structure, the inflatable modular structure having at least two longerons, an inflatable bladder having an opening on opposing ends, and a flexible restraint layer having an opening on opposing ends and a plurality of attachment loops on each end, the method of attaching the bulkhead assembly comprising the steps of:

securing the longerons to the bulkhead assembly of claim 8;

securing one opposing end of the inflatable bladder to the bulkhead assembly of claim 8; and

securing the attachment loops to the bulkhead assembly of claim 8.

13. A method for attaching a bulkhead assembly to opposing ends of an inflatable modular structure, the inflatable

modular structure having a truss comprised of at least two longerons and each longeron having a fore and an aft end, an inflatable bladder having a first and second opening on opposing ends, and a flexible restraint layer having a first and second opening on opposing ends and a plurality of attachment loops on each end, the method of attaching the bulkhead assemblies comprising the steps of:

securing the fore ends of the longerons to a first bulkhead assembly as in claim 1;

securing the aft ends of the longerons to a second bulkhead assembly as in claim 3;

securing the first opposing end of the inflatable bladder to a first bulkhead assembly as in claim 1;

securing the second opposing end of the inflatable bladder to a second bulkhead assembly as in claim 3;

securing the attachment loops on the first opposing end of the restraint layer to a first bulkhead as in claim 1; and

securing the attachment loops on the second opposing end of the restraint layer to a second bulkhead as in claim 3 such that the restraint layer substantially encompasses the inflatable bladder.

14. A method for attaching a bulkhead assembly to opposing ends of an inflatable modular structure, the inflatable modular structure having a truss comprised of at least two longerons and each longeron having a fore and an aft end, an inflatable bladder having a first and second opening on opposing ends, and a flexible restraint layer having a first and second opening on opposing ends and a plurality of attachment loops on each end, the method of attaching the bulkhead assemblies comprising the steps of:

securing the fore ends of the longerons to a first bulkhead assembly as in claim 8;

securing the aft ends of the longerons to a second bulkhead assembly as in claim 8;

securing the first opposing end of the inflatable bladder to a first bulkhead assembly as in claim 8;

securing the second opposing end of the inflatable bladder to a second bulkhead assembly as in claim 8;

securing the attachment loops on the first opposing end of the restraint layer to a first bulkhead as in claim 8; and

securing the attachment loops on the second opposing end of the restraint layer to a second bulkhead as in claim 8.

15. An inflatable modular structure utilizing two bulkhead assemblies, the inflatable modular structure having at least two longerons each having fore and aft ends, an inflatable bladder having an opening on opposing ends, and a flexible restraint layer having an opening on opposing ends and a plurality of attachment loops on each end, the inflatable modular structure utilizing two bulkhead assemblies comprising:

a first and second bulkhead assembly as in claim 3;

the fore ends of the plurality of longerons securedly attached to a plurality of longeron sleeves on the first bulkhead assembly;

the aft ends of the plurality of longerons securedly attached to a plurality of longeron sleeves on the second bulkhead assembly;

one end of the inflatable bladder being attached to the first bulkhead assembly;

the opposing end of the inflatable bladder being attached to the second bulkhead assembly;

one end of the restraint layer being attached to the first bulkhead assembly;

the opposing end of the restraint layer being attached to the second bulkhead assembly.

16. An inflatable modular structure utilizing two bulkhead assemblies, the inflatable modular structure having at least two longerons each having fore and aft ends, an inflatable bladder having an opening on opposing ends, and a flexible restraint layer having an opening on opposing ends and a plurality of attachment loops on each end, the inflatable modular structure utilizing two bulkhead assemblies comprising:

a first and second bulkhead assembly as in claim 8;

the fore ends of the plurality of longerons securedly attached to a plurality of longeron sleeves on the first bulkhead assembly;

the aft ends of the plurality of longerons securedly attached to a plurality of longeron sleeves on the second bulkhead assembly;

one end of the inflatable bladder being attached to the first bulkhead assembly;

the opposing end of the inflatable bladder being attached to the second bulkhead assembly;

one end of the restraint layer being attached to the first bulkhead assembly;

the opposing end of the restraint layer being attached to the second bulkhead assembly.

17. An inflatable modular structure utilizing two bulkhead assemblies, the inflatable modular structure having at least two longerons each having fore and aft ends, an inflatable bladder having an opening on opposing ends, and a flexible restraint layer having an opening on opposing ends and a plurality of attachment loops on each end, the inflatable modular structure utilizing two bulkhead assemblies comprising:

a first bulkhead assembly as in claim 3;

a second bulkhead assembly as in claim 6 and further comprising an access opening;

means for securing the fore ends of the plurality of longerons to the first bulkhead assembly;

means for securing the aft ends of the plurality of longerons to the second bulkhead assembly;

means for securing one end of the inflatable bladder to the first bulkhead assembly;

means for securing the opposing end of the inflatable bladder to the second bulkhead assembly;

means for securing one end of the restraint layer to the first bulkhead assembly;

means for securing the opposing end of the restraint layer to the second bulkhead assembly such that the flexible restraint layer substantially encompasses the inflatable bladder.

18. An inflatable modular structure utilizing two bulkhead assemblies, the inflatable modular structure having at least two longerons each having fore and aft ends, an inflatable bladder having an opening on opposing ends, and a flexible restraint layer having an opening on opposing ends and a plurality of attachment loops on each end, the inflatable modular structure utilizing two bulkhead assemblies comprising:

a first and second bulkhead assembly each as in claim 8;

means for securing the fore ends of the plurality of longerons to the first bulkhead assembly;

means for securing the aft ends of the plurality of longerons to the second bulkhead assembly;

means for securing one end of the inflatable bladder to the first bulkhead assembly;

means for securing the opposing end of the inflatable bladder to the second bulkhead assembly;

means for securing one end of the restraint layer to the first bulkhead assembly;

means for securing the opposing end of the restraint layer to the second bulkhead assembly such that the restraint layer substantially encompasses the inflatable bladder.

19. A longitudinal restraint fitting being substantially "U" shaped defining opposing posts and the posts being adapted to receive a pin and each longitudinal restraint fitting further comprising a roller adapted to receive a pin and the roller being disposed between the opposing posts and the pin cooperating with the posts and the roller such that the roller is rotatable.

20. A method of securing a longitudinal strap having a loop to a longitudinal restraint fitting on a bulkhead comprising the steps of:

Securing the longitudinal restraint fitting of claim 19 to a bulkhead;

Placing the roller of the longitudinal restraint fitting of claim 19 through the loop;

Placing the roller of claim 19 between the posts of claim 19; and

Securing the pin through the roller and posts.

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