

# Enduralock

## *Enduralock® Nut Plate (mechanically locking & self-aligning)*

### **White Paper** – Comparison of Nut Plate fastening solutions

#### **Issue:**

Fastener interfaces are critical to structural stiffness and thermal management performance in spacecraft, aircraft, missile, and rocket applications.

There are many access panels on aircraft, spacecraft, and other flying objects, which are secured to the structure by bolts. Since in most cases there is limited or no access to the inner side of a structure, a nut plate is used as a female threaded device. The panels often have complex three-dimensional shapes, so hole-to-hole misalignment becomes a significant factor. This can result in unnecessary additional labor and time-consuming efforts to align the bolts to the mating nut plates to prevent quality and performance issues related to misalignment. Currently available floating nut plates of conventional configuration (NAS standard, MIL standard, and/or OEM standard) are designed to provide only for a limited amount of radial float to attempt to compensate for radial misalignment. While trying to account for radial misalignment, currently available nut plates leave the major issue of axial misalignment unresolved, as the nut element cannot “tilt” to accommodate an off-axis bolt. Forced assembly of a misaligned bolt and a nut plate can result in damage of the bolt, threads, nut plate, and assembly components.

No current nut plate technology provides for a secondary mechanical lock with reusability. This can be of significant importance during the assembly of critical subsystems that are exposed to high vibration environments, such as during the launch of a missile, rocket or a spacecraft. With the increased focus on modular architecture for in-space robotic construction and maintenance, there is a greater need for an ideal fastener construct incorporating a locking nut plate that can also be reused for structure repurposing and for maintenance.

Another issue that conventional nut plates have is that this entire class of female threaded fasteners rely on friction only as the means of locking the fastened joint. Normally, this locking feature is achieved by mechanically deforming a portion of the nut element of the nut plate (crimping). Although this technology is widely used in the fastener industry, it does not deliver a perfectly fastened assembly, as would occur with a positive mechanical lock.

A significant problem exists with maintenance involving the removal and reapplication of access panels utilizing retained bolt assemblies and current nut plate technologies. This results in increased time and labor consumed in the reapplication of the panels. Large panels (such as fuselage fairings) may have hundreds of bolts retained (typically with axially sliding retaining rings) to the rim of the panel for ease of assembly. The technician performing maintenance is required to align the axis of each bolt with its corresponding nut plate’s axis before engaging the first bolt. This is a time-consuming task, which usually involves more than

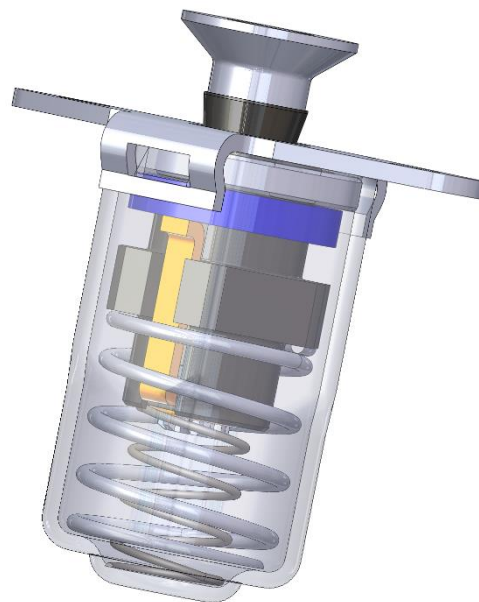
one technician working in coordination. Furthermore, the retaining rings can bind and break easily, which can cause FOD (foreign object debris).

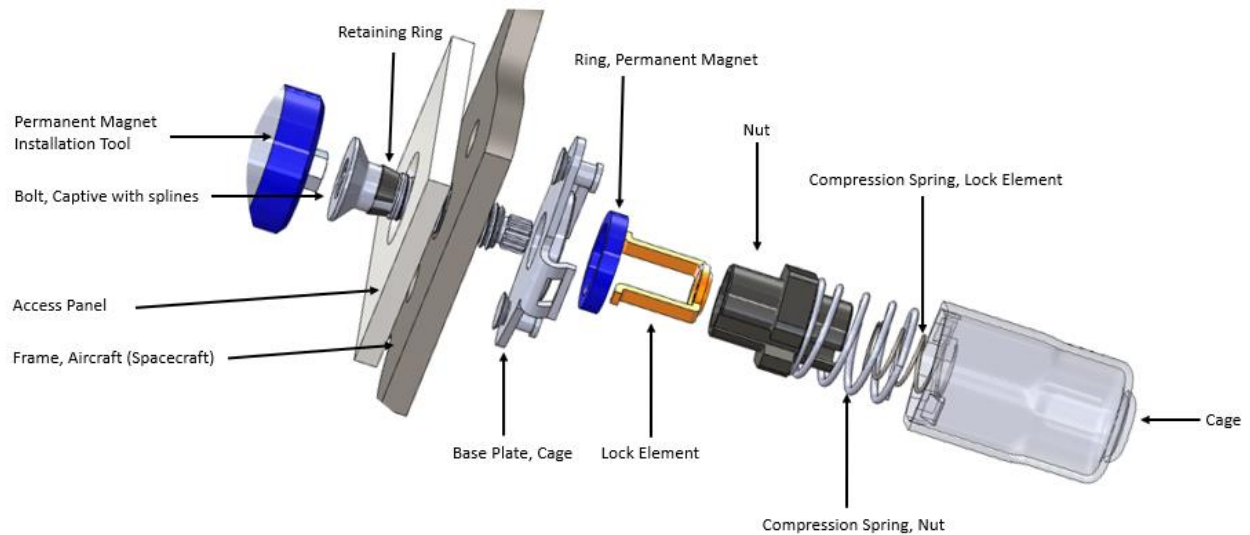
### **Solution: Enduralock's Mechanically Locking Nut Plate**

Enduralock proposes a novel nut plate system for panel-substructure assembly in aircraft, space vehicles, rockets, and missiles. The proposed solution is axially self-aligning, which enables engagement of the bolt with the nut plate, even when the axis of the nut plate and the axis of the bolt are not aligned. Enduralock's nut plate is axially spring-loaded and features a positive mechanical lock, which can significantly reduce the maintenance time involving removal and reapplication of large panels with retained bolts. In its resting state, the nut plate is mechanically positively locked to the bolt. The positive mechanical lock is deactivated by the magnetic field generated by a tool equipped with an electromagnetic attachment.

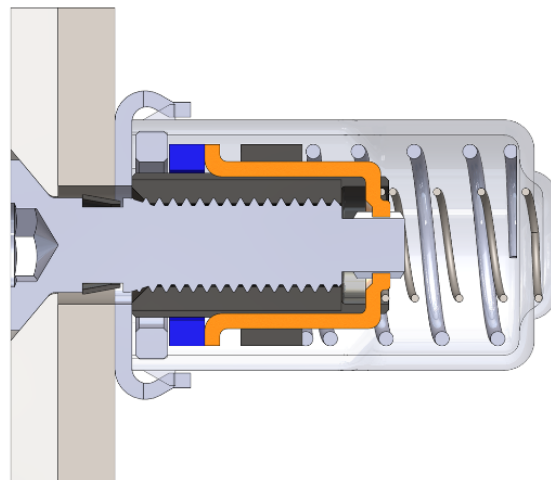
Enduralock's self-aligning nut plate technology (without proposed locking mechanism) received a new National Aerospace Standard (NAS9938), and it was a final selection in the AFWERX Space Challenge in November 2020.

The proposed Enduralock nut plate consists of a nut element, magnetic locking element, hex shaped shell body, plug, and a spring. The outer shell can either be bonded or riveted to the substructure. The nut assembled in the shell is positioned such that the hex flats in both the nut element and the shell align in a parallel position, thus constraining the relative rotation of the nut element and the shell. The cylindrical spring positioned in the shell enables the nut to float in the axial direction and to tilt off its own axis. A ring plug, whose outer diameter is defined with a tight tolerance in relation to its distance between the flats of the hex shaped shell body, is used to secure the nut and spring in the shell. The magnetic lock element provides for a positive mechanical lock with the bolt when a magnetic force is not being exerted. It disengages with the delivery of a magnetic field by the tool.



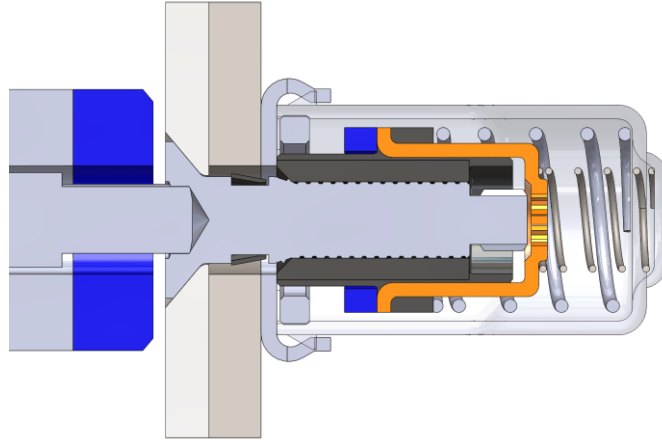


**Below is description of the main functions of the proposed nut plate:**



**Locked Position**

- Without the presence of a properly positioned and oriented magnetic field at the panel's surface, the mechanism is normally locked. Relative angular motion between the nut and the bolt is prevented by the locking element.
- The locking element is kept engaged with the bolt's splines by the inner compression spring.
- Relative angular motion between the nut and the locking element is prevented by radially opposed keyways machined in the nut.
- The locking element's teeth and the bolt's splines are designed to allow meshing, even if they are not perfectly aligned.



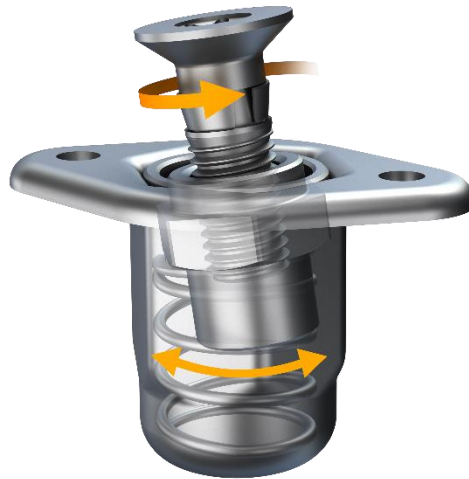
### Unlocked Position

- Once the installation tool with magnetic ring reaches the proximity of the access panel surface, the locking element is displaced axially, which allows the bolt to rotate freely.
- When the installation is complete, and the tool is retracted, the mechanism automatically returns to the locked position.
- The splines and the locking element's teeth can be designed to allow for meshing, even if they are not perfectly aligned.

### **Advantages offered by the proposed design:**

- The bolt's strength is not affected by the locking mechanism. The smallest load-bearing cross section is the thread minor diameter.
- High vibration resistance is provided by the positive mechanical lock.
- During installation and removal, the locking mechanism is disengaged, which allows for a free-running bolt.
- No wear of the locking mechanism occurs during installation and removal.
- The nut and locking mechanism are axially and radially floating.
- The design allows for a fixed position bolt retaining ring, which reduces the chance of FOD (foreign object debris).
- Accommodation exists for +/-8° angular misalignment of the bolt.
- Cage subassembly can be removable and replaceable.
- Nut plate has a minimum of 25 cycles of reusability (current nut plates have 15).

Enduralock's nut plate (without mechanical lock) was subjected to tensile testing in accordance with MIL-STD-1312-8A / NASM 1312-8 Rev. 2 and to torque out/reusability testing in accordance with NASM25027. The nut plate passed both design validation tests successfully. Enduralock has completed a project with a scope of obtaining new National Aerospace Standard (NAS) part numbers for its self-aligning nut plate (without mechanical lock) with sponsorship from Bell Helicopter and Boeing Helicopter. A new NAS standard (NAS9938) was issued in February of 2021.



The materials specified for the components are common aerospace alloys, such as A-286, 17-4 PH, AISI 4140/ 4130, and titanium alloys. For special applications, the nut plates could be manufactured from ceramics or composite materials. Enduralock can offer the technology in all commonly used industry thread sizes (.1900-32, .2500-28, .3125-24, .3750-24, .4375-20 and .5000-20).

While the decision to choose a suitable technology is subject to the application under consideration, there are critical factors that assist in this decision, which are as follows:

#### **Installation Time:**

The time invested in the installation of fasteners has a significant impact on the cost of production and maintenance. To increase productivity and efficiency, the mechanical technology must be easy to apply during installation and easy to remove for maintenance. The time saved during installation and removal, due to the ease of fastener application, helps reduce the expense of the assembly and maintenance of the system in the after-market, thus lowering the overall lifecycle cost of the assembly. Enduralock's nut plate technology, with its axially self-aligning and spring-loaded mechanism, delivers significant reduction of time and cost for access panel installation and removal.

#### **Lower risk of FOD:**

Conventional nut plates systems often use a captive bolt with a retaining ring which floats axially along longitudinal grooves in the bolt produced by EDM (electrical discharge machining). This ring often binds and sometimes breaks inside these grooves, which leads to the undesired result of FOD (foreign object

debris). In Enduralock's proposed nut plate system, the bolt has a retainer that is fixed in a static position in a radial groove on the shank of the bolt. This design dramatically reduces the possibility of breakage of the retaining ring and FOD.

### **Re-Usability:**

In general, conventional nut plates are rated for a minimum of 15 installation/removal cycles of the mating bolt for a required installation and break-away torque. The proposed nut plate design delivers superior reusability performance (minimum of 25 cycles), which increases the life cycle of the assembly and lowers the number of required spare parts. The allowance for axial misalignment eliminates the possibility of cross-threading or damage to the fasteners, structure, and panel.

### **High Temperature Resistance:**

The fastener components and the assembly components tend to expand when exposed to high temperature environments. With materials of different coefficients of thermal expansion, the components expand to different extents, resulting in fastener preload loss and eventually the failure of the assembly. Hence, high temperature resistant fastener technologies are designed to address this issue. The proposed nut plate design, materials, and finishes fully comply to the requirements of applications where a higher ambient temperature is present.

### **Positive Mechanical Locking Feature:**

The proposed nut plate features a positive mechanical locking mechanism that is deactivated by a tool with an electro-magnet attachment.

### **Allowance for axial misalignment:**

The axially spring-loaded nut element design allows for engagement of off-axis bolts, and it self-aligns the bolts during bolt tightening. This is advantageous in the automation of a subsystems integration process in space using a transport system and a specialized end-effector used in conjunction with a robotic arm.

### **Summary**

Enduralock's nut plate technology can play a major role in avoiding quality and performance issues during the assembly of panels. It can also save significant time and labor involved in the assembly and maintenance tasks on structures with large panels. The self-aligning feature of the technology can be used to install and maintain modules or systems in space vehicles, satellites, and other structures built in space. The reduction in labor time through the ease of installation and maintenance enabled by the technology, while also providing a positive mechanical lock, will provide for quality assurance. The self-aligning feature makes the nut plate ideal for robotic in-space assembly and for maintenance of space structures.