A payload launch lock mechanism includes a base, a preload clamp, a fastener, and a shape memory alloy (SMA) actuator. The preload clamp is configured to releasibly restrain a payload. The fastener extends, along an axis, through the preload clamp and into the base, and supplies a force to the preload clamp sufficient to restrain the payload. The SMA actuator is disposed between the base and the clamp. The SMA actuator is adapted to receive electrical current and is configured, upon receipt of the electrical current, to supply a force that causes the fastener to elongate without fracturing. The preload clamp, in response to the fastener elongation, either rotates or pivots to thereby release the payload.
FIG. 1

FIG. 2
PAYLOAD LAUNCH LOCK MECHANISM

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

This invention was made with Government support under NNG09HR00C awarded by NASA. The Government has certain rights in this invention.

TECHNICAL FIELD

The present invention generally relates to releasable locks for spacecraft payloads, and more particularly relates to a pivoting payload launch lock.

BACKGROUND

Many spacecraft include one or more payloads that are released after the spacecraft attains orbit. During spacecraft launch, relatively large vibration and thrust loads may be imparted on the payloads. Thus, payloads are typically mounted on the spacecraft using launch lock devices that are configured to both restrain the payloads against these vibration and thrust loads, and to subsequently release the payloads when the spacecraft attains orbit.

Commonly used launch lock devices are configured to release a payload by breaking a bolt using either pyrotechnics or a shape memory alloy (SMA). While generally safe, reliable, and robust, these launch lock devices do exhibit certain drawbacks. For example, breaking the bolt may transmit relatively high loads from high frequency acceleration (e.g., shock) to the payload. This can potentially cause damage to the payload.

Low-shock launch lock devices have been utilized using various techniques, some involving SMA materials that are used to stretch a bolt instead of breaking a bolt, thereby opening a gap and releasing the payload. This gap equates to a payload range of motion before stops are hit. Current state of the art approaches for such devices have limited dynamic ranges, and therefore result in the payload having a limited range of motion allowable, due to the specific implementation details.

Hence, there is a need for a payload launch lock device that sufficiently restrains a payload during launch, that subsequently releases the payload without transmitting relatively high loads to the payload (i.e. low shock), and increases the available range of payload motion. The present invention addresses at least this need.

BRIEF SUMMARY

In one embodiment, and by way of example only, a payload launch lock mechanism includes a base, a preload clamp, a fastener, and a shape memory alloy (SMA) actuator. The preload clamp is pivotally mounted on the base and is configured to releasibly restrain a preload. The fastener extends, along a first axis, through the preload clamp and into the base, and supplies a force to the preload clamp sufficient to restrain the preload. The SMA actuator is disposed between, and engages, the base and the fastener. The SMA actuator is adapted to receive electrical current and is configured, upon receipt of the electrical current, to supply a force that causes the fastener to elongate without fracturing. The preload clamp, in response to the fastener elongation, rotates about the axis and releases the payload.

In another example embodiment, a payload launch lock mechanism includes a base, a preload clamp, a fastener, and a shape memory alloy (SMA) actuator. The preload clamp is pivotally mounted on the base and is configured to releasibly restrain a preload. The fastener extending, along a first axis, through the preload clamp and into the base, and supplies a force to the preload clamp sufficient to restrain the preload. The SMA actuator is disposed between, and engages, the base and the fastener. The SMA actuator is adapted to receive electrical current and is configured, upon receipt of the electrical current, to supply a force that causes the fastener to elongate without fracturing. The preload clamp, in response to the fastener elongation, rotates about the axis and releases the payload.

Detailed Description

The following detailed description is merely exemplary in nature and is not intended to limit the invention or the applic-
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cation and uses of the invention. As used herein, the word
"exemplary" means "serving as an example, instance, or
illustration." Thus, any embodiment described herein as
"exemplary" is not necessarily to be construed as preferred or
advantageous over other embodiments. All of the embod-
iments described herein are exemplary embodiments provided
to enable persons skilled in the art to make or use the inven-
tion and not to limit the scope of the invention which is
defined by the claims. Furthermore, there is no intention to be
bound by any expressed or implied theory presented in the
preceding technical field, background, brief summary, or the
following detailed description.

Referring now to FIGS. 1 and 2, one embodiment of a
payload launch lock mechanism 100 is depicted and includes
a base 102, a preload clamp 104, a fastener 106, and a shape
memory alloy (SMA) actuator 108. The base 102 may com-
prise an integral portion of a vehicle, such as a spacecraft, or
it may be implemented as a separate structure and coupled
to the vehicle.

The preload clamp 104 is rotationally mounted relative to
the base 102 and is configured to releasably restrain a payload
112. The preload clamp 104, which in the depicted embodi-
ment is configured as a toe clamp, is rotatable between a
locked position, which is the position depicted in FIGS. 1-3,
and an unlocked position, which is the position depicted in
FIG. 4. The preload clamp 104 includes a hardware opening
114, and is rotationally mounted via the fastener 106 and
suitable mounting hardware. Although the mounting hard-
ware may vary, in the depicted embodiment it includes a
spherical bearing 116, a first load washer 118, and a second
washer 122.

The fastener 106 extends, along an axis 124, through the
hardware opening 114, the spherical bearing 116, the first
load washer 118, and the second washer 122, and into the base
102. The fastener 106 includes a first end section 126, a
second end section 128, and a necked-down section 132. The
first end section 126 has threads formed thereon that engage
mating threads that are formed in a threaded opening 134 in
the base 102. The necked-down section 132 is disposed inter-
mediate the first end section 126 and the second end section
128, and has a diameter that is less than the diameters of the
first and second end sections 126, 128. The fastener 106 is
threaded into the threaded opening 134 and, via an adjustment
head 136 formed on the second end section 128, is adjusted to
supply a force to the preload clamp 104 that is sufficient to
restrain the payload 112 and retain the preload clamp in the
locked position.

The SMA actuator 108 is disposed between the base 102
and the preload clamp 104. The SMA actuator 108 is adapted
to receive electrical current via, for example, a plurality of
non-illustrated electrical leads. The SMA actuator 108 is con-
figured, upon receipt of the electrical current, to expand
and supply a force to the fastener 106. The force supplied
to the fastener is sufficient to cause the fastener 106, and more
specifically the necked-down section 132 of the fastener 106,
to elongate without fracturing. The amount that the fastener
106 elongates may vary, and may depend, for example, upon
the SMA actuator, the material composition of the fastener
106, and the dimensions of the necked-down section 132.
Nonetheless, the amount of fastener elongation is sufficient to
displace the preload clamp 104.

As FIGS. 1 and 2 further depict, the payload launch mecha-
nism 100 also preferably includes a spring 138. The spring
138 is coupled between the base 102 and the preload clamp
104 and is disposed concentric with the axis 124. The spring
138 is configured, when the preload clamp 104 is rotated from
the unlocked position to the locked position, to supply a
torsion force to the preload clamp 104. It may thus be appre-
ciated that when the SMA actuator 108 supplies the force that
causes the fastener 106 to elongate and displace the preload
clamp 104, the torsion force from the spring 138 causes the
preload clamp 104 to rotate about the axis 124 and release the
payload 112.

The configuration of the payload launch mechanism 100
depicted in FIGS. 1-4 and described above is merely exem-
plary of one particular embodiment, and could be imple-
mented using numerous alternative configurations. One such
alternative configuration is depicted in FIGS. 5-8. The alter-
native payload launch mechanism 500 depicted in FIGS. 5-8
is configured similar to the embodiment depicted in FIGS.
1-4. As such, like reference numerals in FIGS. 5-8 refer to like
parts of the embodiment depicted in FIGS. 1-4. The main
differences between these embodiments are that the preload
clamp 104 in FIGS. 5-8 is not configured as toe clamp, and at
least a portion of the payload 112 is concentric with the axis
124. It may thus be appreciated that the payload launch
mechanism 500 depicted in FIGS. 5-8 operates substantially
equivalent to the one depicted in FIGS. 1-4, and further descrip-
tion of this embodiment will not be provided.

Another alternative embodiment is depicted in FIGS. 9-12.
As may be readily apparent, the payload launch mechanism
900 depicted in FIGS. 9-12 is similar to the embodiment
depicted in FIGS. 1-4, in that it includes the base 102, the
preload clamp 104, the fastener 106, and the SMA actuator
108. This alternative embodiment also includes the identical
(or substantially identical) mounting hardware 116, 118, and
122 as the other embodiments. It is noted, however, that this
embodiment does not include the same spring 138. Moreover,
as will be described, the preload clamp 104 does not release
the payload 112 by rotating about the axis 124.

As seen most clearly in FIG. 10, the payload launch mecha-
nism 900 of this embodiment does indeed include a spring
1002. Although the spring 1002 is coupled between the base
102 and the preload clamp 104, and supplies a force to the
preload clamp 104, this force is not a torsion force about the
axis 124. Rather, as depicted most clearly in FIGS. 11 and 12,
the force is one that, upon elongation of the fastener 106,
causes the preload clamp 104 to pivot about a second axis 902
that is perpendicular to the axis 124. Thus, rather than rotating
from the locked position to the unlocked position, the preload
clamp pivots from the locked position (FIGS. 9-11) to the
unlocked position (FIG. 12).

The payload launch lock mechanisms 100, 500, 900
disclosed herein will sufficiently restrain a payload 112 during
launch and, due to the rotating or pivoting nature of the
payload clamps 104, allow subsequent release of the payload
112 without transmitting relatively high loads to the payload
112, and with larger payload ranges of motion than known
mechanisms that do not have rotating or pivoting mecha-
nisms.

While at least one exemplary embodiment has been pre-
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sented in the foregoing detailed description of the invention,
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it should be appreciated that a vast number of variations exist.
It should also be appreciated that the exemplary embodiment
or exemplary embodiments are only examples, and are not
intended to limit the scope, applicability, or configuration of
the invention in any way. Rather, the foregoing detailed
description will provide those skilled in the art with a conve-
nient road map for implementing an exemplary embodiment
of the invention. It being understood that various changes
may be made in the function and arrangement of elements
described in an exemplary embodiment without departing
from the scope of the invention as set forth in the appended
claims.
What is claimed is:
1. A payload launch lock mechanism, comprising:
a base;
a preload clamp rotationally mounted on the base and configured to releasibly restrain a payload;
a fastener extending, along an axis, through the preload clamp and into the base, the fastener supplying a force to the preload clamp sufficient to restrain the payload and including a first end section, a second end section, and a necked-down section, the necked-down section disposed intermediate the first end section and the second end section and having a diameter less than the first end section and the second end section;
a shape memory alloy (SMA) actuator disposed between the base and the preload clamp, the SMA actuator adapted to receive electrical current and configured, upon receipt of the electrical current, to supply a force that causes the necked down section of the fastener to elongate without fracturing,
wherein the preload clamp, in response to the elongation of the necked down section, rotates about the axis and releases the payload.
2. The mechanism of claim 1, further comprising:
a spring coupled between the base and the preload clamp, and configured to supply a torsion force to the preload clamp.
3. The mechanism of claim 2, wherein:
the preload clamp is rotatable between a locked position and an unlocked position; and
the torsion force urges the preload clamp toward the unlocked position.
4. The mechanism of claim 2, wherein the spring is disposed concentric with the axis.
5. A payload launch lock mechanism, comprising:
a base;
a preload clamp rotationally mounted on the base and configured to releasibly restrain a payload, the preload clamp rotatable between a locked position and an unlocked position;
a fastener extending, along an axis, through the preload clamp and into the base, the fastener supplying a force to the preload clamp sufficient to restrain the payload and including a first end section, a second end section, and a necked-down section, the necked-down section disposed intermediate the first end section and the second end section and having a diameter less than the first end section and the second end section;
a spring coupled between the base and the preload clamp, and configured to supply a torsion force to the preload clamp that urges the preload clamp toward the unlocked position;
a shape memory alloy (SMA) actuator disposed between the base and the preload clamp, the SMA actuator adapted to receive electrical current and configured, upon receipt of the electrical current, to supply a force that causes the necked down section of the fastener to elongate without fracturing,
wherein the preload clamp, in response to the elongation of the necked down section, rotates about the axis and releases the payload.