



US 20210300598A1

(19) **United States**

(12) **Patent Application Publication**

Beck et al.

(10) **Pub. No.: US 2021/0300598 A1**

(43) **Pub. Date: Sep. 30, 2021**

(54) **SATELLITE DEPLOYER WITH EXTERNALLY ADJUSTABLE PAYLOAD RESTRAINT**

F16C 33/24 (2006.01)
E05D 3/08 (2006.01)
E05D 7/00 (2006.01)
E05F 3/20 (2006.01)
B60P 7/135 (2006.01)
B60P 7/16 (2006.01)
B26D 5/12 (2006.01)
E05F 1/10 (2006.01)

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(52) **U.S. Cl.**
CPC *B64G 1/22* (2013.01); *F16C 29/005* (2013.01); *F16C 33/24* (2013.01); *E05D 3/08* (2013.01); *E05D 7/00* (2013.01); *B64G 1/645* (2013.01); *B60P 7/135* (2013.01); *B60P 7/16* (2013.01); *B26D 5/12* (2013.01); *E05F 1/105* (2013.01); *F16C 2326/47* (2013.01); *E05F 3/20* (2013.01)

(21) Appl. No.: **17/343,614**

(22) Filed: **Jun. 9, 2021**

Related U.S. Application Data

(63) Continuation of application No. 16/051,271, filed on Jul. 31, 2018, now Pat. No. 11,059,609.

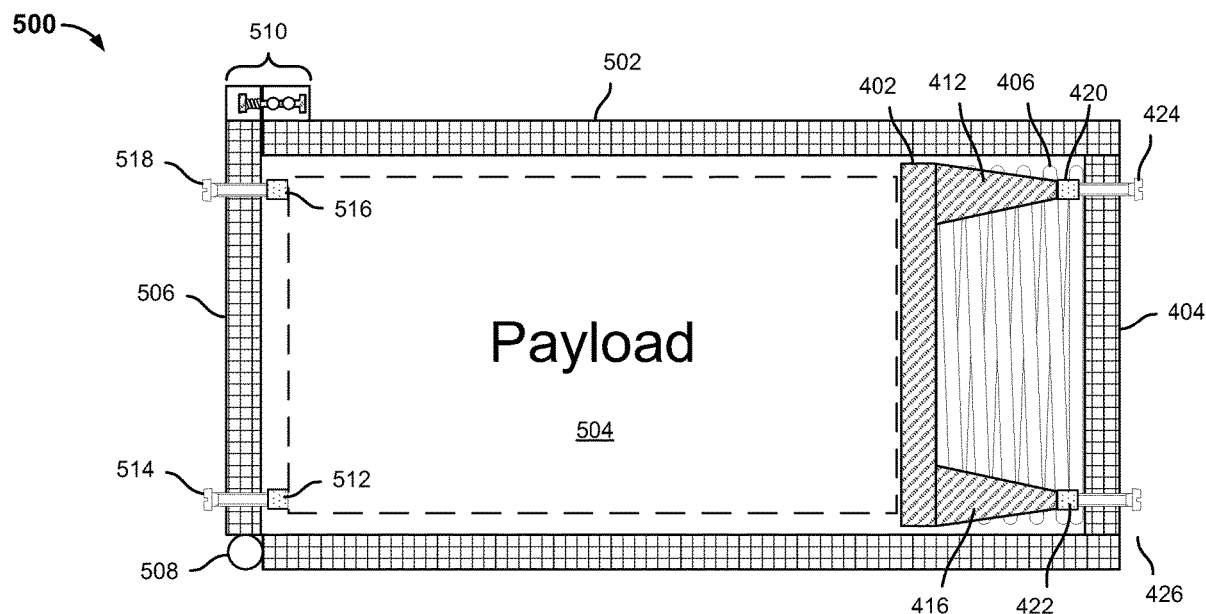
(60) Provisional application No. 62/541,493, filed on Aug. 4, 2017.

Publication Classification

(51) **Int. Cl.**
B64G 1/22 (2006.01)
F16C 29/00 (2006.01)

(57) **ABSTRACT**

A satellite dispenser and method of using same are disclosed. In various embodiments, a satellite dispenser as disclosed herein includes a dispenser body defining an interior cavity to accommodate a payload; and a plurality of externally adjustable restraints positioned within the interior cavity and configured to be extended further into the interior cavity by actuation of a manual interface external to the interior cavity.



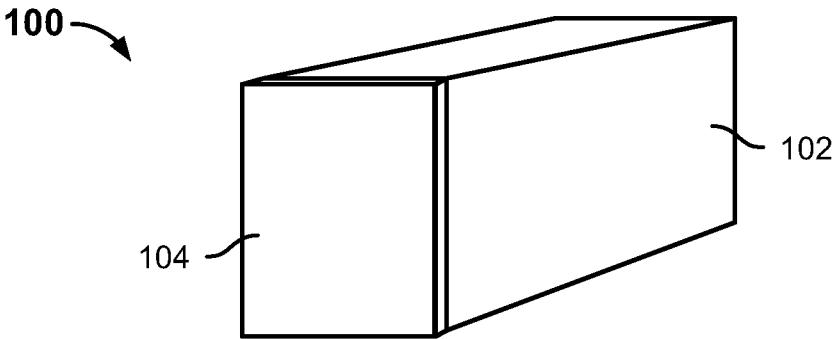


FIG. 1A

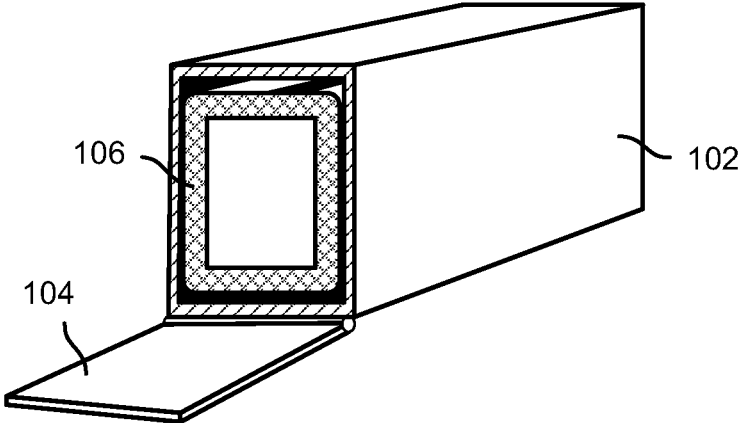


FIG. 1B

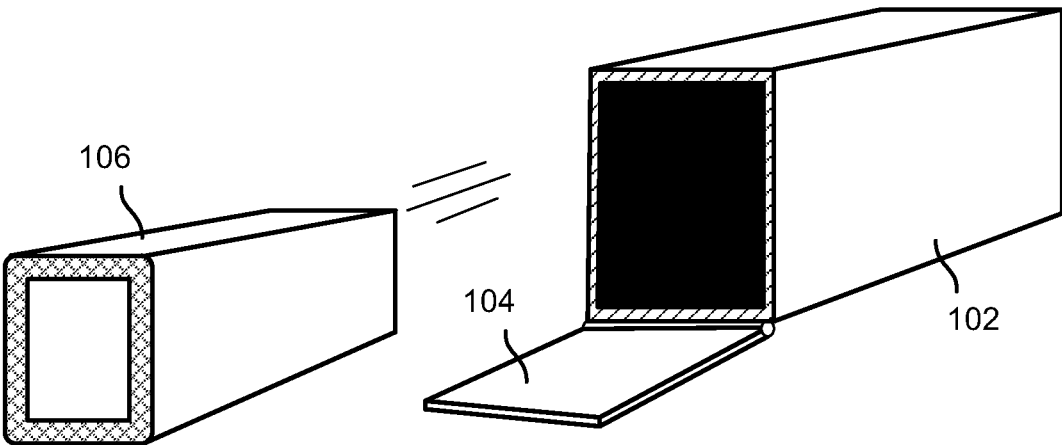


FIG. 1C

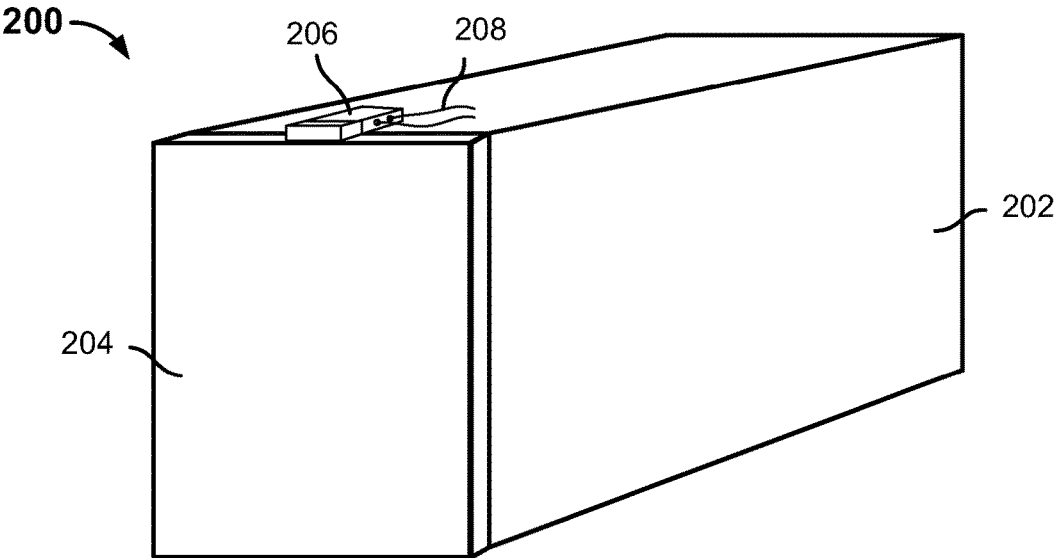


FIG. 2A

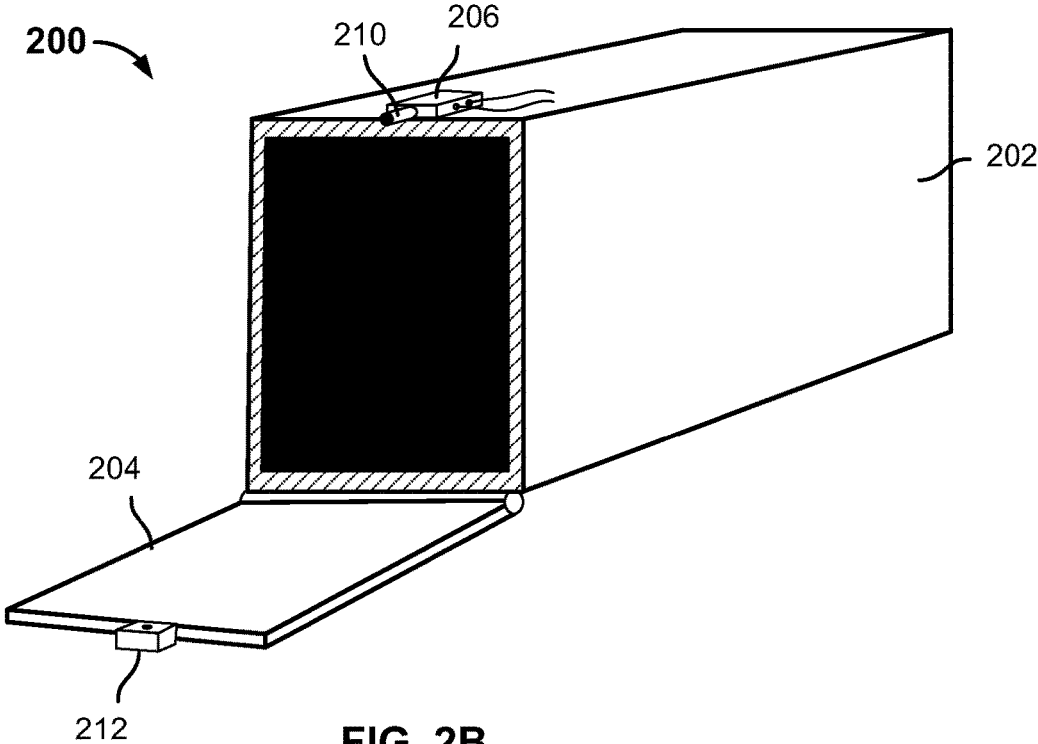


FIG. 2B

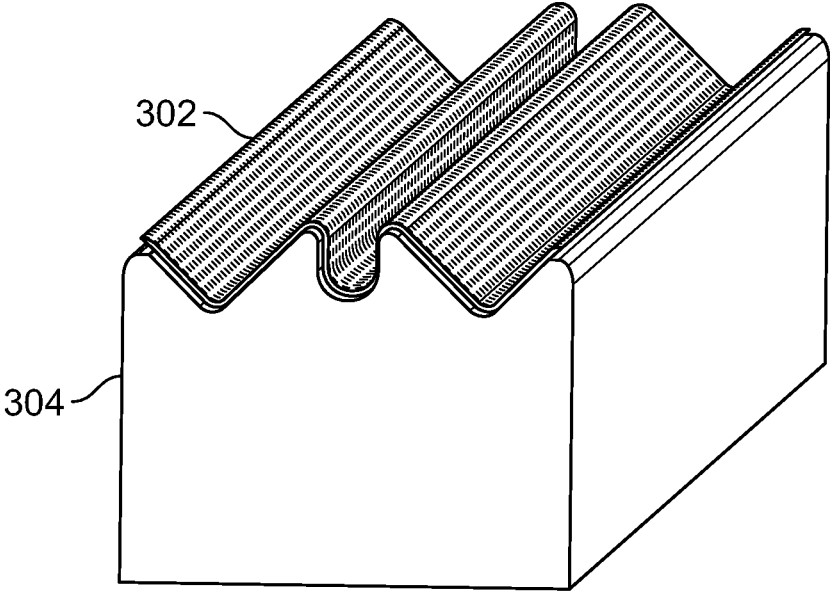


FIG. 3A

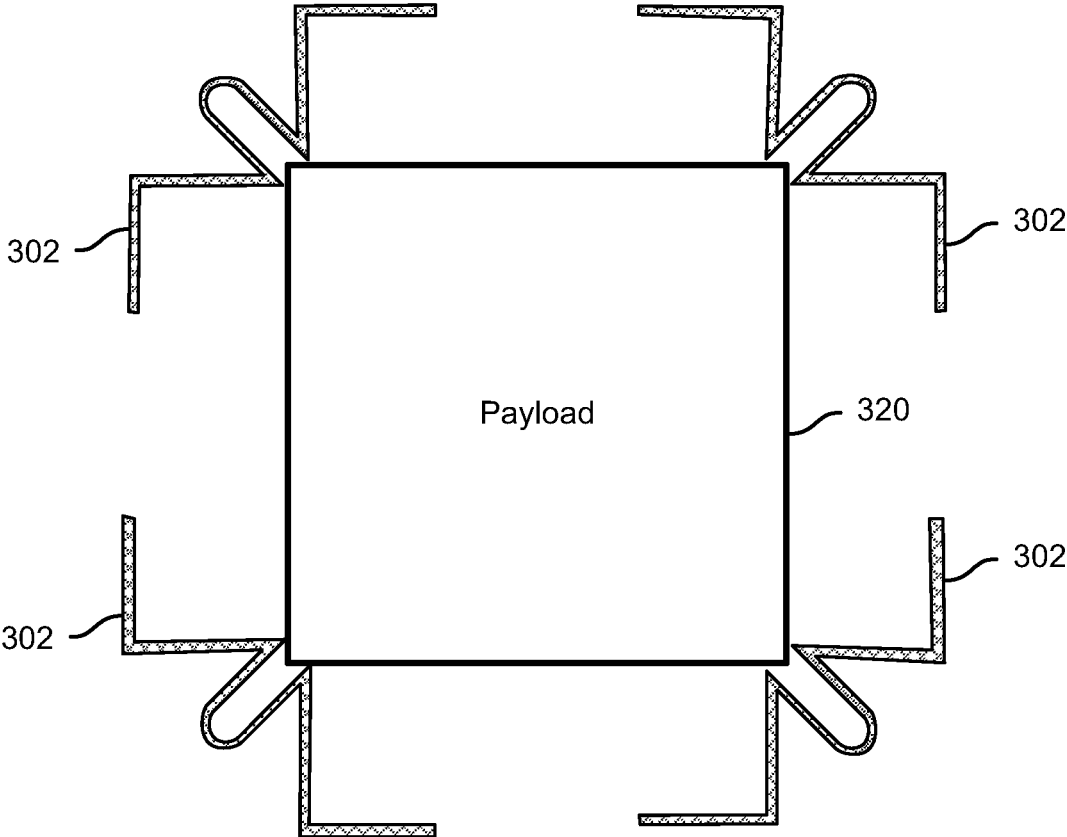


FIG. 3B

400

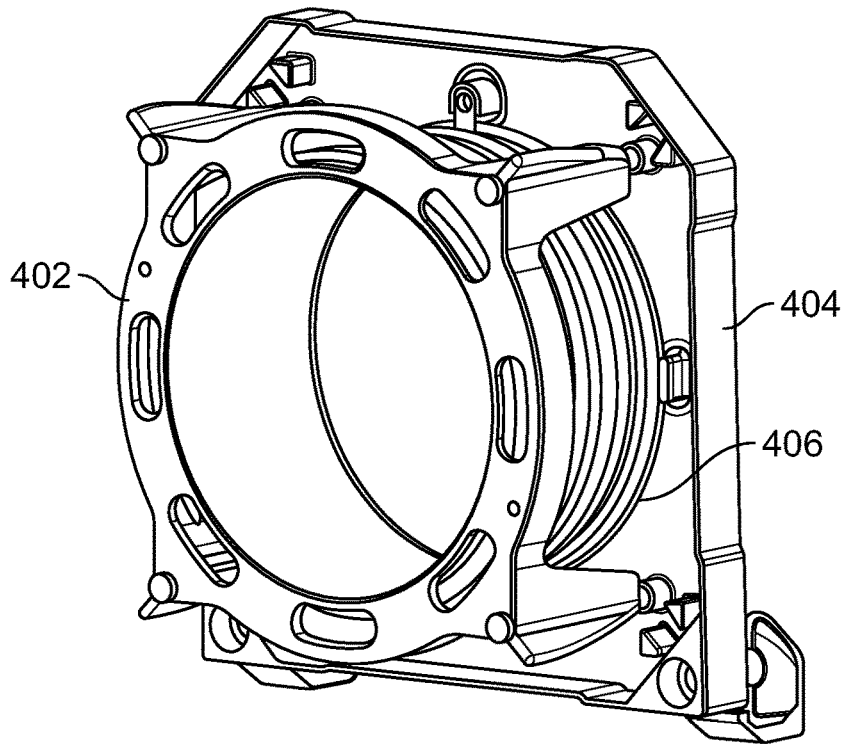


FIG. 4A

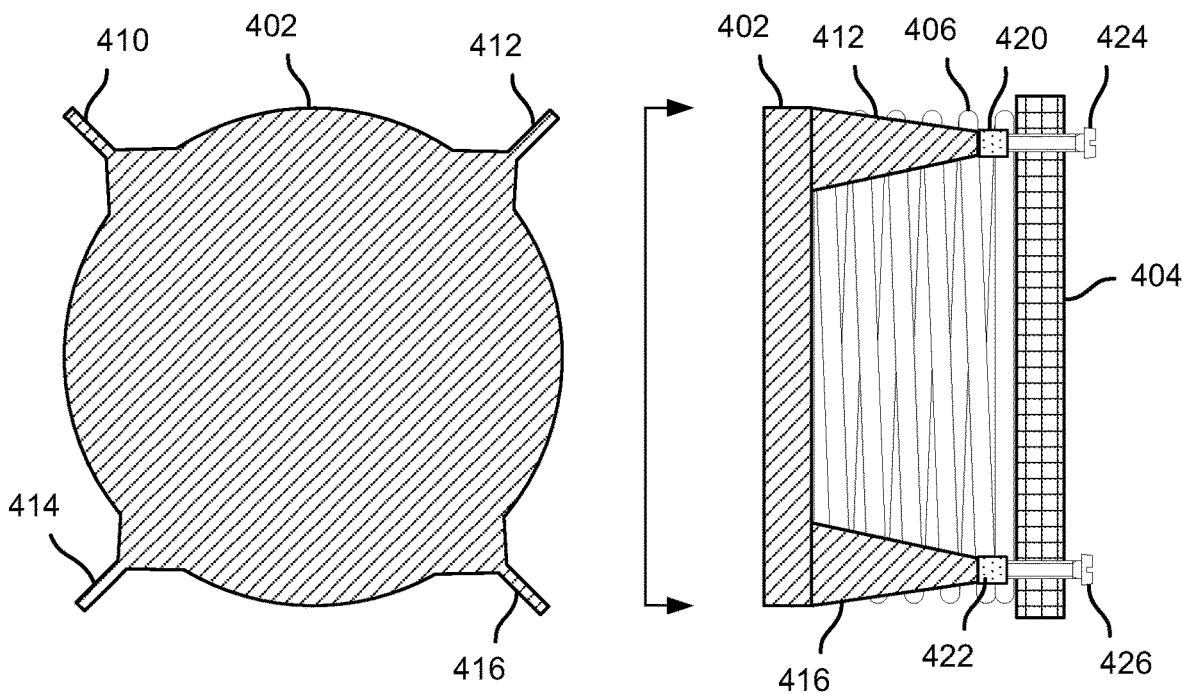


FIG. 4B

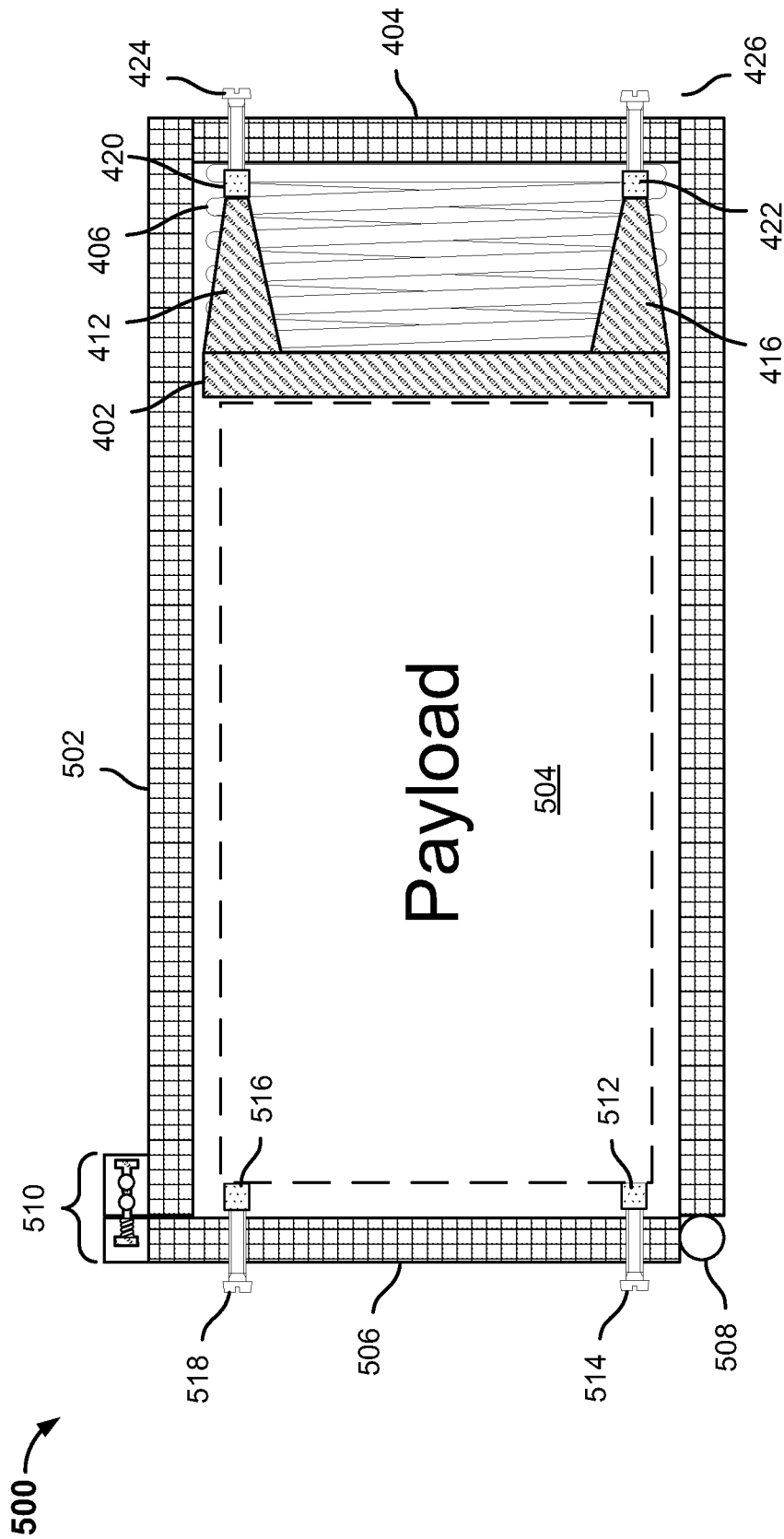


FIG. 5

**SATELLITE DEPLOYER WITH
EXTERNALLY ADJUSTABLE PAYLOAD
RESTRAINT**

CROSS REFERENCE TO OTHER
APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 16/051,271, entitled SATELLITE DEPLOYER WITH EXTERNALLY ADJUSTABLE PAYLOAD RESTRAINT filed Jul. 31, 2018 which is incorporated herein by reference for all purposes, which claims priority to U.S. Provisional Application No. 62/541,493, entitled SMALL SCALE SATELLITE DEPLOYER filed Aug. 4, 2017 which is incorporated herein by reference for all purposes.

GOVERNMENT LICENSE RIGHTS

[0002] This invention was made with Government support under Contract No. 2014-14031000011 awarded by a United States Government Agency. The United States Government has certain rights in the invention.

BACKGROUND OF THE INVENTION

[0003] Small scale satellites, such as CubeSat or other small satellites, may be launched into space in a launch vehicle that includes a plurality of such satellites, each contained in a “dispenser” device, sometimes referred to as a small scale satellite “deployer”, configured to deploy the small scale satellite in a controlled manner, e.g., to achieve a target orbit. The terms “dispenser” and “deployer” are used interchangeably in this specification.

[0004] Satellites conforming to the CubeSat Design Specification may have a size and form factor of a corresponding type or class of CubeSat as defined by the standard. The size and form factor of a CubeSat is based on a standard 10×10×11.35 cm3 unit designed to provide 10×10×10 cm3 (or 1 liter) of useful volume. CubeSats of different types may comprise a different number of such units. For example, CubeSats comprising 1, 3, 6, or 12 units, sometimes designated as 1 U, 3 U, 6 U, and 12 U CubeSats, respectively, may be encountered. Other satellites comprising other whole or fractional numbers of standard units may be launched and deployed.

[0005] Small scale satellite dispensers typically have a shape, size, and form factor to accommodate a corresponding small scale satellite, and commonly have a door that provides access to a payload area of the dispenser. The small scale satellite (payload) is loaded into the dispenser through the opening associated with the door, with the door in the open position. The door is closed and secured in the closed position. The dispenser may be arranged with other dispensers in a chassis configured to accommodate multiple dispensers. The chassis is loaded into a launch vehicle, such as a rocket, and launched into space. Control circuits initiate deployment of the small scale satellite at a time, orientation, etc. associated with the target orbit of each respective small scale satellite. Typically, a satellite is deployed by causing the dispenser door to open at a precise time, resulting in the small scale satellite being ejected from the dispenser and into orbit. Solar panels, antennae, and other appendages and auxiliary equipment may open, extend, or otherwise deploy once the small scale satellite has been ejected from the dispenser.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Various embodiments of the invention are disclosed in the following detailed description and the accompanying drawings.

[0007] FIG. 1A is a diagram illustrating an embodiment of a small scale satellite dispenser.

[0008] FIG. 1B is a diagram illustrating an embodiment of the small scale satellite dispenser **100** of FIG. 1A with the door **104** open.

[0009] FIG. 1C is a diagram illustrating an embodiment of the small scale satellite dispenser **100** of FIG. 1A with the door **104** open and the payload **106** ejected from the payload area defined by dispenser body **102**.

[0010] FIG. 2A is a diagram illustrating an embodiment of a small scale satellite dispenser provided with a pyrotechnic cutter door release mechanism prior to cutter activation.

[0011] FIG. 2B is a diagram illustrating an embodiment of a small scale satellite dispenser provided with a pyrotechnic cutter door release mechanism after cutter activation.

[0012] FIG. 3A is a diagram illustrating an embodiment of a composite guide rail and a mold to fabricate same.

[0013] FIG. 3B is a diagram illustrating an embodiment of a satellite dispenser with composite guide rails.

[0014] FIG. 4A is a diagram illustrating an embodiment of a satellite dispenser pusher plate assembly.

[0015] FIG. 4B is a diagram illustrating front and side views of the satellite dispenser pusher plate assembly **400** of FIG. 4A.

[0016] FIG. 5 is a diagram illustrating an embodiment of a satellite dispenser with externally adjustable payload restraint(s).

DETAILED DESCRIPTION

[0017] The invention can be implemented in numerous ways, including as a process; an apparatus; a system; a composition of matter; a computer program product embodied on a computer readable storage medium; and/or a processor, such as a processor configured to execute instructions stored on and/or provided by a memory coupled to the processor. In this specification, these implementations, or any other form that the invention may take, may be referred to as techniques. In general, the order of the steps of disclosed processes may be altered within the scope of the invention. Unless stated otherwise, a component such as a processor or a memory described as being configured to perform a task may be implemented as a general component that is temporarily configured to perform the task at a given time or a specific component that is manufactured to perform the task. As used herein, the term ‘processor’ refers to one or more devices, circuits, and/or processing cores configured to process data, such as computer program instructions.

[0018] A detailed description of one or more embodiments of the invention is provided below along with accompanying figures that illustrate the principles of the invention. The invention is described in connection with such embodiments, but the invention is not limited to any embodiment. The scope of the invention is limited only by the claims and the invention encompasses numerous alternatives, modifications and equivalents. Numerous specific details are set forth in the following description in order to provide a thorough understanding of the invention. These details are provided for the purpose of example and the invention may

be practiced according to the claims without some or all of these specific details. For the purpose of clarity, technical material that is known in the technical fields related to the invention has not been described in detail so that the invention is not unnecessarily obscured.

[0019] A small scale satellite dispenser with one or more externally adjustable payload restraints is disclosed. In various embodiments, a payload is held securely in place inside the dispenser by one or more externally adjustable spacers, sometimes referred to herein as a “tab” or “foot”, positioned on the inside face of the door and/or the dispenser end plate and extending into the dispenser to an extent and/or applying to the payload a degree of force that is adjustable by applying a prescribed degree of torque to a input interface, such as a fastener and/or fastener head, accessible from an outside face of the door. In some embodiments, the prescribed torque may be determined empirically. For example, for a given payload, tests may be performed to determine how much the payload vibrates inside the dispenser under given conditions. In various embodiments, the feet are low profile to avoid interfering with satellite deployment.

[0020] FIG. 1A is a diagram illustrating an embodiment of a small scale satellite dispenser. In the example shown, dispenser **100** includes a dispenser casing or body **102** with a door **104** at one end. In the state shown in FIG. 1A, the dispenser door **104** is closed, as it would be subsequent to a small scale satellite being loaded into the dispenser **100** but before deployment.

[0021] FIG. 1B is a diagram illustrating an embodiment of the small scale satellite dispenser **100** of FIG. 1A with the door **104** open. A small scale satellite **106** is visible in the payload area defined by dispenser body **102**. The state shown in FIG. 1B may be associated with loading the payload **106** into the dispenser **100**, but prior to the door **104** being closed, and/or just prior to ejection of payload **106** after the door **104** being opened.

[0022] FIG. 1C is a diagram illustrating an embodiment of the small scale satellite dispenser **100** of FIG. 1A with the door **104** open and the payload **106** ejected from the payload area defined by dispenser body **102**. In various embodiments, the payload **106** may have been ejected at least in part by a spring-loaded pusher plate against which the payload **106** had been pressed against during loading of payload **106** into dispenser **100**, thereby compressing one or more springs associated with the pusher plate.

[0023] In various embodiments, the state of dispenser **100** as shown in FIGS. 1B and 1C is attained at least in part by activating a door release mechanism (not shown in FIGS. 1A through 1C) configured to hold door **104** in the closed position prior to activation. Upon activation of the door release mechanism, the door **104** is no longer held in the closed position. In various embodiments, one or more springs compressed by closing door **104** and securing door **104** in the closed position may, upon activation of the door release mechanism, cause the door **104** to be pushed open, as in FIGS. 1B and 1C, allowing the payload **106** to be ejected, as shown in FIG. 1C.

[0024] FIG. 2A is a diagram illustrating an embodiment of a small scale satellite dispenser provided with a pyrotechnic cutter door release mechanism prior to cutter activation. In the example shown, satellite dispenser **200** includes a dispenser body **202** and door **204**. The door **204** is held closed in the state shown by a door release mechanism **206** which in this example includes a wire or cable (not shown in FIG.

2A) to hold the door closed prior to deployment and two pyrotechnic cutters positioned and configured to cut the wire or cable to release the door **204** to enable the door **204** to open. In the example shown, electrical leads **208** are connected to the pyrotechnic cutters included in door release mechanism **206**. In various embodiments, signals and/or power to activate the pyrotechnic cutters is/are provided via leads **208**, e.g., from a driver or similar component comprising and/or otherwise associated with the dispenser **200**.

[0025] FIG. 2B is a diagram illustrating an embodiment of a small scale satellite dispenser provided with a pyrotechnic cutter door release mechanism after cutter activation. In the state shown in FIG. 2B, the pyrotechnic cutters comprising door release mechanism **206** have been fired resulting in the cable or wire holding door **204** closed being cut. In the example shown, the door **204** has been assisted in opening by a spring-loaded pusher **210** being pushed out from the door release mechanism **206** once the wire or cable holding the door **204** shut had been cut. Also shown in FIG. 2B is a recess or cavity **212** into which a door side portion of the wire or cable that had been holding the door **204** closed has been pulled, e.g., by a spring-loaded plunger configured to extend into the cavity **212** pulling the door end of the cut wire or cable into cavity **212**. In various embodiments, the wire or cable retraction mechanism configured to pull the free end of the cut wire or cable into cavity **212** ensures the loose (door) end of the cut wire or cable does not interfere with ejection and/or deployment of the small scale satellite from dispenser **200**.

[0026] FIG. 3A is a diagram illustrating an embodiment of a composite guide rail and a mold to fabricate same. In the example shown, layers **302** of carbon (or other) fiber reinforced fabric that has been pre-impregnated with a resin system, such as epoxy, are laid up on a mold **304**. Mold **304** may be made of machined aluminum or another durable material with predictable thermal expansion behaviors for the elevated temperature at which the composite guide rail is cured.

[0027] In various embodiments, to form a composite guide rail as disclosed herein, the mold **304** is polished, laminate layers **302** are laid on top, the layers **302** are topped with a peel-ply perforated release film and breather material, and the assembly **302**, **304** is placed in a vacuum bag. Once the mold **304** and laminate **302** are sealed in the vacuum bag, the bag is purged of all gasses with a vacuum pump. The assembly **302**, **304** is cured in a high pressure, high temperature autoclave for the specified time required by the pre-preg laminates **302**.

[0028] In various embodiments, composite guide rails as disclosed herein may be carbon composite rails with a layer of silicon carbide on the payload dispenser interface. The silicon carbide provides a very hard and smooth surface for the CubeSat rails to interface with. In some embodiments, a silicon carbide layer is laid right on top of the carbon fiber laminate layers (e.g., layers **302** in FIG. 3A) during the fabrication process.

[0029] FIG. 3B is a diagram illustrating an embodiment of a satellite dispenser with composite guide rails. In the example shown in FIG. 3B, a finished composite guide rail is shown in positions at the four corners of the satellite dispenser payload chamber (of the dispenser body, not shown in FIG. 3B). In various embodiments, the four corners of the payload **320**, e.g., CubeSat rails or other small scale satellite corner/edge structures, engage and ride on the inner

guide defined by the central lobe of the guide rail 302. In various embodiments, the silicon carbide layer on the side of guide rails 302 that face and engage the payload 320 enables the payload 320 to slide more freely along the guide rails 302, e.g., during satellite ejection and deployment.

[0030] FIG. 4A is a diagram illustrating an embodiment of a satellite dispenser pusher plate assembly. In the example shown, pusher plate assembly 400 includes a pusher plate 402 coupled to a dispenser end plate or panel 404 by a spring 406. In various embodiments, a satellite loaded into a dispenser that includes pusher plate assembly 400 is pressed against the pusher plate 402, comprising spring 406, enabling the dispenser door to be closed. Upon release of the dispenser door to eject and deploy the satellite, the spring 406 extends and pushes pusher plate 402 in the direction of the dispenser door opening, which in turn pushes the satellite, riding on one or more guide rails, such as guide rails 302 of FIGS. 3A and 3B, out and through the dispenser door opening.

[0031] FIG. 4B is a diagram illustrating front and side views of the satellite dispenser pusher plate assembly 400 of FIG. 4A. As shown in FIG. 4B, the pusher plate 402 includes protrusions 410, 412, 414, and 416 at locations on pusher plate 402, each of which aligns, in various embodiments, with a corresponding groove comprising a guide rail (e.g., guide rail 302) positioned in an interior corner of a dispenser payload area.

[0032] In the example shown, protrusions 410, 412, 414, and 416 are formed as an integral part of the pusher plate 402 and extend back towards the end plate as tapered posts, the distal ends of which engage, when the dispenser is loaded and spring 406 is compressed, with corresponding nylon (or other polymer) adjustable “feet”, represented in FIG. 4B by feet 420 and 422. Each of the tapered posts comprising the four protrusions (410, 412, 414, 416) aligns opposite a corresponding one of the feet. Each of the feet (e.g., 420, 422) is adjustable in its extent into the payload area of the dispenser and/or the force applied to the pusher plate 402 via the protrusion 410, 412, 414, and 416 with which it is aligned by an adjustment screw (or similar structure), represented in FIG. 4B by adjustment screws 424 and 426. In various embodiments, the nylon (or other) feet 422, 424 and associated adjustment screws 424, 426 are torqued to a prescribed torque to secure the payload firmly in the payload area, e.g., to avoid movement during flight, which could damage the satellite.

[0033] FIG. 5 is a diagram illustrating an embodiment of a satellite dispenser with externally adjustable payload restraint(s). In the example shown, the satellite dispenser 500 includes an interior payload area defined by four longitudinal side walls 502, end plate or panel 404, and door 506. As shown, a small scale satellite payload 504 is positioned in the dispenser 500. Door 506 is hinged at the bottom edge, as shown, at hinge 508 and is held closed in the state shown by door release mechanism 510. In the example shown, the payload 504 is held securely in place by adjustment of feet on the four protrusions of the pusher plate 402, represented in FIG. 5 by feet 420 and 422, and four feet at each corner of the inner face of door 506, represented in FIG. 5 by feet 512 and 516. In various embodiments, the respective external adjustment screws (or other external adjustment interfaces), represented in FIG. 5 by adjustment

screws 424, 426, 514, and 518, are torqued, each to a prescribed torque, to ensure the payload 504 is held securely in place.

[0034] In various embodiments, at least the dispenser door feet, such as feet 512, 516, are shaped to have a low profile, e.g., not to extend too far beyond the inner face of the door 506, to minimize the risk of interference with ejection of the payload 504 once the door 506 is released and springs open.

[0035] In various embodiments, the degree of torque applied to the external adjustment screws (e.g., screws 424, 426, 514, and 518) is determined empirically, for example for a given payload and/or class or type of payload. For example, vibration sensors may be used to determine for each torque in a range of values and for a given stimulus applied to the dispenser 500 a corresponding amount of vibration that is imparted to the payload 504. An amount of torque determined to ensure vibration below a prescribed or design level is applied.

[0036] In various embodiments, structures and techniques disclosed herein ensures a payload is positioned securely within a dispenser, reducing the risk of damage to the payload due to excessive vibration during flight.

[0037] Although the foregoing embodiments have been described in some detail for purposes of clarity of understanding, the invention is not limited to the details provided. There are many alternative ways of implementing the invention. The disclosed embodiments are illustrative and not restrictive.

What is claimed is:

1. A satellite dispenser, comprising:

a dispenser body defining an interior cavity to accommodate a payload;

a plurality of externally adjustable restraints positioned within the interior cavity and configured to be extended further into the interior cavity by actuation of a manual interface external to the interior cavity,

wherein the plurality of adjustable restraints restrain an assembly that is biased to eject the payload from the satellite dispenser.

2. The satellite dispenser of claim 1, wherein the manual interface is accessible when a payload has been loaded into the interior cavity through a dispenser door opening of the dispenser and a dispenser door of the dispenser has been closed.

3. The satellite dispenser of claim 1, wherein the assembly restrained by the plurality of restraints comprises a pusher plate having a plurality of posts and each of at least a subset of the posts is aligned with a corresponding one of the restraints, and the plurality of restraints extend through an end plate to engage the at least the subset of posts of the pusher plate.

4. The satellite dispenser of claim 3, wherein in response to the plurality of adjustable restraints being actuated in a manner that disengages the plurality of adjustable restraints from the at least the subset of posts, a biasing element applying force on the pusher plate causes a payload to be ejected from the satellite.

5. The satellite dispenser of claim 4, further comprising: a dispenser door configured to enclose the payload in the dispenser body when the door biased to a closed position,

wherein in response to the biasing of the door to the closed position being released and the plurality of adjustable restraints being actuated in a manner that

disengages the plurality of adjustable restraints from the at least the subset of posts, the payload is ejected from the satellite dispenser.

6. The satellite dispenser of claim **1**, further comprising: an end plate at a first end of the interior cavity, wherein at least a subset of the restraints are positioned on or in the end plate,

wherein the respective externally accessible manual interfaces of the restraints positioned on or in the end plate extend through the end plate.

7. The satellite dispenser of claim **6**, wherein the respective externally accessible manual interfaces of the restraints positioned on or in the end plate comprise adjustment screws.

8. The satellite dispenser of claim **1**, wherein at least a subset of the restraints are positioned on or in a dispenser door of the dispenser.

9. The satellite dispenser of claim **8**, wherein the respective externally accessible manual interfaces of the restraints positioned on or in the dispenser door extend through the dispenser door.

10. The satellite dispenser of claim **8**, wherein the respective externally accessible manual interfaces of the restraints positioned on or in the dispenser door comprise adjustment screws.

11. The satellite dispenser of claim **1**, wherein the plurality of restraints comprise nylon or another polymer.

12. The satellite dispenser of claim **1**, wherein the plurality of restraints have a low profile to avoid interfering with ejection of a payload from the dispenser.

13. A method of loading a satellite dispenser, comprising: inserting a satellite into the satellite dispenser, wherein the satellite dispenser comprises:

a dispenser body defining an interior cavity to accommodate the satellite;

a plurality of externally adjustable restraints positioned within the interior cavity, wherein the plurality of adjustable restraints restrain an assembly that is biased to eject the satellite from the satellite dispenser;

closing a dispenser door of the satellite dispenser to seal the satellite inside the satellite dispenser; and

adjusting a plurality of externally adjustable manual interfaces, wherein each of the manual interfaces is associated with a corresponding one of the plurality of restraints, each of the manual interfaces is adjusted to corresponding a prescribed torque, and at least a subset of the plurality of restraints are correspondingly adjusted to a position at which the subset of the plurality of restraints secure the satellite.

14. The method of claim **13**, wherein the prescribed torque is determined at least in part by iteratively applying varying amounts of torque, and for each torque applied performing a test to determine a measure of how securely the satellite is held in place.

15. The method of claim **14**, wherein the test comprises a vibration test.

16. The method of claim **13**, wherein the externally adjustable manual interfaces comprise screws or other fasteners.

17. The method of claim **13**, wherein the plurality of restraints comprise nylon or other polymer feet that are disposed on the assembly.

18. The method of claim **13**, wherein the plurality of externally adjustable manual interfaces and associated interior payload restraints are distributed at opposite ends of the satellite dispenser.

19. The method of claim **18**, wherein the plurality of externally adjustable manual interfaces and associated interior payload restraints includes two or more externally adjustable manual interfaces and associated interior payload restraints at each of the opposite ends of the satellite dispenser.

20. The method of claim **13**, wherein the assembly restrained by the plurality of restraints comprises a pusher plate having a plurality of posts and each of at least a subset of the posts is aligned with a corresponding one of the restraints, and the plurality of restraints extend through an end plate to engage the at least the subset of posts of the pusher plate.

* * * * *