

Testbench for IMU characterization and verification under combined vibration, rotation and temperature environments

Leonardo B. Farconi¹, Bastiaan Deul¹, Stephan Theil¹

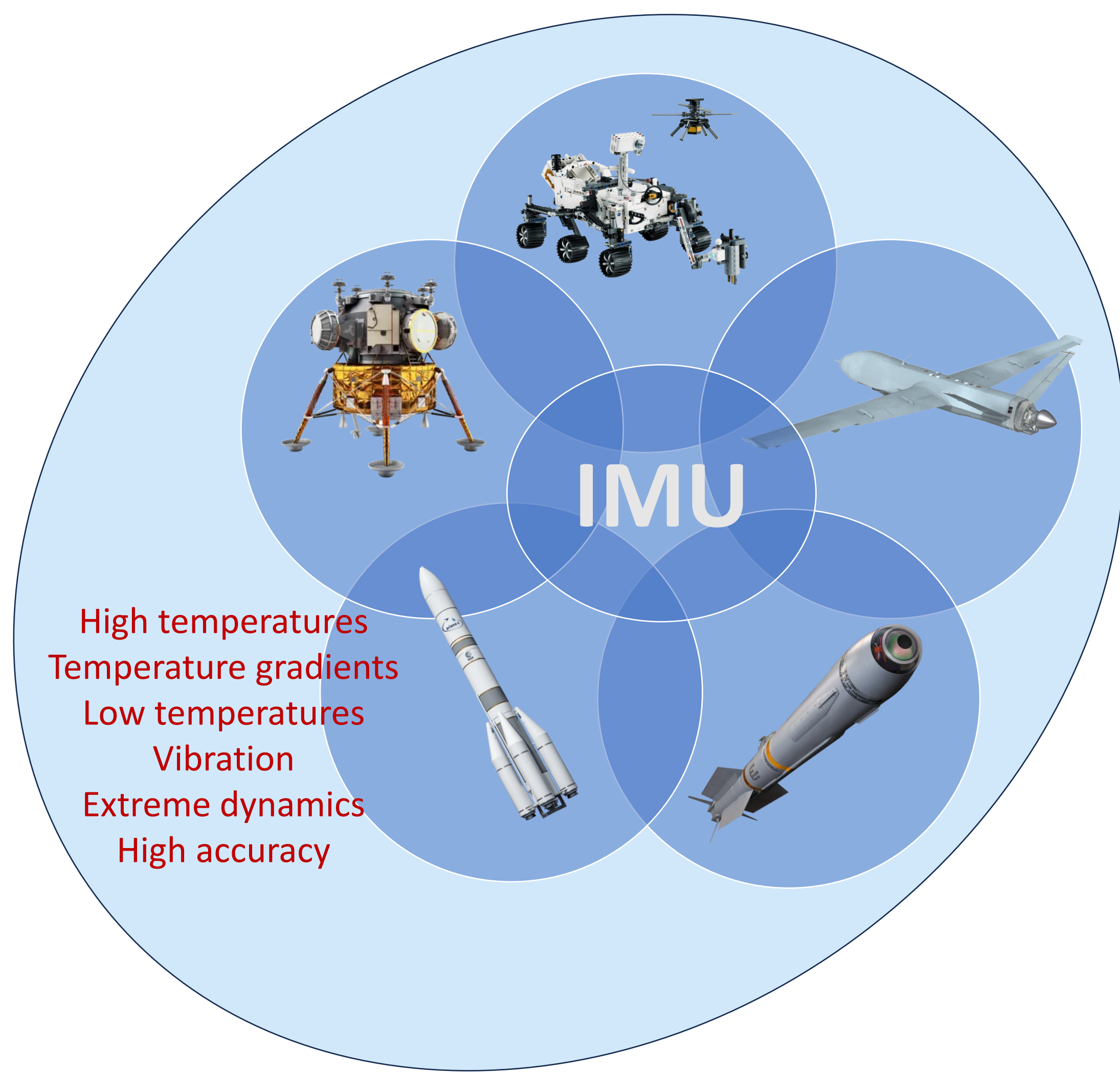


Fig. 1 – Demanding IMU applications. Images from lego.com, pngtree.com, pngall.com, pngimg.com, spacenews.com, emojiStock.com

THE PROBLEM

Despite evolution in IMU technology, characterizing their behavior in representative conditions remains a challenge. This is especially relevant for missions like the ones represented in Figure 1.

Production testing, which focuses on parameters such as scale factor and bias under static and isolated conditions, fails to capture nonlinear dynamics excited during operations. Existing higher-order estimation methods, such as those proposed in the IEEE 1293:2018 standard, are also complex and in our assessment, require further improvement for routine use in space applications due to the number of test cases required and dedicated test engineering.

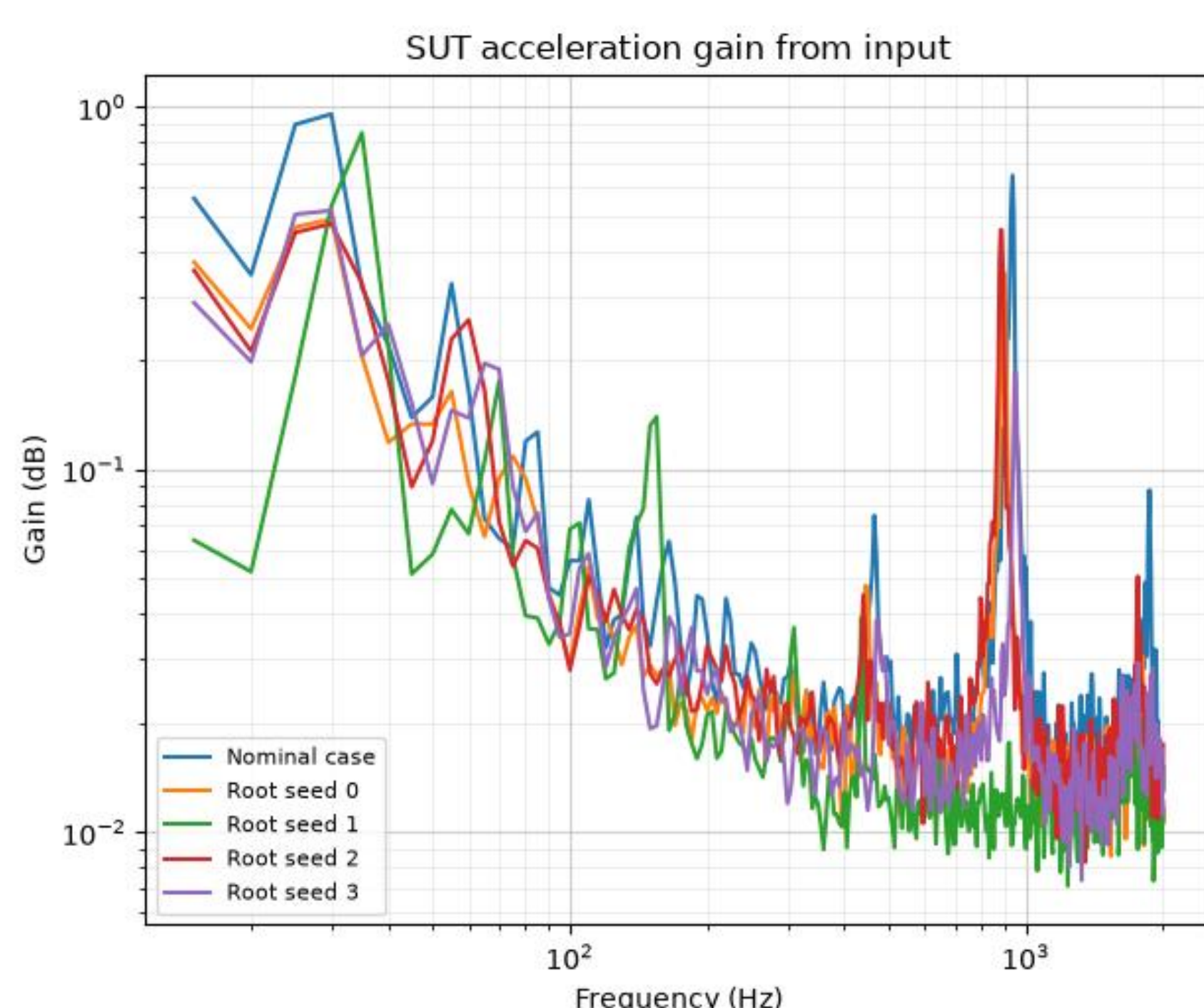


Fig. 3 – Simulated dynamic system response for random system variations (Monte Carlo subset). Figure by the Authors.

THE SOLUTION

To address these limitations, we are developing a testbench (Fig. 2) at DLR Bremen that combines **vibration, rotation and temperature** excitation and provides **6-DOF displacement, velocity, and acceleration** data in a reusable, accessible and standardized manner.

Due to its combined capabilities, the number of test cases and configurations is greatly reduced. The system's ability to provide sufficiently exciting environmental conditions for each sensor axis also supports observability of effects and correction of misalignment errors.

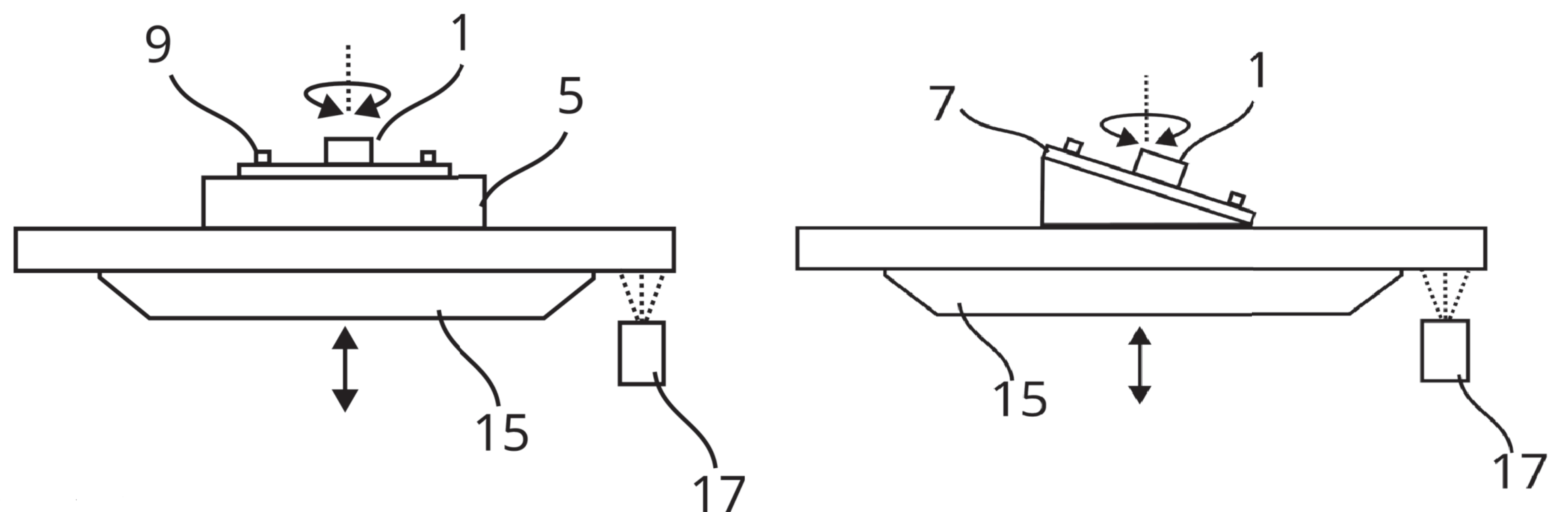
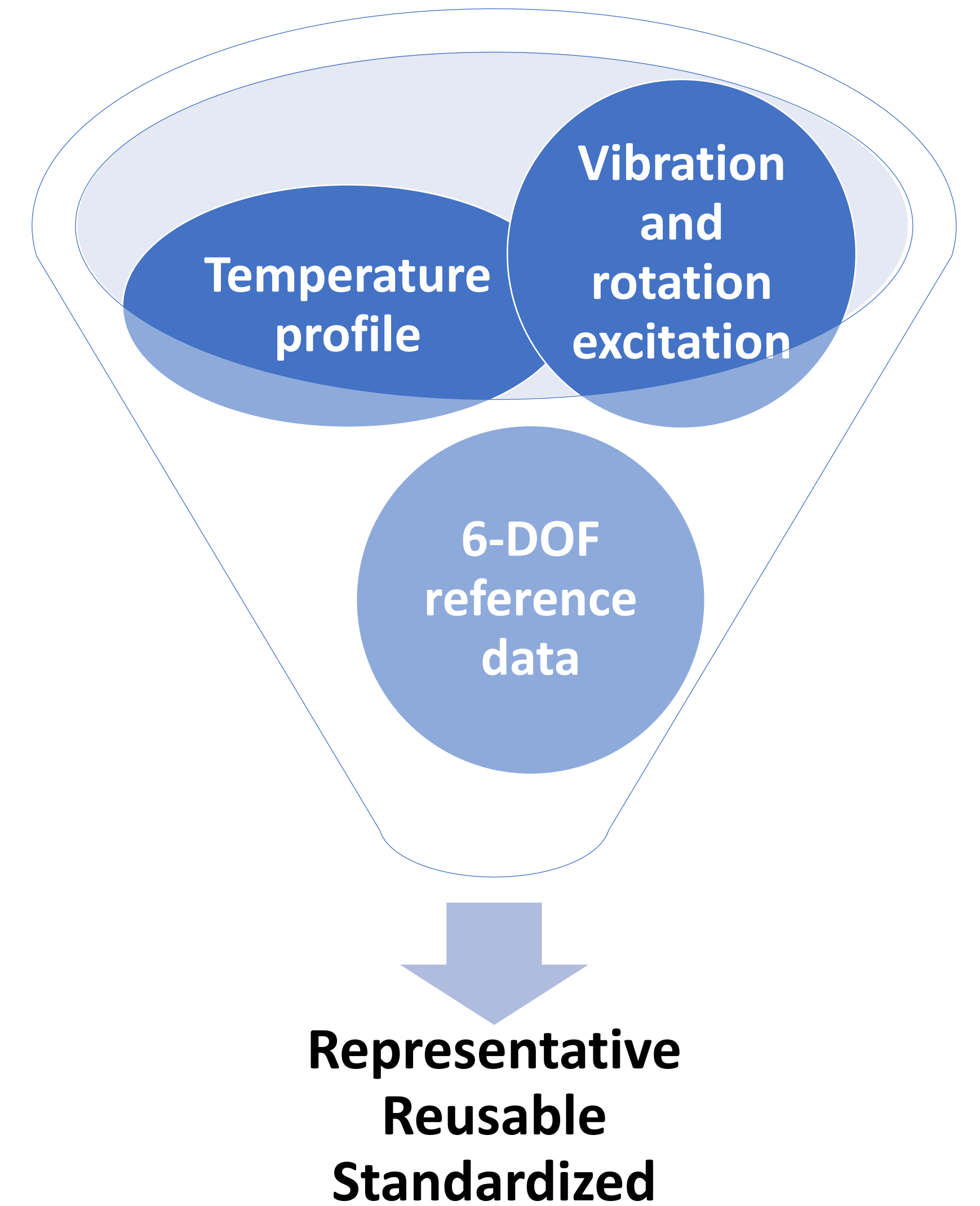


Fig. 2 – Two test configurations of the testbench. Image from Deutsche Patent 10 2024 118 279.2, „Rotationstisch mit verkipperbarer Sensoraufnahme“.

VERIFICATION APPROACH

Such a complex design with moving parts imposes a great instrumentation challenge. The verification follows two main paths: **mechanical design** and **data processing**. For the mechanical design, both sine and random tests were performed to analyze and optimize the design and assure that the **resonances are kept to a minimum**, even though they cannot be completely eliminated.

To estimate the accuracy and validate the data processing, a **virtual shaker simulation** was then put in place. The goal is not to fully replicate the behavior of the test setup quantitatively, but rather to **qualitatively include effects** that can decrease accuracy, and with that assess the robustness of the data processing. Figure 3 shows an example of the different virtual resonant modes of some Monte Carlo variations of the same system.

Mechanical design optimization

- Verify through testing that the influence of the mechanical system is kept to a minimum.

Virtual shaker

- Generate known physical effects and their variations
- Evaluate the robustness and accuracy of the data processing against these variations.

Next steps include obtaining a full accuracy profile and defining the test cases and processing steps.