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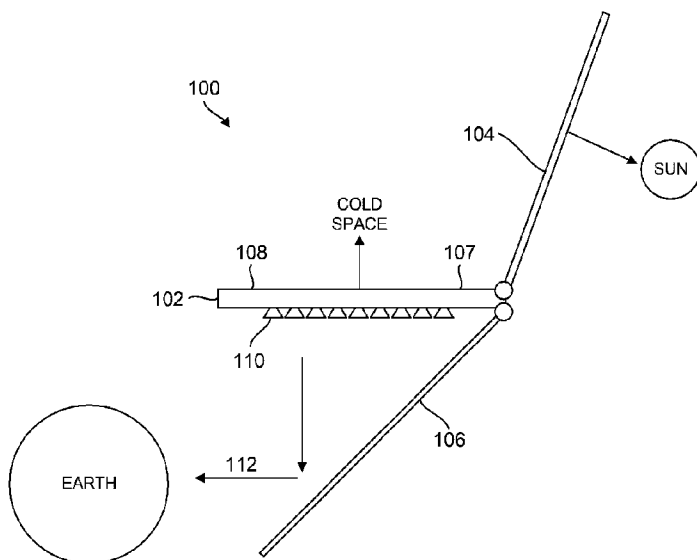
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(54) Title: STACKABLE PANCAKE SATELLITE



(57) **Abrégé/Abstract:**

A stackable pancake satellite that is configured so that a plurality of the satellites can be stacked within a payload fairing of a launch vehicle. Each satellite includes sections that are folded or rotated together prior to launch, and unfolded or rotated away from each other when deployed. A first section is a satellite body having a first side that acts as a thermal radiator and a second side opposite the first side that includes an antenna. A second section includes one or more solar panels attached adjacent to the first side of the satellite body. A third section includes a splash plate reflector attached adjacent to the second side of the satellite body that reflects signals between Earth and the antenna. When deployed, the solar panels are pointed towards the Sun and the splash plate reflector directs the signals between the Earth and the antenna.

ABSTRACT

A stackable pancake satellite that is configured so that a plurality of the satellites can be stacked within a payload fairing of a launch vehicle. Each satellite
5 includes sections that are folded or rotated together prior to launch, and unfolded or rotated away from each other when deployed. A first section is a satellite body having a first side that acts as a thermal radiator and a second side opposite the first side that includes an antenna. A second section includes one or more solar panels attached adjacent to the first side of the satellite body. A third section includes a
10 splash plate reflector attached adjacent to the second side of the satellite body that reflects signals between Earth and the antenna. When deployed, the solar panels are pointed towards the Sun and the splash plate reflector directs the signals between the Earth and the antenna.

STACKABLE PANCAKE SATELLITE

BACKGROUND INFORMATION

5 **1. Field**

The present disclosure relates to satellites, and in particular, to a stackable pancake satellite.

2. Description of the Related Art

10 Satellites and other spacecraft are used for a number of different purposes, including communication, navigation, observation and research. However, launching satellites into space is expensive.

 There are many factors that contribute to the high cost of launching satellites. Moreover, these factors constrain satellite design decisions. Two of the most
15 fundamental constraints on satellite design decisions are the number of satellites supported by a launch vehicle, and the geometry of a payload fairing for the launch vehicle, which sets limits on the geometry of the satellites.

 Consequently, it is desirable if the satellite design supports storing more than one satellite on the launch vehicle. It is also desirable to have a satellite design that
20 optimizes the geometry of the satellites for use within the geometry of the payload fairing.

 What is needed, then, are improved designs for satellites.

SUMMARY

25 The present disclosure describes a stacked satellite system, a method for launching the stacked satellite system, and a method for fabricating a satellite for use in the stacked satellite system.

 The stacked satellite system comprises a plurality of satellites configured for being stacked within a payload fairing of a launch vehicle. The satellites are
30 disposed within the payload fairing of the launch vehicle in a stacked column configuration prior to launch. The plurality of satellites comprises at least one top

satellite disposed vertically on top of at least one bottom satellite within the payload fairing of the launch vehicle, wherein a structure bears launch loads for both the top and bottom satellites. The satellites are passively dispensed from the payload fairing of the launch vehicle upon reaching orbit.

5 Each of the satellites includes a plurality of sections that are hinged together, wherein the sections are folded or rotated together prior to launch, and unfolded or rotated away from each other when deployed upon reaching orbit. A periphery outline of the sections when folded together is oval, elliptical, round or polygonal in shape. The sections, when folded together, maintain a
10 substantially flat profile.

 A first one of the sections is a satellite body having a first side that acts as a thermal radiator and a second side opposite the first side that includes at least one antenna, which in one embodiment comprises a multi-beam antenna. The first one of the sections also includes bus and payload units mounted on or with the thermal
15 radiator.

 A second one of the sections includes at least one solar panel, and possibly two or more solar panels, attached adjacent to the first side of the satellite body, wherein light from the Sun is converted to electricity by the solar panel. In one embodiment, the solar panel comprises a multi-segmented array that is configured to
20 be at least partially folded onto itself.

 A third one of the sections includes at least one splash plate reflector attached adjacent to the second side of the satellite body, wherein radio frequency signals between Earth and the antenna of the satellite are reflected by the splash plate reflector.

25 The satellite body has a cavity on the first side and a hollow region on the second side, such that, when folded together, the solar panels are folded and stowed within the hollow region, the antenna is disposed within the cavity, and the splash plate reflector is stored adjacent to the antenna in the cavity.

 In one embodiment, the thermal radiator and the solar panel are disposed
30 within the hollow region, and the solar panel comprises a plurality of foldable solar arrays that, when folded, are enclosed within the hollow region. In another

embodiment, the solar panel includes a plurality of panel elements having substantially the same shape, and the plurality of panel elements are each folded upon each other to fit within the hollow region.

When deployed, the solar panel is rotated away from the first side of the satellite body, so that the solar panel is pointed towards the Sun, and the splash plate reflector is rotated away from the second side of the satellite body to direct the signals between the Earth and the antenna. One or more mechanisms are employed to keep the solar panel pointed at the Sun, the splash plate reflector pointed at the Earth, and the thermal radiator pointed into space.

The method for launching a stacked satellite system comprises stacking a plurality of satellites within a payload fairing of a launch vehicle, wherein each of the satellites is configured as described above, launching the plurality of satellites into orbit using the launch vehicle, and serially dispensing each of the plurality of satellites from the payload fairing of the launch vehicle upon reaching orbit. In one embodiment, the satellites are passively dispensed from the payload fairing of the launch vehicle upon reaching orbit.

Orbit phasing is maintained with at least one thruster located on the satellite body by rotating the satellite body so that a desired thrust angle for the thruster is achieved, firing the thruster, and then restoring the satellite body to its original position after firing the thruster.

In one embodiment, there is provided a stacked satellite system. The system includes a plurality of satellites configured for being stacked within a payload fairing of a launch vehicle, and each of the plurality of satellites includes a plurality of sections, that are hingedly attached to each other. The plurality of sections are folded or rotated together prior to launch, and the plurality of sections are unfolded or rotated away from each other when deployed upon reaching orbit. The system further includes a first one of the plurality of sections is a satellite body having a first side that acts as a thermal radiator and a second side opposite the first side that includes at least one antenna, and a second one of the plurality of sections includes at least one solar panel attached adjacent to the first side of the satellite body, wherein light from the

Sun is converted to electricity by the at least one solar panel. The system further includes a third one of the plurality of sections includes at least one splash plate reflector attached adjacent to the second side of the satellite body, wherein radio frequency signals between Earth and the at least one antenna are reflected by the at least one splash plate reflector, and when deployed, the at least one solar panel is rotated away from the first side of the satellite body, so that the at least one solar panel is pointed towards the Sun, and the at least one splash plate reflector is rotated away from the second side of the satellite body to direct the signals between the Earth and the at least one antenna.

A periphery outline of the plurality of sections of each satellite when folded together may be oval, elliptical, round or polygonal in shape.

The plurality of sections of each satellite when folded together, may maintain a substantially flat profile.

The satellite body of each satellite may have a cavity on the first side and a hollow region on the second side, such that, when folded together, the at least one solar panel of each satellite is folded and stowed within the hollow region, the at least one antenna of each satellite is disposed within the cavity, and the at least one splash plate reflector of each satellite is stored adjacent to the at least one antenna in the cavity.

The system may include a polygonal closeout member covers the first side of the satellite body of each satellite surrounding the cavity, and the first side of the satellite body of each satellite that acts as the thermal radiator and the at least one solar panel of each satellite are disposed within the hollow region, and the at least one solar panel comprises a plurality of foldable solar arrays that, when folded, are enclosed within the hollow region.

The at least one solar panel of each satellite may include a plurality of panel elements having substantially the same shape, and the plurality of panel elements are each folded upon each other to fit within the hollow region.

The at least one solar panel of each satellite may include two or more solar panels.

The at least one solar panel of each satellite may include a multi-segmented array that is configured to be at least partially folded onto itself.

The plurality of satellites may be disposed within the payload fairing of the launch vehicle in a stacked column configuration prior to launch.

5 The plurality of satellites may include at least one top satellite disposed vertically on top of at least one bottom satellite within the payload fairing of the launch vehicle, wherein a plurality of corner fitting bear launch loads for both the top and bottom satellites.

10 The plurality of satellites may be passively dispensed from the payload fairing of the launch vehicle upon reaching orbit.

The first one of the plurality of sections of each satellite may include bus and payload units mounted on or with the first side of the satellite body of each satellite that acts as the thermal radiator.

The at least one antenna of each satellite may include a multi-beam antenna.

15 At least one thruster may be attached to the satellite body of each satellite to maintain orbit phasing.

20 the at least one solar panel of each satellite may be pointed at the Sun, the at least one splash plate reflector of each satellite may be pointed at the Earth, and the first side of the satellite body of each satellite that acts as the thermal radiator may be pointed into space.

25 In another embodiment, there is provided a method for launching a stacked satellite system. The system includes stacking a plurality of satellites within a payload fairing of a launch vehicle. Each of the plurality of satellites includes a plurality of sections that are hingedly attached to each other, wherein the plurality of sections are folded or rotated together prior to launch, and the plurality of sections are unfolded or rotated away from each other when deployed upon reaching orbit. A first one of the plurality of sections is a satellite body having a first side that acts as a thermal radiator and a second side opposite the first side that includes at least one antenna. A second one of plurality of the sections includes at least one solar panel attached adjacent to
30 the first side of the satellite body, wherein light from the Sun is converted to electricity

by the at least one solar panel. A third one of the plurality of sections includes at least one splash plate reflector attached adjacent to the second side of the satellite body, wherein radio frequency signals between Earth and the at least one antenna are reflected by the at least one splash plate reflector . The system may include launching
5 the plurality of satellites into orbit using the launch vehicle, and serially dispensing each of the plurality of satellites from the payload fairing of the launch vehicle upon reaching orbit, such that, when each of the plurality of satellites is deployed, the second one of the plurality of sections is rotated away from the first side of the satellite body so that the at least one solar panel is pointed towards the Sun, and the third one
10 of the plurality of sections is rotated away from the second side of the satellite body so that the at least one splash plate reflector directs the radio frequency signals between Earth and the at least one antenna.

A periphery outline of the plurality of sections of each satellite when folded together may be oval, elliptical, round or polygonal in shape.

15 The plurality of sections of each satellite when folded together, may maintain a substantially flat profile.

The satellite body of each satellite may have a cavity on the first side and a hollow region on the second side, such that, when folded together, the at least one solar panel of each satellite is folded and stowed within the hollow region, the at least
20 one antenna of each satellite is disposed within the cavity, and the at least one splash plate reflector of each satellite is stored adjacent to the at least one antenna in the cavity.

A polygonal closeout member may cover the first side of the satellite body of each satellite surrounding the cavity, and the first side of the satellite body of each
25 satellite that acts as thermal radiator and the at least one solar panel of each satellite may be disposed within the hollow region, and the at least one solar panel of each satellite comprises a plurality of foldable solar arrays that, when folded, are enclosed within the hollow region.

The plurality of satellites may include at least one top satellite disposed
30 vertically on top of at least one bottom satellite within the payload fairing of the launch

vehicle, wherein a plurality of corner fittings bear launch loads for both the top and bottom satellites.

The plurality of satellites may be passively dispensed from the payload fairing of the launch vehicle upon reaching orbit.

5 The at least one solar panel of each satellite is pointed at the Sun, the splash plate reflector of each satellite is pointed at the Earth, and the first side of the satellite body of each satellite that acts as the thermal radiator may be pointed into space, upon reaching orbit.

10 Orbit phasing may be maintained with a thruster located on the satellite body of each satellite by rotating the satellite body of each satellite so that a desired thrust angle for the thruster is achieved, firing the thruster, and then restoring the satellite body of each satellite to its original position after firing the thruster.

15 In another embodiment, there is provided a method for fabricating a satellite that is configured for being stacked with one or more other satellites within a payload fairing of a launch vehicle. The method involves fabricating a plurality of sections that are hingedly attached to each other. The plurality of sections are folded or rotated together prior to launch, and the plurality of sections are unfolded or rotated away from each other when deployed upon reaching orbit. A first one of the plurality of sections is a satellite body having a first side that acts as a thermal radiator and a
20 second side opposite of the first side that includes at least one antenna. A second one of the plurality of sections includes at least one solar panel attached adjacent to the first side of the satellite body, wherein light from the Sun is converted to electricity by the at least one solar panel. A third one of the plurality of sections includes at least one splash plate reflector attached to the second side of the satellite body, wherein
25 radio frequency signals between Earth and the at least one antenna are reflected by the at least one splash plate reflector. Such that, when deployed, the at least one solar panel is rotated away from the first side of the satellite body, so that the at least one solar panel is pointed towards the Sun, and the at least one splash plate reflector is rotated away from the second side of the satellite body to direct the radio frequency
30 signals between the Earth and the at least one antenna.

In another embodiment, there is provided an apparatus. The apparatus includes at least one satellite having a plurality of sections that are attached to each other. The plurality of sections are folded or rotated together prior to launch, and the plurality of sections are unfolded or rotated away from each other when deployed upon
5 reaching orbit. A first one of the plurality of sections is a satellite body that includes at least one antenna. A second one of the plurality of sections includes at least one solar panel attached to the satellite body for converting light from the Sun to electricity. A third one of the plurality of sections includes at least one splash plate reflector attached to the satellite body for reflecting radio frequency signals between Earth and
10 the at least one antenna. When deployed, the at least one solar panel is rotated away from the satellite body to point towards the Sun, and the at least one splash plate reflector is rotated away from the satellite body to direct the radio frequency signals between the Earth and the at least one antenna.

The satellite body may have a first side that acts as a thermal radiator and a
15 second side opposite the first side that includes the at least one antenna.

The at least one solar panel may be attached to the first side of the satellite body.

The at least one splash plate reflector may be attached to the second side of the satellite body.

The at least one solar panel may be pointed at the Sun, the at least one splash
20 plate reflector may be pointed at the Earth, and the first side of the satellite body that acts as the thermal radiator may be pointed into space.

The satellite body may have a cavity on the first side and a hollow region on the second side, such that, when folded together, the at least one solar panel may be folded and stowed within the hollow region, the at least one antenna may be disposed
25 within the cavity, and the at least one splash plate reflector may be stored adjacent to the at least one antenna in the cavity.

The apparatus may include a polygonal closeout member covers the first side of the satellite body surrounding the cavity; and the first side of the satellite body that acts as the thermal radiator and the at least one solar panel are disposed within the

hollow region, and the at least one solar panel may include a plurality of foldable solar arrays that, when folded, are enclosed within the hollow region.

5 The at least one solar panel may include a plurality of panel elements having substantially the same shape, and the plurality of panel elements are each folded upon each other to fit within the hollow region.

The first one of the plurality of sections may include bus and payload units mounted on or with the first side of the satellite body that acts as the thermal radiator.

The at least one solar panel may include two or more solar panels.

10 The at least one solar panel may include a multi-segmented array that is configured to be at least partially folded onto itself.

The at least one antenna may include a multi-beam antenna.

At least one thruster may be attached to the satellite body to maintain orbit phasing.

15 A periphery outline of the plurality of sections, when folded together, may be oval, elliptical, round or polygonal in shape.

The plurality of sections, when folded together, may maintain a substantially flat profile.

The at least one satellite may include a plurality of satellites configured for being stacked within a payload fairing of a launch vehicle.

20 The plurality of satellites may be disposed within the payload fairing of the launch vehicle in a stacked column configuration prior to launch.

The plurality of satellites may include at least one top satellite disposed vertically on top of at least one bottom satellite within the payload fairing of the launch vehicle, and each bottom satellite may include a plurality of corner fittings that bear launch loads for the bottom satellite and the at least one top satellite.

25 The plurality of satellites may be passively dispensed from the payload fairing of the launch vehicle upon reaching orbit.

30 In another embodiment, there is provided a method. The method involves fabricating at least one satellite having a plurality of sections that are attached to each other, wherein the plurality of sections are folded or rotated together prior to launch,

and the plurality of sections are unfolded or rotated away from each other when deployed upon reaching orbit. The method further involves a first one of the plurality of sections is a satellite body that includes at least one antenna. The method further involves a second one of the plurality of sections includes at least one solar panel
5 attached to the satellite body for converting light from the Sun to electricity; and a third one of the plurality of sections includes at least one splash plate reflector attached to the satellite body for reflecting radio frequency signals between Earth and the at least one antenna. The method further involves when deployed, the at least one solar panel is rotated away from the satellite body, so that the at least one solar panel is
10 pointed towards the Sun, and the at least one splash plate reflector is rotated away from the satellite body to direct the radio frequency signals between the Earth and the at least one antenna.

In another embodiment, there is provided a method. The method involves stacking at least one satellite within a payload fairing of a launch vehicle. The at least
15 one satellite having a plurality of sections that are attached to each other, wherein the plurality of sections are folded or rotated together prior to launch, and the plurality of sections are unfolded or rotated away from each other when deployed upon reaching orbit. A first one of the plurality of sections is a satellite body that includes at least one antenna and a second one of the plurality of sections includes at least one solar
20 panel attached to the satellite body for converting light from the Sun to electricity. A third one of the plurality of sections includes at least one splash plate reflector attached to the satellite body for reflecting radio frequency signals between Earth and the at least one antenna, and launching the at least one satellite into orbit using the launch vehicle. Dispensing the at least one satellite from the payload fairing of the
25 launch vehicle upon reaching orbit, such that, when the at least one satellite is deployed, the second one of the plurality of sections is rotated away from the first one of the plurality of sections so that the at least one solar panel is pointed towards the Sun, and the third one of the plurality of sections is rotated away from the first one of the plurality of sections so that the at least one splash plate reflector directs the
30 radio frequency signals between Earth and the at least one antenna.

The at least one satellite may include a plurality of satellites configured for being stacked within the payload fairing of the launch vehicle.

The plurality of satellites may be disposed within the payload fairing of the launch vehicle in a stacked column configuration prior to launch.

- 5 The plurality of satellites may include at least one top satellite disposed vertically on top of at least one bottom satellite within the payload fairing of the launch vehicle, and each bottom satellite includes a plurality of corner fittings that bear launch loads for the bottom satellite and the at least one top satellite.

- 10 The plurality of satellites may be passively dispensed from the payload fairing of the launch vehicle upon reaching orbit.

DRAWINGS

Referring now to the drawings in which like terminology and reference numbers represent corresponding parts throughout:

15

FIG. 1 is a side view of a stackable pancake satellite configured for being stacked within a payload fairing of a launch vehicle, according to one embodiment.

FIG. 2A is a side view of a plurality of satellites, according to one embodiment.

FIG. 2B is a top view of a stack of satellites, according to one embodiment.

5 FIG. 3 illustrates three top views of stacks of satellites, illustrating different possible cross-sections.

FIG. 4A illustrates another example of a stackable pancake satellite, according to one embodiment.

10 FIG. 4B illustrates a side view of the satellite of FIG. 4A, according to one embodiment.

FIG. 4C illustrates a top view of the satellite of FIG. 4A, according to one embodiment.

FIG. 4D shows a plurality of satellites in a stacked column configuration disposed within a payload fairing of a launch vehicle, according to one embodiment.

15 FIG. 5 illustrates a deployed satellite on orbit, according to one embodiment.

FIG. 6 illustrates a cross-section view of one embodiment of the satellite, wherein various embedded systems are located within separated sections in the satellite body.

20 FIG. 7 is a flowchart of a satellite or spacecraft manufacturing method, according to one embodiment.

FIG. 8 is an illustration of the components of a satellite or spacecraft manufactured in FIG. 7, according to one embodiment.

DETAILED DESCRIPTION

25 In the following description of the preferred embodiment, reference is made to the accompanying drawings which form a part hereof, and in which is shown by way of illustration a specific embodiments. It is to be understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present disclosure.

30

Overview

A stackable pancake satellite is comprised of a plurality of sections that are folded or rotated together into a flat configuration for launch, and are unfolded or rotated away from each other when deployed in orbit. The sections include a satellite body with a thermal radiator and an antenna, a solar cell panel, and a splash plate reflector for signals transmitted and received by the antenna. When folded into the flat configuration, a plurality of the satellites are stacked within a payload fairing of a launch vehicle.

Technical Details

FIG. 1 is a side view of a stackable pancake satellite **100** configured for being stacked within a payload fairing of a launch vehicle, according to one embodiment. In this embodiment, the satellite **100** is a platform that includes a plurality of substantially flat sections, segments or panels **102**, **104**, **106** that are hingedly attached to each other, wherein the sections **102**, **104**, **106** are folded or rotated together for launch, and unfolded or rotated away from each other when deployed upon reaching orbit. In this embodiment, the satellite **100** is a three-panel spacecraft.

A first one of the sections **102** of the satellite **100** is a satellite body **102** having a first (top) flat side that acts as a thermal radiator **108** and a second (bottom) side opposite the first side that includes at least one antenna **110**. The first section **102** may also include bus and payload units (not shown) mounted on or with the thermal radiator **108**. The antenna **110** may comprise a multi-beam or phased array antenna **110** that include service and feeder-link arrays (not shown).

A second one of the sections **104** of the satellite **100** includes at least one solar panel **104** attached adjacent to the first side of the satellite body **102** with a sun-active surface of the solar panel **104** pointing away from the satellite body **102** and towards the Sun, wherein light from the Sun is converted to electricity by one or more solar cells of the solar panel **104**.

A third one of the sections **106** of the satellite **100** includes at least one splash plate reflector **106** attached adjacent to the second side of the satellite body **102**,

wherein radio frequency (RF) signals **112** between Earth and the antenna **110** are reflected by the splash plate reflector **106**.

When deployed, the solar panel **104** is rotated away from the first (top) side of the satellite body **102**, so that the solar panel **104** is pointed towards the Sun, and
 5 the splash plate reflector **106** is rotated away from the second (bottom) side of the satellite body **102** to direct the signals **112** between the Earth and the antenna **110**.

The terms top/bottom, up/down, and left/right used herein are relative terms that describe the relative position of the described elements. It is understood the satellite **100** may be at any orientation in space relative to an observer so that these
 10 terms may assume correspondingly different values.

One or more mechanisms may be employed to keep the solar panel **104** pointed at the Sun, the splash plate reflector **106** pointed at Earth, and the thermal radiator **108** pointed into cold space. Preferably, all of this occurs while the satellite **100** follows a circular track on orbit to keep the signals **112** pointed at the Earth.

FIG. **2A** is a side view of a plurality of satellites **200a**, **200b**, **200c**, **200d**, **200e**, and **200f**, each of which includes a satellite body **202**, at least one solar panel **204** and at least one splash plate reflector **206**. The plurality of satellites **200a**, **200b**, **200c**, **200d**, **200e**, and **200f** are folded and arranged in a stack **208**, so that they can be stowed for launch within a payload fairing of a launch vehicle (not shown).
 15 Although FIG. **2A** shows six satellites **200a**, **200b**, **200c**, **200d**, **200e**, and **200f** arranged in the stack **208**, this not intended to be limiting and any number of satellites **200** may be so arranged.
 20

FIG. **2B** is a top view of the stack **208**, illustrating that a periphery outline of the sections of the satellites **200a**, **200b**, **200c**, **200d**, **200e**, and **200f** when folded together is substantially oval or elliptical in shape.
 25

FIG. **3** illustrates three top views of stacks **300**, **302**, and **304** of satellites, illustrating different possible cross-sections for the satellites, including substantially round **300**, hexagonal **302**, and octagonal **304** cross-sections. In various embodiments, a periphery outline of the sections of each satellite, when folded together and stacked, is round **300** or polygonal (e.g. hexagonal **302**, octagonal **304**, etc.) in shape. Other cross-sections may be used as well.
 30

FIG. 4A illustrates another example of a stackable pancake satellite **400**, according to one embodiment. In this embodiment, the satellite **400** includes a satellite body **402**, two or more solar panels **404a**, **404b**, an antenna **406** comprising a C and Ka band array, and a splash plate reflector **408**. The satellite body **402** has a cavity on the first side and a hollow region on the second side, such that, when folded together, the second one of the sections, comprising the two solar panels **404a**, **404b**, is folded and stowed within the hollow region. A thermal radiator (not shown) is also disposed within the hollow region. On an opposite side of the satellite body **402**, the antenna **406** is stored within the cavity of the satellite body **402**. The third one of the sections, comprising the splash plate reflector **408**, is stored adjacent to the antenna **406** in the cavity.

In one embodiment, each of the solar panels **404a**, **404b** includes a plurality of panel elements having substantially the same shape, and the plurality of panel elements are each folded upon each other to fit within the hollow region. In another embodiment, each of the solar panels **404a**, **404b** comprises a multi-segmented array that is configured to be at least partially folded onto itself, prior to being stowed within the hollow region.

Also shown is a thruster **410** attached to an exterior panel of the satellite body **402**. In one embodiment, the satellite **400** may use “all electric propulsion” with one thruster **410** or any number of independent thrusters **410**.

FIG. 4B illustrates a side view of the satellite **400** of FIG. 4A, according to one embodiment. The relative positions of the satellite body **402**, two solar panels **404a**, **404b**, and splash plate reflector **406**, are shown when folded. A polygonal closeout member **412** covers the first side of the satellite body **402** surrounding the cavity.

FIG. 4C illustrates a top view of the satellite **400** of FIG. 4A, according to one embodiment. The top view shows the hexagonal egg-crate structure **414** of the satellite body **402**.

FIG. 4D shows a plurality of satellites **400** in a stacked column configuration **416** disposed within a payload fairing **418** of a launch vehicle **420** prior to launch, according to one embodiment. The plurality of satellites **400** comprises at least one top satellite **400** disposed vertically on top of at least one bottom satellite **400** within

the payload fairing **418** of the launch vehicle **420**, wherein a structure bears launch loads for both the top and bottom satellites **400**. Upon reaching orbit, each of the satellites **400** in the stack **416** is passively and serially dispensed from the payload fairing **418** of the launch vehicle **420** without the use of a dedicated dispensing apparatus, although active dispensing may also be used.

FIG. **5** illustrates a deployed satellite **500** on orbit, according to one embodiment. In this embodiment, the satellite **500** is comprised of a satellite body **502**, solar panel **504** and splash plate reflector **506**, wherein the solar panel **504** and splash plate reflector **506** are attached at different points on the satellite body **502**. The satellite body **502** has a first (right) side that acts as a thermal radiator **508** and a second (left) side opposite the first side that includes an integrated antenna **510**.

Both the solar panel **504** and splash plate reflector **506** are shown deployed. When deployed, the solar panel **504** is rotated away from the satellite body **502**, so that the solar panel **504** is pointed towards the Sun. Similarly, when deployed, the splash plate reflector **506** is rotated away from the satellite body **502** to direct the signals **512** between the Earth and the antenna **510**.

The arrows **514** at the top of the satellite body **502** indicate a yaw orientation about a center (nadir) axis of the satellite body **502** to keep the solar panel **504** pointed at the Sun (i.e., normal to the Sun on both axes), the splash plate reflector **506** pointed at Earth, and the thermal radiator **508** pointed away from the Sun into cold space.

In addition, at least one thruster **516** is attached to one end of the satellite body **502**, or another suitable location on the satellite body **502**, to maintain orbit phasing. In one embodiment, the thruster **516** is a single fixed thruster, although multiple smaller thrusters with an identical thrust direction are used in other embodiments. Orbit phasing is maintained by periodically rotating the satellite body **502** (e.g. with reaction wheels) so that a desired thrust angle for the thruster **516** is achieved, firing the thruster **516**, and then restoring the satellite body **502** to its original position after firing the thruster **516**. This process can be performed during orbit maintenance windows when there is no traffic demand (e.g., when a LEO

satellite **500** is over the ocean and/or another satellite in a constellation can absorb extra capacity temporarily).

FIG. **6** illustrates a cross-section view of one embodiment of the satellite **600**, wherein the satellite body **602** has a hexagonal egg-crate structure **604**, which is a load-bearing stacking structure. The body **602** includes a plurality of radially separated sections defined by a plurality of intercostal members **608**, each surrounded by an outer perimeter panel **610**, wherein the intercostal members **608** and adjacent outer perimeter panels **610** are joined by a plurality of elongated corner fittings **612**. The various embedded systems stored in the radially separated sections include avionics **616**, power controller and batteries **618**, other payload electronics **620**, solar panel drives **622**, canting reaction wheels **624**, thruster **626**, thruster assembly **628** including tanks, and a splash plate reflector mount **630**. When the satellite **600** is stacked, with a top satellite **600** disposed vertically on a bottom satellite **600**, the plurality of elongated corner fittings **612** for the bottom satellite **600** bear the loads for both the top and bottom satellites **600**.

Satellite Fabrication

Embodiments of the disclosure may be described in the context of a satellite or spacecraft fabricating method **700** as shown in FIG. **7**, wherein the resulting satellite or spacecraft is shown in FIG. **8**.

As illustrated in FIG. **7**, during pre-production, exemplary method **700** may include specification and design **702** of the satellite **800** and material procurement **704**. During production, component and subassembly manufacturing **706** and system integration **708** of the satellite **800** takes place, which include fabricating the satellite **800**, body **802**, solar panels **804**, splash plate reflector **806**, and various systems **808** described herein. Thereafter, the satellite **800** may go through certification and delivery **710** in order to be placed in service **712**. The satellite **800** may also be scheduled for maintenance and service **714** (which includes modification, reconfiguration, refurbishment, and so on), before being launched.

Each of the processes of method **700** may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., a customer). For the

purposes of this description, a system integrator may include without limitation any number of spacecraft manufacturers and major-system subcontractors; a third party may include without limitation any number of vendors, subcontractors, and suppliers; and an operator may be a satellite company, military entity, service organization, and so on.

As shown in FIG. 8, the satellite **800** fabricated by exemplary method **700** may include a body **802**, solar panels **804**, and splash plate reflector **806**, as described in more detail above, with a plurality of systems **808**. Examples of such systems **808** include, but are not limited to, one or more of a propulsion system **810**, an electrical system **812**, a communications system **814**, and a power system **816**. Any number of other systems may be included.

Benefits

A number of benefits are derived from the stackable pancake satellite. Moreover, these benefits address DFMAT (Design for Manufacturing, Assembly, and Test) issues concerning the stackable pancake satellite.

For example, some of those benefits include:

- The systems, sub-systems, sections, panels, units, and components are manufactured and tested in volume to reduce cost.
- The thermal radiator provides a direct path to radiate waste heat to space without the need for complex and mass heavy heat pipes.
- Sections or panels may be built and tested in the best respective factories on production lines:
 - Functional and performance testing is minimal (possibly ~1 hour per spacecraft); and
 - Environmental and burn-in test when deemed appropriate.
- Sections or panels assembled and stacked for launch:
 - Potentially at launch site; and
 - Minimal spacecraft level testing other than interconnection and mechanism validation (possibly ~1 hour per spacecraft).

- Multiple satellites can be launched at one time, thereby reducing the launch costs per satellite.

A number of basic problems are solved by of the stackable pancake satellite. For example, the stackable pancake satellite packages the maximum number of spacecraft into a fairing in the simplest manner (i.e. minimizing the number of
 5 deployments, folds, thermal interfaces, eliminating the need for heat pipes, etc.) to provide the lowest cost and highest reliability.

This is especially true when the performance of the spacecraft is driven by the area of three critical elements: the area of the payload aperture, the area of the
 10 thermal radiator for waste heat dissipation, and the area of the solar panels for power generation.

While propulsion is an important issue, it is not as significant as these three critical elements. The stackable pancake satellite configuration is enabled in part by a very modest propulsion system allowing the depth (e.g. height in the stack) of the
 15 spacecraft to be small. This is mostly due to a modest acceleration requirement.

The stackable pancake satellite configuration is enhanced by the chosen configuration of small, electrically powered thrusters, but could have been realized with other thruster technologies including traditional chemical thrusters. The particular thruster technology was chosen for mass savings, using what should be a
 20 more readily produced thruster in high volume, and for ease of manufacturing at final integration.

Other configurations may not be packaged as efficiently in the fairing and/or wind up with complex deployments to achieve the desired areas; hence, the virtue of the pancake satellite configuration.

25 Throughout the development, optimization for low earth orbit (LEO), with altitudes from ~**500** kilometers (km) to ~**1500** km, was a central focus. However, the stackable pancake satellite may be inserted into all inclinations from virtually any launch site and using any launch vehicle throughout.

30

Alternatives

The description of the different embodiments set forth above has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications
5 and variations will be apparent to those of ordinary skill in the art.

EMBODIMENTS IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A stacked satellite system, comprising:

5

a plurality of satellites configured for being stacked within a payload fairing of a launch vehicle;

10

each of the plurality of satellites includes a plurality of sections that are hingedly attached to each other, wherein the plurality of sections are folded or rotated together prior to launch, and the plurality of sections are unfolded or rotated away from each other when deployed upon reaching orbit;

15

a first one of the plurality of sections is a satellite body having a first side that acts as a thermal radiator and a second side opposite the first side that includes at least one antenna;

20

a second one of the plurality of sections includes at least one solar panel attached adjacent to the first side of the satellite body, wherein light from the Sun is converted to electricity by the at least one solar panel; and

25

a third one of the plurality of sections includes at least one splash plate reflector attached adjacent to the second side of the satellite body, wherein radio frequency signals between Earth and the at least one antenna are reflected by the at least one splash plate reflector;

30

when deployed, the at least one solar panel is rotated away from the first side of the satellite body, so that the at least one solar panel is pointed towards the Sun, and the at least one splash plate reflector is rotated

away from the second side of the satellite body to direct the signals between the Earth and the at least one antenna.

5 2. The system of claim 1, wherein a periphery outline of the plurality of sections of each satellite when folded together is oval, elliptical, round or polygonal in shape.

 3. The system of claims 1 or 2, wherein the plurality of sections of each satellite, when folded together, maintain a substantially flat profile.

10

 4. The system of any one of claims 1 to 3, wherein the satellite body of each satellite has a cavity on the first side and a hollow region on the second side, such that, when folded together, the at least one solar panel of each satellite is folded and stowed within the hollow region, the at least one antenna of each
15 satellite is disposed within the cavity, and the at least one splash plate reflector of each satellite is stored adjacent to the at least one antenna in the cavity.

 5. The system of claim 4, further comprising:

20

 a polygonal closeout member covers the first side of the satellite body of each satellite surrounding the cavity; and

25

 the first side of the satellite body of each satellite that acts as the thermal radiator and the at least one solar panel of each satellite are disposed within the hollow region, and the at least one solar panel of each satellite comprises a plurality of foldable solar arrays that, when folded, are enclosed within the hollow region.

30

 6. The system of claims 4 or 5, wherein the at least one solar panel of each satellite includes a plurality of panel elements having substantially the same

shape, and the plurality of panel elements are each folded upon each other to fit within the hollow region.

- 5 7. The system of any one of claims **1** to **6**, wherein the at least one solar panel of each satellite comprises two or more solar panels.
- 10 8. The system of any one of claims **1** to **7**, wherein the at least one solar panel of each satellite comprises a multi-segmented array that is configured to be at least partially folded onto itself.
- 15 9. The system of any one of claims **1** to **8**, wherein the plurality of satellites are disposed within the payload fairing of the launch vehicle in a stacked column configuration prior to launch.
- 20 10. The system of any one of claims **1** to **9**, wherein the plurality of satellites comprises at least one top satellite disposed vertically on top of at least one bottom satellite within the payload fairing of the launch vehicle, wherein a plurality of corner fittings bear launch loads for both the top and bottom satellites.
- 25 11. The system of any one of claims **1** to **10**, wherein the plurality of satellites are passively dispensed from the payload fairing of the launch vehicle upon reaching orbit.
- 30 12. The system of any one of claims **1** to **11**, wherein the first one of the plurality of sections of each satellite includes bus and payload units mounted on or with the first side of the satellite body of each satellite that acts as the thermal radiator.
- 30 13. The system of any one of claims **1** to **12**, wherein the at least one antenna of each satellite comprises a multi-beam antenna.

14. The system of any one of claims **1** to **13**, wherein at least one thruster is attached to the satellite body of each satellite to maintain orbit phasing.

5 **15.** The system of any one of claims **1** to **14**, wherein the at least one solar panel of each satellite is pointed at the Sun, the at least one splash plate reflector of each satellite is pointed at the Earth, and the first side of the satellite body of each satellite that acts as the thermal radiator is pointed into space.

10 **16.** A method for launching a stacked satellite system, comprising:

stacking a plurality of satellites within a payload fairing of a launch vehicle, wherein:

15 each of the plurality of satellites includes a plurality of sections that are hingedly attached to each other, wherein the plurality of sections are folded or rotated together prior to launch, and the plurality of sections are unfolded or rotated away from each other when deployed upon reaching orbit;

20 a first one of the plurality of sections is a satellite body having a first side that acts as a thermal radiator and a second side opposite the first side that includes at least one antenna;

25 a second one of plurality of the sections includes at least one solar panel attached adjacent to the first side of the satellite body, wherein light from the Sun is converted to electricity by the at least one solar panel; and

30 a third one of the plurality of sections includes at least one splash plate reflector attached adjacent to the second side of the satellite

body, wherein radio frequency signals between Earth and the at least one antenna are reflected by the at least one splash plate reflector;

5 launching the plurality of satellites into orbit using the launch vehicle;
and

10 serially dispensing each of the plurality of satellites from the payload
fairing of the launch vehicle upon reaching orbit, such that, when
each of the plurality of satellites is deployed, the second one of the
plurality of sections is rotated away from the first side of the satellite
body so that the at least one solar panel is pointed towards the Sun,
and the third one of the plurality of sections is rotated away from the
15 second side of the satellite body so that the at least one splash plate
reflector directs the radio frequency signals between Earth and the
at least one antenna.

17. The method of claim **16**, wherein a periphery outline of the plurality of sections
of each satellite when folded together is oval, elliptical, round or polygonal in
20 shape.

18. The method of claims **16** or **17**, wherein the plurality of sections of each
satellite, when folded together, maintain a substantially flat profile.

25 19. The method of any one of claims **16** to **18**, wherein the satellite body of each
satellite has a cavity on the first side and a hollow region on the second side,
such that, when folded together, the at least one solar panels of each satellite
is folded and stowed within the hollow region, the at least one antenna of each
satellite is disposed within the cavity, and the at least one splash plate reflector
30 of each satellite is stored adjacent to the at least one antenna in the cavity.

20. The method of claim **19**, wherein:

a polygonal closeout member covers the first side of the satellite body of each satellite surrounding the cavity; and

5

the first side of the satellite body of each satellite that acts as thermal radiator and the at least one solar panel of each satellite are disposed within the hollow region, and the at least one solar panel of each satellite comprises a plurality of foldable solar arrays that, when folded, are enclosed within the hollow region.

10

21. The method of any one of claims **16** to **20**, wherein the plurality of satellites comprises at least one top satellite disposed vertically on top of at least one bottom satellite within the payload fairing of the launch vehicle, wherein a plurality of corner fittings bear launch loads for both the top and bottom satellites.

15

22. The method of any one of claims **16** to **21**, wherein the plurality of satellites are passively dispensed from the payload fairing of the launch vehicle upon reaching orbit.

20

23. The method of any one of claims **16** to **22**, wherein the at least one solar panel of each satellite is pointed at the Sun, the splash plate reflector of each satellite is pointed at the Earth, and the first side of the satellite body of each satellite that acts as the thermal radiator is pointed into space, upon reaching orbit.

25

24. The method of any one of claims **16** to **23**, wherein orbit phasing is maintained with a thruster located on the satellite body of each satellite by rotating the satellite body of each satellite so that a desired thrust angle for the thruster is achieved, firing the thruster, and then restoring the satellite body of each satellite to its original position after firing the thruster.

30

25. A method for fabricating a satellite that is configured for being stacked with one or more other satellites within a payload fairing of a launch vehicle, the method comprising:

5

fabricating a plurality of sections that are hingedly attached to each other, wherein:

10

the plurality of sections are folded or rotated together prior to launch, and the plurality of sections are unfolded or rotated away from each other when deployed upon reaching orbit;

15

a first one of the plurality of sections is a satellite body having a first side that acts as a thermal radiator and a second side opposite of the first side that includes at least one antenna;

20

a second one of the plurality of sections includes at least one solar panel attached adjacent to the first side of the satellite body, wherein light from the Sun is converted to electricity by the at least one solar panel;

25

a third one of the plurality of sections includes at least one splash plate reflector attached to the second side of the satellite body, wherein radio frequency signals between Earth and the at least one antenna are reflected by the at least one splash plate reflector;

30

such that, when deployed, the at least one solar panel is rotated away from the first side of the satellite body, so that the at least one solar panel is pointed towards the Sun, and the at least one splash plate reflector is rotated away from the second side of the satellite body to direct the radio frequency signals between the Earth and the at least one antenna.

26. An apparatus, comprising:

at least one satellite having a plurality of sections that are attached to each other, wherein the plurality of sections are folded or rotated together prior to launch, and the plurality of sections are unfolded or rotated away from each other when deployed upon reaching orbit;

a first one of the plurality of sections is a satellite body that includes at least one antenna;

a second one of the plurality of sections includes at least one solar panel attached to the satellite body for converting light from the Sun to electricity; and

a third one of the plurality of sections includes at least one splash plate reflector attached to the satellite body for reflecting radio frequency signals between Earth and the at least one antenna;

when deployed, the at least one solar panel is rotated away from the satellite body to point towards the Sun, and the at least one splash plate reflector is rotated away from the satellite body to direct the radio frequency signals between the Earth and the at least one antenna.

27. The apparatus of claim **26**, wherein the satellite body has a first side that acts as a thermal radiator and a second side opposite the first side that includes the at least one antenna.

28. The apparatus of claim **27**, wherein the at least one solar panel is attached to the first side of the satellite body.

29. The apparatus of claim 27, wherein the at least one splash plate reflector is attached to the second side of the satellite body.
- 5 30. The apparatus of claim 27, wherein the at least one solar panel is pointed at the Sun, the at least one splash plate reflector is pointed at the Earth, and the first side of the satellite body that acts as the thermal radiator is pointed into space.
- 10 31. The apparatus of claim 27, wherein the satellite body has a cavity on the first side and a hollow region on the second side, such that, when folded together, the at least one solar panel is folded and stowed within the hollow region, the at least one antenna is disposed within the cavity, and the at least one splash plate reflector is stored adjacent to the at least one antenna in the cavity.
- 15 32. The apparatus of claim 31, further comprising:
- a polygonal closeout member covers the first side of the satellite body surrounding the cavity; and
- 20 the first side of the satellite body that acts as the thermal radiator and the at least one solar panel are disposed within the hollow region, and the at least one solar panel comprises a plurality of foldable solar arrays that, when folded, are enclosed within the hollow region.
- 25 33. The apparatus of claim 31, wherein the at least one solar panel includes a plurality of panel elements having substantially the same shape, and the plurality of panel elements are each folded upon each other to fit within the hollow region.

34. The apparatus of claim **27**, wherein the first one of the plurality of sections includes bus and payload units mounted on or with the first side of the satellite body that acts as the thermal radiator.
- 5 35. The apparatus of claim **26**, wherein the at least one solar panel comprises two or more solar panels.
36. The apparatus of claim **26**, wherein the at least one solar panel comprises a multi-segmented array that is configured to be at least partially folded onto itself.
- 10 37. The apparatus of claim **26**, wherein the at least one antenna comprises a multi-beam antenna.
38. The apparatus of claim **26**, wherein at least one thruster is attached to the satellite body to maintain orbit phasing.
- 15 39. The apparatus of claim **26**, wherein a periphery outline of the plurality of sections, when folded together, is oval, elliptical, round or polygonal in shape.
40. The apparatus of claim **26**, wherein the plurality of sections, when folded together, maintain a substantially flat profile.
- 20 41. The apparatus of claim **26**, wherein the at least one satellite comprises a plurality of satellites configured for being stacked within a payload fairing of a launch vehicle.
- 25 42. The apparatus of claim **41**, wherein the plurality of satellites are disposed within the payload fairing of the launch vehicle in a stacked column configuration prior to launch.
- 30

5 **43.** The apparatus of claim **41**, wherein the plurality of satellites comprises at least one top satellite disposed vertically on top of at least one bottom satellite within the payload fairing of the launch vehicle, and each bottom satellite includes a plurality of corner fittings that bear launch loads for the bottom satellite and the at least one top satellite.

44. The apparatus of claim **41**, wherein the plurality of satellites are passively dispensed from the payload fairing of the launch vehicle upon reaching orbit.

10 **45.** A method, comprising:

 fabricating at least one satellite having a plurality of sections that are attached to each other, wherein the plurality of sections are folded or rotated together prior to launch, and the plurality of sections are unfolded or rotated away from each other when deployed upon reaching orbit;

 a first one of the plurality of sections is a satellite body that includes at least one antenna;

20 a second one of the plurality of sections includes at least one solar panel attached to the satellite body for converting light from the Sun to electricity; and

25 a third one of the plurality of sections includes at least one splash plate reflector attached to the satellite body for reflecting radio frequency signals between Earth and the at least one antenna;

30 when deployed, the at least one solar panel is rotated away from the satellite body, so that the at least one solar panel is pointed towards the Sun, and the at least one splash plate reflector is rotated away from the

satellite body to direct the radio frequency signals between the Earth and the at least one antenna.

46. A method, comprising:

5

stacking at least one satellite within a payload fairing of a launch vehicle, wherein:

10

the at least one satellite having a plurality of sections that are attached to each other, wherein the plurality of sections are folded or rotated together prior to launch, and the plurality of sections are unfolded or rotated away from each other when deployed upon reaching orbit;

15

a first one of the plurality of sections is a satellite body that includes at least one antenna;

20

a second one of the plurality of sections includes at least one solar panel attached to the satellite body for converting light from the Sun to electricity; and

25

a third one of the plurality of sections includes at least one splash plate reflector attached to the satellite body for reflecting radio frequency signals between Earth and the at least one antenna;

30

launching the at least one satellite into orbit using the launch vehicle; and

dispensing the at least one satellite from the payload fairing of the launch vehicle upon reaching orbit, such that, when the at least one satellite is deployed, the second one of the plurality of sections is

rotated away from the first one of the plurality of sections so that the at least one solar panel is pointed towards the Sun, and the third one of the plurality of sections is rotated away from the first one of the plurality of sections so that the at least one splash plate reflector directs the radio frequency signals between Earth and the at least one antenna.

5

47. The method of claim **46**, wherein the at least one satellite comprises a plurality of satellites configured for being stacked within the payload fairing of the launch vehicle.

10

48. The method of claim **47**, wherein the plurality of satellites are disposed within the payload fairing of the launch vehicle in a stacked column configuration prior to launch.

15

49. The method of claim **47**, wherein the plurality of satellites comprises at least one top satellite disposed vertically on top of at least one bottom satellite within the payload fairing of the launch vehicle, and each bottom satellite includes a plurality of corner fittings that bear launch loads for the bottom satellite and the at least one top satellite.

20

50. The method of claim **47**, wherein the plurality of satellites are passively dispensed from the payload fairing of the launch vehicle upon reaching orbit.

25

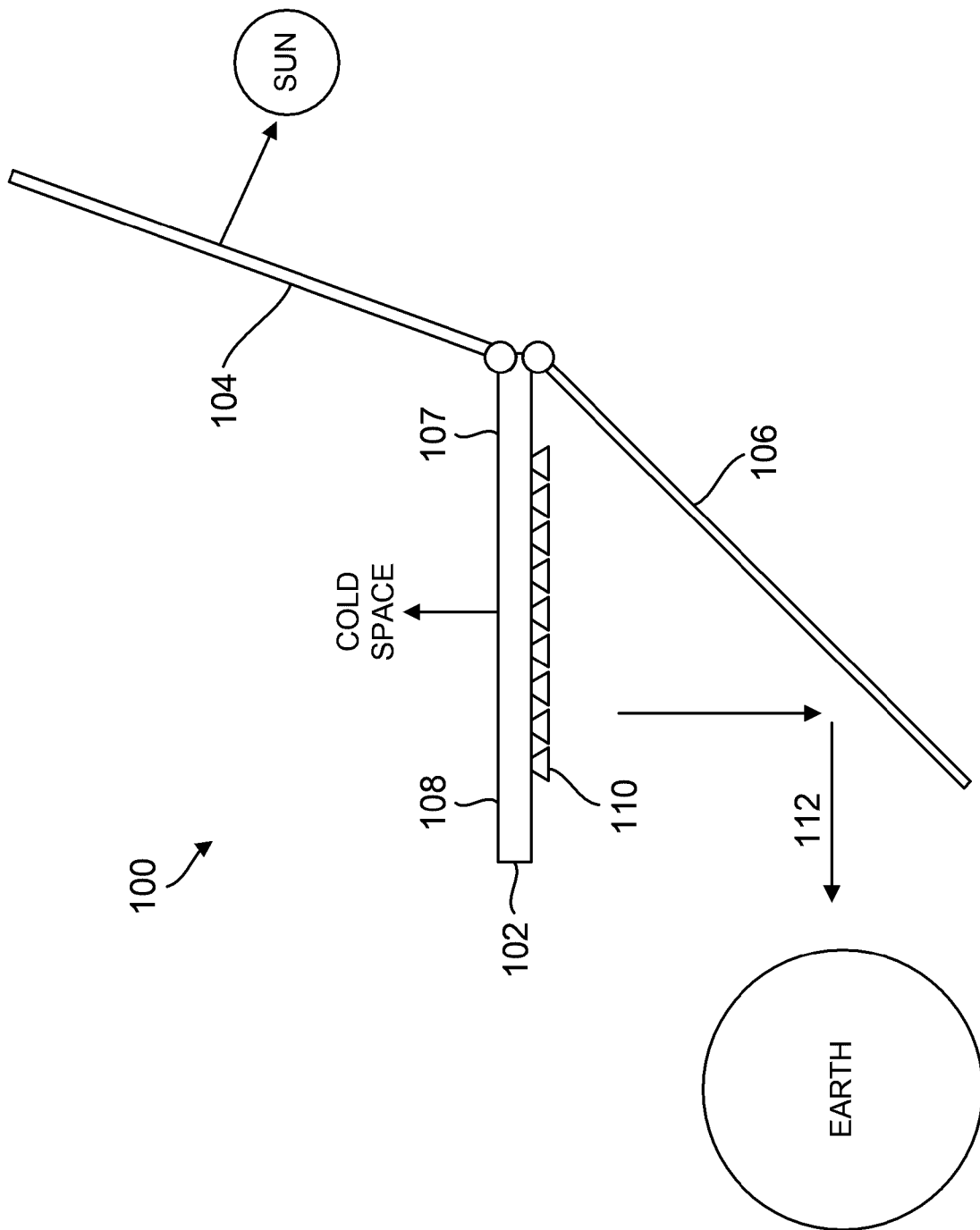


FIG. 1

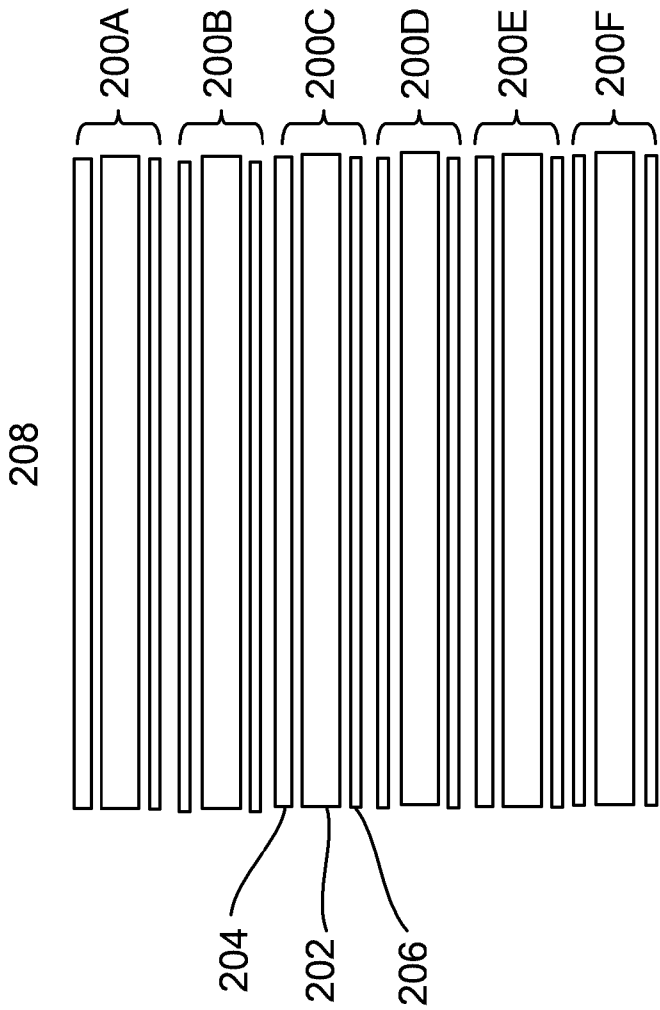
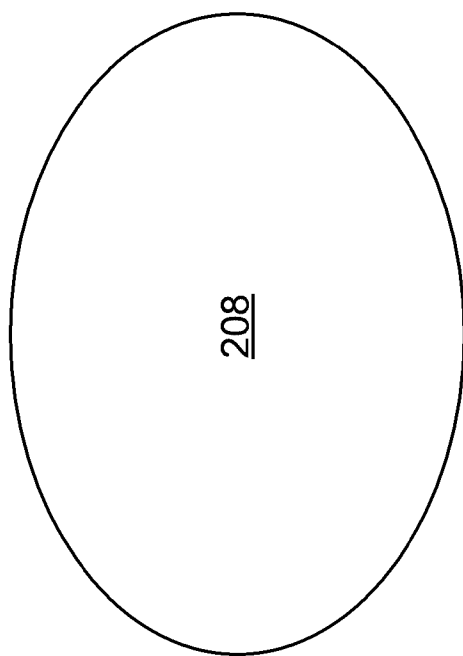


FIG. 2A



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FIG. 2B

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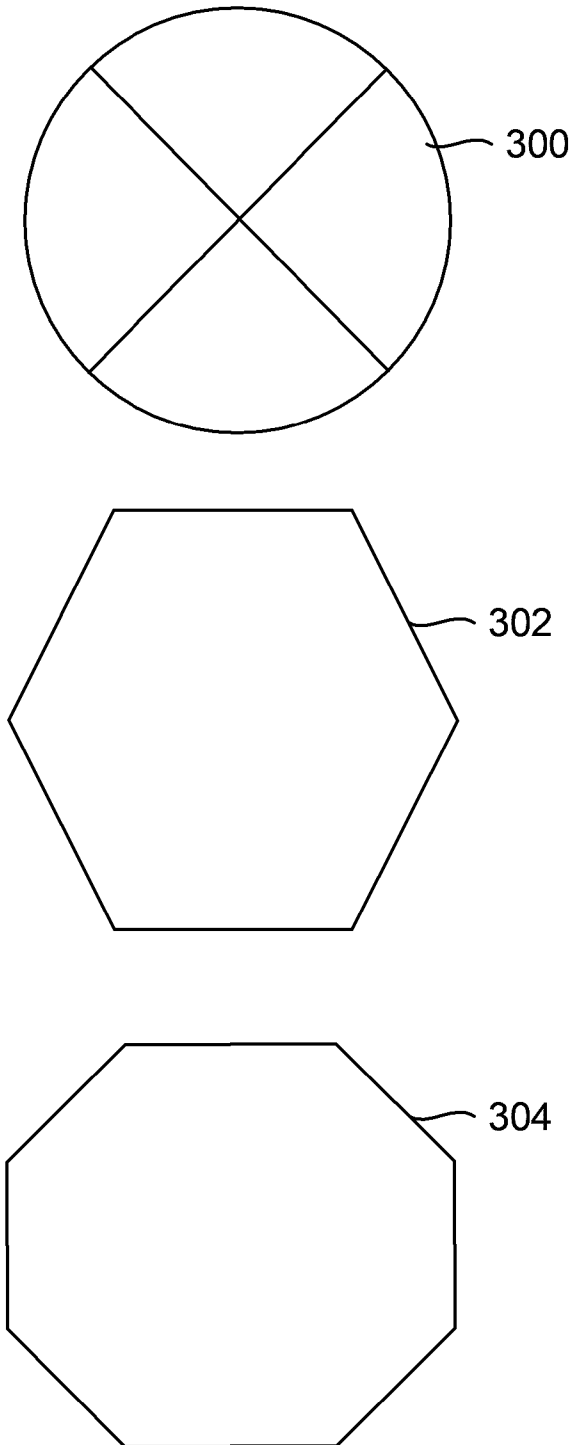


FIG. 3

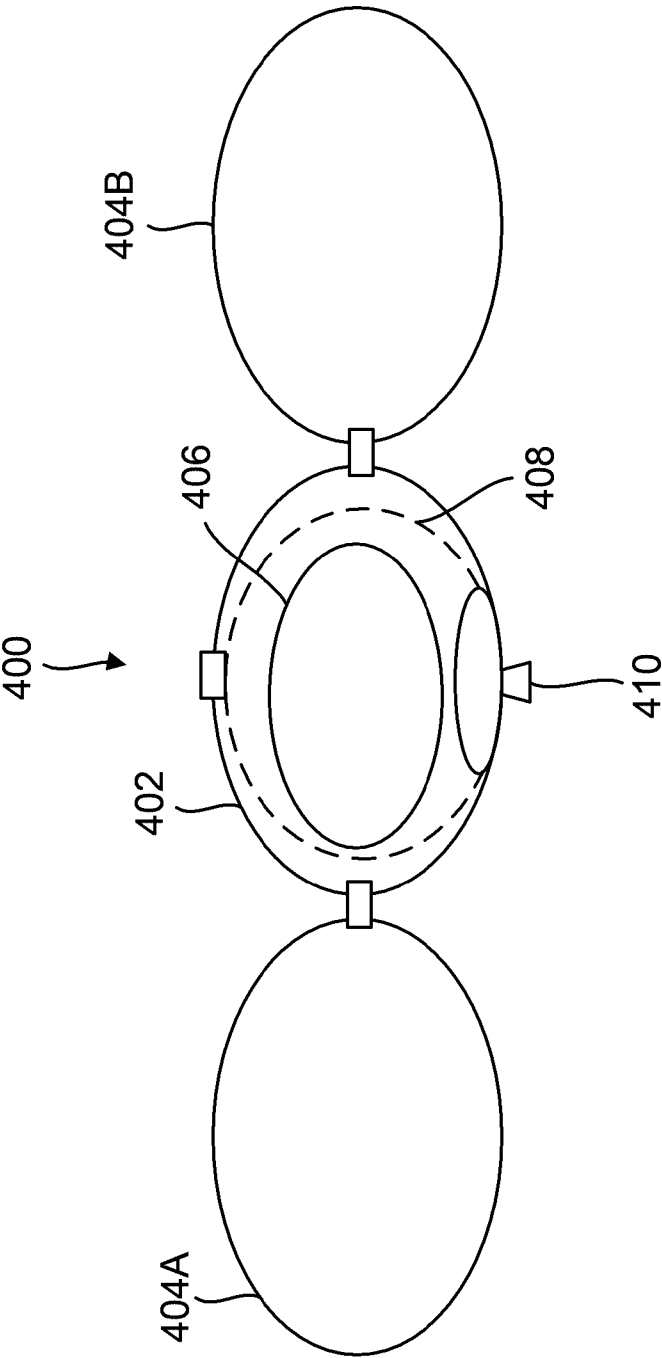


FIG. 4A

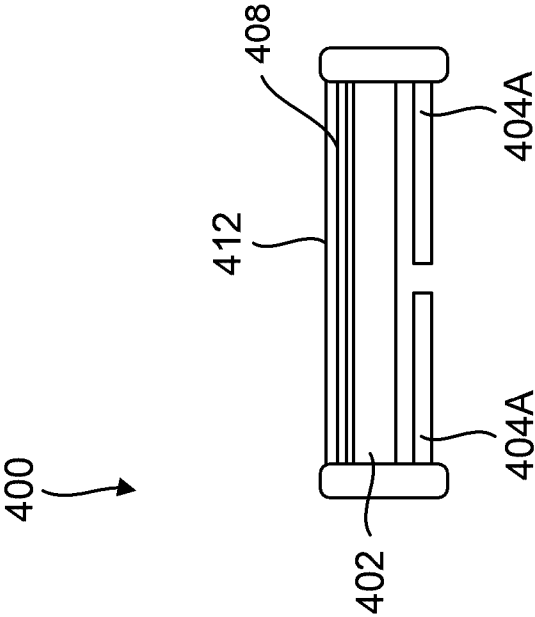


FIG. 4B

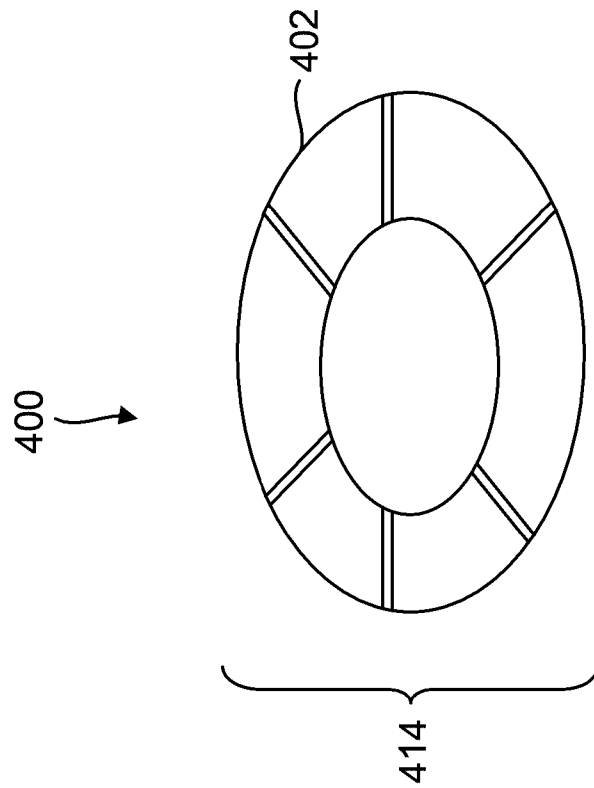


FIG. 4C

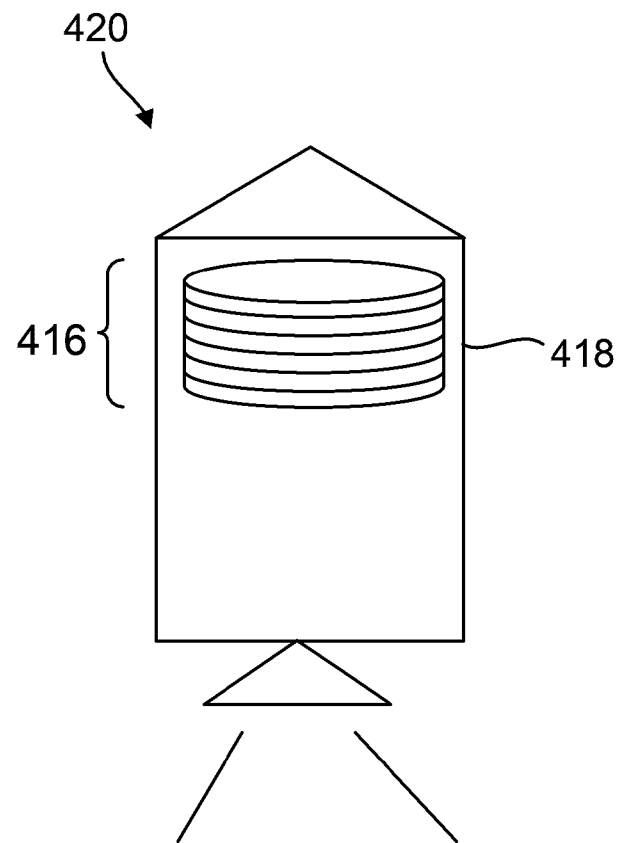


FIG. 4D

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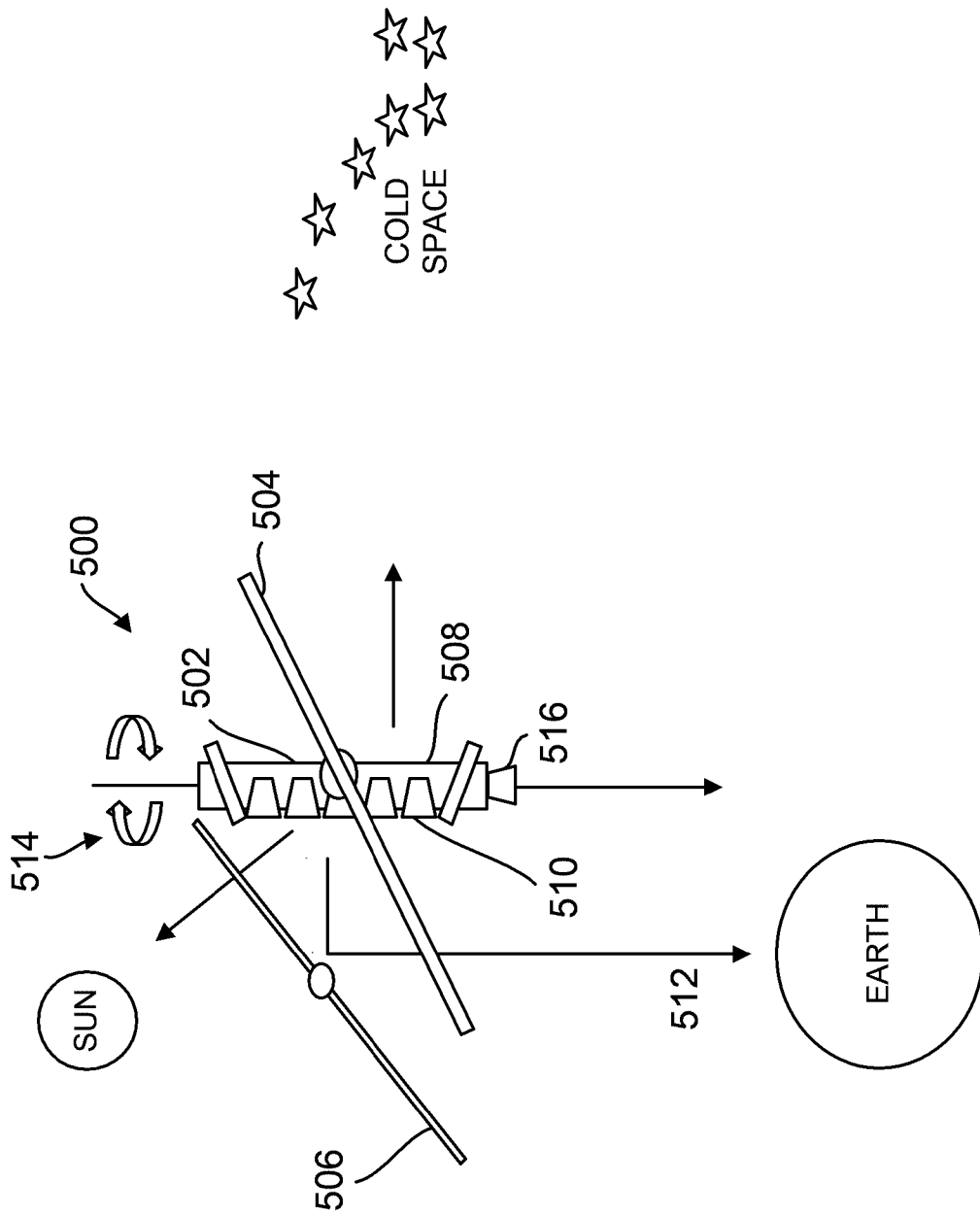


FIG. 5



Fig. 6

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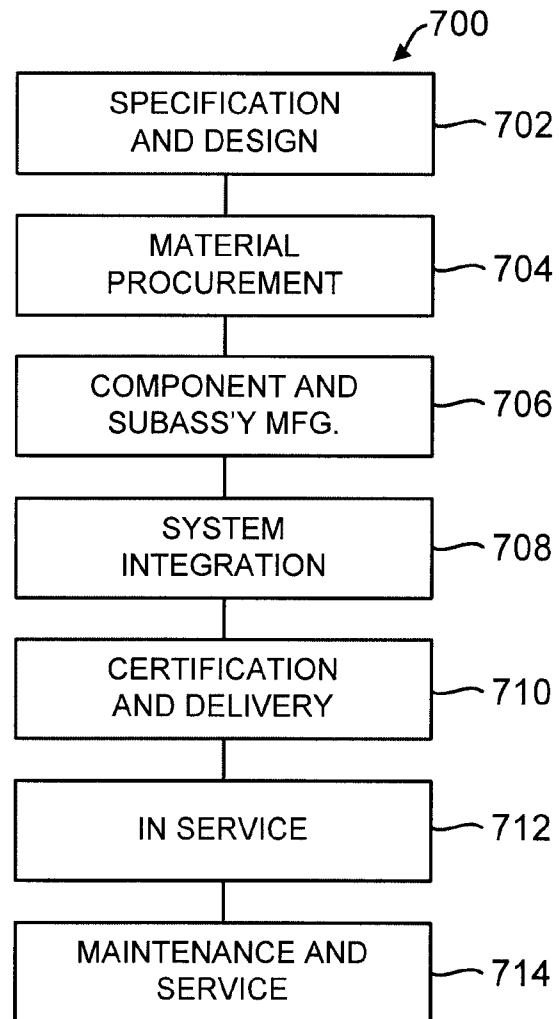


FIG. 7

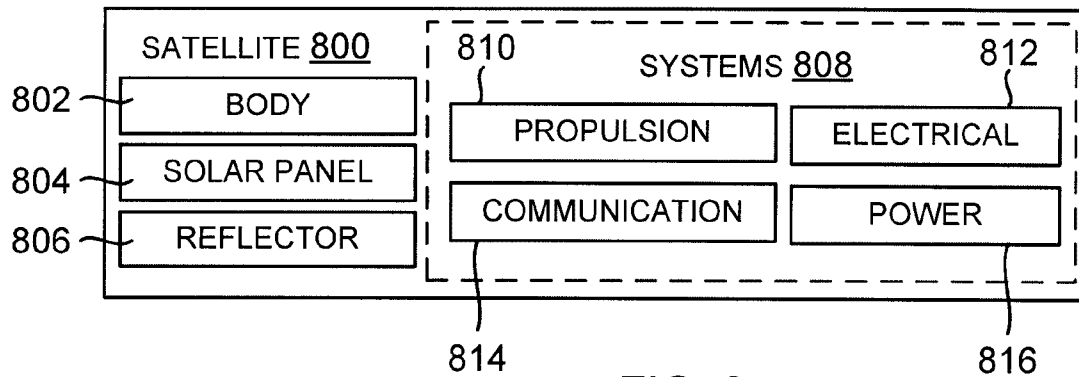


FIG. 8

