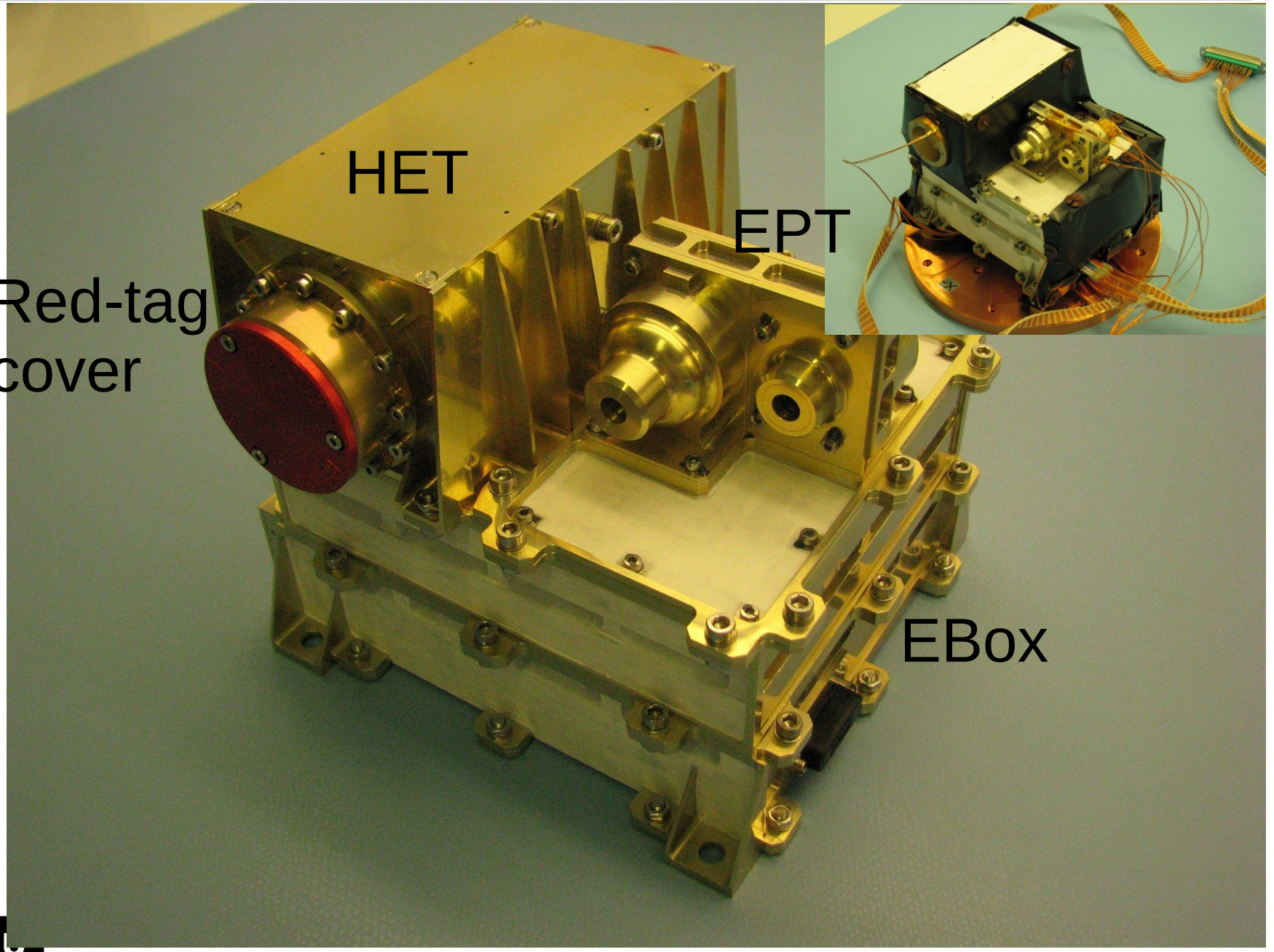
CAU input to EPT-HET STM DRB

Plan for the review:

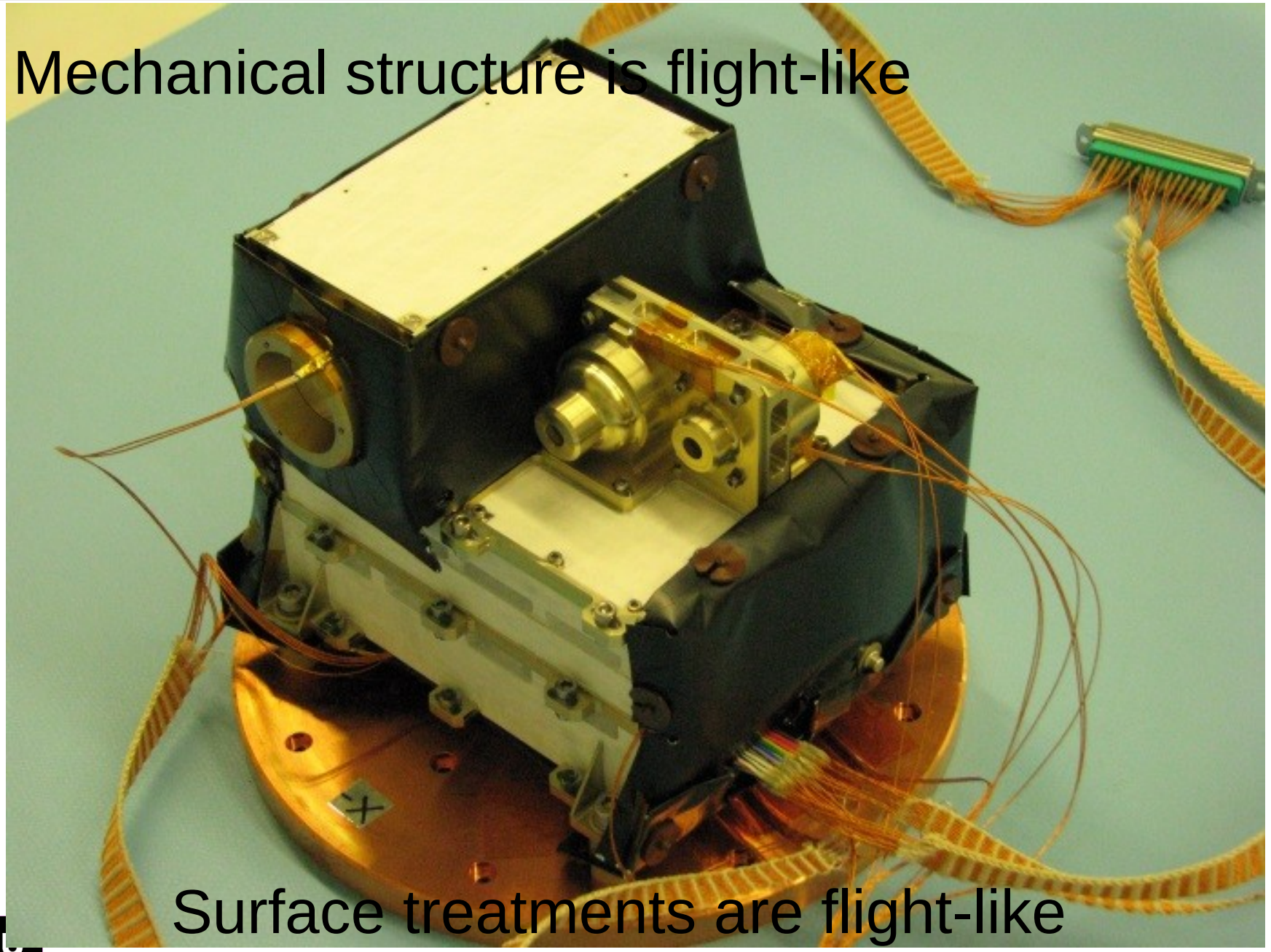
- Introduction: Fidelity of EPT-HET STM
- Go through ESA agenda point by point
- Visit clean room to inspect STM

Bob Wimmer
For the CAU/Kiel team

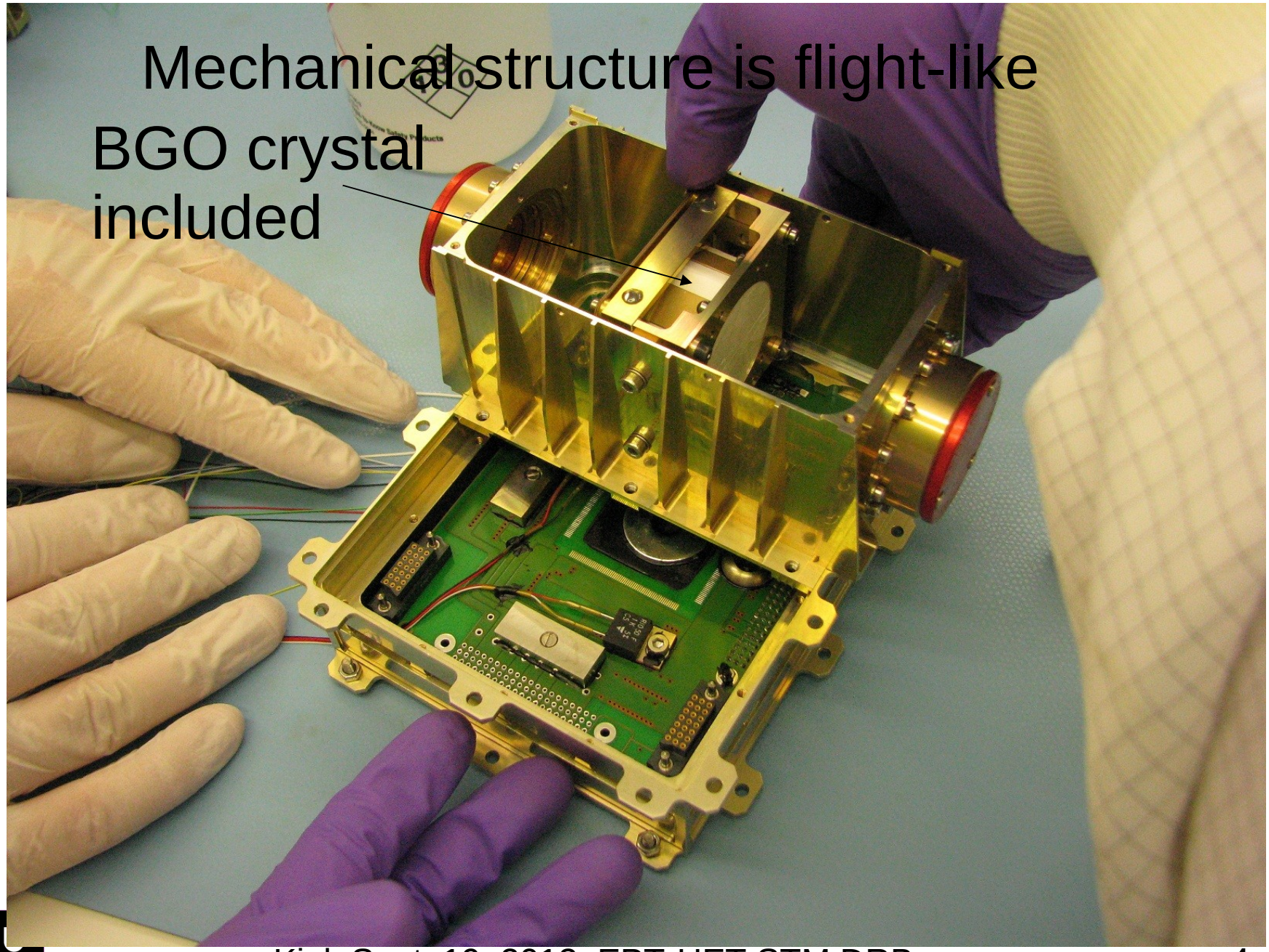
Fidelity of STM



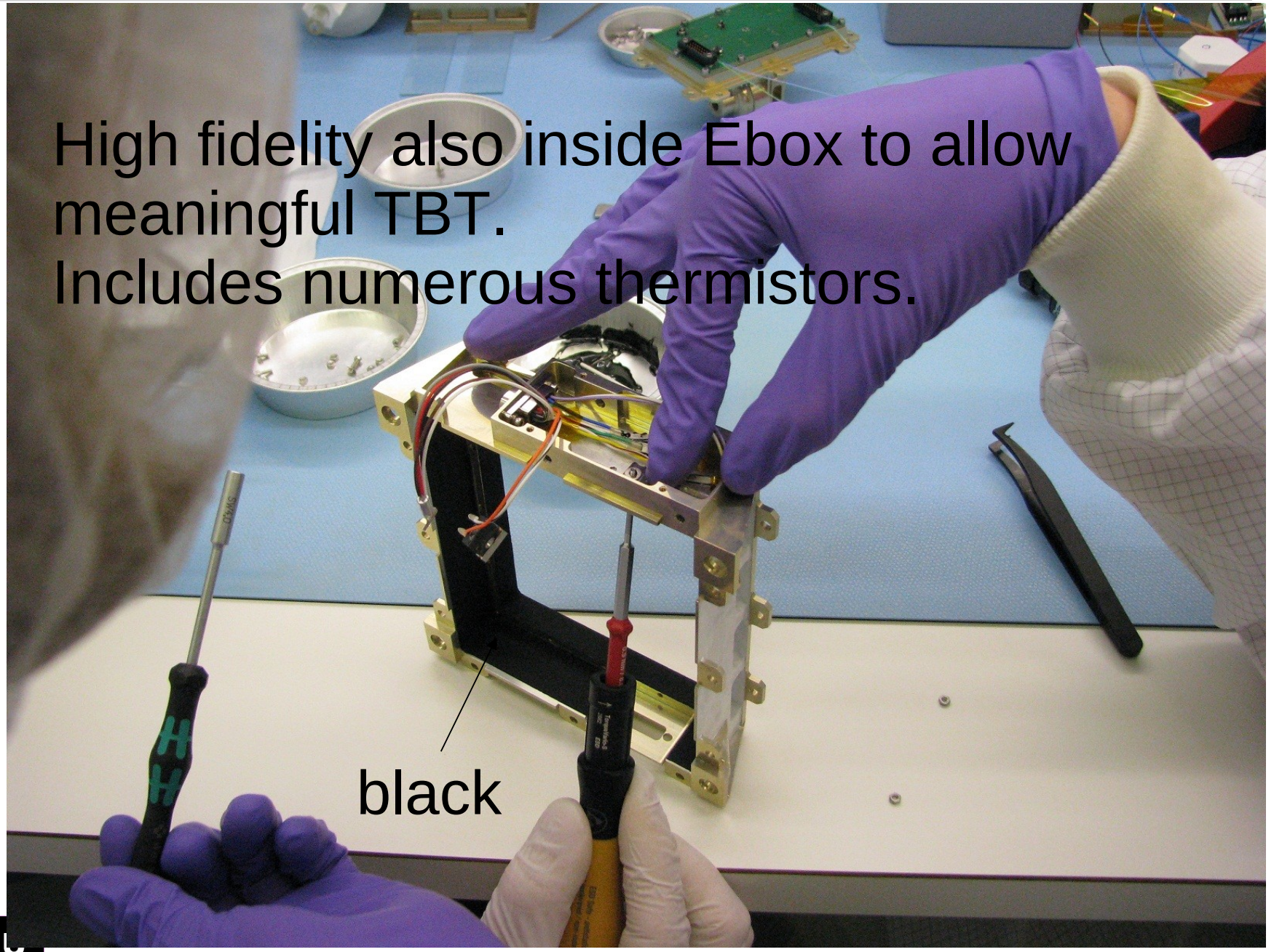
Fidelity of STM



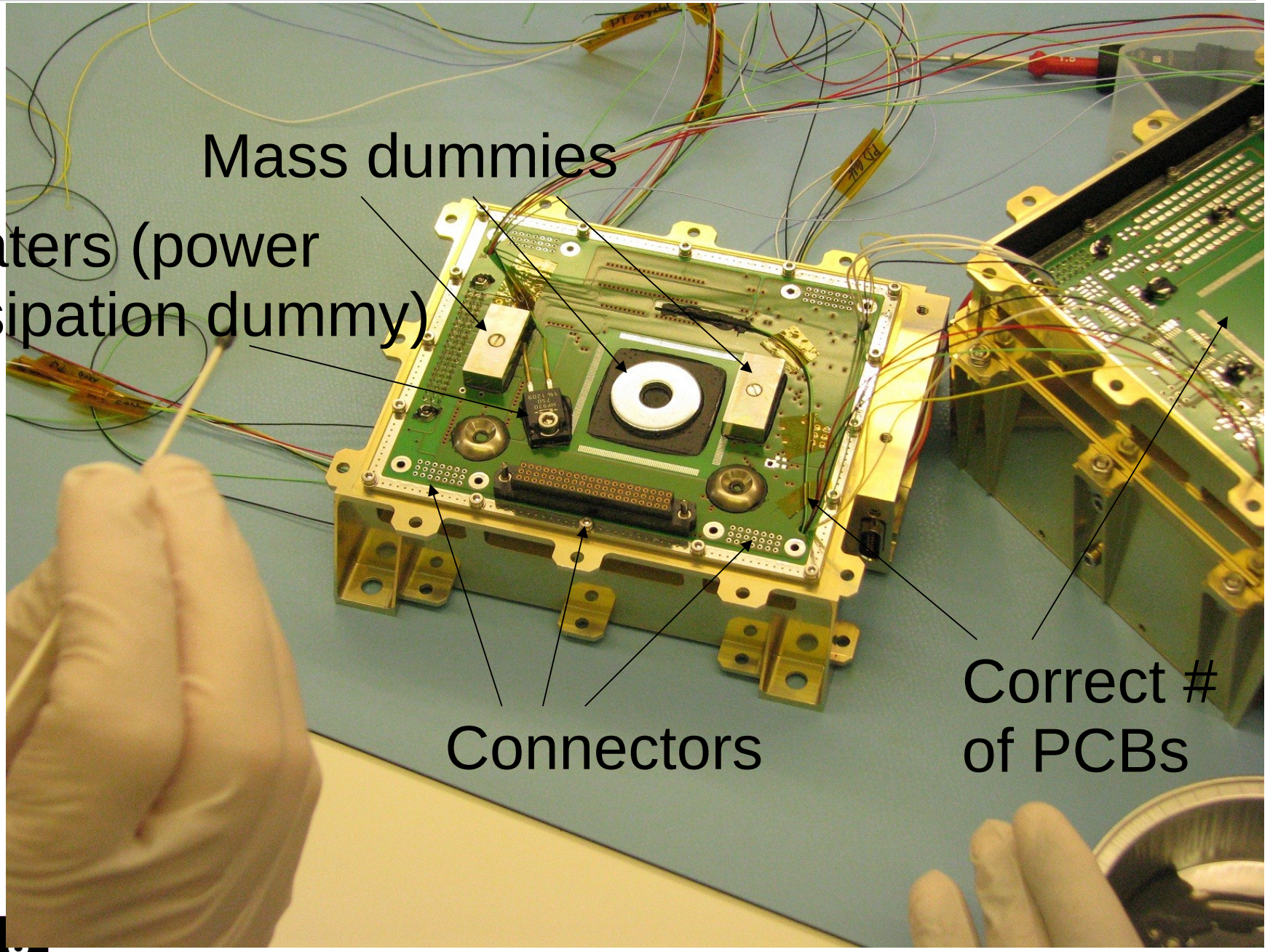
Fidelity of STM



Fidelity of STM

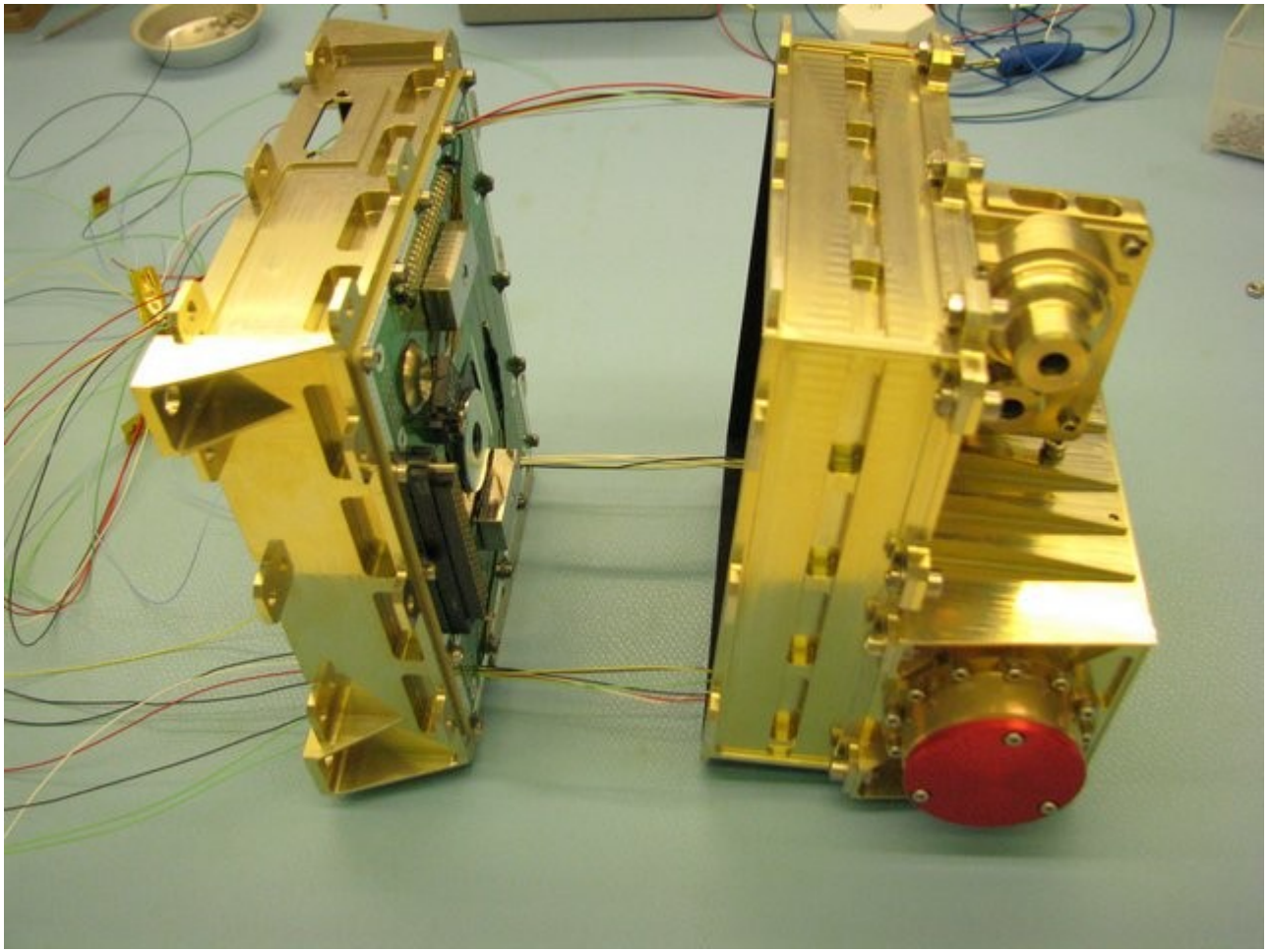


Fidelity of STM



Fidelity of STM

All this complexity is in the STM and was shaken and baken.



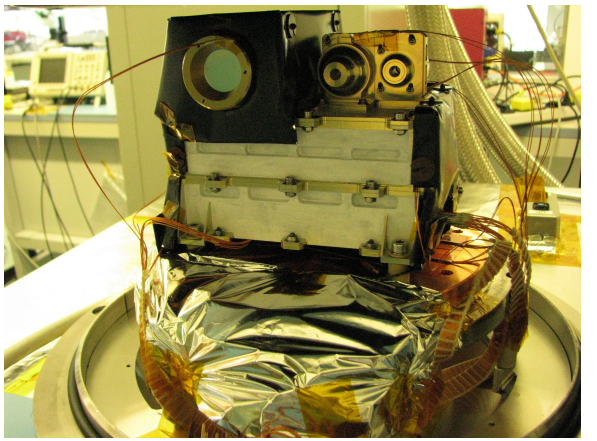
Purpose of the Delivery Review

To accept the instrument by ESA and at the same time by the Prime Contractor

To assess if the instrument configured HW~~, SW, GSE~~ and EIDP can be accepted for delivery

To authorise the instrument HW, ~~SW and GSE~~ shipment to the Prime Contractor

*Apart from shipping infrastructure EPT-HET STM has **no** SW and **no** GSE (heaters and flying leads are considered to be part of STM).*



We are considering only EPT-HET STM.
STEP has no CAU-provided STM.

Criteria for successful Pre-Shipment & FAR

1) The configured HW conforms to the EID-A and related NRs requirements and to an approved design configuration (→ *Presentation*)

2) The configured HW is fully tested and all tests subjected to successful TRB(s) (→ *Presentation*)

3) The configured HW is free from material and workmanship deficiencies (→ *Presentation, go to clean room (point 6)*)

4) Non-conformances are closed-out (or open ones are compatible with the delivery) (→ *Presentation, discussion*)

5) Relevant EIDP and shipping documents are complete, detailed and accurate (→ *Presentation*)

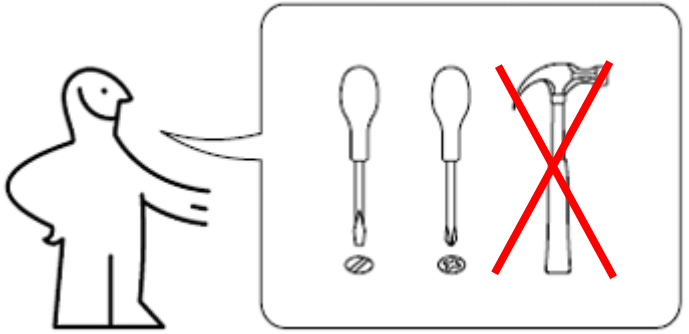
6) The configured HW and shipping "GSE" are made accessible for inspection and test before packing. (→ *Go to clean room*)

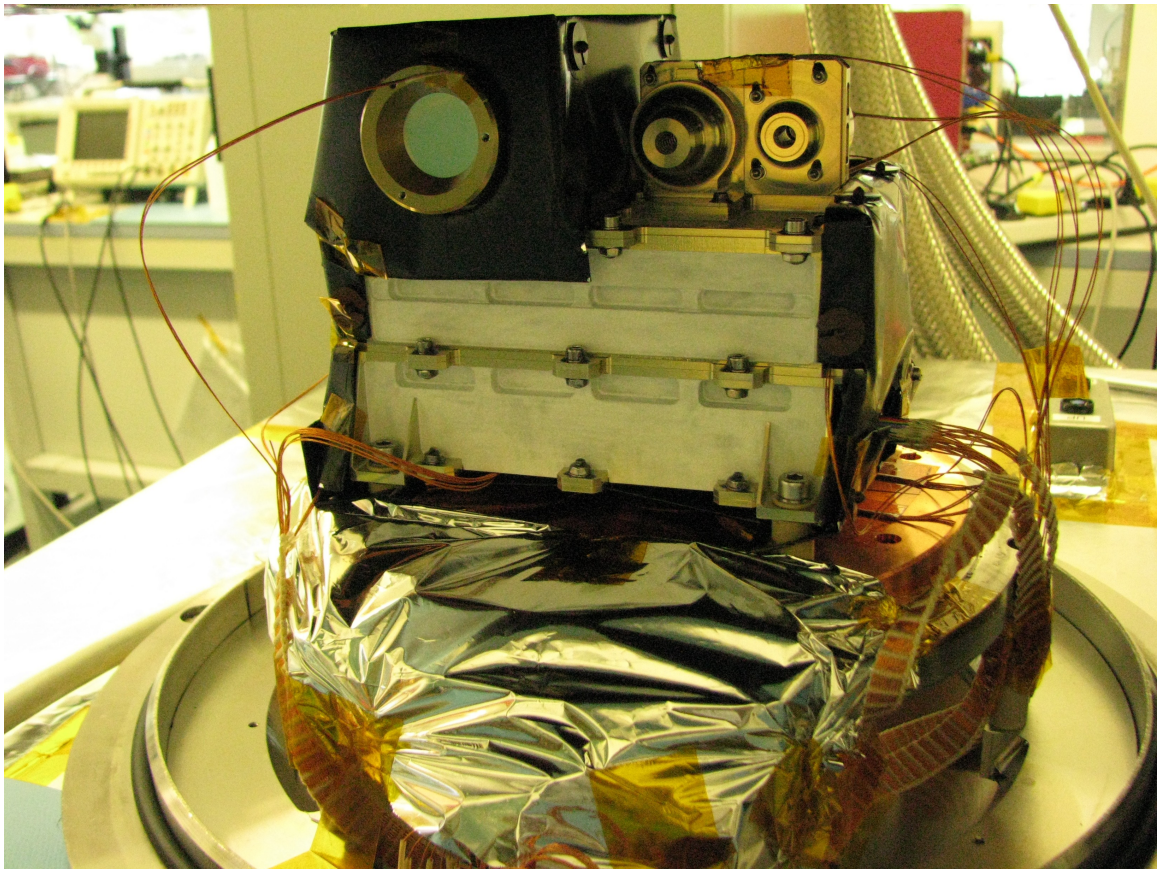
Identification of items under delivery (including loose items & spares)

What is being delivered?

One EPT-HET STM incl.:

- Heaters and flying leads
- One separate set of MLI
- Assembly instructions





STM delivered w/o additional mounting hardware. All (M5) mounting screws, washers, nuts need to be provided by ASUK. See SO-EPD-KIE-LI-0004-iss1_rev1-EPT-HET_STM_Shipping_list.pdf for details.

Applicable requirements

From EID-A:
See compliance and verification matrix:
SO-EPD-KIE-TM-0002_iss1_rev0_EPT-HET_STM_verification-matrix.xls
and following slides 12-14

Internal CAU requirements:

- Retire or at least more clearly identify structural and thermal risks (This was fully achieved, we found a problem (crystal holder), and redesigned and reworked it. It is much better to find such problems with the STM than with a later model...)
- Develop manufacturing details and improve design for FM development.
- Develop assembly and integration procedures for the sensor heads and the whole instrument.
- Fit check electronics components and test el. connectivity as input for parallel FM-board development.
- Fit check and verify MLI performace and design.

Applicable requirements (EID-A) Structural tests

Qualification sine vibration

EIDA R-497: The PI shall ensure that units mounted on the spacecraft panels are designed to withstand without degradation the sinusoidal environment as defined in table below at unit/structure interface.

Axis	Frequency (Hz)	Qualification
Out of plane	5-20	15 mm
	20-100	24 g
In plane	5-20	9.9 mm
	20-100	16 g
		2 Oct/min

Qualification random vibration

EIDA R-499: The PI shall ensure that each unit is designed to withstand without degradation the random environment as defined in the table below at unit/structure interface.

Axis	Frequency (Hz)	Qualification*
Perpendicular to mounting plane (1 axis)	20-100 100-500 500-2000	+12 dB/Oct 1 g^2/Hz -8 dB/Oct 26.3 g rms
Parallel to mounting plane	20-100 100-500 500-2000	+4 dB/Oct 0.1 g2/Hz -3 dB/Oct 10.7 g rms

*Duration for Qualification is 2 min.

Applicable requirements (EID-A) Thermal balance test

***EIDA R-517*: The PI shall verify the thermal design and functionalities of each unit by dedicated thermal vacuum tests and by thermal balance tests.**
In particular:
Thermal balance (TB) test(s) at STM level and at FM level
Thermal vacuum (TV) cycling test at FM level
***EIDA R-520*: The PI shall ensure that the equipment is tested in a thermal vacuum environment having a pressure of 0.0013 Pa (10^{-5} Torr) or less.**
***EIDA R-521*: The PI shall perform the TB test(s) using adequate test instrumentation and test set-up (e.g. number and position of temperature sensors, heaters) to provide accurate data (e.g. temperatures, voltages, unit dissipations)**
***EIDA R-522*: The PI shall ensure that the TB test(s) conditions are clearly defined and reproducible, so that accurate and reliable input for thermal model correlation can be provided.**
***EIDA R-523*: The PI shall ensure that the TB test(s) consist of at least a hot and a cold steady-state phase and several transient phases that simulate boundary conditions experienced during the mission, including actual Sun exposure (when applicable).**
***EIDA R-524*: The PI shall ensure that the TB test(s) conditions encompass, as far as possible, the worst thermal conditions expected throughout all mission phases (including simulation of radiative and conductive external interfaces)**
***EIDA R-525*: The PI shall ensure that the test item is a fully thermally representative configuration.**
In particular the thermal hardware shall be flight representative as far as any critical interface.
***EIDA R-526*: The PI shall assume that each steady state phase is reached when the temperatures of the unit does not vary by more than 1C/3 hour.**

Applicable requirements (EID-A) Test tolerances

EIDA R-440: *The PI shall respect the following test tolerances, unless otherwise specified.*

Structural test

Sinusoidal vibration:

–Acceleration, amplitude ± 10%

–Frequency above 50 Hz ± 2%

Random vibration:

–Power spectrum density (50 Hz or narrower)

20 to 500 Hz ± 1.5 dB

500 to 2000 Hz ± 3.0 dB

Overall g rms ± 1.5 dB

Thermal balance test

Temperature:

–Tmax: 0 to +3°C

–Tmin: 0 to -3°C

–Within the temperature range: -55°C to +150°C

Pressure:

–Equal or above 0.1 mbar 10%

–Below 0.1 mbar 50%

Requests for waivers and deviations

Filename	EPD codification	Description	Delivered	Status
SO-EPD-KIE-RD-0001_iss1_rev1_RfD_for_mass_properties.pdf	SO-EPD-KIE-RD-0001	RFD for mass properties	24.05.2013	Accepted, Closed
SO-EPD-KIE-RD-0002_iss1_rev1_RfD_for_qualification_level_sine_vibration.pdf	SO-EPD-KIE-RD-0002	RFD for qualification level sine vibration	24.05.2013	Accepted, Closed

Request for waivers and deviations

1. RfD mass properties, SO-EPD-KIE-RD-0001 (Accepted)

Description:
We request to verify the two mass properties tolerances, Center of Gravity (CoG) and Moments of Inertia (MoI), by calculated values and not measured ones. (EIDA R-539)

1. Note: This RFD is applied to STM

2. RfD qualification level sine vibration, SO-EPD-KIE-RD-0002 (Accepted)

Description:
We request to reduce the qualification sine vibration amplitude from 15mm to 12mm for out of plane axis in frequency range of 5 to 20 Hz. (EIDA R-497)

Note: This RFD will be applied to PQM. In fact, STM was tested in the original qualification level mentioned in EIDA.

Approved as-design (CIDL)

See SO-EPD-KIE-LI-0002-iss1_rev2-STM-CIDL-ABCL.pdf

(part of EIDP)

Status of change proposals

CAU did not *propose* changes, we have *made* changes to design:

Rework of the crystal holder (discussed in detail in NCR docs)

The redesigned and reworked STM was reshaken.

As-built (ABCL) / Discrepancies as-designed vs. as-built

Also covers “Identification of discrepancies build standard vs. flight design baseline”

ABCL is the evolution of CIDL and EPD has one single doc for both as agreed with the EPD PA manager. No answer from ESA so far, EPD assumes it is ok.

Status	Description	STM	FM
Approved*	EPT-Detectors	Not included.	Full functional detector stacks.
Approved*	HET-Detectors	Only det carriers.	Full functional detectors.
Approved*	EPT Collimators	No internal blackening.	
Approved*	PCBs, EEEs	Stainless steel mass dummies.	Full electronics components.
Ongoing design work	Choice of radiator surfaces	Reflective white paint on radiative surfaces.	SSM under consideration.
Ongoing design work	MLI design	MLI on HET head’s side walls.	Under consideration: Free HET off MLI, use op heaters. (Sun illumination issue)
Ongoing design work	Mounting surface structure of ebox	Ebox wall surface structure uneven.	Under consideration: SSM (see above) might require flat mounting surface.
Approved*	Survival heaters	Heaters with “TO-220” housing.	Certified foil heaters. (Most probably RICA)

* per outcome of TRR, July 18th 2013 in Kiel

Non-conformances

CAU NCR Status List, Issue 1, Date 03.07.2013					
NCR No	Classification	Issue / Date	Item Affected	Status	Description of Non-Conformance
SO-EPD-KIE-NC-0001	Minor	25.06.2013	EPT-HET STM	Closed	Following Y-axis vibration, an electrical function test was carried out. Open circuit was found for photo-diode #2
SO-EPD-KIE-NC-0002	Major	25.06.2013	EPT-HET STM	Open	Nonconformance in step 85 and step 100 of the test procedure. There is more than 10% change in resonance amplitudes before and after qualification-level random vibration.

Non-conformances

1st vibration test (July 25, 2013) was unsuccessful. Large change in frequency and in amplitude after y-axis qualification run.

Was considered major NC
Three actions required:

- identify root cause
  (ppt: EPT -HET STM vibration test failure Investigations, 20.08.2013)
- define rework
  (doc: Rework Plan and Report of STM of EPT-HET, SO-EPD-KIE-PL-0003, 1/0, 23.08.2013)
- rework and retest
  (doc: EPT-HET STM Random-Sine vibration test report, SO-EPD-KIE-TR-0005, 12.09.2013)

All three actions were performed. Retest was successful.

EPD Certificate of Conformance

Christian-Albrechts-Universität zu Kiel

Certificate of conformity
Solar Orbiter
Energetic Particles Detector
(EPD)

Reference: SO-EPD-KIE-CE-0001
Issue: 1 **Rev:** 0 (Draft)
Date: 2013-09-16
Page: 1

ITEM

Doc No SO-EPD-KIE-CE-001	**Project** Solar Orbiter		**Log**
Item Name EPT-HET	**Item part no.** T0080046-01	**Item serial no.** STM	**Customer code**
Customer	**Contract no.**	**Intended use** S/C level AIT	

REFERENCE OF HARDWARE CONFORMITY

Contract requirements		**Operational documents**		**Deliverable documents**	
Document no.	**Iss/rev**	**Document no.**	**Iss/rev**	**Document no.**	**Iss/rev**
EID-A		None		EPT-HET STM EIDP	
EID-B					

STATEMENT OF CONFORMITY

It is hereby certified that apart from the deviations or waivers noted in the "Remarks" box below, the whole of the supplies detailed above conform in all respects to the specification(s), drawing(s) and condition(s) or requirements(s) with respect to the specification(s), drawing(s) and condition(s) or requirements(s) of the contract.

SO-EPD-KIE-RD-0001: Verification of physical properties COG and MOI by calculation
SO-EPD-KIE-RD-0002: Reduce sine vibration qualification amplitude

PI: _____ Date: _____

PA: Michael L. Richards Date: 16 Sept 2013

Christian-Albrechts-Universität zu Kiel

Certificate of conformity
Solar Orbiter
Energetic Particles Detector
(EPD)

Reference: SO-EPD-KIE-CE-0001
Issue: 1 **Rev:** 0 (Draft)
Date: 2013-09-16
Page: 2

ITEM

Document No.	**Project** Solar Orbiter		**Log**
Item Name EPT-HET	**Item part no.** T0080046-01	**Item serial no.** STM	**Customer code**
Customer	**Contract no.**	**Intended use** S/C level AIT	

REFERENCE OF CLEANLINESS CONFORMITY

Contract requirements		**Operational documents**		**Deliverable documents**	
Document no.	**Iss/rev**	**Document no.**	**Iss/rev**	**Document no.**	**Iss/rev**
EID-A		None		EPT-HET EIDP	
EID-B					
SO-EPD-PO-PL-0005	1/1				

STATEMENT OF CONFORMITY

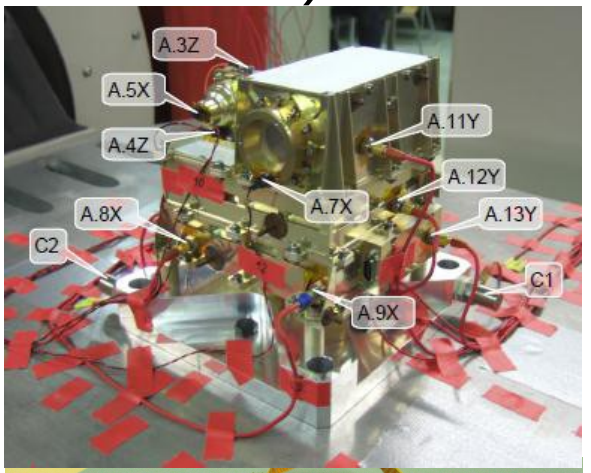
It is hereby certified that apart from the deviations or waivers noted in the "Remarks" box below, the whole of the supplies detailed above conform in all respects to the specification(s), drawing(s) and condition(s) or requirements(s) with respect to the specification(s), drawing(s) and condition(s) or requirements(s) of the contract.

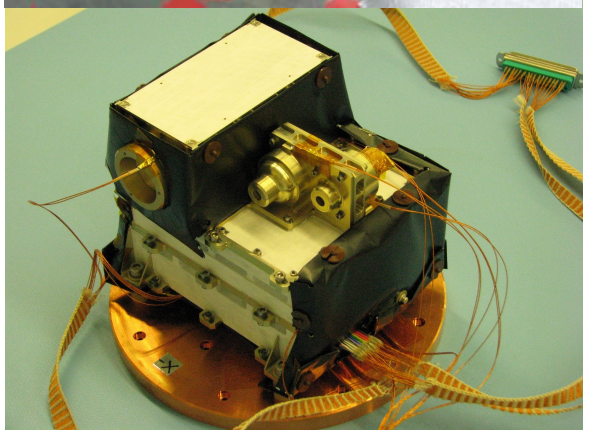
PI: _____ Date: _____

PA: Michael L. Richards Date: 16 Sept 2013

EPD Status wrt. Test flow and review of Test Reports

CAU Test matrix: (excerpt from EPD test matrix)





Models and applicable units	STM	EM		PQM		PFM/FS	
	EPT-HET	STEP	EPT-HET	STEP	EPT-HET	STEP	EPT-HET
FUNCTIONAL & PERFORMANCES TEST							
Visual Inspection	X	X	X	X	X	X	X
Functional Test		X	X	X	X	X	X
Performance Verification (Calibration)		X	X	X	X	X	X
Physical Properies (Mass, CoG, MOI, Dimensions)	X			X	X	X	X
Mechanical Interfaces Check	X			X	X	X	X
Electrical Characteristics & I/F	X	X	X	X	X	X	X
STRUCTURAL TEST							
Sine Vibration Test	Q			Q	Q	Q/A	Q/A
Random Vibration	Q			Q	Q	Q/A	Q/A
Acoustic Noise Test							
Shock Test				Q (TBC)	Q (TBC)		
THERMAL TEST							
Thermal Vacuum Cycling Test				Q	Q	Q/A	Q/A
Thermal Balance Test	Q			Q	Q		
ELECTROMAGNETIC COMPATIBILITY TEST (EMC)							
Bonding, Isolation, Conductivity and Grounding		X	X	X	X	X	X
Conducted Emission		X	X	X	X	X	X
Conducted Susceptibility		X	X	X	X		
Radiated Emission				X	X		
Radiated Susceptibility				X	X		
Electrostatic Discharge (ESD)				X	X		
DC Magnetic Properties Test				X	X	X	X
S/W TEST							
S/W Validation Tests	NA						
PURGING RATE							
Purging Rate Verification	NA						
NOTE:							
A = Acceptance Level							
Q= Qualification Level							
Q/A= Qualification Level for Acceptance duration							

Test reports:

EPT-HET STM Random-Sine Vibration Test Report	SO-EPD-KIE-TR-0005	12.09.2013
EPT-HET STM Thermal Balance Test Report	SO-EPD-KIE-TR-0006	26.07.2013
EPT-HET STM Physical Properties Test Report	SO-EPD-KIE-TR-0007	26.07.2013

Status wrt. Verification and Qualification (Verification Matrix, Qualification Status list), including also approval status of materials, processes and EEE parts

Verification: See previous slide
Qualification: Parts under CPPA control, sensors, see previous slide

DMPL:
Status as per MPCB meeting July 10 2013, Alcala
(Ref. SOL-EST-MN-5052).
Outcome: Delta MPCB review required to be held by telecon.
All actions considered to be normal work.

EEE parts:
Under CPPA control, but N/A for STM

Log-book contents, e.g.: Mate/De-mate Cycles Records, Limited Life Item Records, Temporary Installation Records, Operational Cycles

C A U ieap Christian-Albrechts-Universität zu Kiel	Electron Proton Telescope and High Energy Telescope (EPT-HET) Logbook of the Structural and Thermal Model	Page | 1 Compiled by: J. Steinhagen & S.R. Kulkarni

Similar log books will be kept for PQM, FM, and FS.

Mate/demate was performed on both, 15- and 25-pin, connectors for TBT only:
Mate: 02.07.2013
De-mate: 17.07.2013

STM has no limited life items.

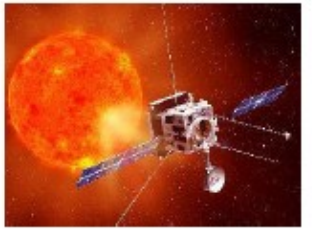
MLI was installed for TBT and removed for subsequent rework.

STM has no real “operational cycles”.

LOGBOOK

of the EPT-HET - Structural and Thermal Model (STM)

EPT-HET/Solar Orbiter



File name: SO-EPD-KIE-LB-0002_iss1_rev0_EPT-HET-STM-Logbook.doc

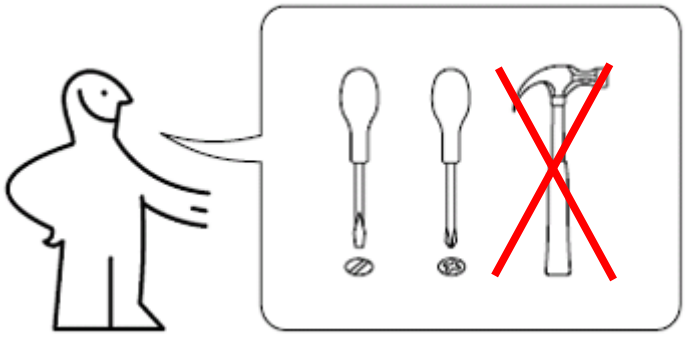
This document describes the Structural and Thermal Model (STM) development for the Electron Proton Telescope and High Energy Telescope (EPT-HET) at a low level.

IEAP, Christian-Albrechts-Universität Kiel, Leibnizstrasse 11, 24118 Kiel, Germany

Integration, Operation and Maintenance Manual, including any operational limitation and safety precautions

See SO-EPD-KIE-IF-0001-iss1_rev5-EPT-HET_STM_Interface_Control_Document.pdf

MLI and STM to be hand carried to ASUK in two separate boxes (because of cabin baggage size limitations)



Packing, Unpacking, Storage, Transport and Handling procedures (including cleaning procedures)

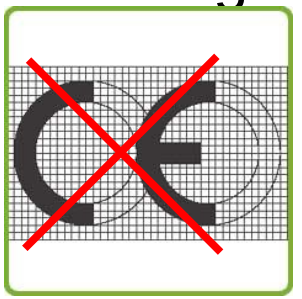
Packing, storing, transport, and handling is described in:

SO-EPD-KIE-PR-0001-iss1_rev1-EPT-HET_STM_Packing-storing-transport-handling_procedure.pdf

Compatibility with rules, regulations and standards in receiving country (e.g. CE declaration of conformity).

CAU does **not** know rules, regulations and standards in receiving country.
CAU does **not** plan to find out about all possible rules in receiving country.

*CAU will **not** provide a CE declaration of conformity*



CAU considers STM to be a (sophisticated) “piece of metal”.

Proof-load certificates for hoisting devices.

N/A for CAU-shipped parts.

CAU not responsible for hoisting devices in receiving institution.

Final SAR (for FM) ; Residual Hazard Sheets (for STM and EM)

N/A for STM

Reports from mass properties measurements

No mass and physical properties measurements performed as per the following waivers.

Filename	EPD codification	Description	Delivered	Status
SO-EPD-KIE-RD-0001_iss1_rev1_RfD_for_mass_properties.pdf	SO-EPD-KIE-RD-0001	RFD for mass properties	24.05.2013	Closed
SO-EPD-KIE-RD-0002_iss1_rev1_RfD_for_qualification_level_sine_vibration.pdf	SO-EPD-KIE-RD-0002	RFD for qualification level sine vibration	24.05.2013	Closed

Reports from metrology measurements (e.g. mechanical I/Fs)

CAU Manufacturing Process:

Design/Engineering

Manufacturing

3d CAD-file

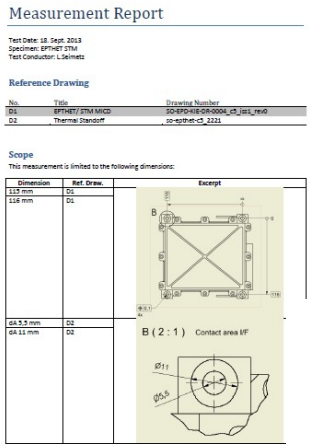
Vault: version control & backups

Get 3d file from vault

Machine from 3d cad-file

Fit check with mating parts

Verification of relevant dims. (MICD)


Measurement Report

Test Date: 18. Sept. 2013
Specimen: EPTHET STM
Test Conductor: L.Selmetz

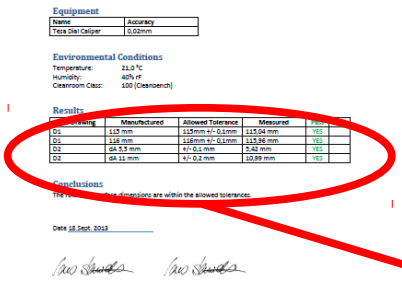
Reference Drawing

No.	Title	Drawing Number
D1	EPTHET/ STM MICD	SO-EPD-HIE-DR-0004_c3_jas1_rev0
D2	Thermal Standoff	so-epthet-c3_2221

Scope

This measurement is limited to the following dimensions:

Dimension	Ref. Draw.	Excerpt
115 mm	D1	
116 mm	D1	
dA 5,5 mm	D2	
dA 11 mm	D2	


Equipment

Name	Accuracy
Tesa Dial Caliper	0,02mm

Environmental Conditions

Temperature: 21,0 °C
Humidity: 40% rF
Cleanroom Class: 100 (Cleanbench)

Results

Ref Drawing	Manufactured	Allowed Tolerance	Measured	Pass
D1	115 mm	115mm +/- 0,1mm	115,04 mm	YES
D1	116 mm	116mm +/- 0,1mm	115,96 mm	YES
D2	dA 5,5 mm	+/- 0,1 mm	5,42 mm	YES
D2	dA 11 mm	+/- 0,2 mm	10,99 mm	YES

Conclusions

The measured dimensions are within the allowed tolerances.

Date 18.Sept. 2013

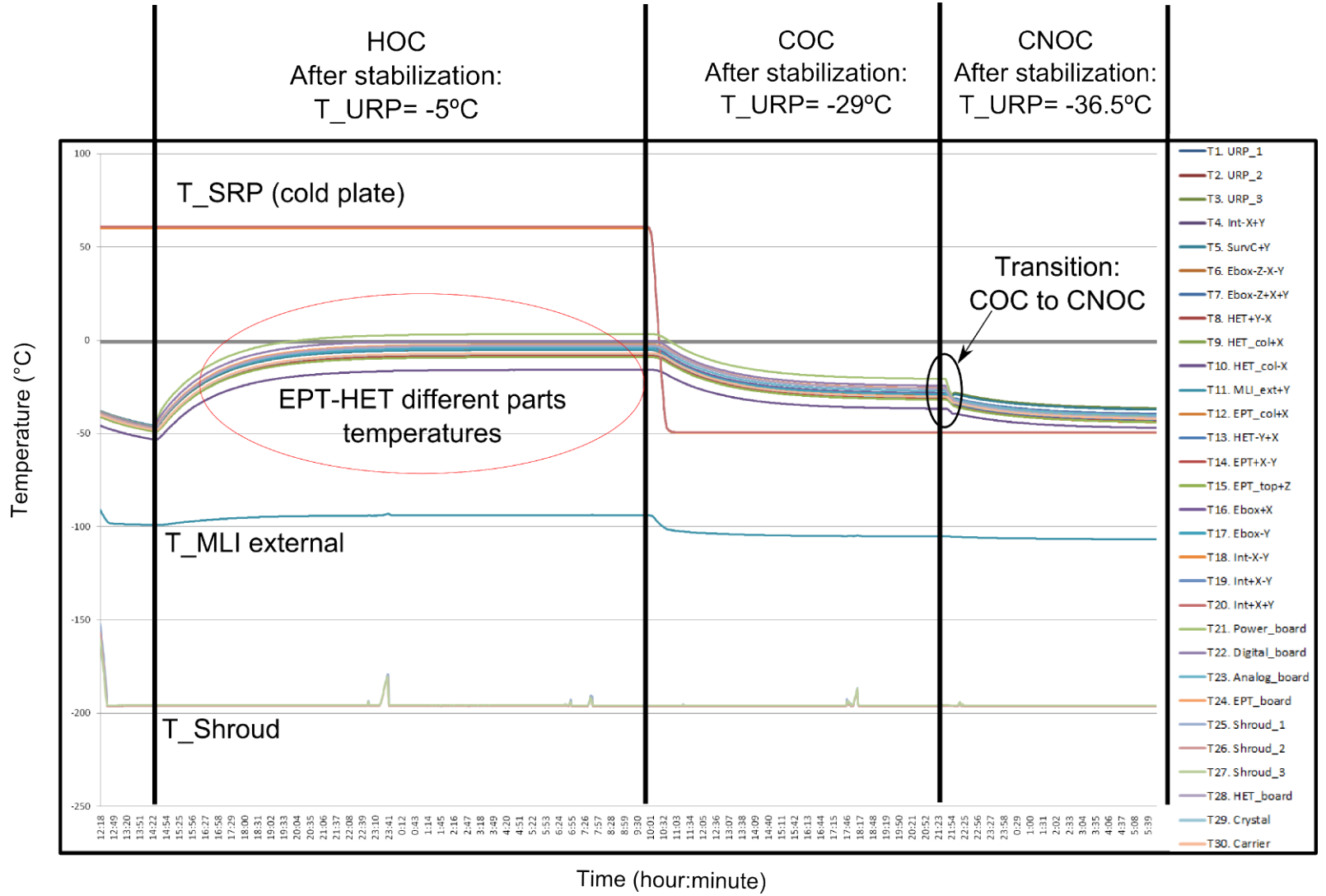
Results

Ref Drawing	Manufactured	Allowed Tolerance	Measured	Pass	Fail
D1	115 mm	115mm +/- 0,1mm	115,04 mm	YES	
D1	116 mm	116mm +/- 0,1mm	115,96 mm	YES	
D2	dA 5,5 mm	+/- 0,1 mm	5,42 mm	YES	
D2	dA 11 mm	+/- 0,2 mm	10,99 mm	YES	

Reports from cleanliness measure-ments and bakeouts verification

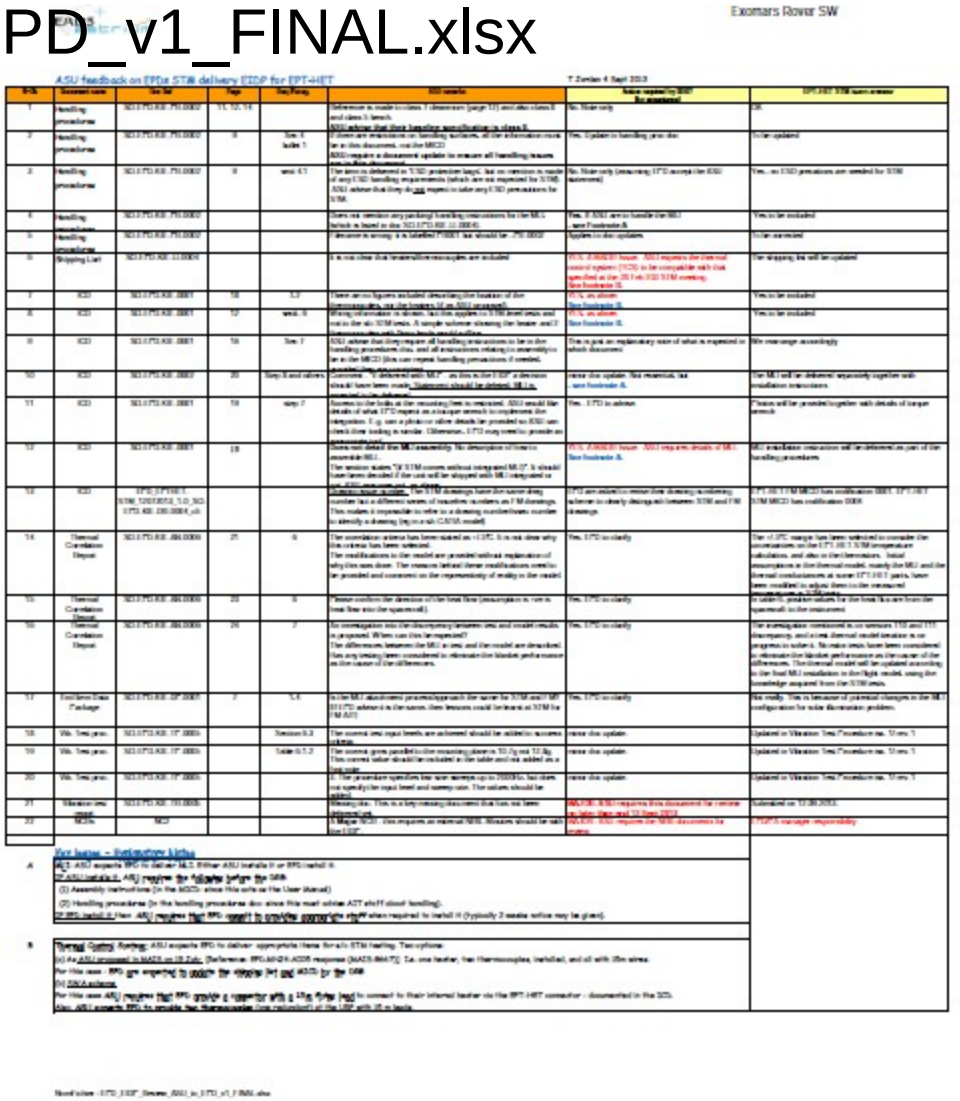
STM to be visibly clean (Can be verified by visual inspection)

EPT-HET STM Logbook SO-EPD-KIE-LB-0002 (issue1/rev.1)



Feed-back from the review of other sections of EIDP, e.g.: interface control drawings, electrical circuit diagram

See separate spreadsheet EPD_EIDP_Review_ASU_to_EPD_v1_FINAL.xlsx with CAU responses.



Visual inspection of the hardware with magnifier, white and UV light for overall status and cleanliness (pictures/reports to be added to the data package)

To be seen in Point 6 of the agenda:

“The configured HW and GSE are made accessible for inspection and test before packing.”

N/A for STM

Packing list (including list of loose items & spares)

SO-EPD-KIE-LI-0004-iss1_rev1-EPT-HET_STM_Shipping_list.pdf

Loose items & spares: Thermal washers

EPT-HET STM ships in two containers:

1st container:
- STM (with 2 thermocouples at URP with 15 m leads)
- supporting docs

2nd container
- MLI
- 15 m cables with one end connectors and other end flying leads (two sets, one for survival another for internal heaters)
- 1 set of documents (handing procedure doc, pictures, proforma invoice, MLI export Licence)
- some pairs of gloves (optional)

Status of shipping documents / Logistics details for shipping operations

Proforma invoice is being prepared, according to all parties this is the only needed document.

Logistics details:
CAU will hand carry STM to ASUK in 2 shipping containers

SO-EPD-KIE-LI-0004-iss1_rev1-EPT-HET_STM_Shipping_list.pdf gives all details

Open/Deferred Works

Flying leads need to be re-made.

AOB

At the time of preparing this presentation, there was no “AOB”.

Should there be some after this meeting, list AOB here online:

-
-
-

Conclusions

Criteria for successful Pre-Shipment & FAR

1) The configured HW conforms to the EID-A and related NRs requirements and to an approved design configuration (yes)

2) The configured HW is fully tested and all tests subjected to successful TRB(s) (yes)

3) The configured HW is free from material and workmanship deficiencies (yes)

4) Non-conformances are closed-out (or open ones are compatible with the delivery) (yes)

5) Relevant EIDP and shipping documents are complete, detailed and accurate (yes)

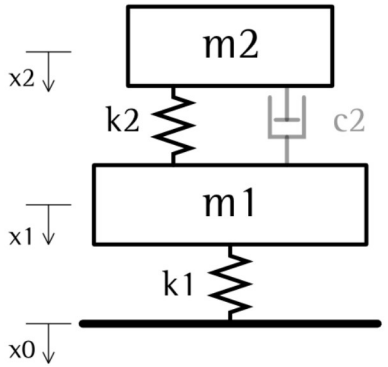
6) The configured HW and shipping “GSE” are made accessible for inspection and test before packing. (yes)

Backup slides

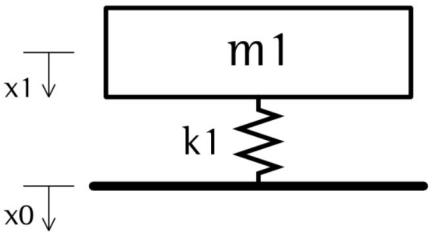
What went wrong in STM vibe?

A medium mass must have 'settled down':

System w. 2 coupled masses



Single mass



Such s system is governed by set of two coupled differential eqs.:

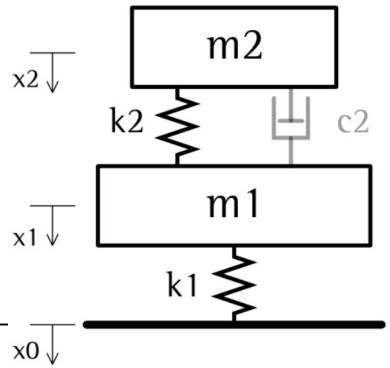
$$m_1\ddot{x}_1 + 2b_1\dot{x}_1 + D_1x_1 + D_{12}(x_1 - x_2) = k\sin\omega t$$

$$m_2\ddot{x}_2 + 2b_2\dot{x}_2 + D_2x_2 + D_{12}(x_2 - x_1) = k\sin\omega t$$

Which has a characteristic class of solutions, as shown on next slide.

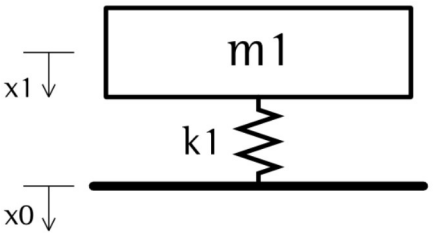
What went wrong in STM vibe?

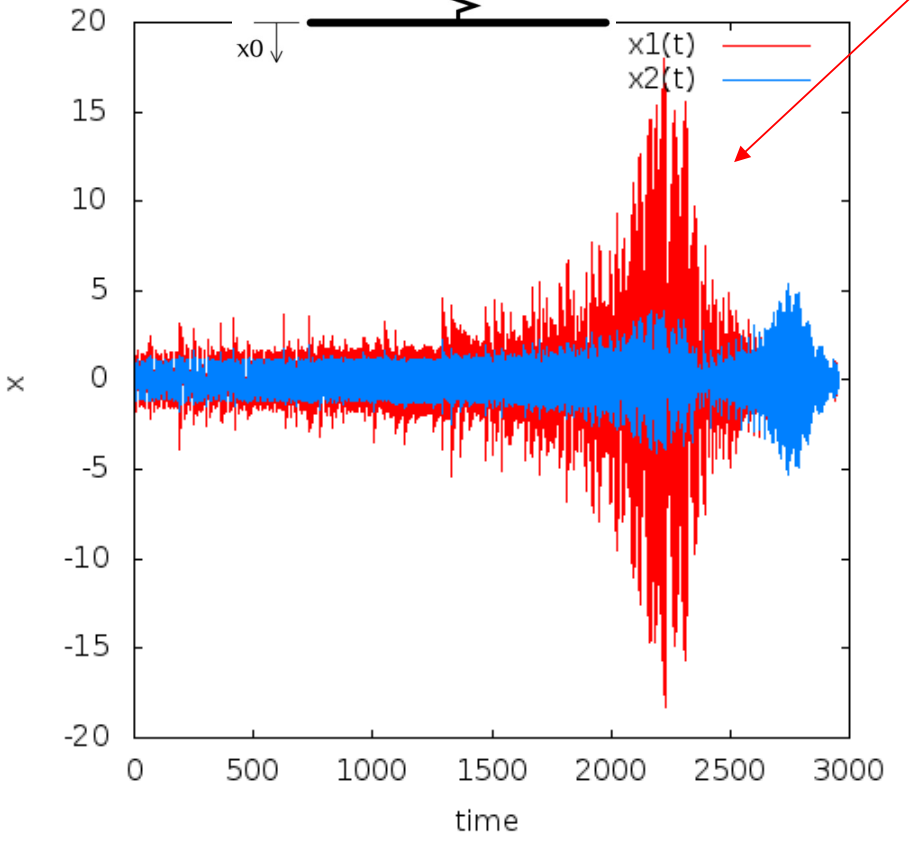
System w. 2 coupled masses

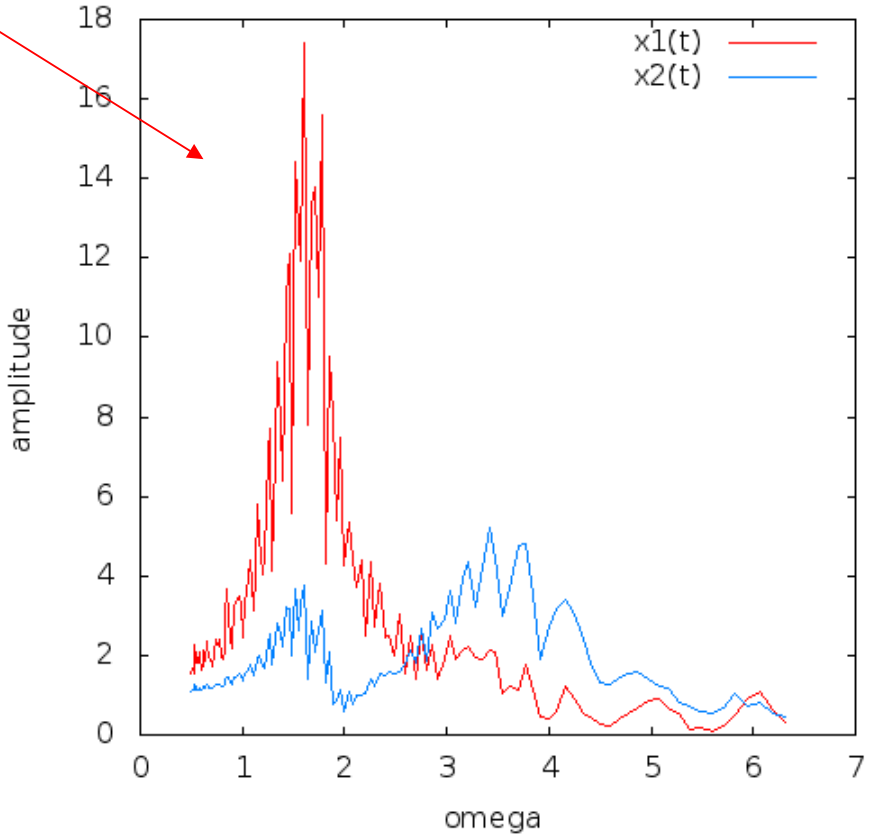


Simple integration of those ODEs.

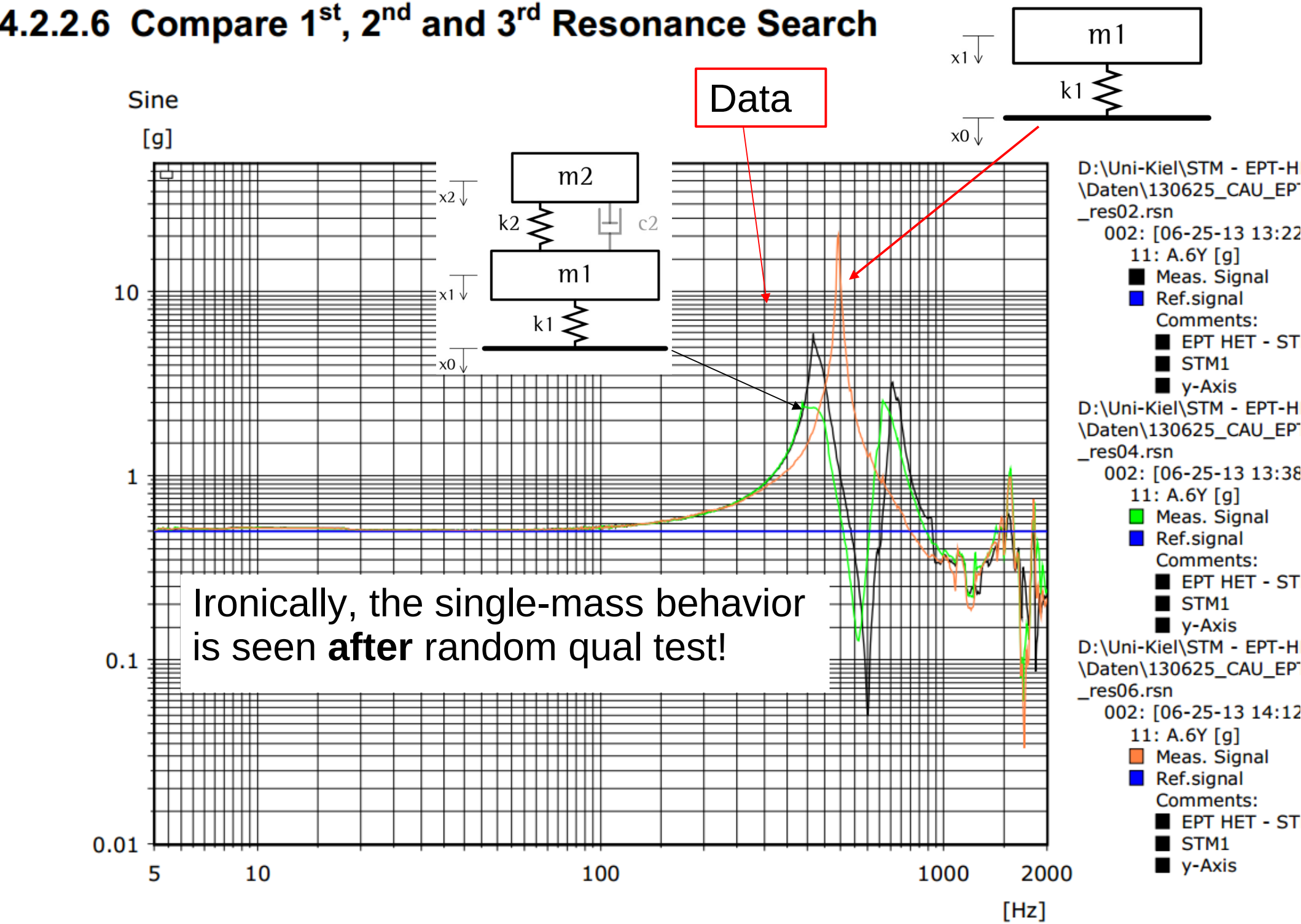
Single mass

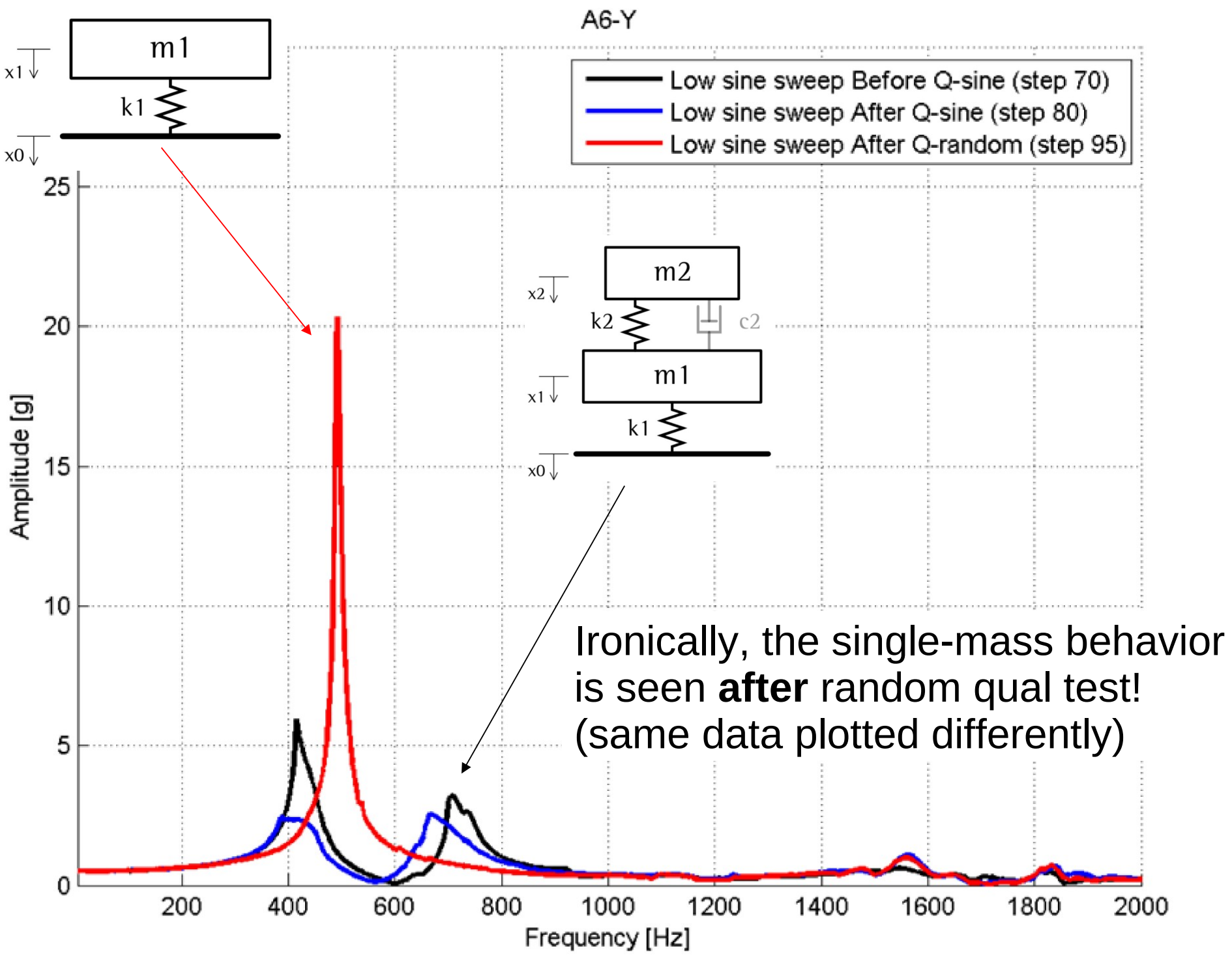






4.2.2.6 Compare 1st, 2nd and 3rd Resonance Search

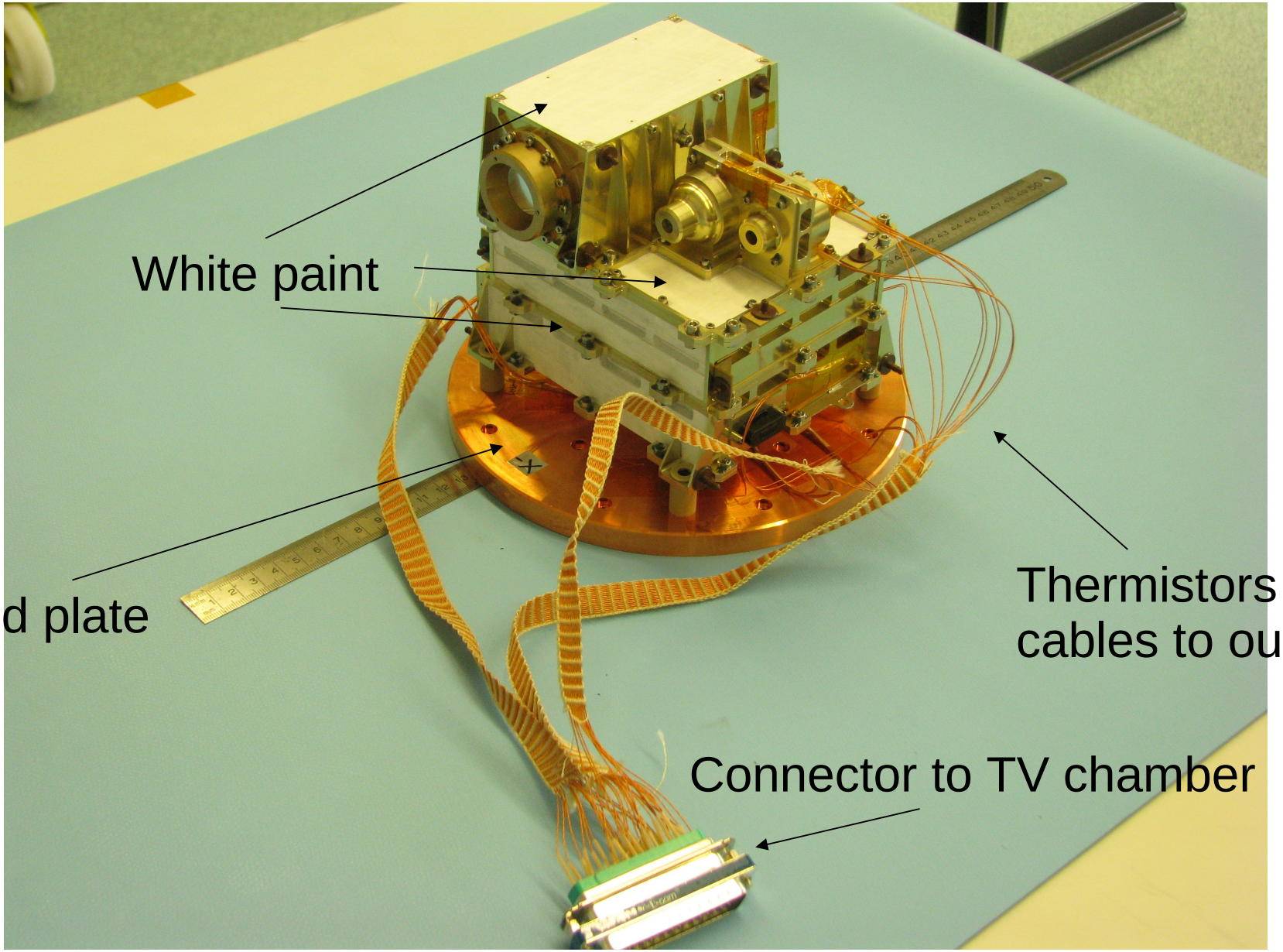




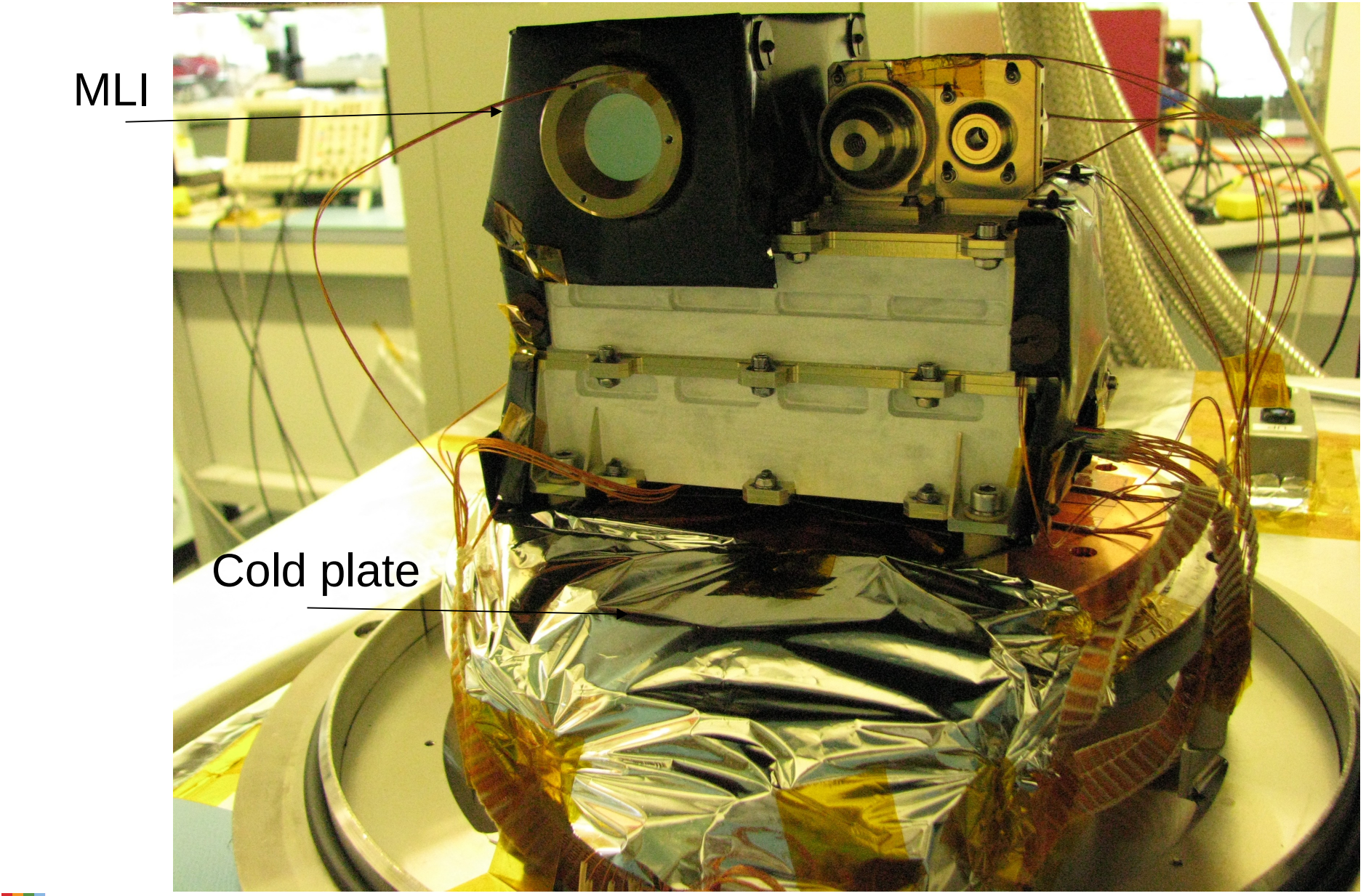
Ironically, the single-mass behavior is seen **after** random qual test! (same data plotted differently)

EPT-HET STM TBT

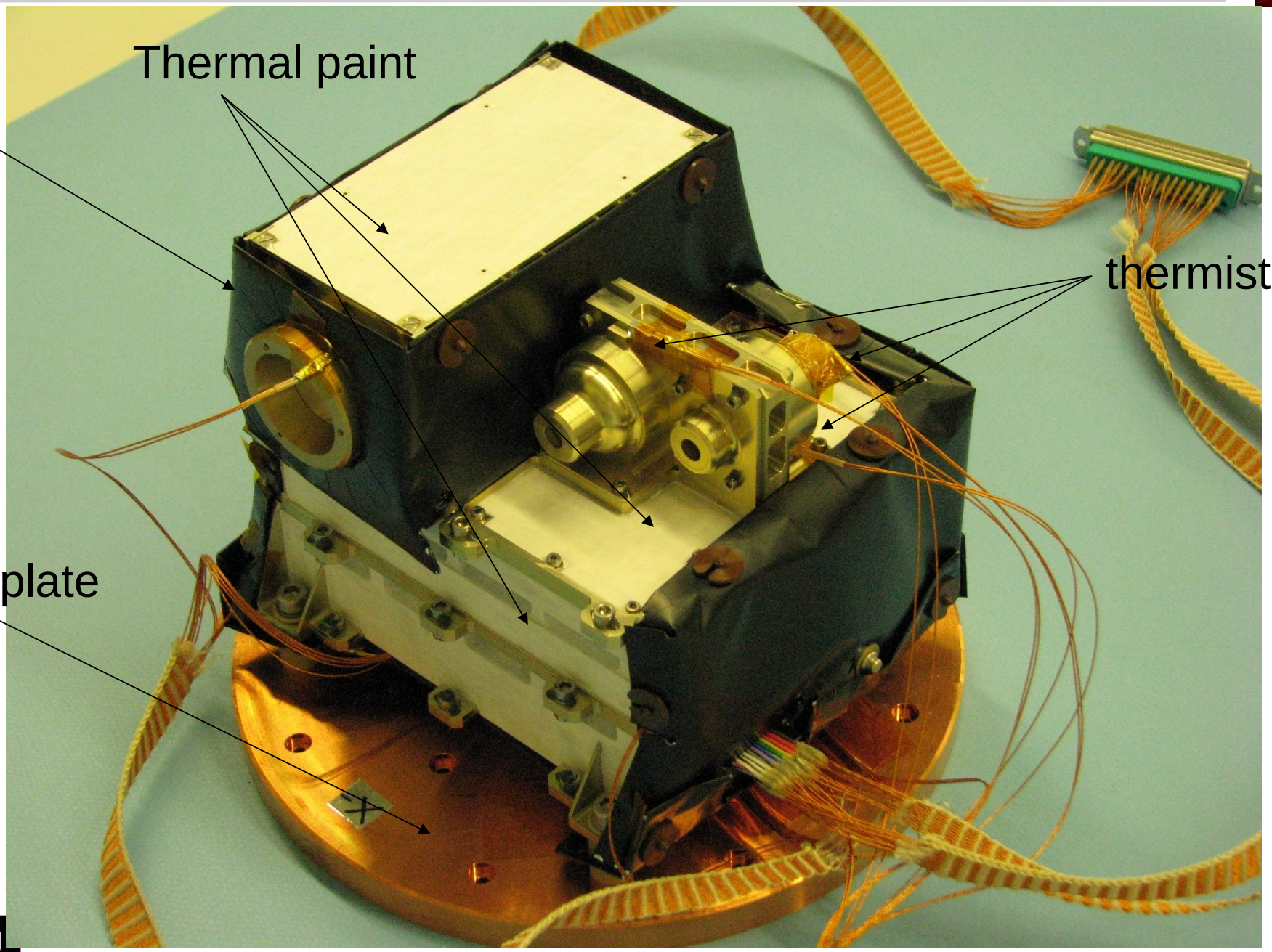
EPT-HET STM TBT Test



EPT-HET STM before closeout



EPT-HET STM before closeout



EPT-HET STM TBT Test

Test ran successfully and data were submitted to IDR/UPM and discussed with them. This input was critical for the validation of the TMM and RTMM.

Test report EPT-HET STM Thermal Balance Test Report was submitted.
(SO-EPD-KIE-TR-0006)
26.07.2013