

## What you need to know in terms of ball bearing engineering for aerospace mechanisms

Ball bearings are critical in these mechanisms to reduce friction, ensure smooth motion, and provide reliable operation under the extreme conditions of space and launch.

Many space missions have experienced significant disruptions, and some have even been aborted due to ball bearing performance problems.

One of the main issues is that we often fail to anticipate the impact of poor bearing choice. While the bearing may seem like a simple mechanical component initially, a precise understanding of its behavior is crucial to ensure longevity.



Premium ball bearing engineering is therefore key to ensuring mission success and protecting financial investment.

### Ball bearings in space mechanisms

Ball bearings are integral to numerous space mechanisms, including:

- Reaction wheels and gyroscopes
- Turbopumps
- Telescope mechanisms
- Wheel assemblies for rovers
- Actuators
- Solar Array Drives
- Antenna Pointing Mechanisms
- Other deployable structures

### The Stakes of Effective Ball Bearing Engineering

Understanding the critical factors in designing and engineering ball bearings for space applications is essential for ensuring their performance and reliability. Below are the key considerations:

- Bearings must perform well under operational conditions in space AND also withstand the conditions of launch.

- Bearings must function effectively both during terrestrial qualification AND in space. However, it is nearly impossible to simulate zero gravity during qualification tests for instance, so this must be considered and anticipated.
- Bearings must operate reliably for extended periods and/or at critical moments. For instance, a Reaction Wheel Assembly (RWA) on a space probe may "awaken" after several years of travel, raising consideration that it is absolutely necessary to deal with.



## Frequent problems in aerospace mechanisms bearings

A wide range of challenges are faced by space mechanisms. Here are just a few examples of the problems that can be expertly handled:

- **Cage Instability:** Often misunderstood, cage instability can harm mechanisms like Reaction Wheels Assemblies (RWA) and control moment gyroscopes (CMG). Solutions need to mitigate vibrations, noise, and ensure smooth operation.
- **Ball Speed Variation:** Resulting from misalignment, ball speed variation can be detrimental, especially in critical systems like solar array drives and antenna pointing mechanisms. Preventive measures are necessary to guarantee consistent performance.
- **Thermal Instability:** Alongside cage instability, thermal instability in specific areas of the bearing can lead to catastrophic failures in turbopump bearings. Innovative solutions shall be considered to withstand extreme thermal conditions.
- **Bearing Design Issues:** Poor bearing design can spell disaster for any mechanism, potentially leading to bearing seizures. Relevant expertise should ensure proper design, preventing costly setbacks.

Let's also add that other types of issues can lead to serious consequences, such as a lack of critical review on modeling software results or an « over-reliance » on a COTS approach.

## When should the bearing engineering experts intervene?

Their interventions can occur at various stages:

- **In the engineering phase:** This is obviously the right time.
- **During the qualification process:** It is possible that a problem may arise during qualification (detection of noise, vibrations, unexpected increase in torque, ...). Based on test data and

bearing geometry, a diagnosis can be made and design improvement suggestions can be proposed. It is important to note that a problem may also occur after the qualification phase, even if it is successful. This is the case with cage instability for instance, which has numerous triggers and can occur once a satellite is in orbit, for example, or even after a longer period of time.

- **When a problem occurs in space:** Even though the possibilities for recovery are obviously narrower here, precisely diagnosing a problem undoubtedly adds value and can provide valuable inputs for defining a hybrid problem resolution strategy.

## What will the bearing engineering experts do

Navigating the domain of bearing engineering expertise, here's an overview of the tasks undertaken by the experts:

- They analyze problems using a relevant methodology and right proven engineering tools that does not rely on simplifying assumptions
- They provide clear diagnostics highlighting potential risks on current designs.
- They define the best options in terms of optimized bearing designs, including the cage, highlighting if necessary the advantages and disadvantages of COTS, custom, or hybrid solutions.
- They provide clear recommendations supported by solid and relevant calculations.
- Depending on the project type, they we can supply original designs such as to solve the cage instability problem.



## How APO-GEE does it

- The methods and tools developed by APO-GEE adopt a fundamentally different approach compared to existing tools. While most tools available on the market use a Newtonian formalism to model ball bearing behavior, they often demonstrate limitations or incompleteness due to their reliance on simplifying assumptions about ball kinematics. In contrast to Newton's approach, APO-GEE's methodology allows for the comprehensive computation of ball kinematics, resulting in the true equilibrium of the ball bearing, without approximation.



- APO-GEE approaches engineering application projects as research projects that have led to innovative products, that is, without preconceived notions or biases, and by basing its approach on the physics of rolling.
- Our deep-tech startup structure enables us to react quickly and flexibly, with a positive mindset while ensuring the confidentiality of exchanged data.
- Depending on the projects, we can also collaborate with bearing manufacturers.

## Why APO-GEE?

- Based on more than 12 years of intensive research, APO-GEE has developed distinctive capabilities and tools in application engineering and innovative ball bearing product development for space applications.
- APO-GEE is the sole entity to have fully resolved cage instability issues in RWA, CMG and turbopumps with the Butterfly cage technology (patent pending).
- APO-GEE track record includes partnerships with key players in the space industry (prime contractors, new space, space agency, specialized ball bearing manufacturers), affirming our expertise and reliability.

For unparalleled ball bearing engineering services tailored to the demands of aerospace projects, feel free to contact us.

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