EIB SAS status report

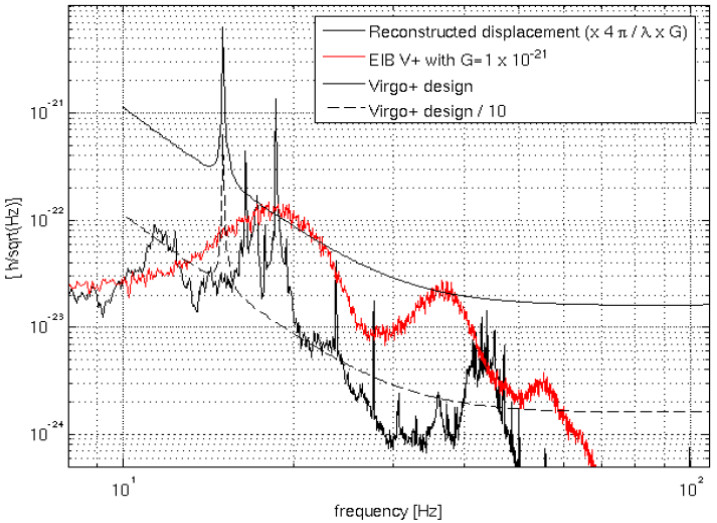
Jo van den Brand, Frans Mul

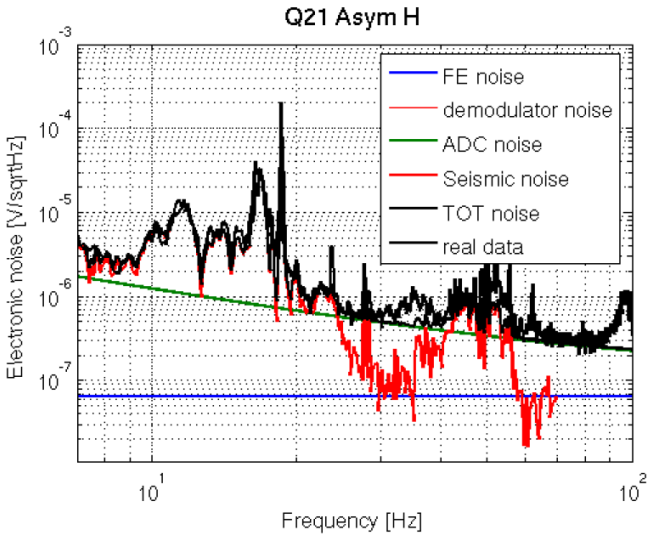
Introduction

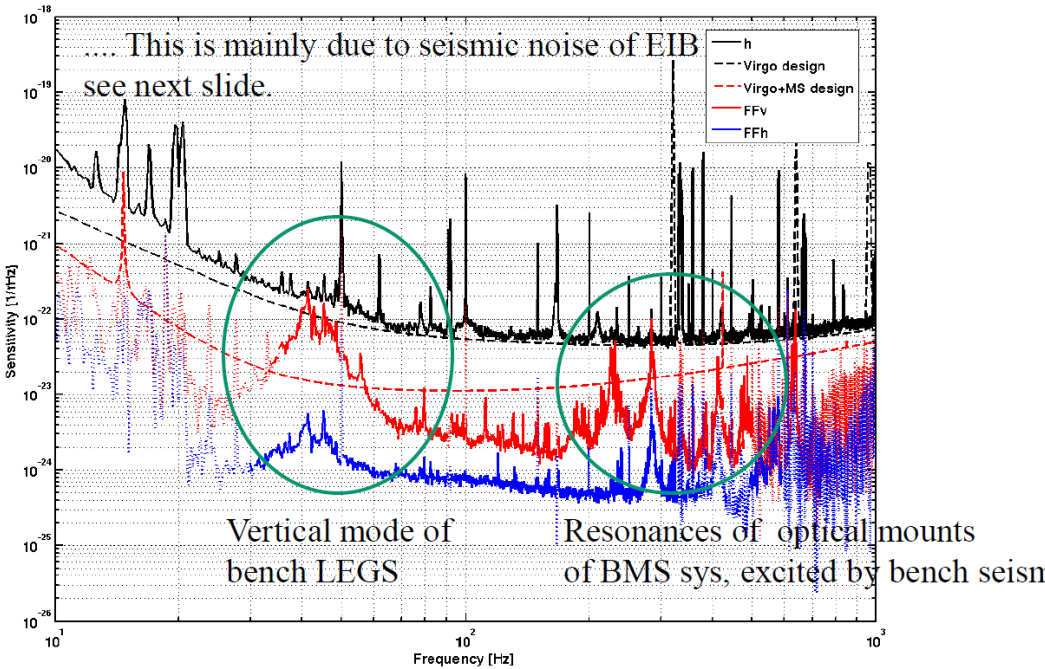
- Introduction
  - General considerations
  - Design issues
- Status of project
  - SAS mechanics
  - Sensors and control
  - Acoustics
- Logistics
  - Manpower
  - Time line
  - Installation
  - Budget

External Injection Bench

- EIB
  - Diffused light
    - Seems ok
  - Beam jitter noise
    - Angular tilt motion
  - B2 photo-diode for AA
    - Horizontal motion
- Implement EIB-SAS
  - Change Request, July 01, 2010

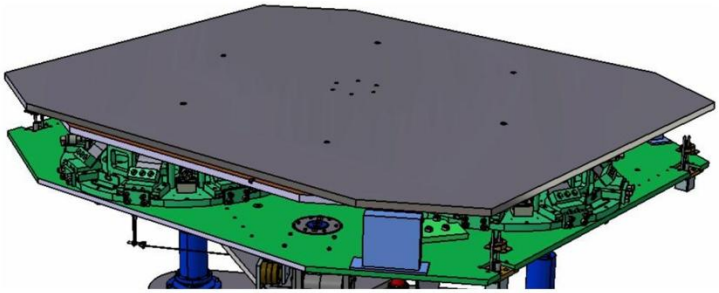


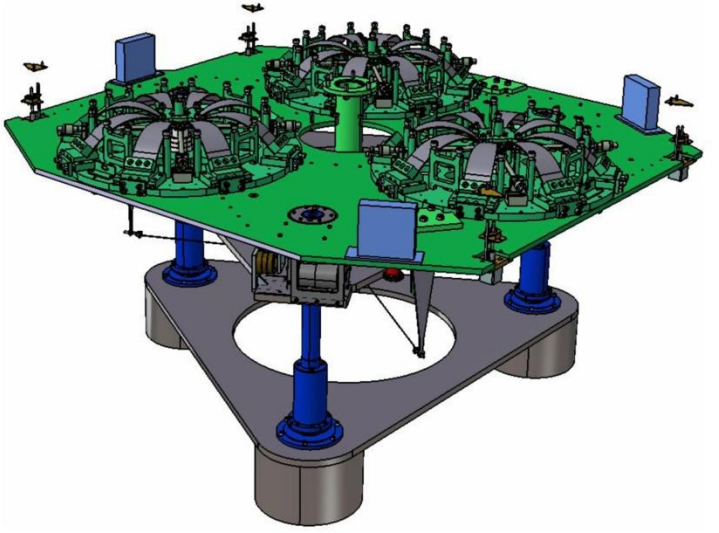




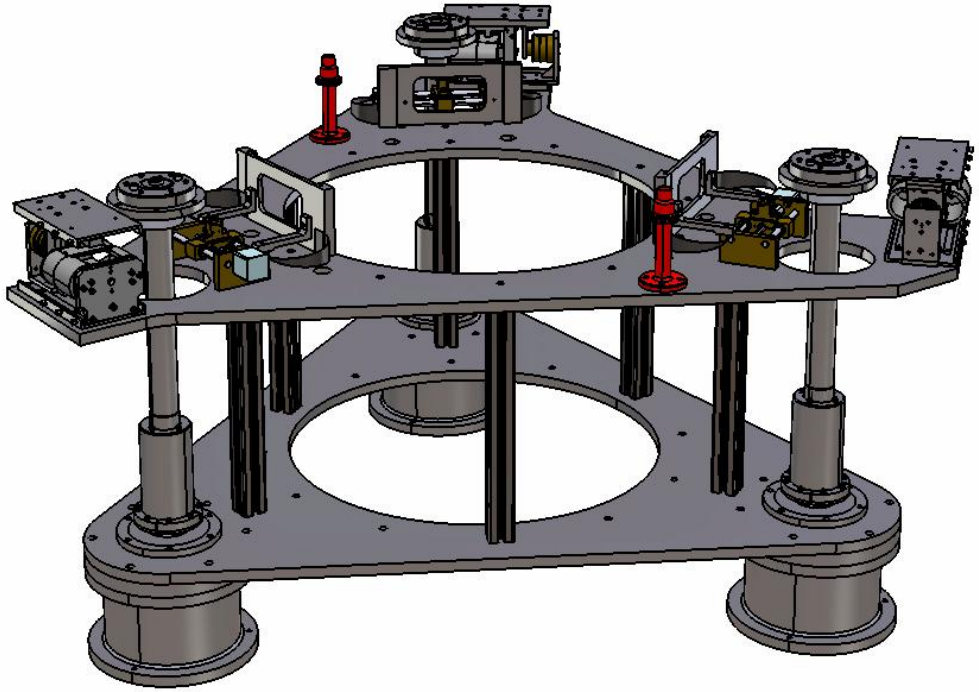
EIB – SAS

- LIGO R&D, TAMA, AEI
  - Riccardo & Alessandro
    - Pisa experience
- Status
  - Engineer (Frans Mul) was stationed at AEI
  - Design finished: June 2010
  - Ordered IP and GAS
  - Delivery main components: August 2010
  - Technical support at Nikhef
  - DAQ from Annecy
  - Short time line





EIB – SAS



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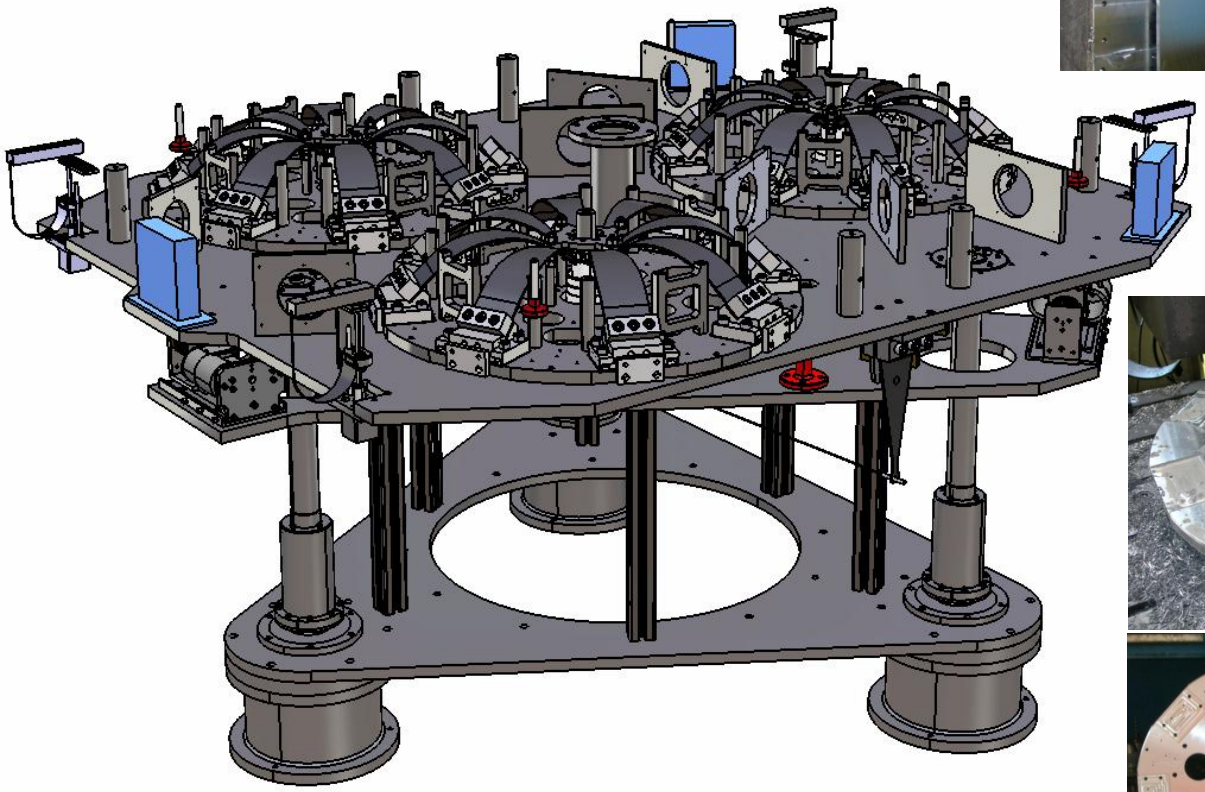

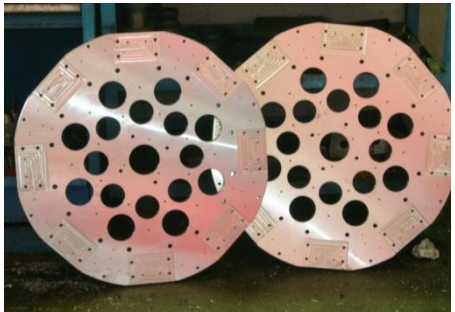

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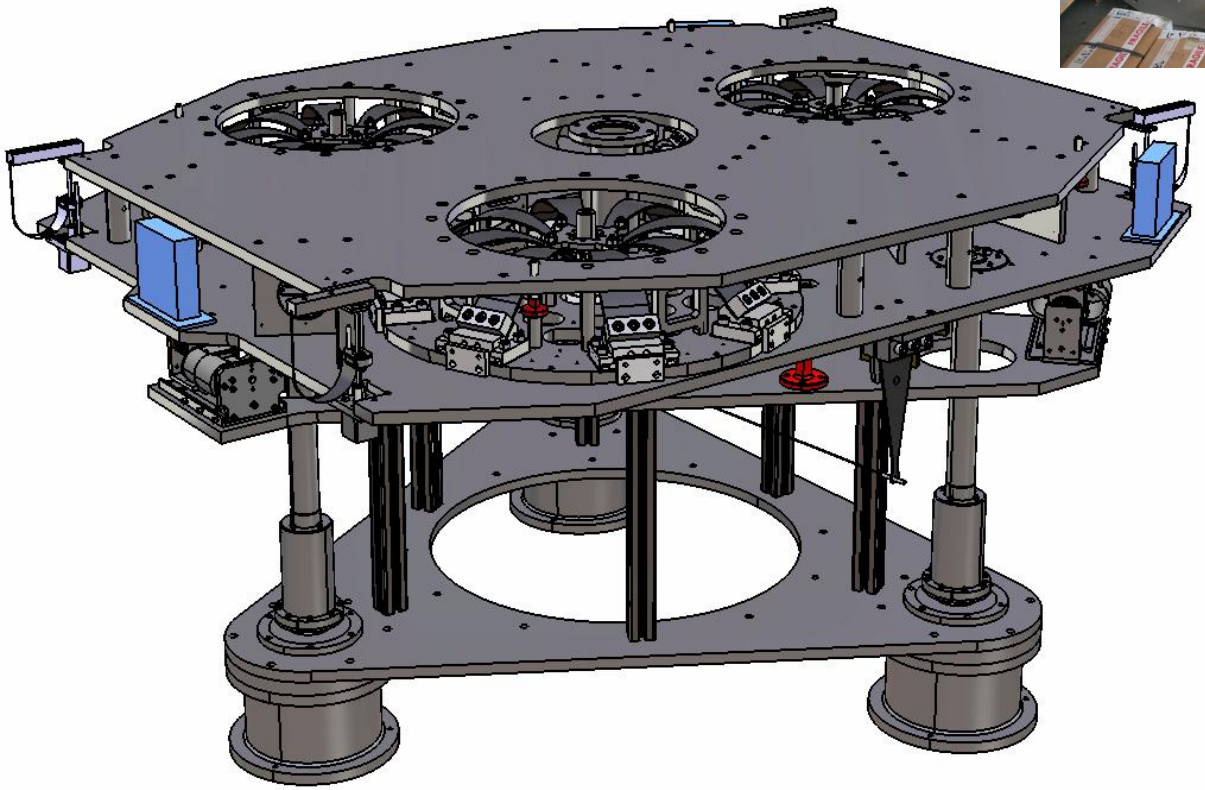

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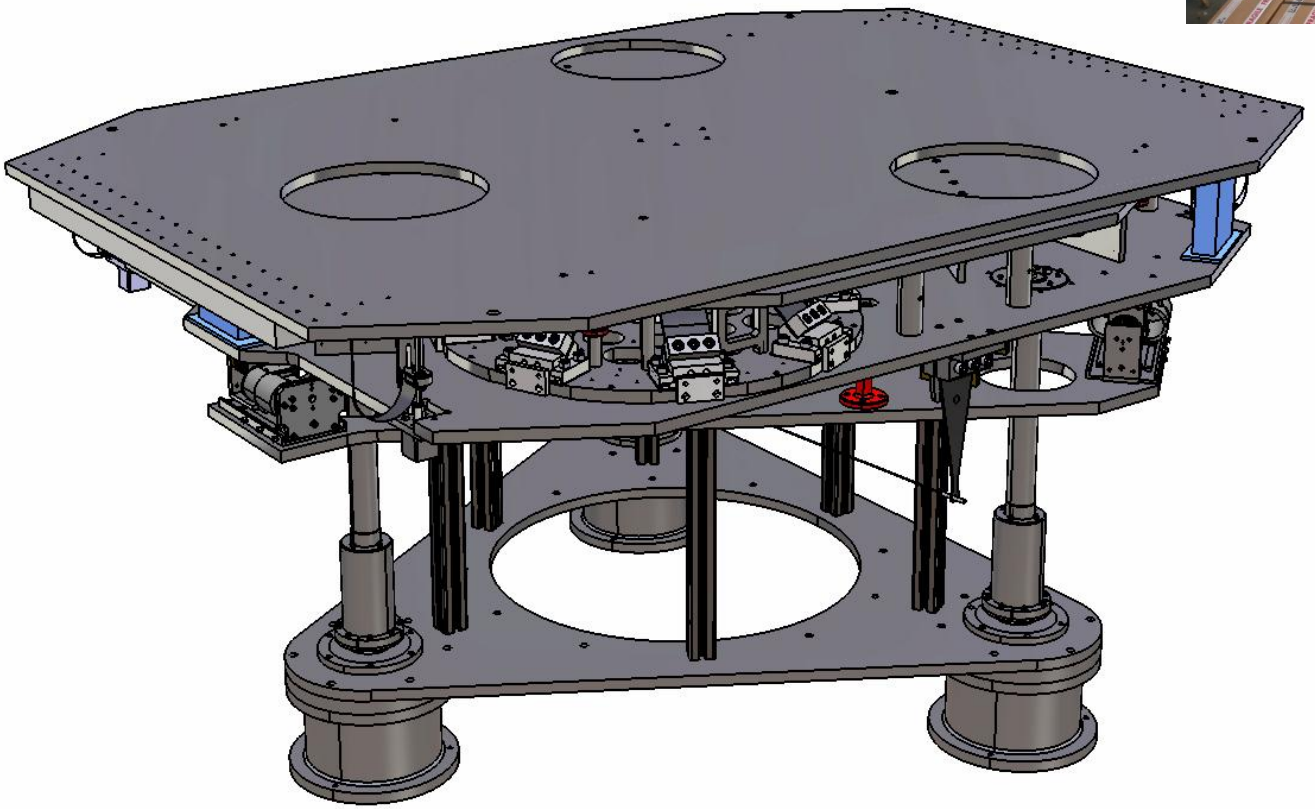
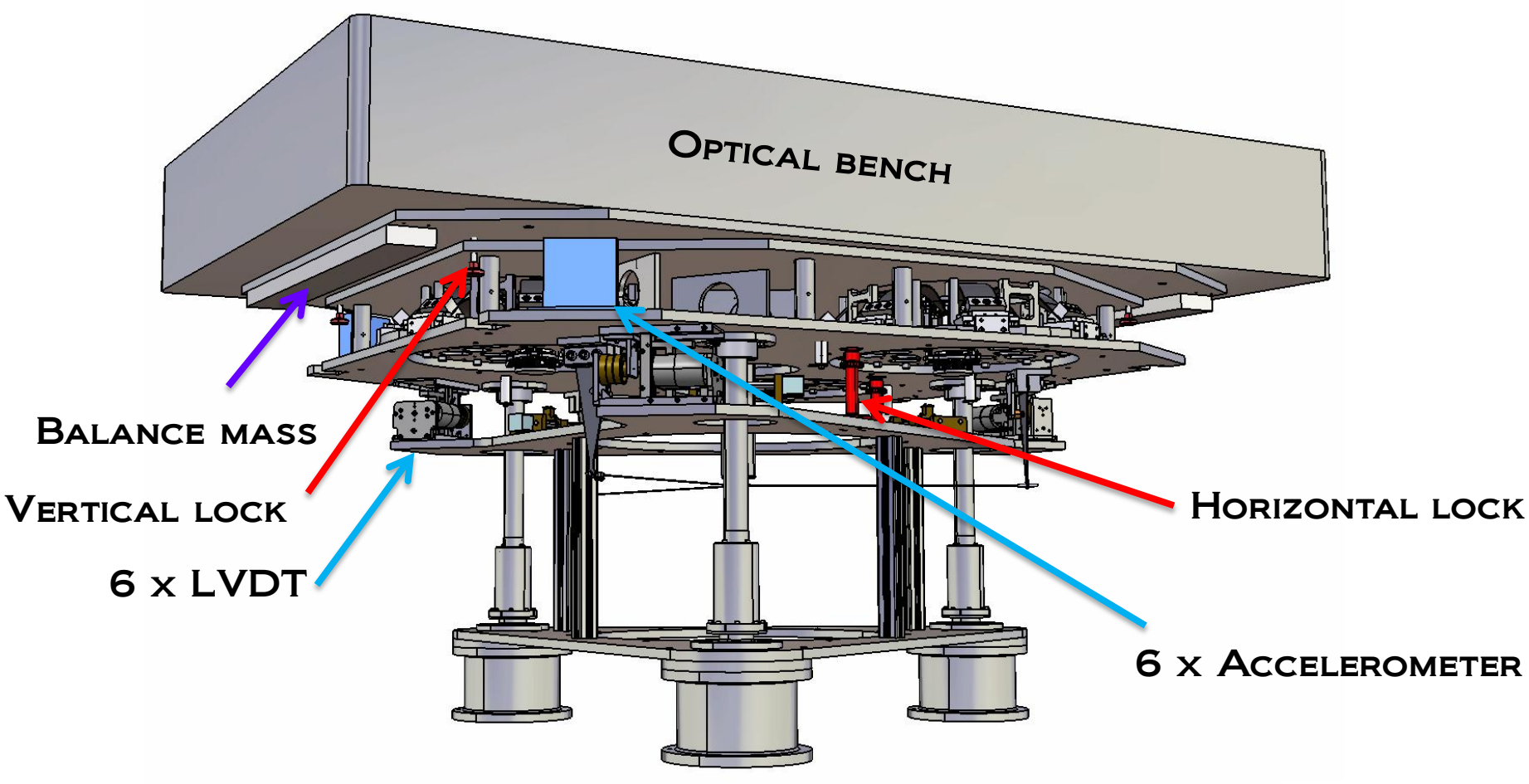
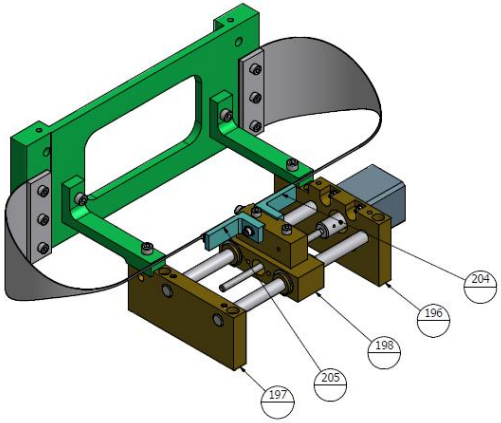
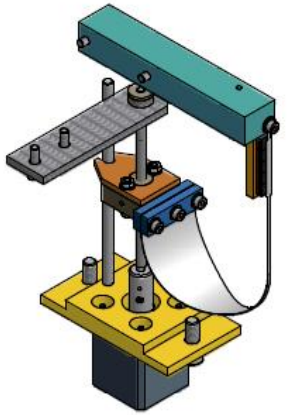


Production mechanics: completed August 15, 2010

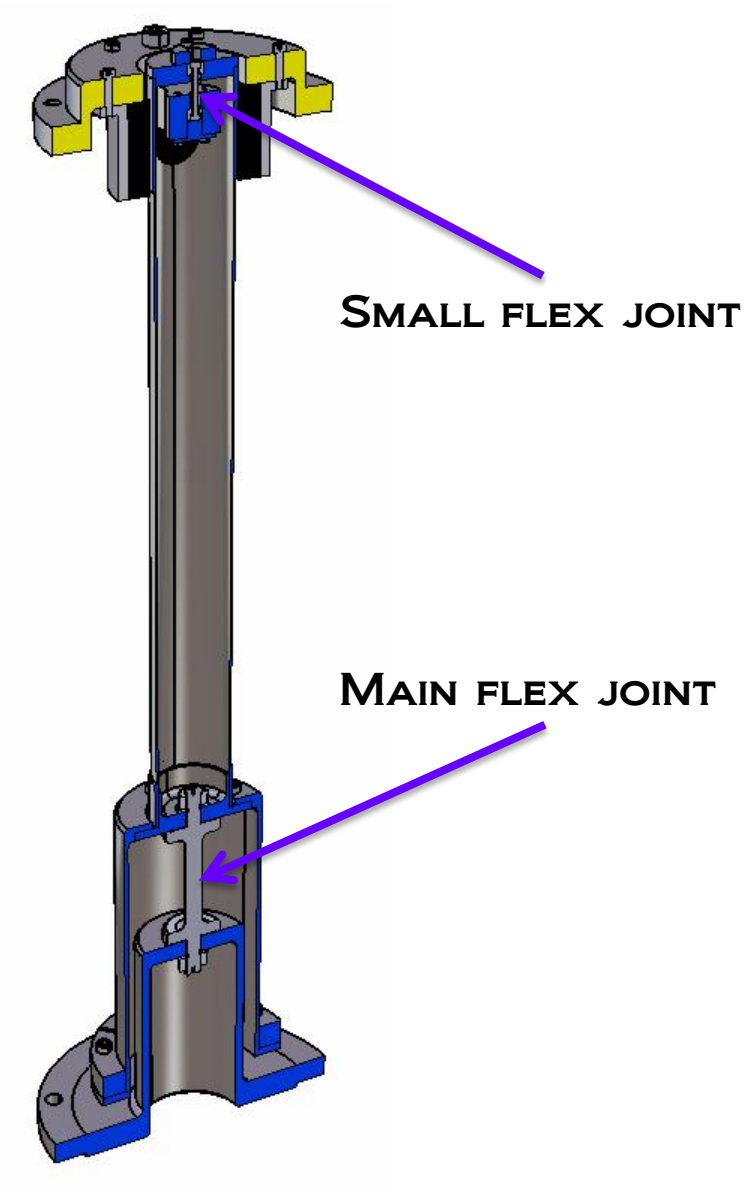


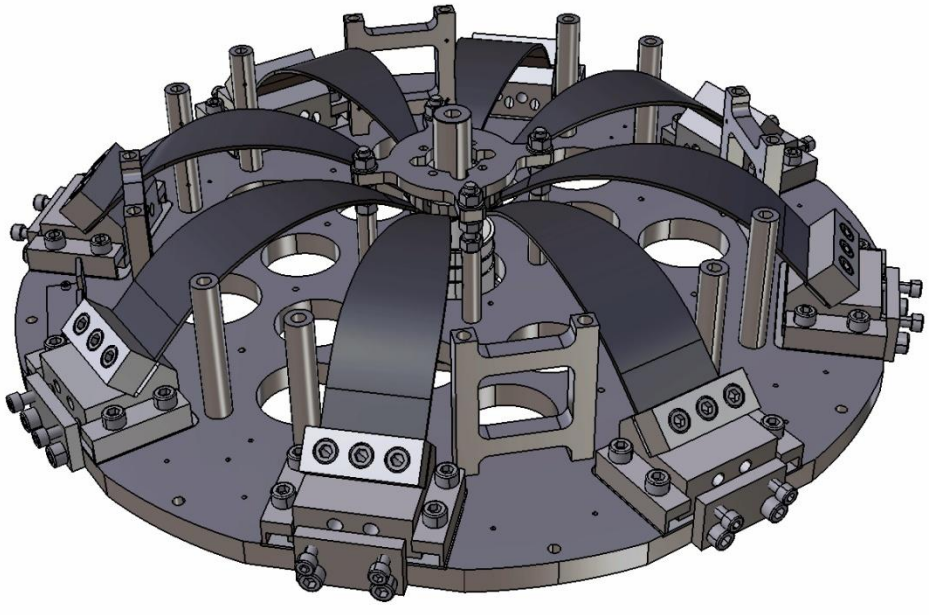
- Horizontal and vertical motion
  - 7 x stepping motors
  - 6 x voice coil actuators
  - Real-time digital control system
    - 800 kHz 18 bit ADCs: LVDTs, geophones
    - DAC for voice coils

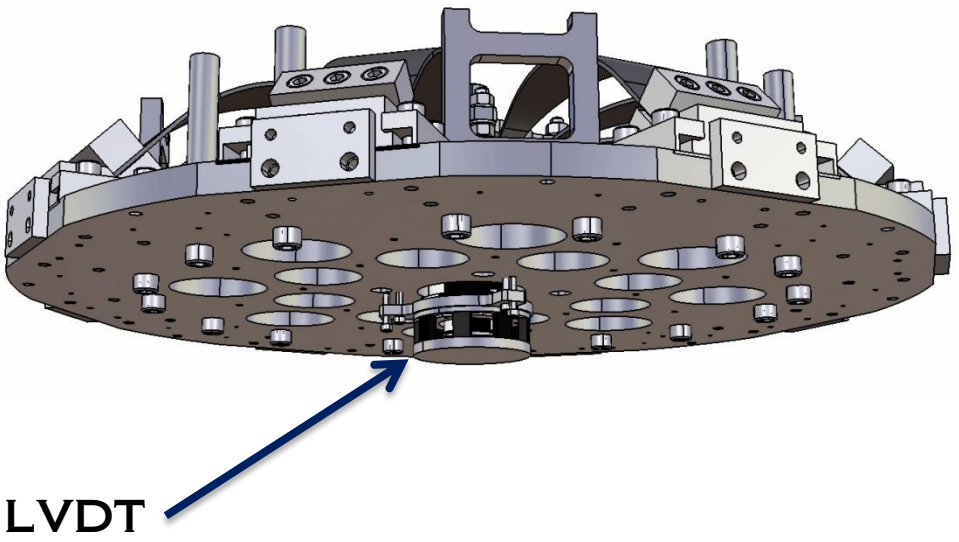




EIB – SAS: IP and GAS

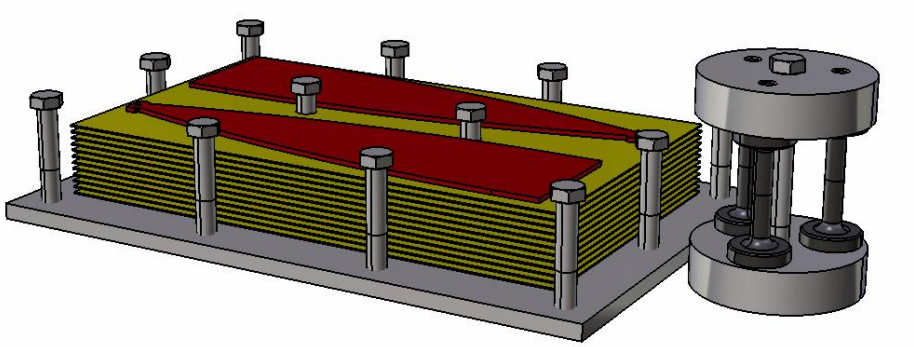


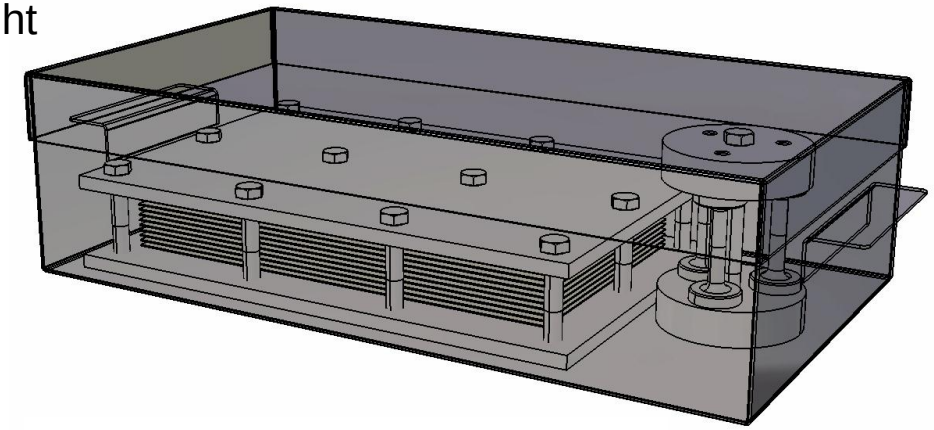


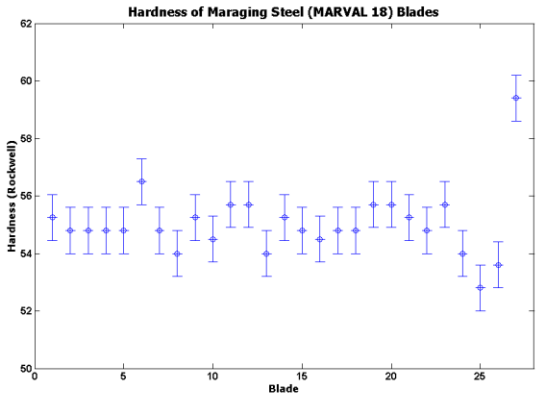


Maraging steel: thermal treatment

- Maraging steel
  - Aubert & Duval: Marval18 steel
  - Application
    - IP flex joints
    - GAS spring blades
  - Blades surface electropolished and light nickel plated (and heat treated)
- Thermal treatment
  - 435 °C for 100 hours under Argon
  - Aging at 200°C 2 - 3 days (later)
  - Rockwell C hardness
    - Initial 20, final 52 – 55
    - Quality control of every component
  - Performed at Nikhef
    - Build-up experience
    - Set-up completed
    - Steel samples in house (ESA)

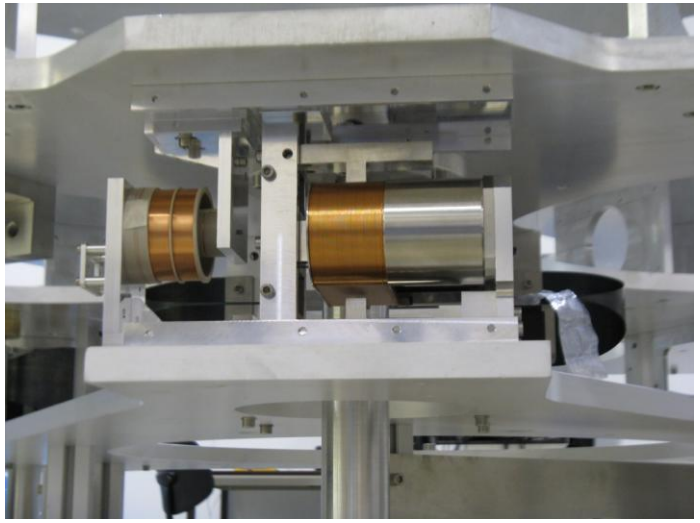


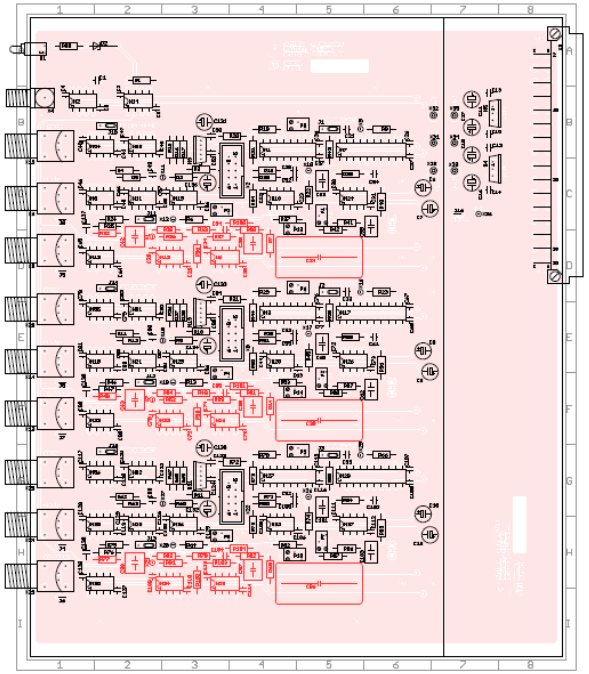




LVDT and actuator

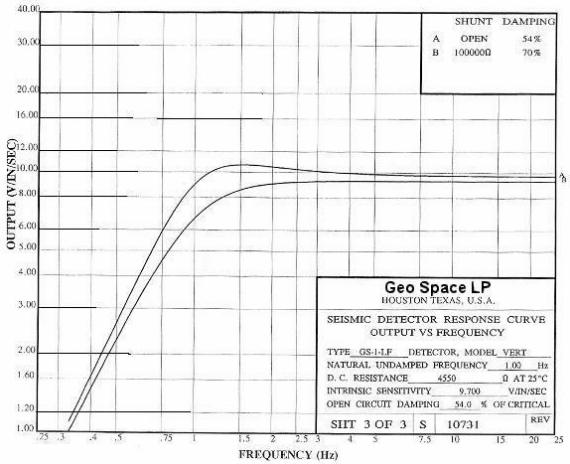
- LVDT and actuators
  - Constructed: 3H and 3V
  - Testing
    - In progress at Nikhef
- Electronics boards
  - Designed by Alessandro Bertolini
  - Four PCBs at Nikhef (from AEI)
  - PCB populated: under test
- Virgo boards
  - Status of Virgo LVDT boards
    - Redesign needed?
  - Replace when Virgo boards are available

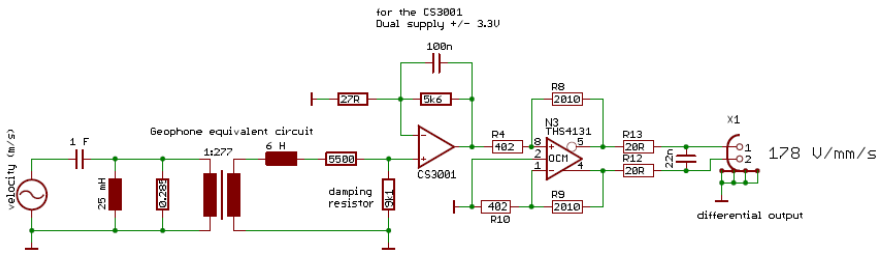


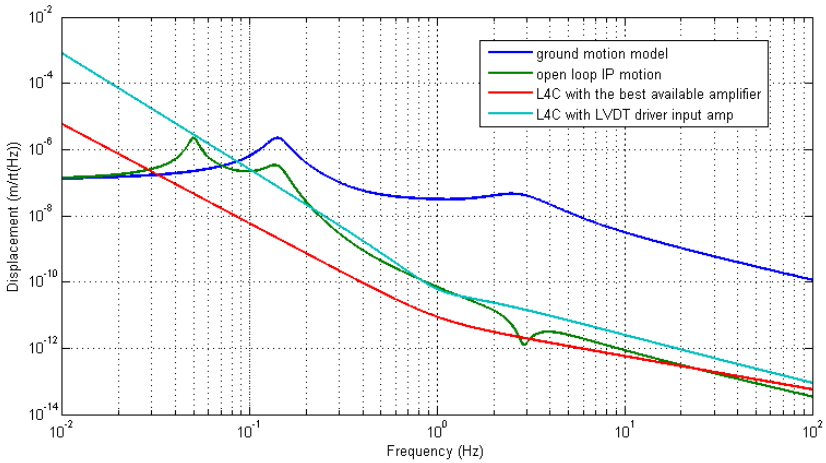


Accelerometers

- Geophones
  - Geospace
    - Qty 4 - GS-1, 1 Hz seismometer, horizontal
    - Qty 4 – HS-1, 2 Hz seismometer, vertical
    - In house
  - PCBs
    - In house and populated
    - Tests in progress
- Accelerometer
  - Alessandro Bertolini
    - Modify gap
    - Implement if needed
    - Under discussion







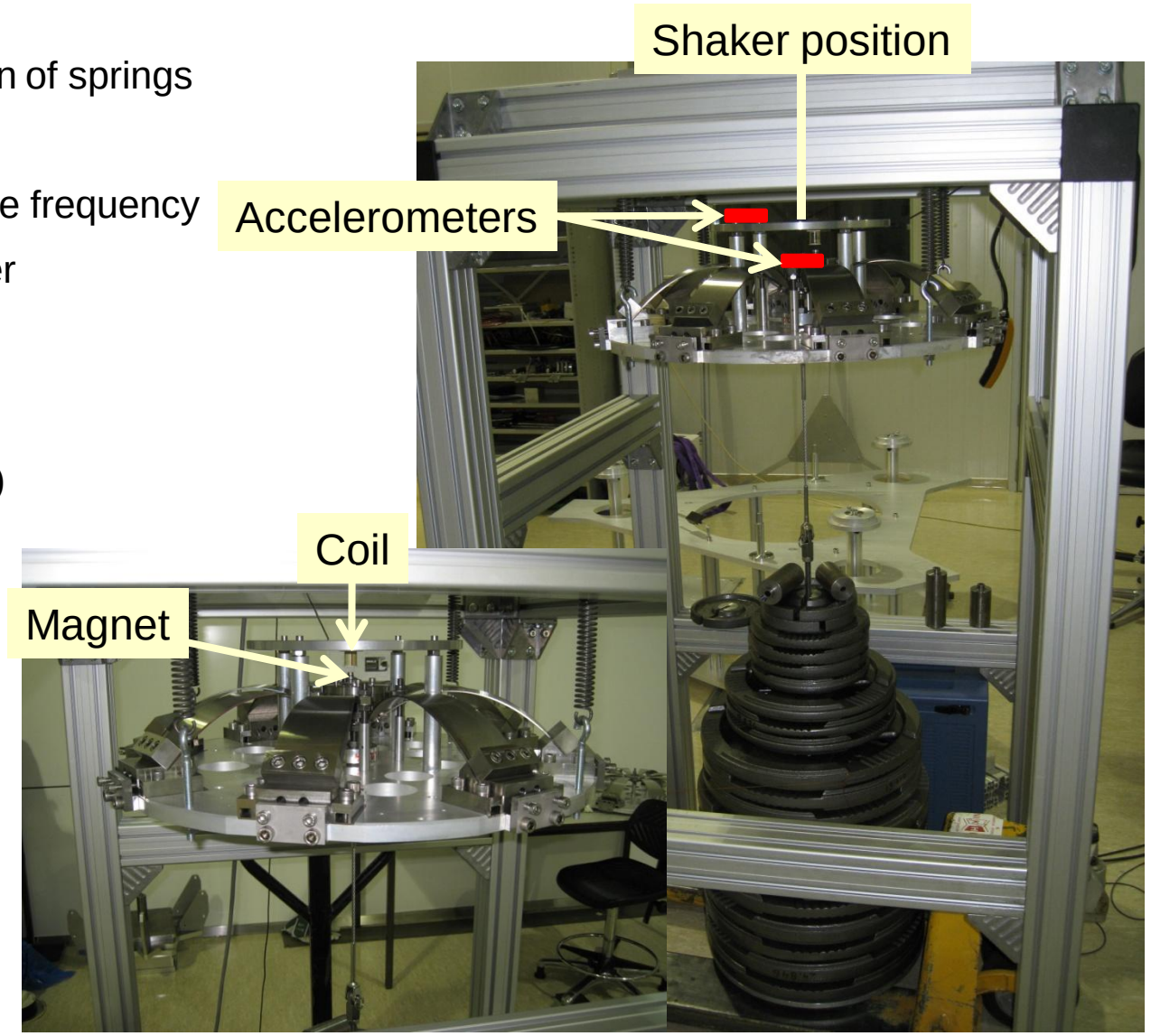
GAS ASSEMBLY

- Assembly
  - Nikhef cleanroom
  - 1 day for 3 GAS filters

Frans Mul
Willem Kuilman
Michiel Jaspers
Gerrit Brouwer
Mark Beker
Mathieu Blom

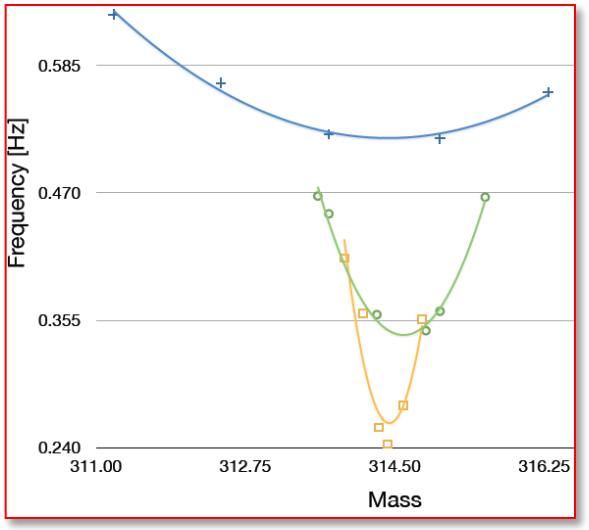
GAS TUNING

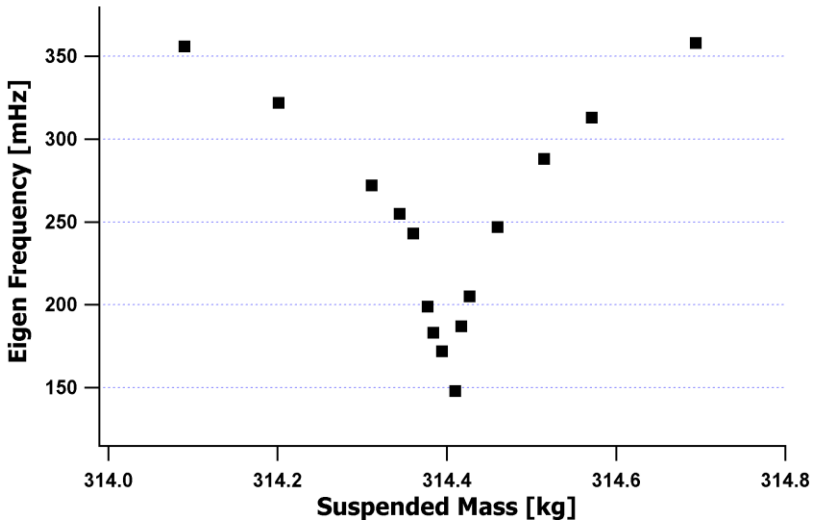
- GAS tuning set-up
  - Adjust compression of springs
  - Vary the load
  - Measure resonance frequency
  - 1 day per GAS filter
- Transfer functions
  - Shaker system
  - Speaker (modified)



GAS TUNING

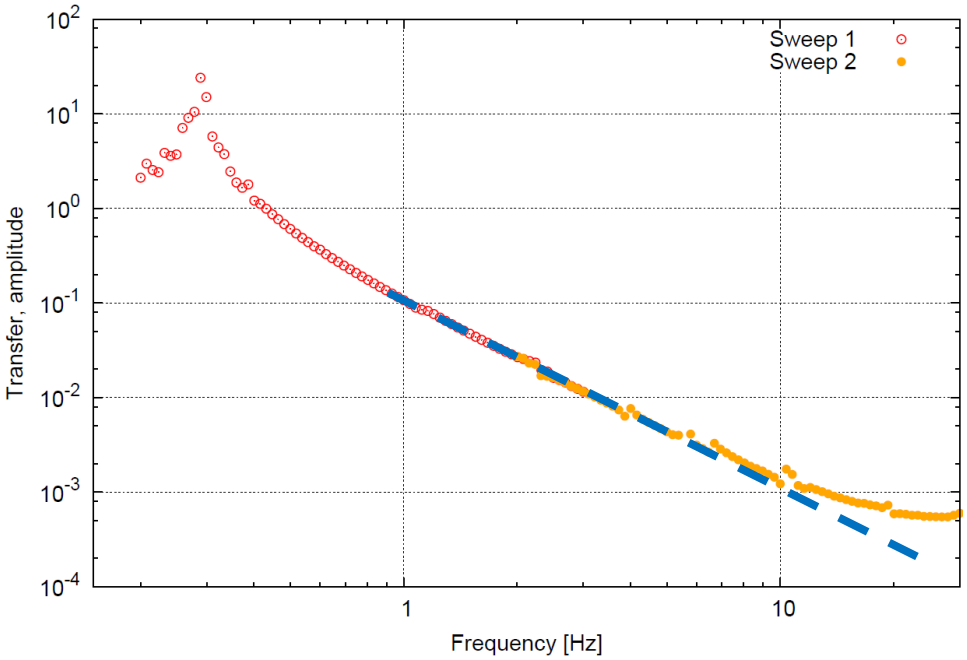
- Tuning results
  - Goal: tune below 300 mHz
  - Achieved < 150 mHz
  - Precise loading
    - Weigh components on bench
    - Decide on frequency setting
  - Quality factor decreases at low frequency

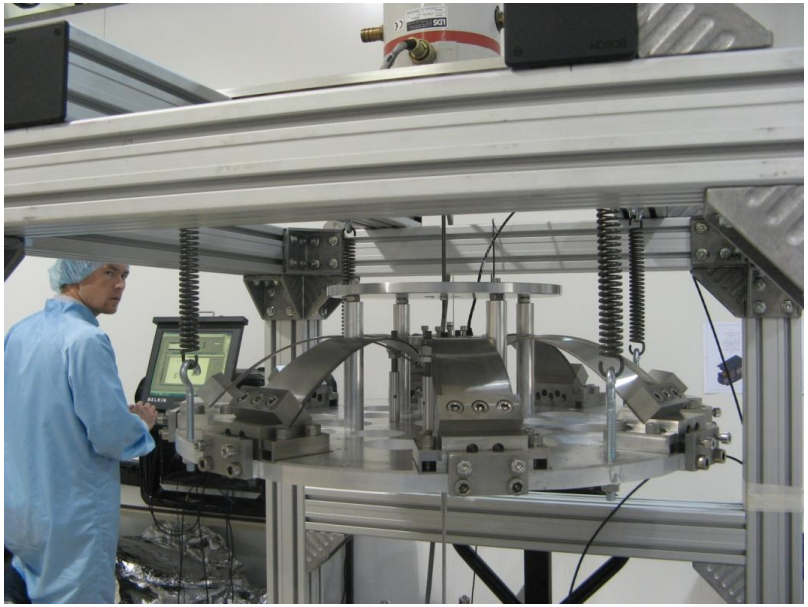


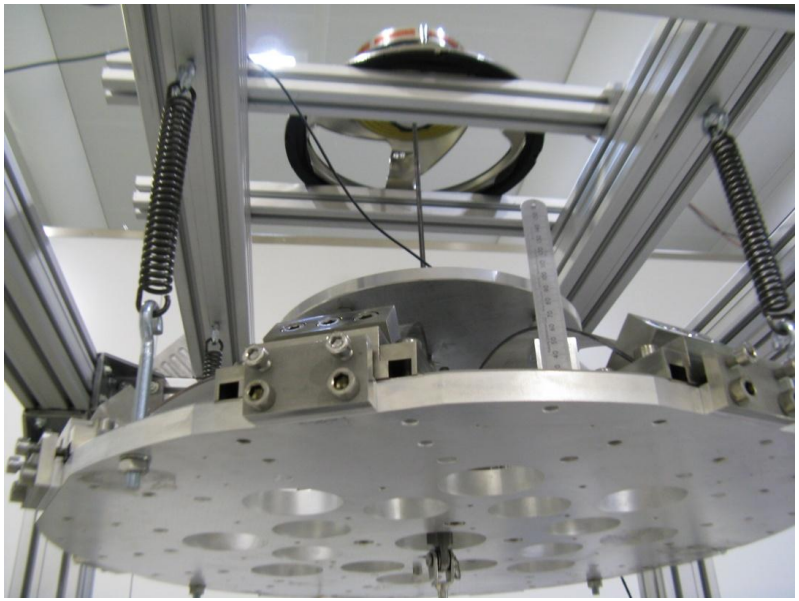


GAS TESTS

- Transfer function
  - 60 dB above 10 Hz
  - Achieved > 65 dB at 20 Hz
  - Precise loading
    - Weigh components on bench
    - Decide on frequency setting
  - Quality factor decreases at low frequency

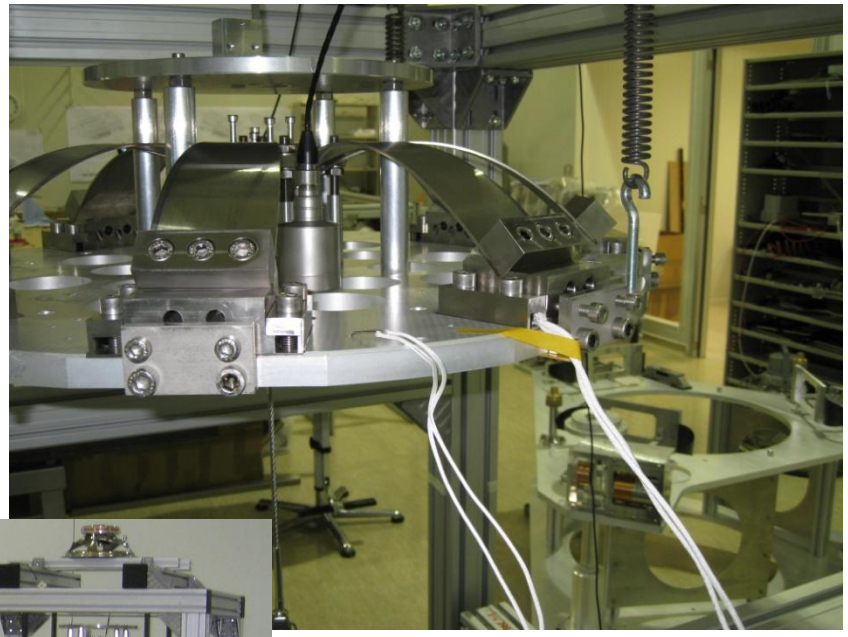






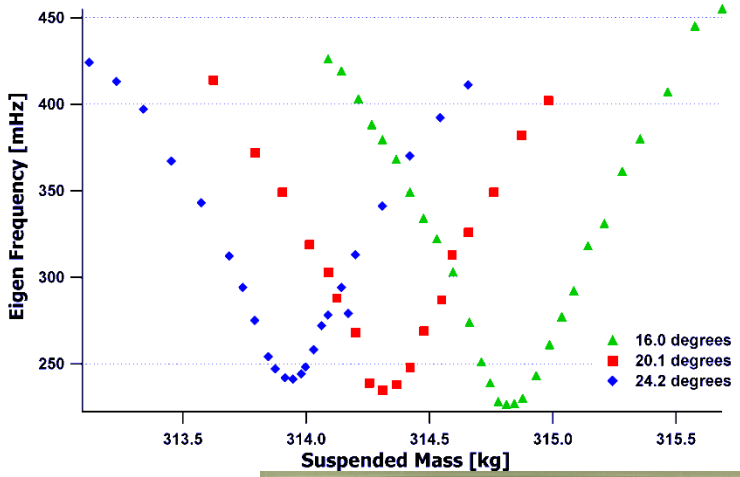
GAS TESTS

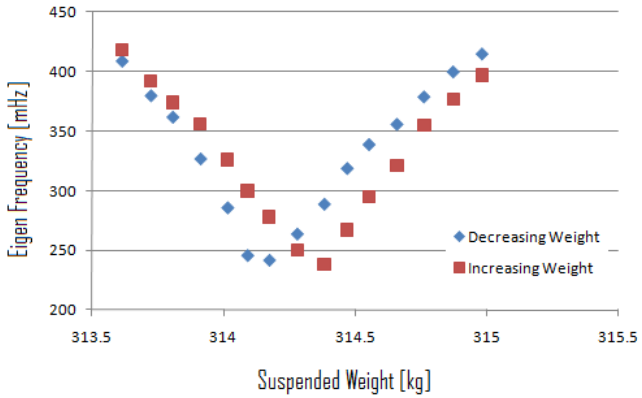
- Temperature dependence
  - Cleanroom: 16 to 24.2 degrees C
  - Thermocouples
  - Measure
    - Vertical displacement
    - Resonance frequency

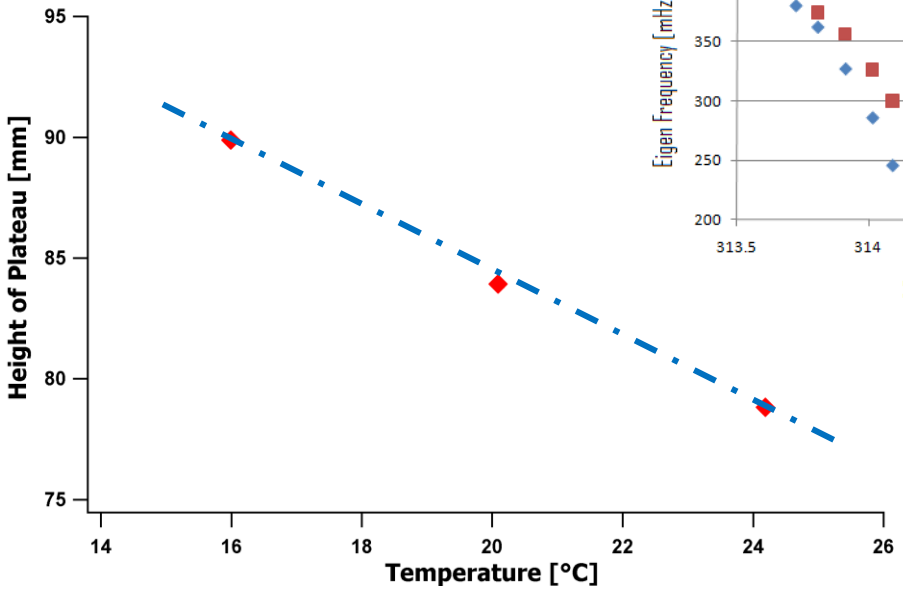


GAS TESTS

- Temperature dependence
  - Move away from resonance as temperature goes up
  - Displacement
    - At 240 mHz
    - 1.4 mm per degree
- Hysteresis

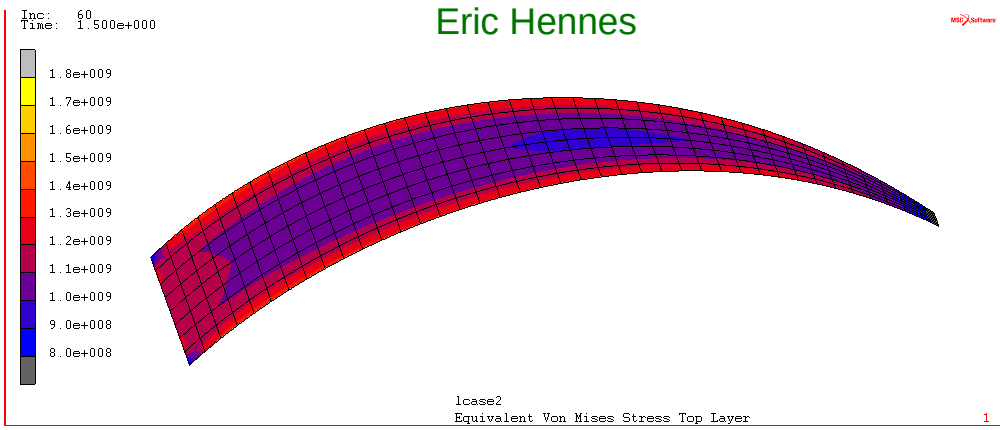


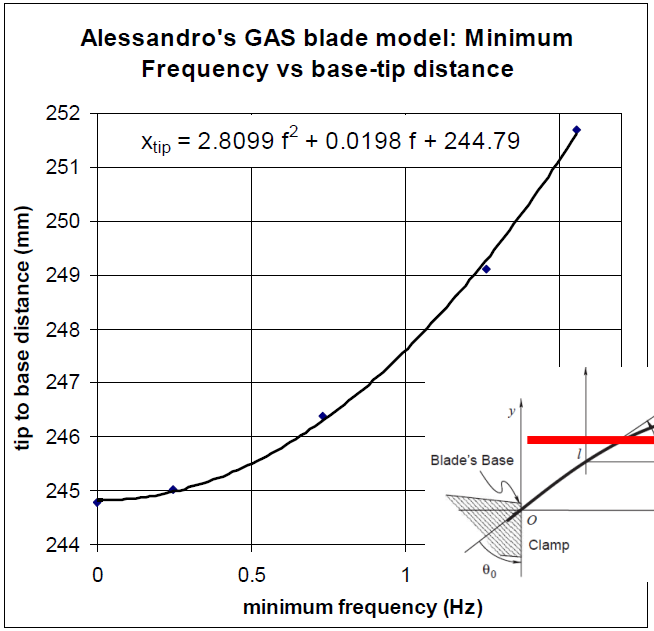




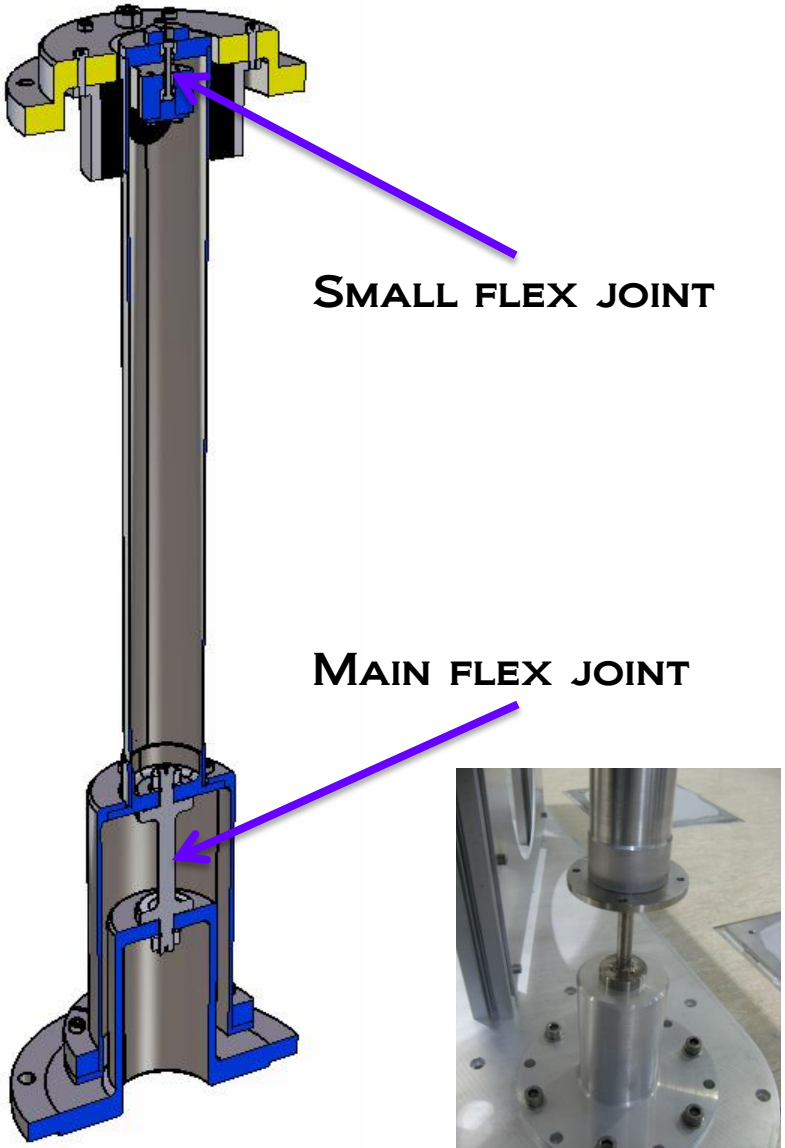
FEA STUDIES

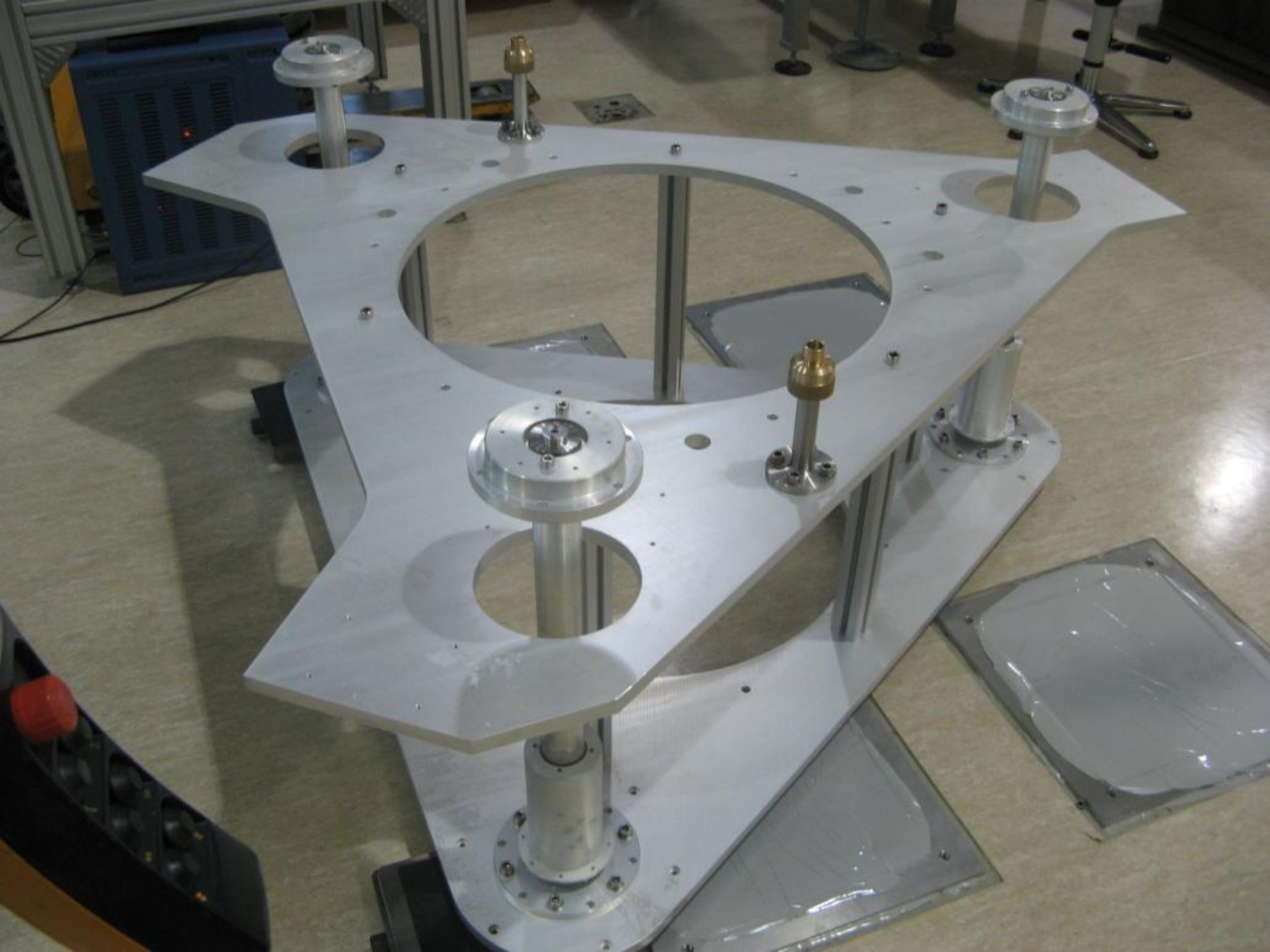
- FEA results
  - Stress distribution
    - Poisson ratio 0.32
    - Width distribution
    - Average stress 1.4 GPa
    - High surface stress
  - Compare FEA to data
    - Temperature stability (cleanroom!)
    - Strain gauges, tensile tests
    - Frequencies, positions
    - Safety aspects
    - Stress corrosion
  - Discuss with experts
    - ESA, Marine
    - Albert Einstein Institute, Caltech, Pisa, …
- Affect GAS design



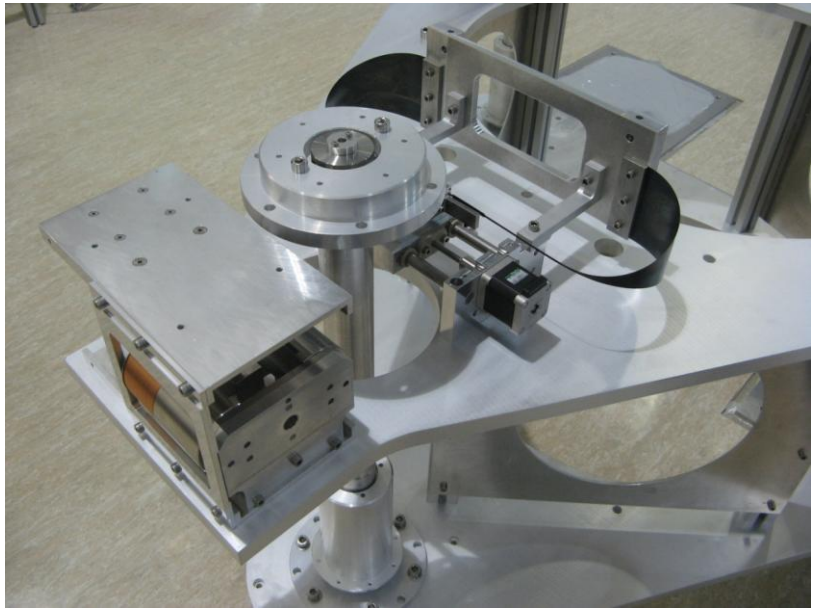


IP assembly





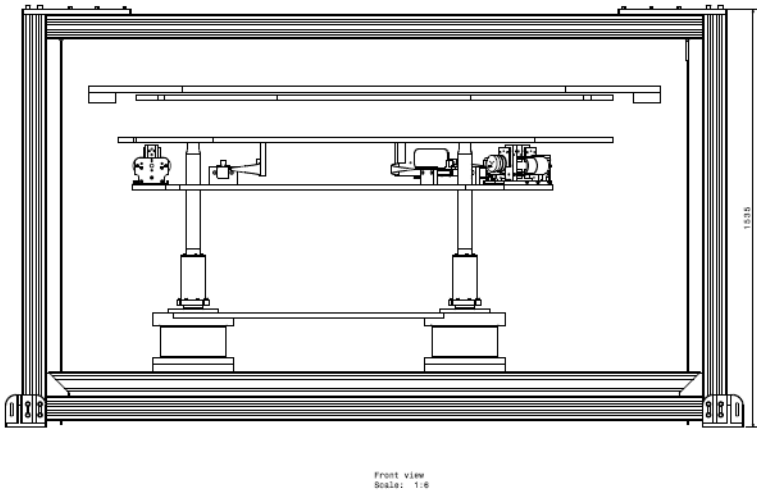

BELKIN

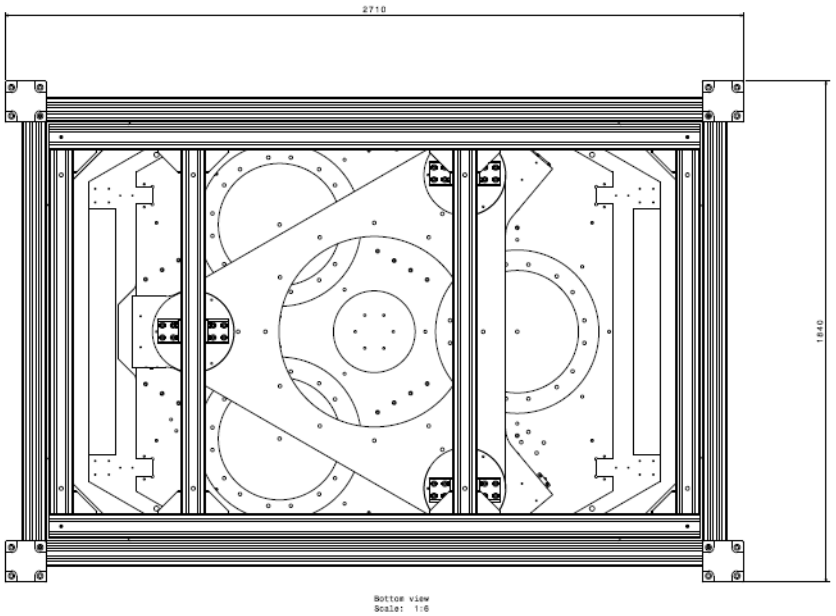


IP tuning

- IP tuning set-up
  - Frame completed
  - Suspend EIB-SAS
  - Shaker, accelerometers
- Tune IP counterweight
  - Improve horizontal transfer function
  - Measure transfer functions

Gert Jan Mul





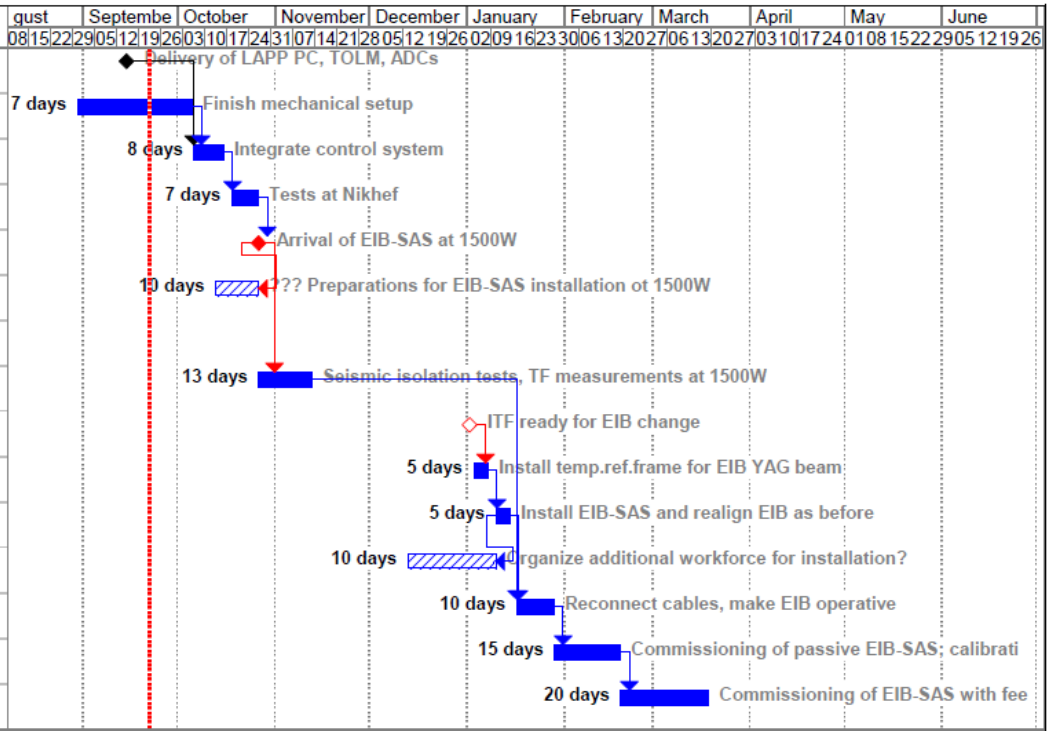
Logistics

- Nikhef manpower reserved
  - Preparation of installation
    - 1500 m laboratory and in ITF
    - Cabling, connectors, path panels
    - Dedicated electrical engineer: Wim Gotink
  - Engineers, technicians and physicists
    - At 1500 m laboratory
    - During installation and commissioning in ITF
- EGO and Virgo assistance needed
  - Preparation of installation
    - Interact with Flavio, Piero, Eric, …
  - Control issues
    - DSP, AD, DA, BIO, CPU, links, crate available
    - LVDTs, actuators, stepping motors, drivers
    - Software development
  - Alignment issues during bench installation
  - Commissioning
    - Passive commissioning
    - Active commissioning

Time line

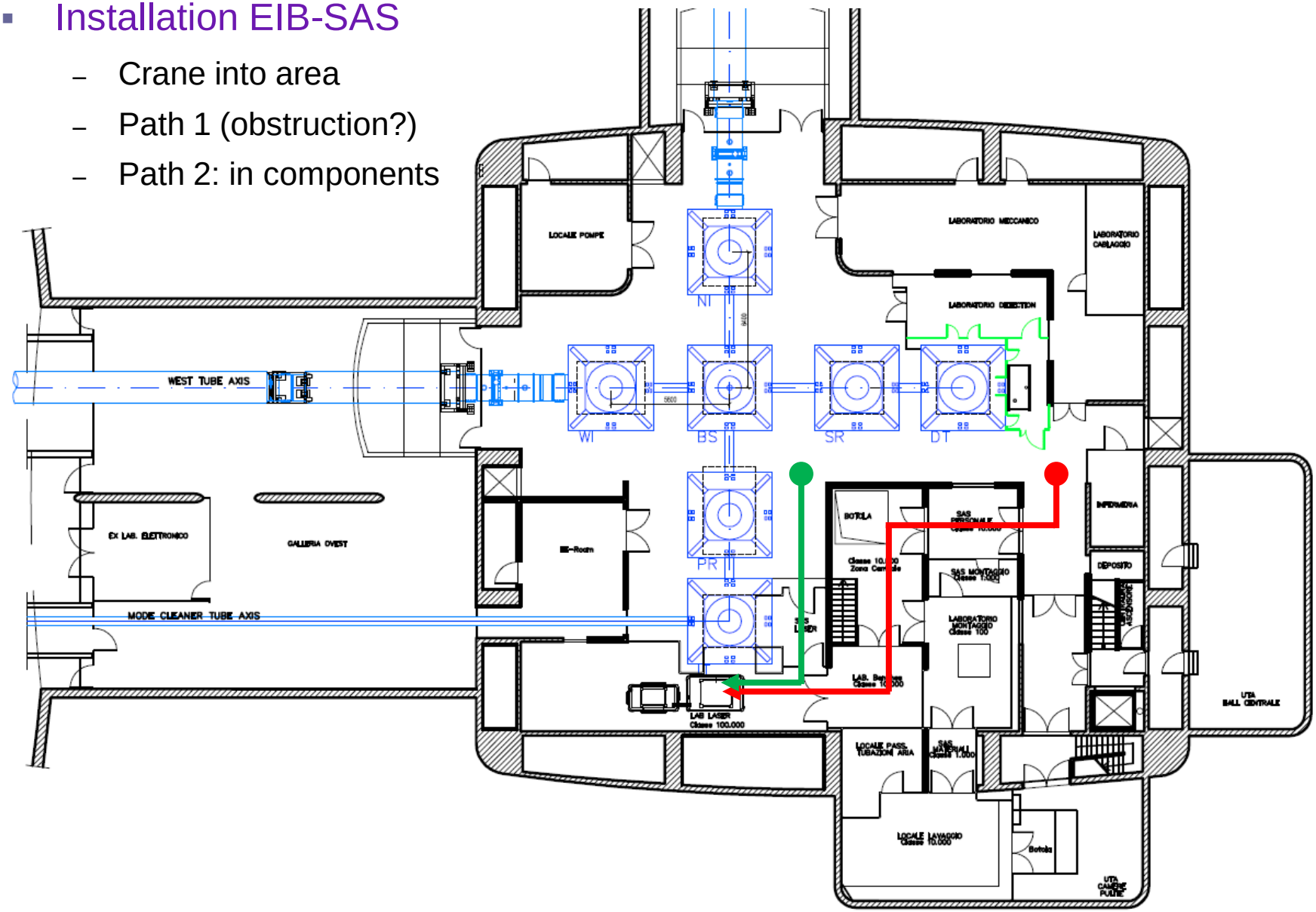
- Milestones
  - EIB-SAS at EGO site
    - Propose November 2010, w4
    - Validate in December 2010, w1 and w2
  - Install in ITF
    - January 2010, w1
    - Consistent with timeline by Henrich

ID	Task Name	Duration	EGO resources
1	Delivery of LAPP PC, TOLM, ADCs	0 days	
2	Finish mechanical setup	27 days	
3	Integrate control system	8 days	
4	Tests at Nikhef	7 days	
5	Arrival of EIB-SAS at 1500W	0 days	
6	??? Preparations for EIB-SAS installation ot 1500W	10 days	
7			
8	Seismic isolation tests, TF measurements at 1500W	13 days	0,5 mE;1 mT;0,5 P
9	ITF ready for EIB change	0 days	
10	Install temp.ref.frame for EIB YAG beam	5 days	
11	Install EIB-SAS and realign EIB as before	5 days	
12	Organize additional workforce for installation?	10 days	
13	Reconnect cables, make EIB operative	10 days	0,5 mE;1 mT;0,5 P
14	Commissioning of passive EIB-SAS; calibration of actuators	15 days	
15	Commissioning of EIB-SAS with feedback from ITF	20 days	



Installation

- Installation EIB-SAS
  - Crane into area
  - Path 1 (obstruction?)
  - Path 2: in components



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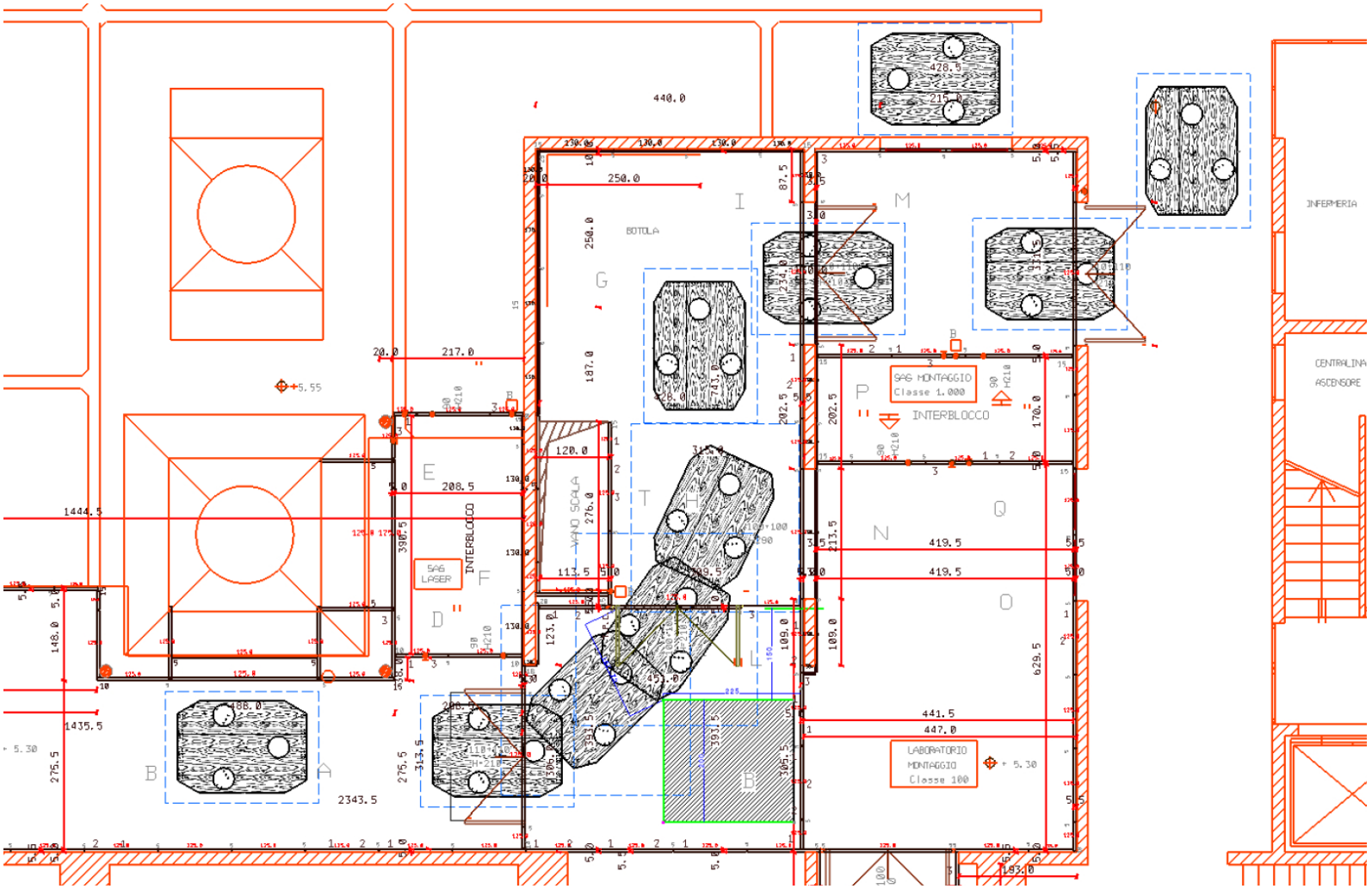


Budget

- Cost breakdown (including VAT)
  - Mechanics
    - GAS, IP, frames
  - Electronics
    - LVDTs, actuators, stepping motors, drivers
  - DAQ
    - From Annecy (not included in overview)
  - Other
    - Cabling
    - Shipping
- Total cost
  - 95 kEuro
  - AdV or V+?

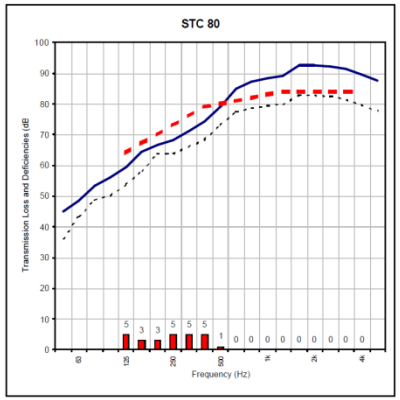
#	Item	Contractor / supplier	Cost (€) (taxes included)	Charged to (EGO/Virgo lab)
	Inverted pendulums	Galli & Morelli Srl	9,900	-
	Geometric anti-springs and tools	Galli & Morelli Srl	23,050	-
	Frame structure	Galli & Morelli Srl	16,600	-
	LVDT/actuators	Galli & Morelli Srl	5,200	-
	Vertical blades	Galli & Morelli Srl	2,250	-
	Horizontal blades	Galli & Morelli Srl	3,050	-
	Shipping to Nikhef	Galli & Morelli Srl	3,000	-
	Stepping motors and controllers	TMC	3,525	-
	GAS tuning set-up	Rimas	970	-
	IP tuning set-up	Rimas	5,797	-
	Geophones	Geospace	4,728	-
	Microphone	Bruel & Kjaer	2,611	-
	Electronics (PCBs, DAQ, etc.)	QPI, NI, etc.	2,552	-
	Cabling (estimate)	Not known yet	5.950	5.950
	Shipping to EGO site (estimate)	Not known yet	3,570	-

Summary

- Development SAS solution for EIB
  - Robust and custom solution
    - Full remote control of positioning
    - 60 dB attenuation in all 6 degrees of freedom
    - Low resonance frequencies
  - Includes full control, damping
  - Minimize risks
    - Install in 1500 m laboratory and validate
- Preparation for installation
  - Set-up discussions
    - Cabling, alignment, etc
  - Organize manpower

Acoustic isolation

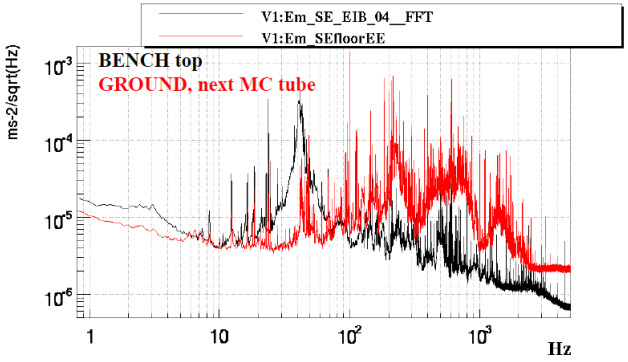
- Shielding approach
  - Quietrock.com
  - Double wall
    - QuietRock QR-545 panels
    - Air space 75 mm
    - Woods studs
    - Acoustic sealant
    - Metal tape
- SAS structure
  - Specific resonances
    - Rigid leg modes (>230 Hz)
    - Banana modes (>420 Hz)
  - Eddy current damping
- Provides temperature stabilization
  - Test in 1500 laboratory



Frequency (Hz)	Airborne Sound Transmission Loss (dB)	95% Confidence Limits
50	45 *	
63	48 *	
80	53 *	± 3.0
100	56 *	± 3.2
125	59 c	± 2.4
160	64 c	± 1.1
200	67	± 1.2
250	68	± 0.9
315	71	± 0.9
400	74	± 0.6
500	79 c	± 0.6
630	85 *	± 0.6
800	87 c	± 0.4
1000	89 *	± 0.4
1250	89 *	± 0.4
1600	93 *	± 0.3
2000	92 *	± 0.2
2500	92 *	± 0.5
3150	91 *	± 0.4
4000	90 *	± 0.4
5000	88 *	± 0.5
Sound Transmission Class (STC) = 80		

Acoustic isolation – exercise

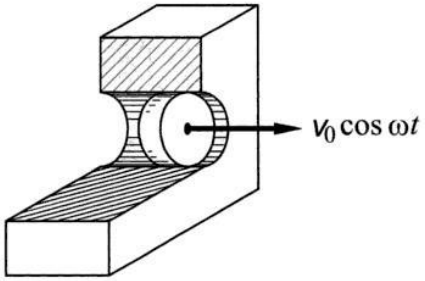
- Normal conversation
  - 40 – 60 dB $\rightarrow$ $2\times10^{-3} - 2\times10^{-2}$ Pa
  - Double wall isolation
    - 60 dB attenuation
    - Sound pressure $2\times10^{-6} - 2\times10^{-5}$ Pa

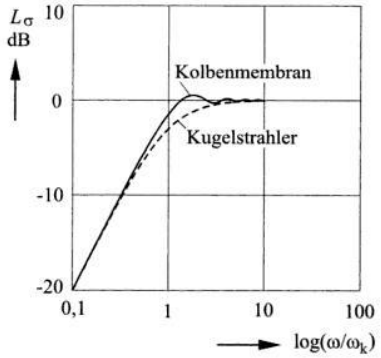


- SAS structure
  - Specific resonances
    - Rigid leg modes (>230 Hz)
    - Assume 200 Hz excitation $\lambda = \frac{v}{f} \approx \frac{300 \text{ m/s}}{200 \text{ Hz}} = 1.5 \text{ m}$
  - Area $A = 2.5\times1.5 \approx 3.5 \text{ m}^2$
  - Force $F = pA = (2\times10^{-5} \text{ Pa})(3.5 \text{ m}^2) = 7\times10^{-5} \text{ N}$
  - Acceleration $a = F/m \approx (7\times10^{-5} \text{ N})/(700 \text{ kg}) = 10^{-7} \text{ m/s}^2$
  - Displacement $x = a/\omega^2 = (10^{-7} \text{ m/s}^2)/(2\pi\cdot200 \text{ Hz})^2 \approx 6\times10^{-14} \text{ m}$
  - Floor noise $x = 10^{-8}\left(\frac{10 \text{ Hz}}{f}\right)^2 \rightarrow 2.5\times10^{-11} \text{ m}/\sqrt{Hz}$
- Damp this excitation

Radiation efficiency

- Definition
  - Radiated acoustic energy P
  - Radiation efficiency $\sigma \equiv \dfrac{P}{\rho_L c_L \overline{v^2}}$
  - For a piston
    - See `Praktische Maschinenakustik', Kollman *et al*.





- For a plate
  - Excitation by sound wave
  - Suppression below critical frequency
    - Due to acoustic short circuit
    - Frequency estimated at 2 kHz
    - Figs below are for steel
    - EIB optical table has 4 mm steel plates

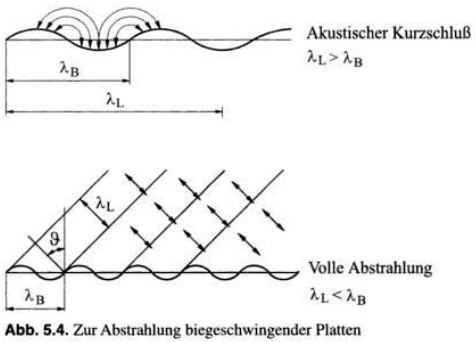
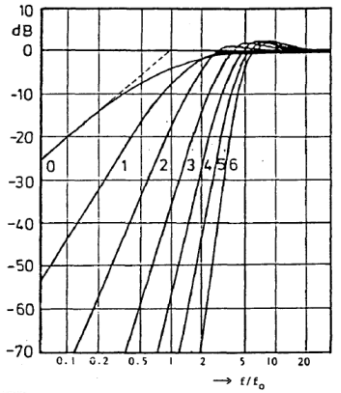
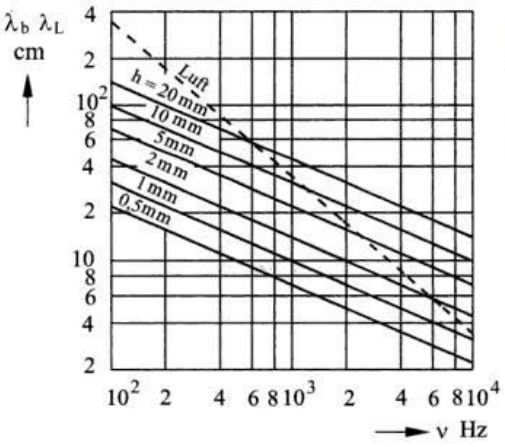
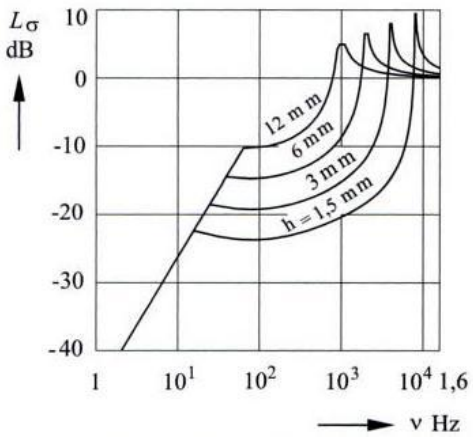
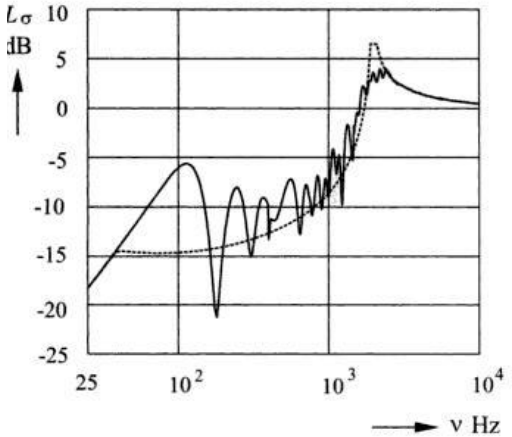


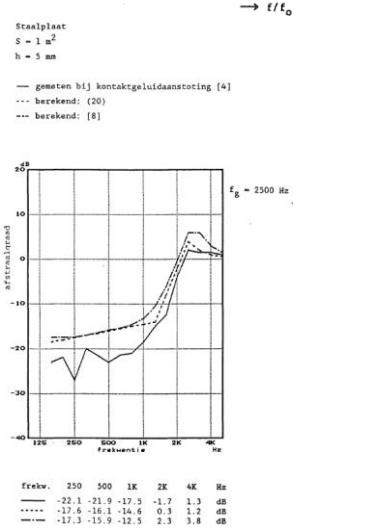
Abb. 5.4. Zur Abstrahlung biegeschwingender Platten





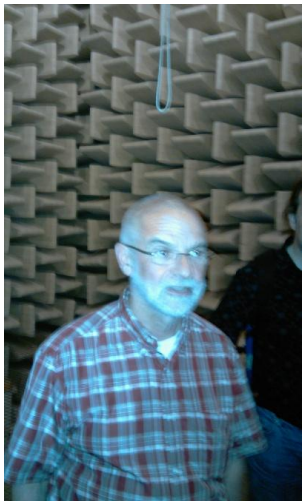


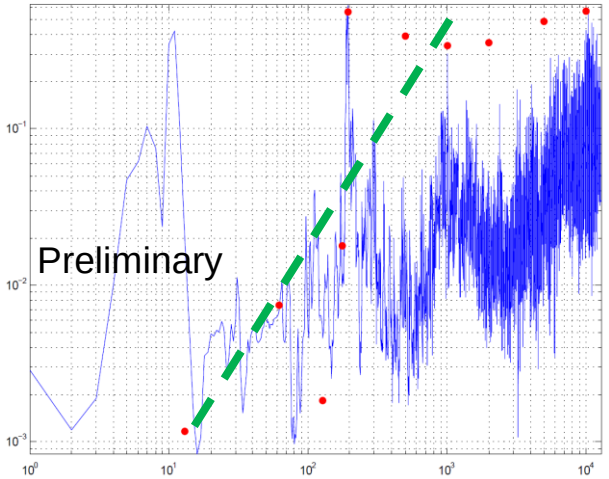


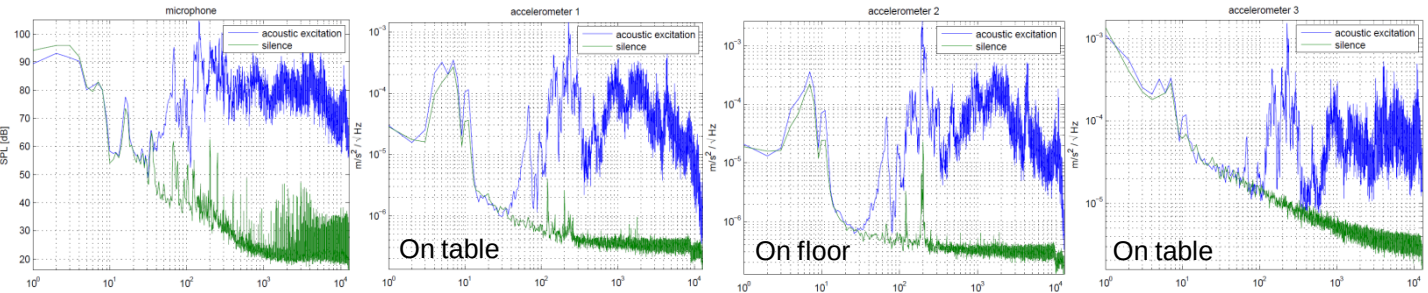


Acoustic coupling

- Acoustics group TNO-TPD Delft
  - Infrastructure available
  - Bert Clairbois
- Measurements
  - Spring-isolated optical table
    - 2.5 x 1 x 0.3 m, 200 kg
  - Excitation
    - Acoustically with shaker
    - White noise (blue curve)
    - harmonic analysis (red data points)
  - Determine radiation efficiency
- Conclusion
  - Suppression below critical frequency
    - Estimated at 2 kHz $f_g \approx 1.8 \frac{c^2 h}{c_1}$







To be continued…