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Non-explosive Actuation for the ORBCOMM™ Satellite

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Abstract

Spool-based non-explosive actuator (NEA) devices are used for three important holddown and release functions during the establishment of the ORBCOMM™ constellation. Non-explosive separation nuts are used to restrain and release the 26 individual satellites into low earth orbit. Cable release mechanisms based on the same technology are used to release the solar arrays and antenna boom.

Introduction

Non-explosive actuators are electro-mechanical devices that use miniature wire-wrapped spools to hold and release applied loads. The spools are made of two matched halves which are held together by the circumferential wire wrap. A mechanical advantage system allows the spool to restrain external loading on the actuator. When release is required, a low voltage and a current of 4.5 amperes is applied across a link wire on the spool. This signal causes the link wire to break and release the wire wrapping on the spools. The spools separate and the mechanical system releases the external loading on the actuator. NEA technology has been used in numerous launch and satellite programs to pull pins, push pins, and release tension loads.

Satellite Holddown And Release

The first ORBCOMM™ production launch is scheduled for early 1995. An air-launched Pegasus launch vehicle will carry two disc-shaped satellites that are stacked together within the Pegasus fairing. Three subsequent launches, scheduled for 1996, will carry payloads with eight stacked satellites.

Each satellite in the stack of eight is attached to the adjacent satellites or, in the case of the bottom satellite, to the Pegasus launch vehicle. The separable joint (Figure 1) between the satellites is established by three load bearing bracket assemblies spaced at 120° from each other and mounted on hard points on adjacent satellites. The load-bearing brackets are fabricated from aluminum-beryllium alloy (AlBeMet™) and the perimeter walls of the satellite ring are fabricated using AlBeMet™ face skins over an aluminum honeycomb core. The bracket flanges house a pair of shear fittings, compression springs, and a Model 9421-2 non-explosive separation nut.

The shear fittings (cups and cones) are match bonded during production so the satellites are perfectly mated when stacked together for launch. The satellite joint is secured by using a bolt and the Model 9421-2 separation nut to preload the cups and cones together. Lateral axial launch loads are reacted by this cup and cone

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arrangement. The cup and cone fittings are machined from titanium and have a hard coat of electroless nickel to prevent surface galling.

The satellite stack is required to have a minimum natural frequency of 20 Hz. The brackets on the satellite rings produce three stiff columns when bolted together and the most recent tests have shown a stack frequency of 21 Hz. A tension preload on the bolts and separation nuts and the match mating of the cup and cone interfaces prevents gapping. As the bolt head can experience a prying load, a larger 9.52 cm (0.375 inch) bolt is used to react these moment loads. The bolt shank is turned down with a 6.35 mm (0.25 inch) thread diameter to mate with the separation nut. The bolt also has an anti-galling coating.

The bottom satellite in the stack carries the maximum load. This load is induced following the release of the Pegasus during launch from a L-1011 aircraft and the subsequent release of the vehicle strain energy. The maximum bending load seen at this interface is 15,591 newton-meters (138,000 inch-pounds). Qualification testing on the structure produced 20,336 newton-meters (180,000 inch-pounds) at the joint and resulted in an axial load of 22,240 newtons (5,000 pounds) in the separation nut and bolt. The separation nut was also destructively tested by application of an axial load of 31,360 newtons (7,000 pounds).

During flight, the payload fairing is removed and the satellites are individually placed into orbit. An electrical command causes the separation nuts to actuate and release the attaching bolt without causing shock of sensitive payload boxes. The three NEA separation nuts on a satellite-to-satellite joint must fire simultaneously to prevent excessive tip-off rates. Each nut must actuate and release within 5 milliseconds of those adjacent to it. The bridge wire characteristics of the separation nuts ensures a minimum dwell time and a tip-off rate well within the design limit of 0.0087 radian/second (0.5 degree/second). The released bolt is contained within a bolt catcher that is integral to the cup portion of each satellite's top brackets

Small calibrated compression springs within the cups are used to push the satellite away after release. The spring preload is adjusted by a compressive nut and the imparted energy provides the correct orbital spacing.

Each ORBCOMM™ satellite has a mass of 42.75 kilograms (95 pounds). The satellite-to-satellite bracket joint assemblies contribute a mass of approximately 2.16 kilograms (4.8 pounds). This is considerably less than the estimated 4.5 to 5.4 kilograms (10 to 12 pounds) that would have been required by clamps and other frangible joints. For a stack of eight satellites, the ORBCOMM™ design results in a mass savings of approximately 18 kilograms (40 pounds).

This satellite holddown and release system has been thoroughly tested to verify its flight readiness. The joints survived all testing and measurements of the source shock from the separation nuts were well within limits.

Solar Array Holddown And Release

After a disc-shaped ORBCOMM™ satellite achieves orbit, another non-explosive actuator is used to open its twin solar panel arrays. The solar panels are hinged to the satellite structural rings and, when stowed, form the top and bottom exterior surfaces of the satellite. During flight and orbital positioning, a Model 8036-100 dual cable release mechanism (Figure 2) restrains two cables that are fastened to the center of the arrays with an adjustable nut. The mechanism uses a NEA spool assembly to restrain and release the ball ends of the cables. The Model 8036-100, which is rated for tension loads up to 445 newtons (100 pounds) from both cables, places an 89 newton (20 pound) preload on the panel, causing a concave deformation of its surface. A cup and cone arrangement, similar to that used on the satellite separation joints, is used with the NEA release mechanism to absorb shear loading. The cable tension prevents gapping between the satellite and the solar array panel. Adjustable axial snubbers are bonded to the backside of the solar panel at four hard points and urethane edge snubbers are used to prevent the edges of adjacent panels from touching while in flight. This system is designed for a first mode static frequency of greater than 30 Hz.

When the Model 8036-100 mechanism receives a command signal, the spool mechanism is actuated and releases the cable ends. Total release time for the mechanism is less than 20 milliseconds and actuation occurs with minimal imparted shock. The solar panels are manufactured from a 6.35 mm (0.25 inch) thick aluminum honeycomb core and 0.127 mm (0.005 inch) graphite epoxy face skins. When preloaded, this panel deforms to a slightly concave shape. When the NEA is actuated, the panel springs open to supply the kick-off force needed to initiate deployment. Small shear-viscous-damped hinges powered by torsion springs deploy the panels to their final position.

Antenna Holddown And Release

The ORBCOMM™ antenna is comprised of a four-segment, deployable boom assembly onto which an array of VHF and UHF quadrifilar helical antennae are mounted. The antenna elements are fabricated from S-glass mesh enabling it to be stowed into a very tight volume. The stowed antenna (Figure 2) is held in the spacecraft until the outboard solar panel is released. Upon release, the antenna bundle is deployed 180 degrees away from the vehicle using a constant force, negator-driven hinge assembly which is shear-viscous-damped to minimize end of travel impact loads. A Model 8036-200 NEA single cable release mechanism holds the antenna bundle together by fastening the fourth boom segment to the first boom segment with a preload of 89 newtons (20 pounds). When a command is received, the NEA spool actuates and the mechanism releases the cable. This frees the bundle and the flexible springs on each boom deploy the segments. The release occurs with minimal imparted shock.

Summary

Non-explosive actuators are used to holddown individual ORBCOMM™ satellites and release them into orbit, to holddown and deploy the solar panel arrays, and to restrain and deploy the antenna. Extensive testing demonstrated that they will reliably holddown the required loads and simultaneously release them with low transmitted shock and no debris or pollution. The resulting designs resulted in an overall mass savings over comparable methods of holddown and release.

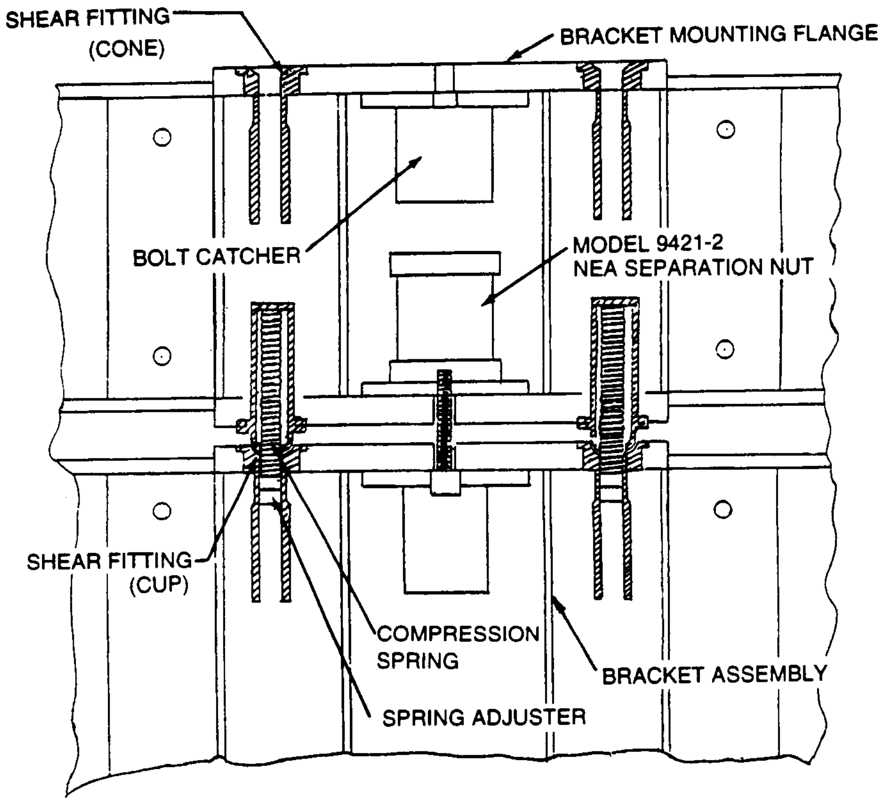

FIGURE 1 - ORBCOMM™ SATELLITE-TO-SATELLITE JOINT

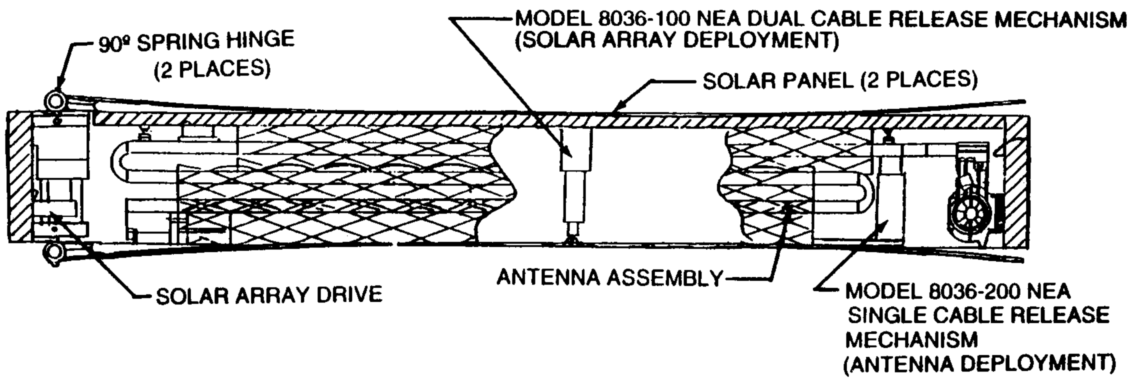

FIGURE 2 - SIDE VIEW SECTIONAL - ORBCOMM™ SATELLITE