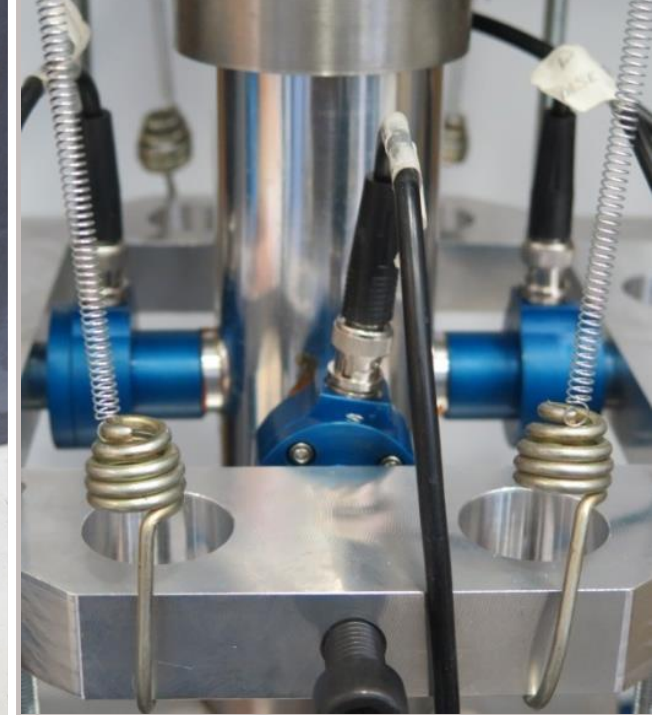


# Erfarenheter från jordbävningss- provning och analys för seismisk kvalificering av utrustning



RISE Research Institutes of Sweden

**Martin Olofsson**

Kemi och Tillämpad Mekanik

[martin.olofsson@ri.se](mailto:martin.olofsson@ri.se)

# RISE Research Institutes of Sweden

- State-owned research institute with a mission to be a strong innovation partner to corporations and society
- 2700 employees offer unique expertise in a wide range of knowledge and application fields (1/3 with a PhD)
- 100 testbeds and demonstration facilities

## Short facts about RISE Applied Mechanics

- 50 researchers, engineers, technicians and admin staff
- Node for solid and structural mechanics inside RISE
- Large experimental & simulation capabilities
- Unique capacity for accredited seismic testing

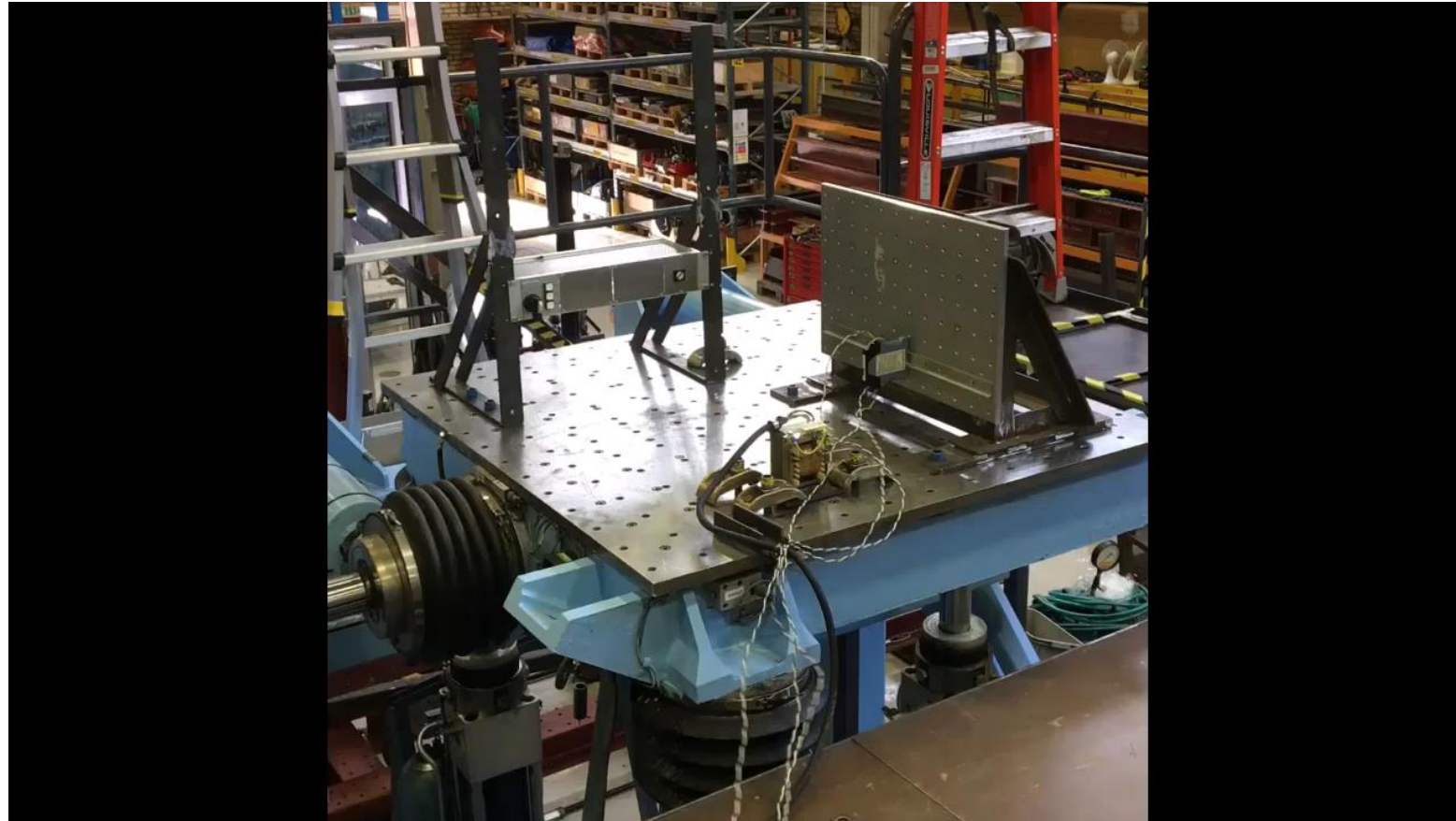


Example of  
load frame for  
material  
testing

Max force  
1.2 MN

# Seismic qualification of safety-critical systems and equipment

- RISE performs seismic testing of
  - Nuclear power plant equipment
  - Electricity transmission systems
  - Telecom and network equipment
  - RISE has a PLC system for detection of contact bounce in relays or switches
- Rigorous standards framework exists
  - IEC, IEEE, Telcordia
- Other products also have demand
  - Building and interior components



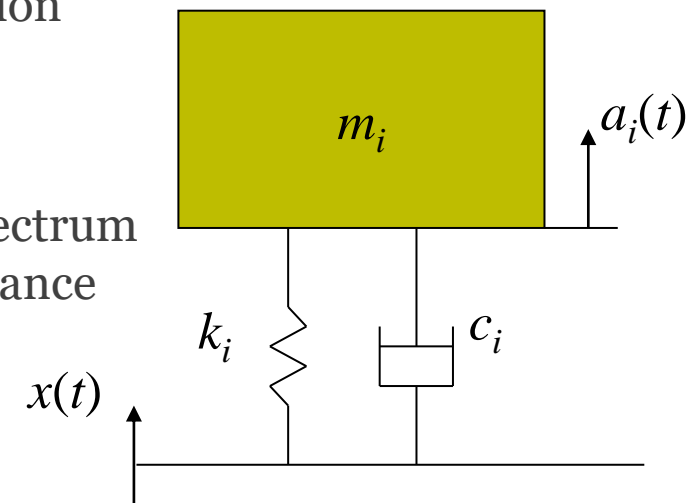
# Accredited test methods

- IEC/IEEE 60980-344:2020 Nuclear facilities – Equipment important to safety – Seismic qualification
- IEEE Std 693:2005 IEEE Recommended Practice for Seismic Design of Substations
- IEC 60068-2-57:2013 Test Ff: Vibration – Time-history and sine-beat method
- IEC 60068-3-3:2019 Supporting documentation and guidance - Seismic test methods for equipment
- IEC 60255-21-3:1993 Vibration, shock, bump and seismic tests on measuring relays and protection equipment - Section 3: Seismic tests
- Telcordia GR-63-CORE NEBS™ Requirements: Physical Protection

# Seismic vibration severity

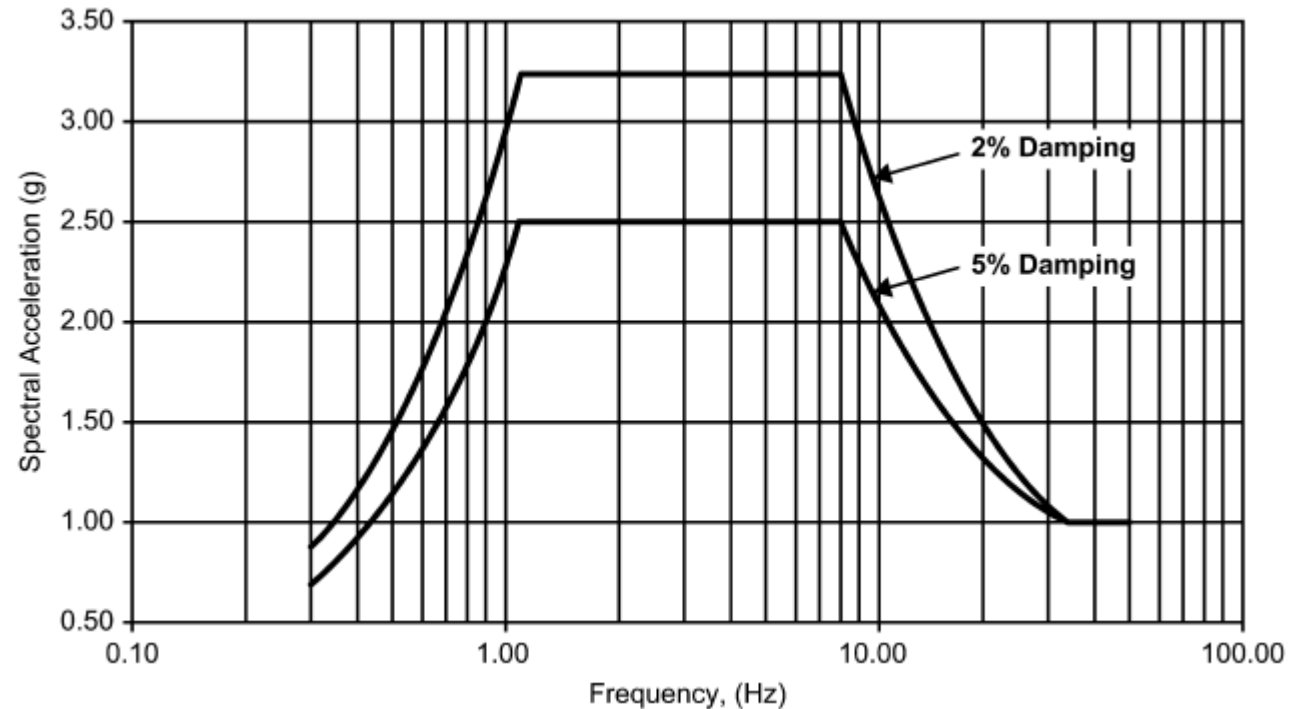
- Triaxial vibration with uncorrelated random, multi-frequency time series
  - Biaxial and single-axis testing is acceptable in most cases.
  - Random multi-frequency is motivated by the random nature of earthquake vibration
  - Alternatives are allowed, like sine sweep or sine beats
  - Measured true earthquake records not suitable
- Test vibration requirement is described as required response spectrum (RRS)
  - Vertical vibration can have different RRS than horizontal vibration
  - A test run is always about 30 s. Full power during at least 15 s.

principle for response spectrum  
- simple model of a resonance



# High performance level RRS from IEEE std 693

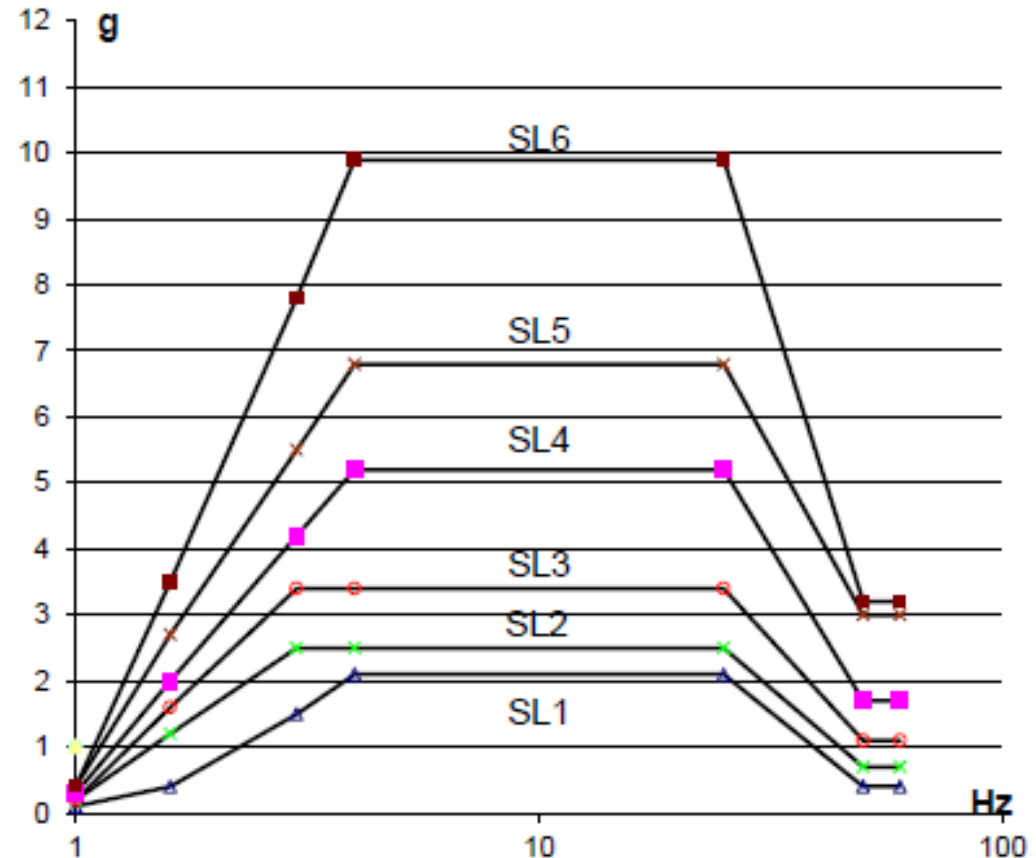
- High performance level is toughest and mostly used, in IEEE std. 693, with RRS level at 2.5 g in the strong part (1.1-8.0 Hz) and 1.0 g ZPA.
- Vertical RRS is 80% of above
- For installations with flexible support structure, equipment shall be qualified to  $2.5 \times \text{RRS}$  to count for potential dynamic amplification of the input acceleration
- Only triaxial testing is recognized in the current 2018 issue



# Generic levels from KBE EP-147

- Biaxial or triaxial independent multifrequency test.
- Same level in all directions
- Unique set of requirements when considering the wide frequency range of the strong part of the spectrum (up to 25 Hz)

Seismic environmental classes - 5 % damping

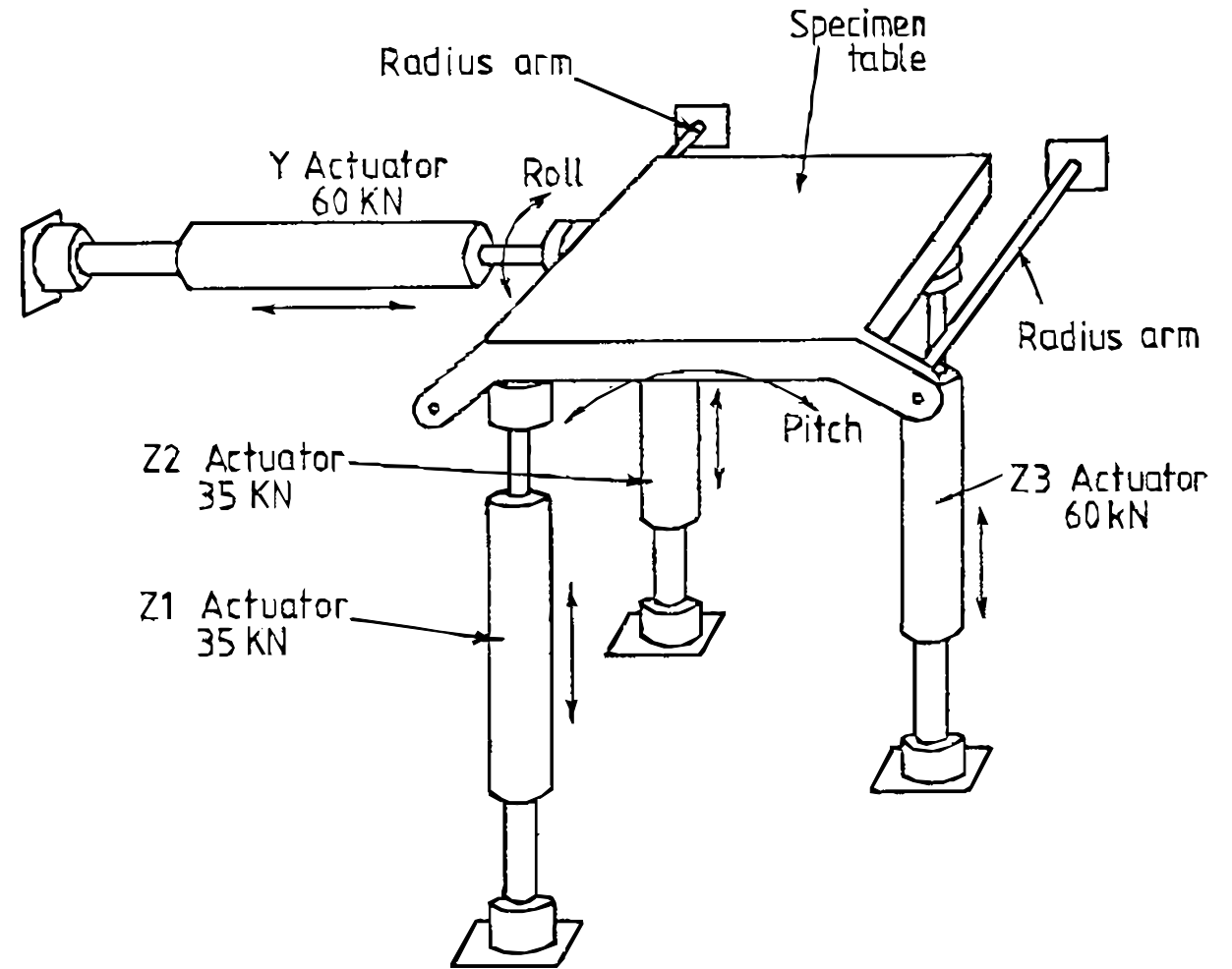
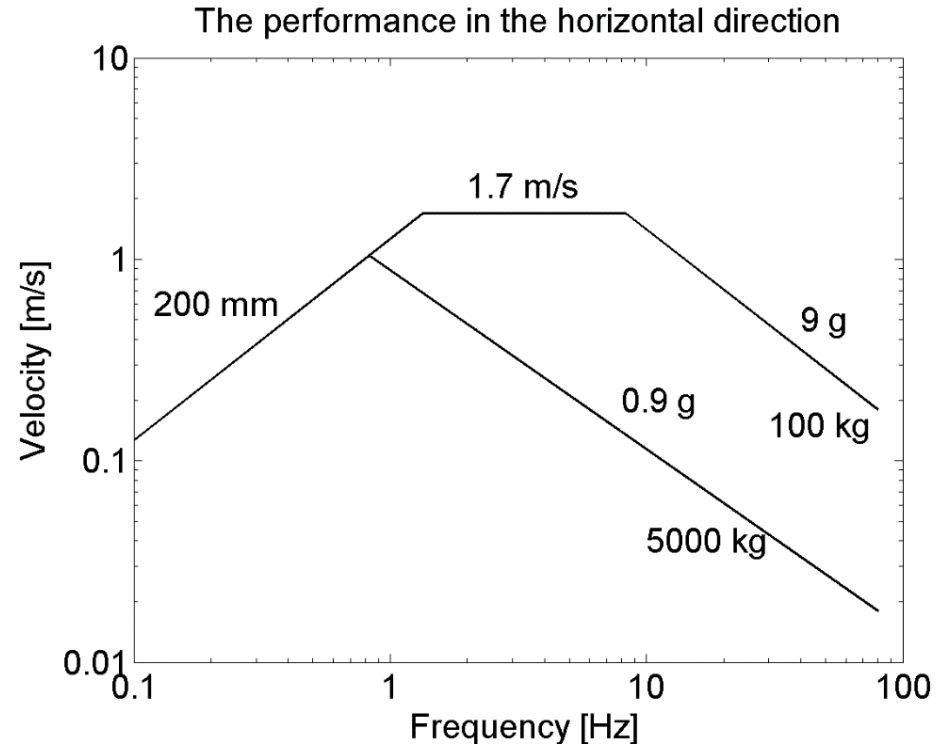


# Response spectrum-equivalent time records

- Earthquake test run records are developed with superposition of many sine waves with frequencies distributed every  $1/12$  octave over the excitation range
- A realization of a true stationary random process is achieved through randomized phase angles of each sine wave
- For biaxial or triaxial excitation the individual time record, for one direction, need to be independent of other records
  - Each record has unique randomization of phase angles
  - Frequency points are shifted by a small frequency value
- In case of physical testing with servo-hydraulic shake table, a final step makes sure that the rig drive signals make the table move in accordance with the synthesized rig target

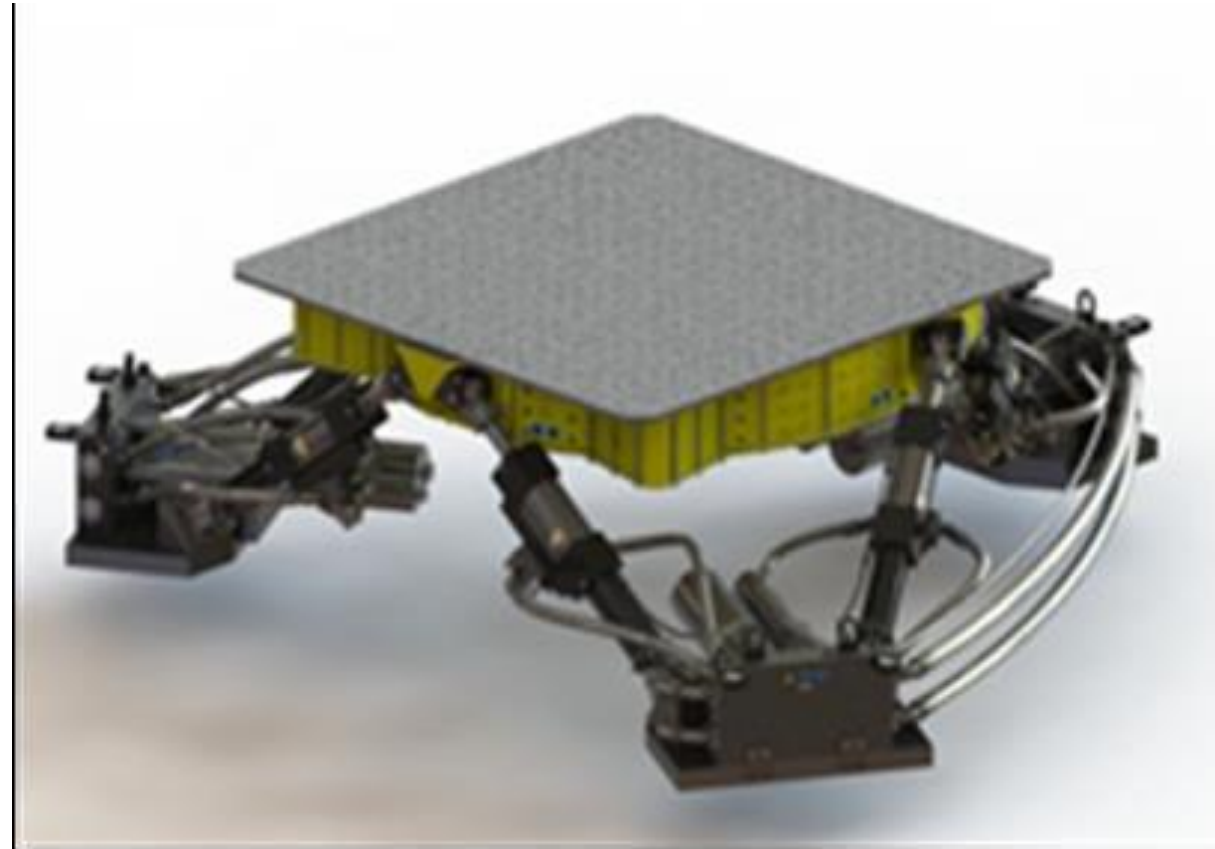


# RISE shake table



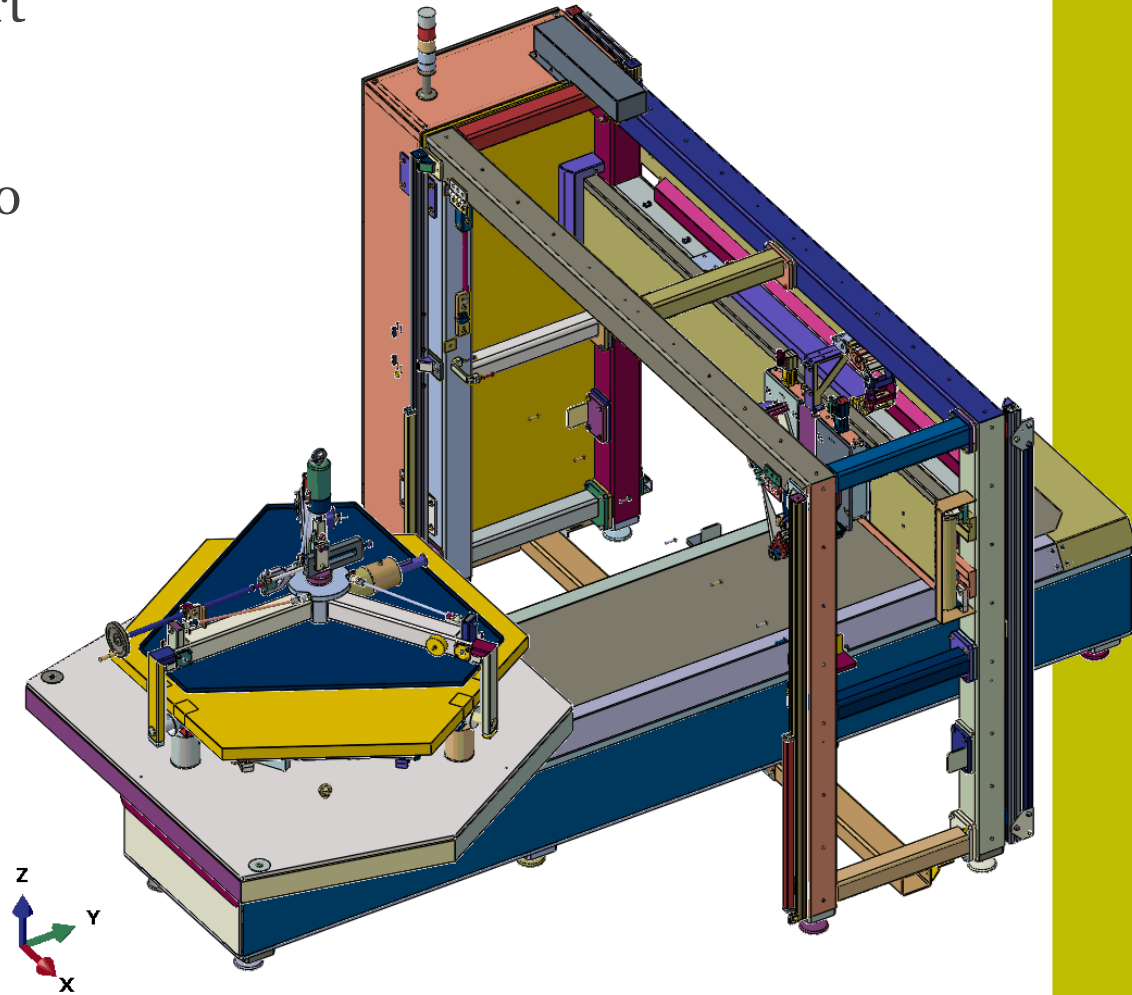
# New RISE shake table?

- 2-tons -> 5 tons
- 4 DOF -> 6 DOF
- Biaxial -> triaxial
- keeping same displacement and acceleration capabilities
- Requests exist but not in enough volume – can you contribute?



# Qualification by Analysis

- RISE has offered seismic analysis support to Fagertröm Industriekonsult, in the development of a mirror cleaning plant for the next Extremely Large Telescope to be built in Chile by European Organisation for Astronomical Research in the Southern Hemisphere (ESO)
- Modal Response Spectrum analysis according to Eurocode 8



# Derivation of Secondary Response Spectra

- Attractive to use random data and a probabilistic viewpoint
- There is a one-to-one relation between a Response Spectrum and a Power Spectral Density of a random process
  - The expected response spectrum values depend on process observation length (higher extreme values observed the longer observation time)
  - With observation length typical for one earthquake, the variance of expected maximum is high (like in real earthquakes)
- Simple relation between PSD matrix of ground motion and PSD matrix of response in a linear primary structure
  - PSD input is diagonal for independent excitations in the different directions
  - PSD response has more populated matrix containing also correlation between outputs, caused by the eigen-modes, a correlation that should be reflected in an excitation description for a secondary structure

# Research at RISE Building and Infrastructure group

- RISE Chemistry and Applied Mechanics has a research group on Building and Infrastructure  
<https://www.ri.se/sv/vad-vigor/expertiser/research-at-building-and-infrastructure-group>
- PhD Michele Godio has research experience in masonry buildings and effects from earthquakes, also from experiments with scaled buildings,  
<https://www.researchgate.net/publication/334108347> Experimental and Numerical Assessment of the Seismic Performance of a Half-Scale Stone Masonry Building Aggregate
- Any requests on scaled building experiments?

