Europa Penetrator Design and Full Scale Survivability Testing

IPPW 11

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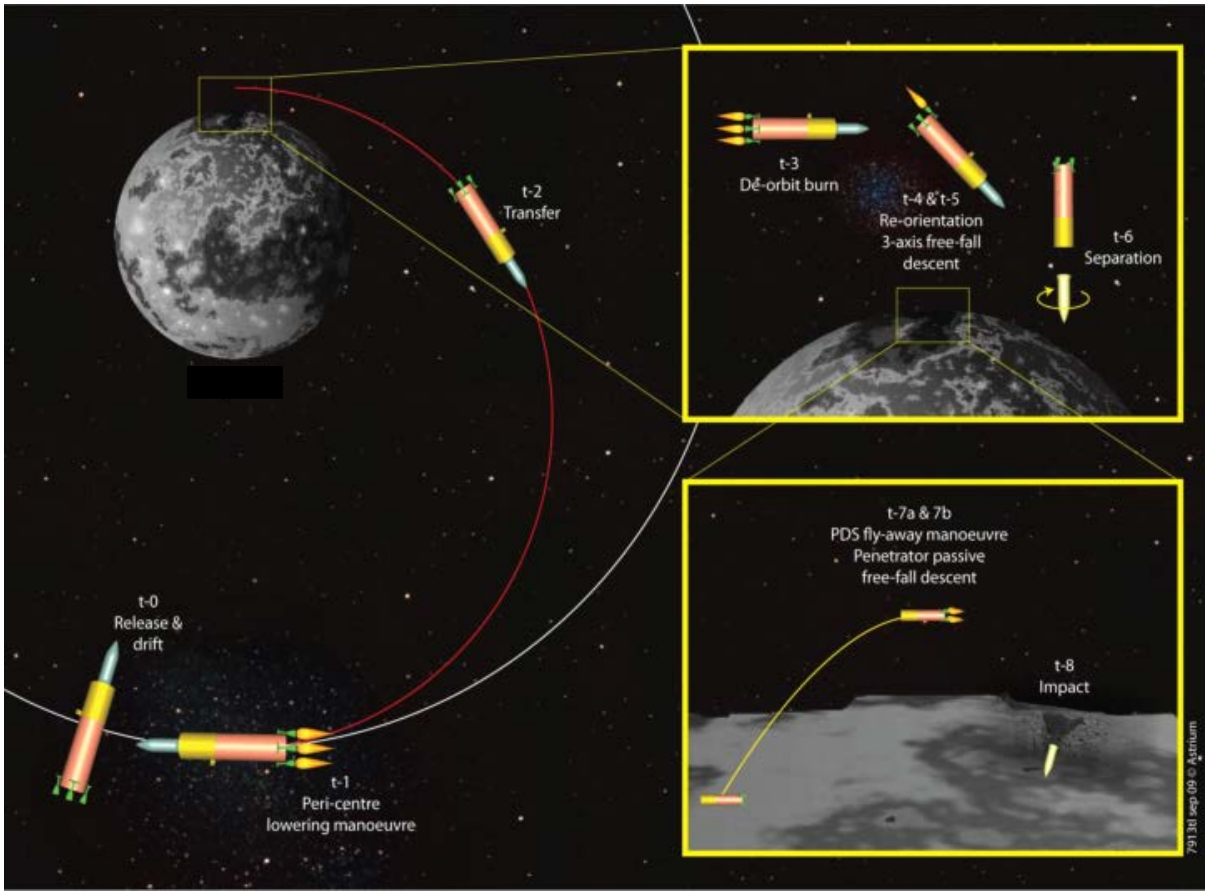
Penetrator Mission Baseline

- Spacecraft carries penetrator until separation from a low circular orbit
- Delivery system controls trajectory to impact
  - De-orbit manoeuvre
  - Spin-up and separation
- Visibility maintained from orbiter during transfer and impact
- Delta-V required 1565 m/s



MOVIE

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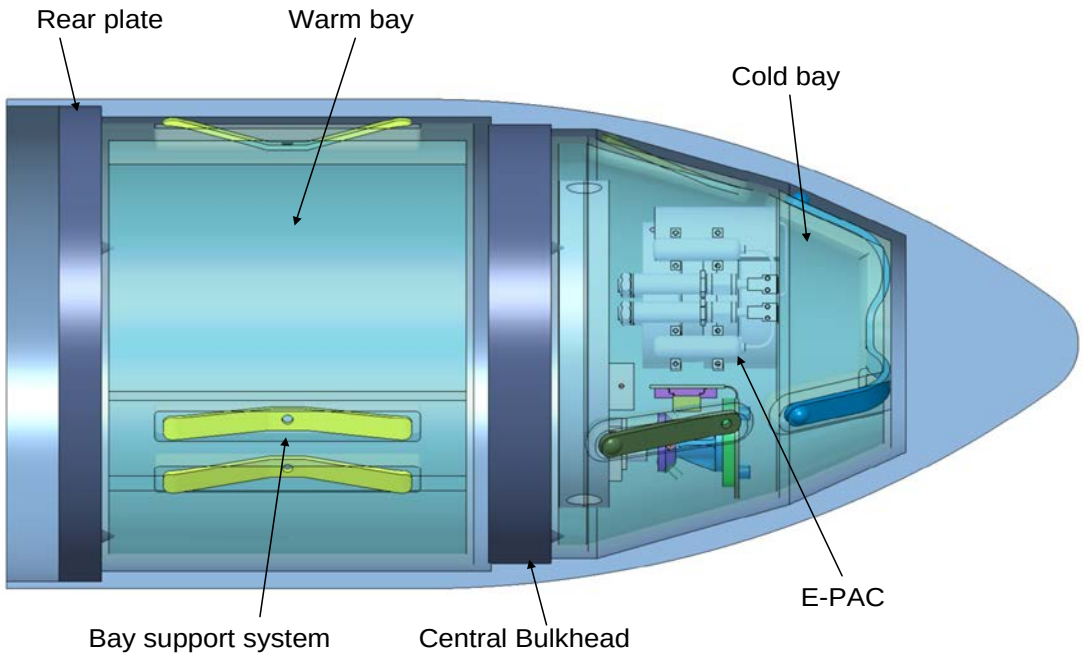
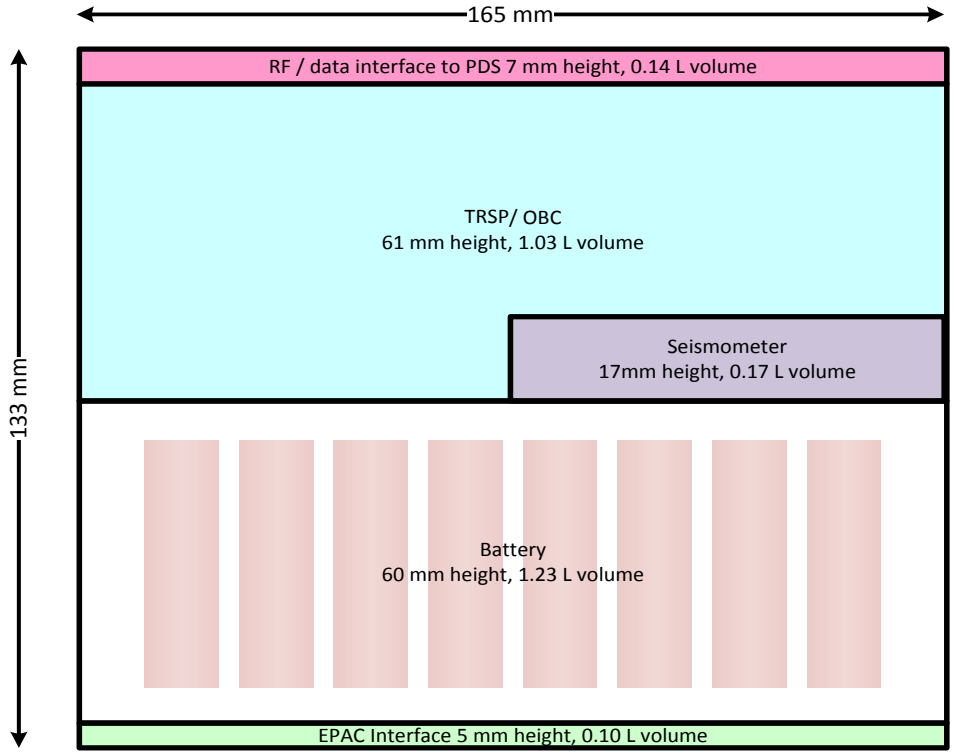
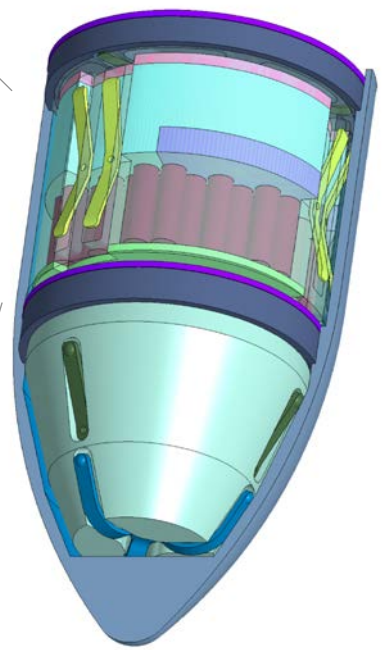
Penetrator Design Overview

- Key science objective Astrobiology
- Sample collection required
- 80K ice, rapid cool down of instruments
  - Front short lifetime bay houses instruments (microscope, mass spectrometer and habitability package)
  - Rear longer lifetime for data relay







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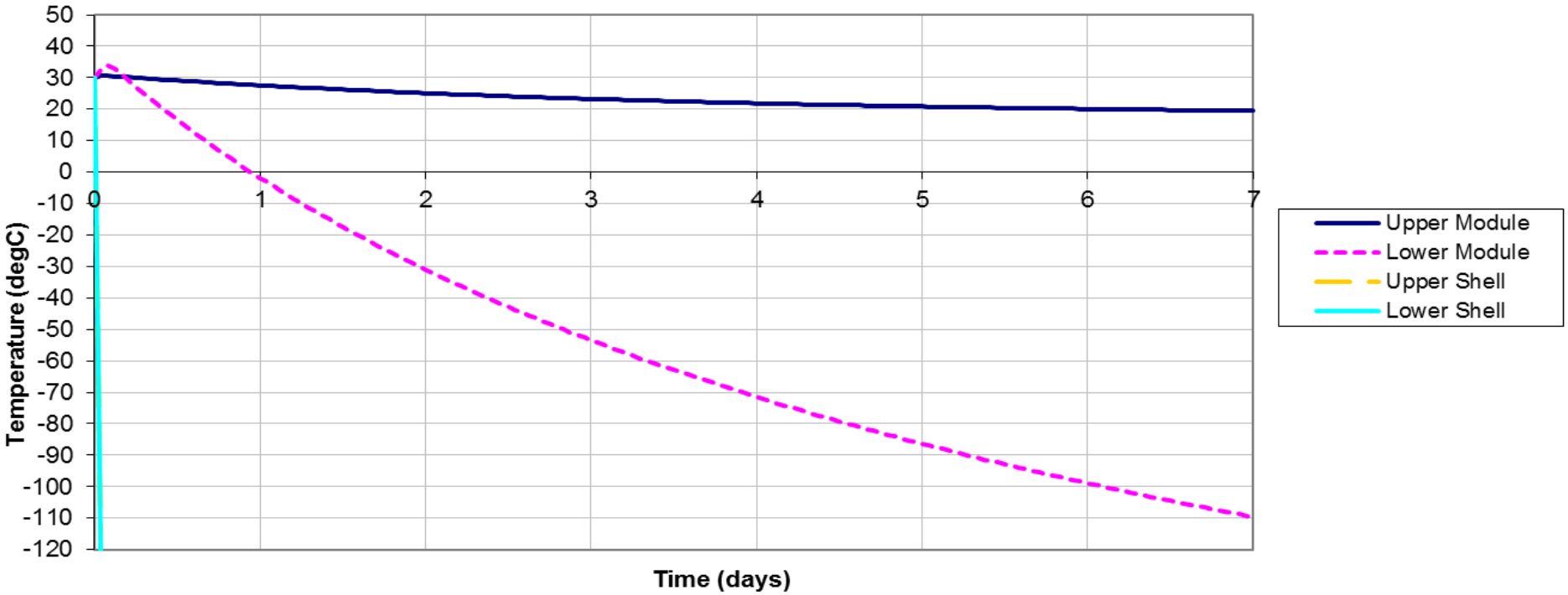
Power and Thermal

- Vacuum flask design minimises heat leaks
- Science operations are carried out in the first day
- Data (12.7 Mbits) is returned via an orbiter within 7 days



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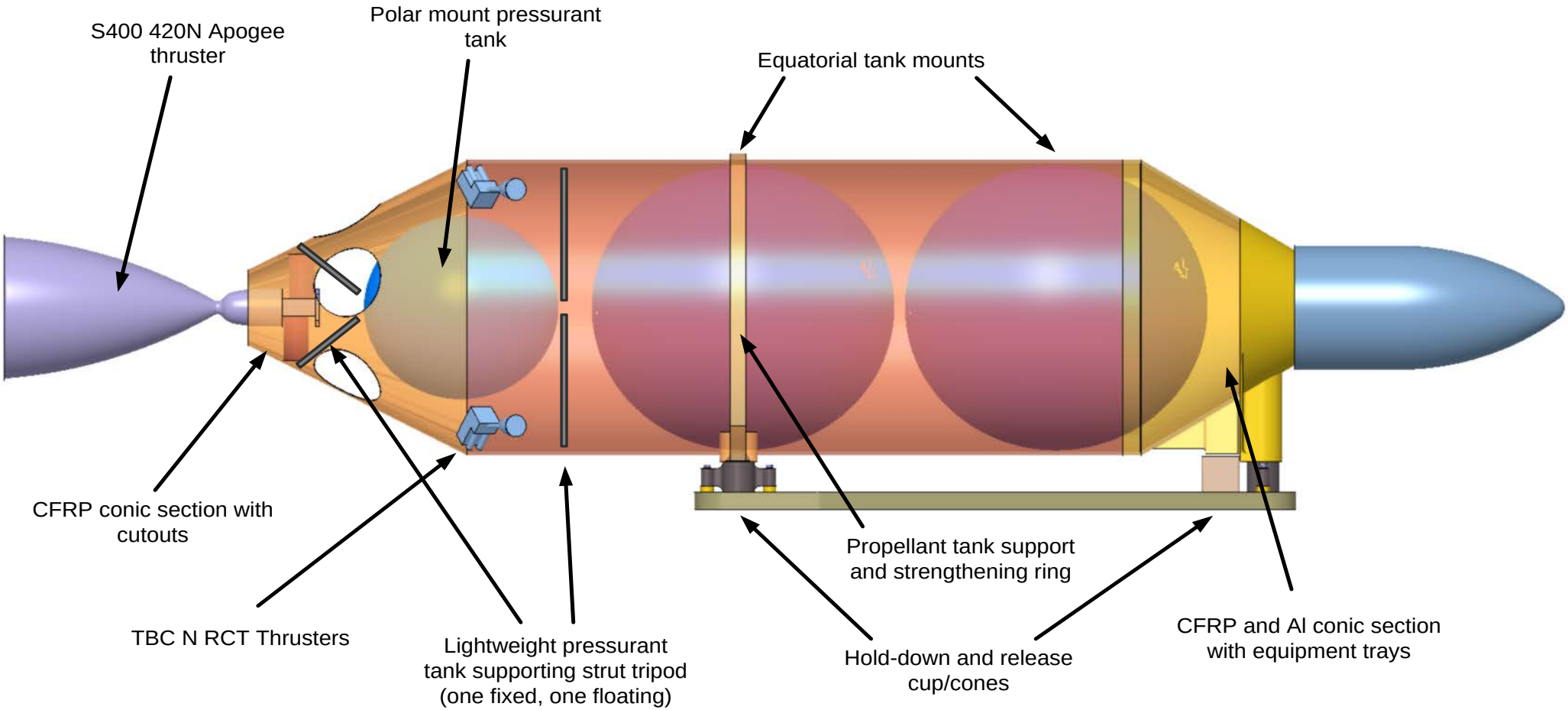
Penetrator Descent Module Configuration



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Penetrator Phase 2

Subsystem	Current Best Estimate (kg)	Design Maturity Margin (kg)	Total CBE + DMM (kg)
Data Handling Subsystem	1.0	0.2	1.2
Power Subsystem	1.2	0.2	1.4
Harness	0.2	0.0	0.2
UHF Communications Subsystem	0.3	0.1	0.4
Inter-compartment Interface System	0.0	0.0	0.1
Warm Bay Payload Instruments	0.3	0.2	0.5
Structure	13.9	2.8	16.7
Thermal Subsystem	0.1	0.0	0.1
Penetrator and Platform TOTAL	**17.1**	**3.5**	**20.6**
Structure	0.7	0.3	1.0
Payloads	2.2	1.1	3.2
Electrical Power and Interfaces	0.0	0.0	0.1
EPAC TOTAL	**2.9**	**1.4**	**4.3**
Structure	7.4	1.5	8.9
Propulsion	29.9	2.0	31.9
Command and Data Handling	0.4	0.1	0.5
Power	0.5	0.1	0.5
Harness	0.8	0.2	1.0
AOCS	0.6	0.1	0.7
PDS TOTAL	**39.5**	**3.9**	**43.4**
DRY TOTAL	**59.5**		**68.3**
System Mass Margin		20%	13.7
DRY TOTAL (incl. System Margin)			**82.0**
Propellant			62.3
Residuals + Uncertainty			2.6
Pressurant			0.0
WET MASS			**146.9**

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System Verification

ESA contract was focussed on maturing technology and reducing risk for penetrator missions

Method applied:

- Impact Modelling for penetrator and critical components
- Small scale impact testing for critical components
- Functional testing for sampling mechanism
- Full scale impact testing to demonstrate mechanical system performance and key items

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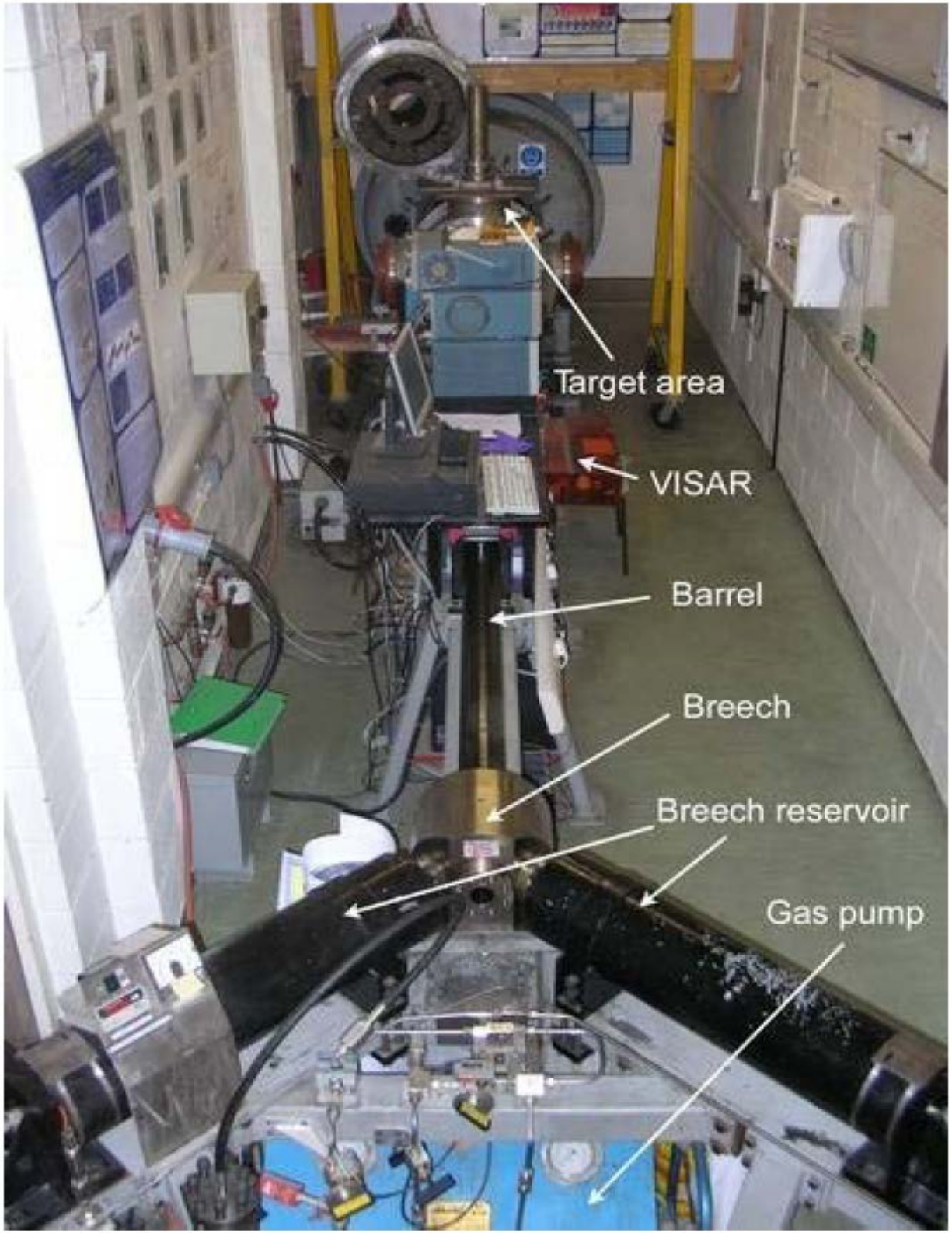

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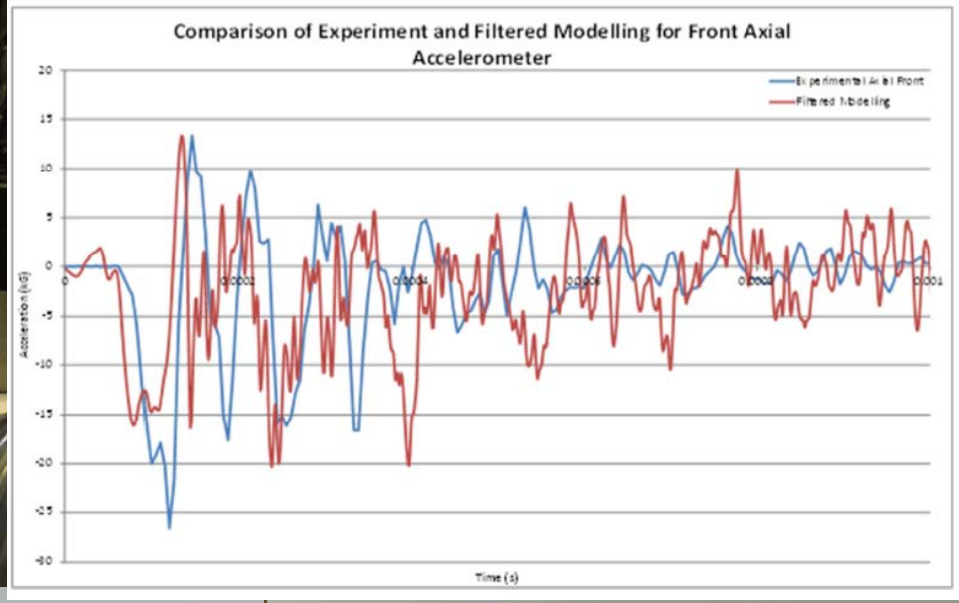
Comparison of Experiment and Filtered Modelling for Front Axial Accelerometer
Experimental Axial Front
Filtered Modelling
Acceleration (kG)
Time (s)
20
15
10
5
0
-5
-10
-15
-20
-25
-30

26/6/2012 15:24

Test

26/6/2012 15:58

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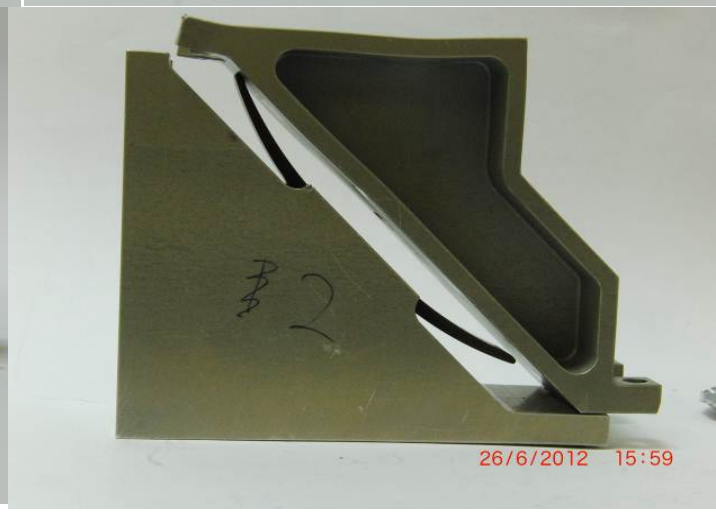
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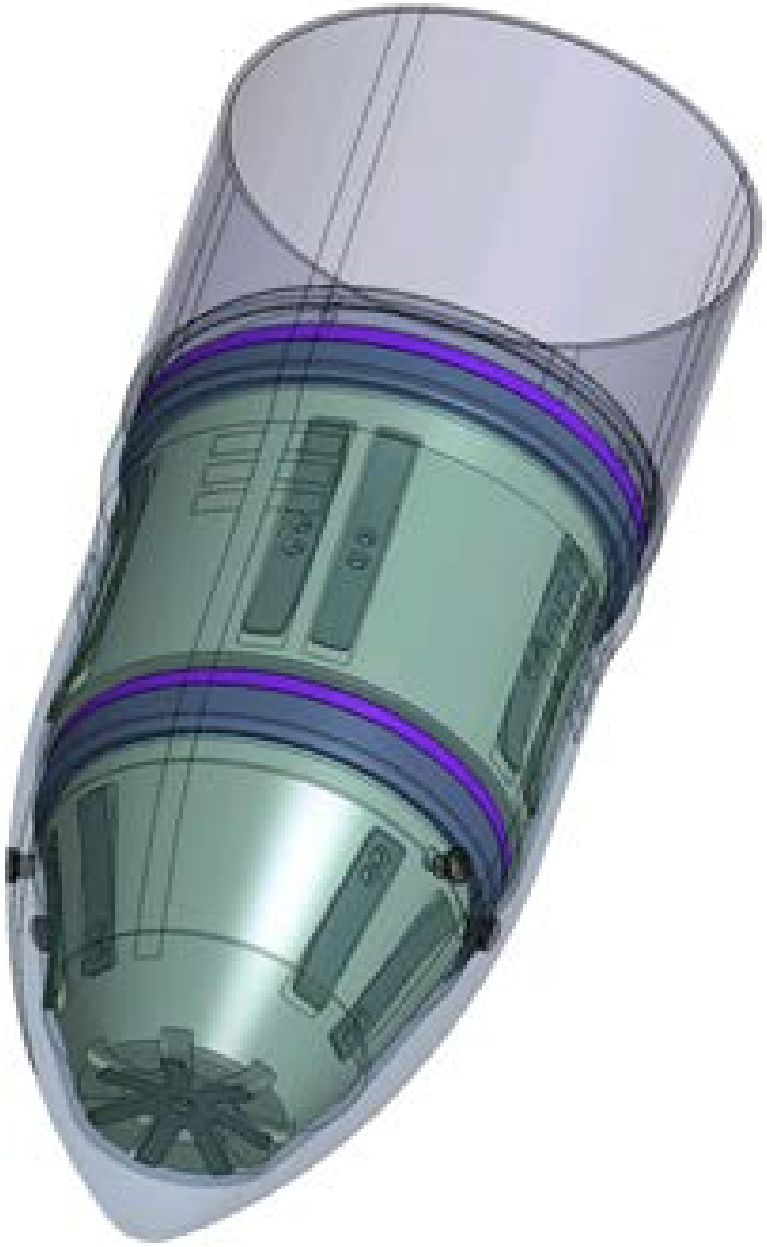
Full Scale Breadboard



Full Scale Tests

- Full scale testing of the penetrator carried out July 2013
- Tests carried out at the QinetiQ operated MoD test range at Pendine
- Rocket sled used to accelerate the Penetrator to a ~300m/s impact velocity
- Two firings carried out, one into sand, one into ice
- Target dimensions 3 x 3 x 3 m

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QinetiQ
QinetiQ
ASTRIUM

CV03 OYL

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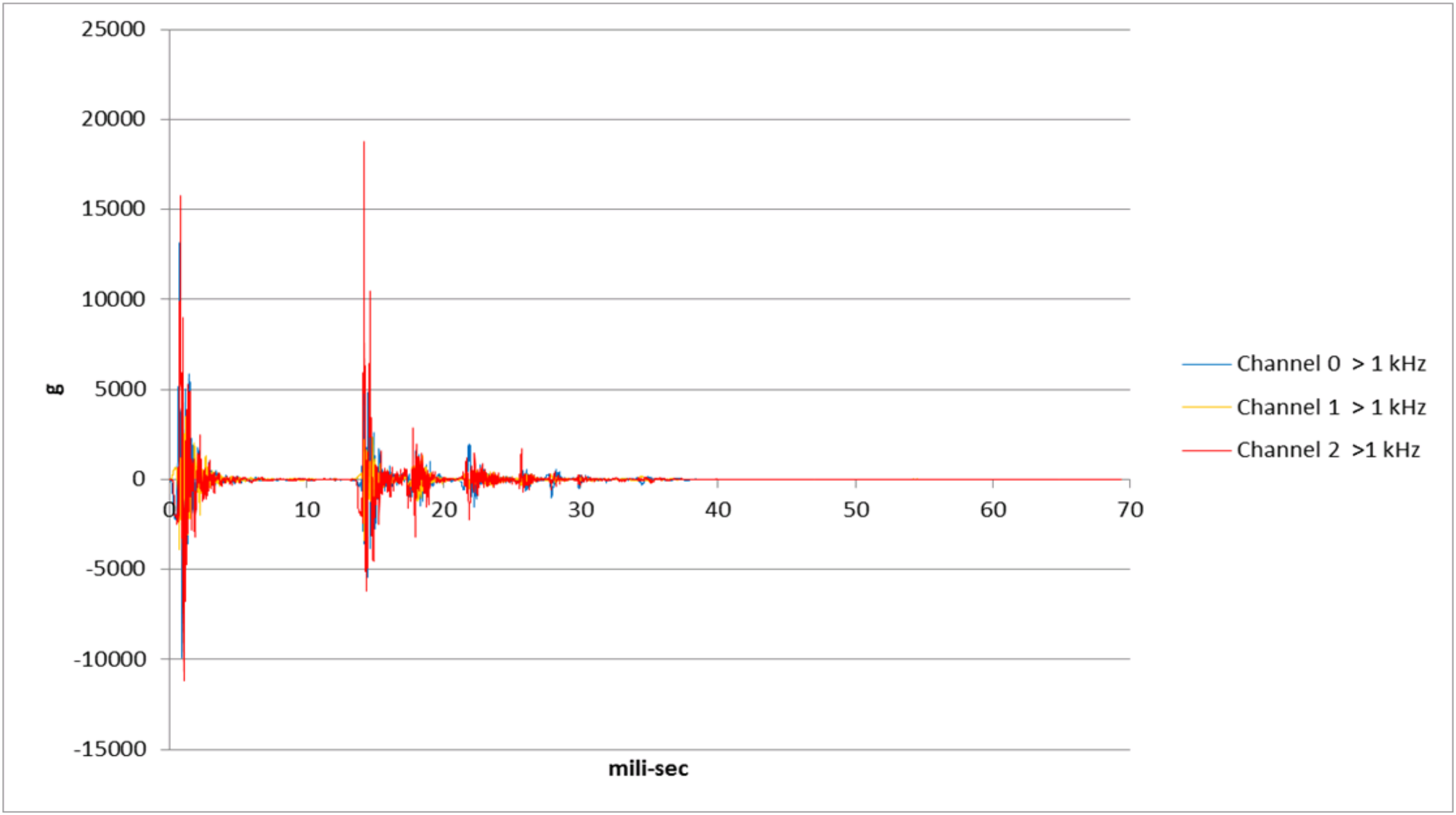
Ice impact

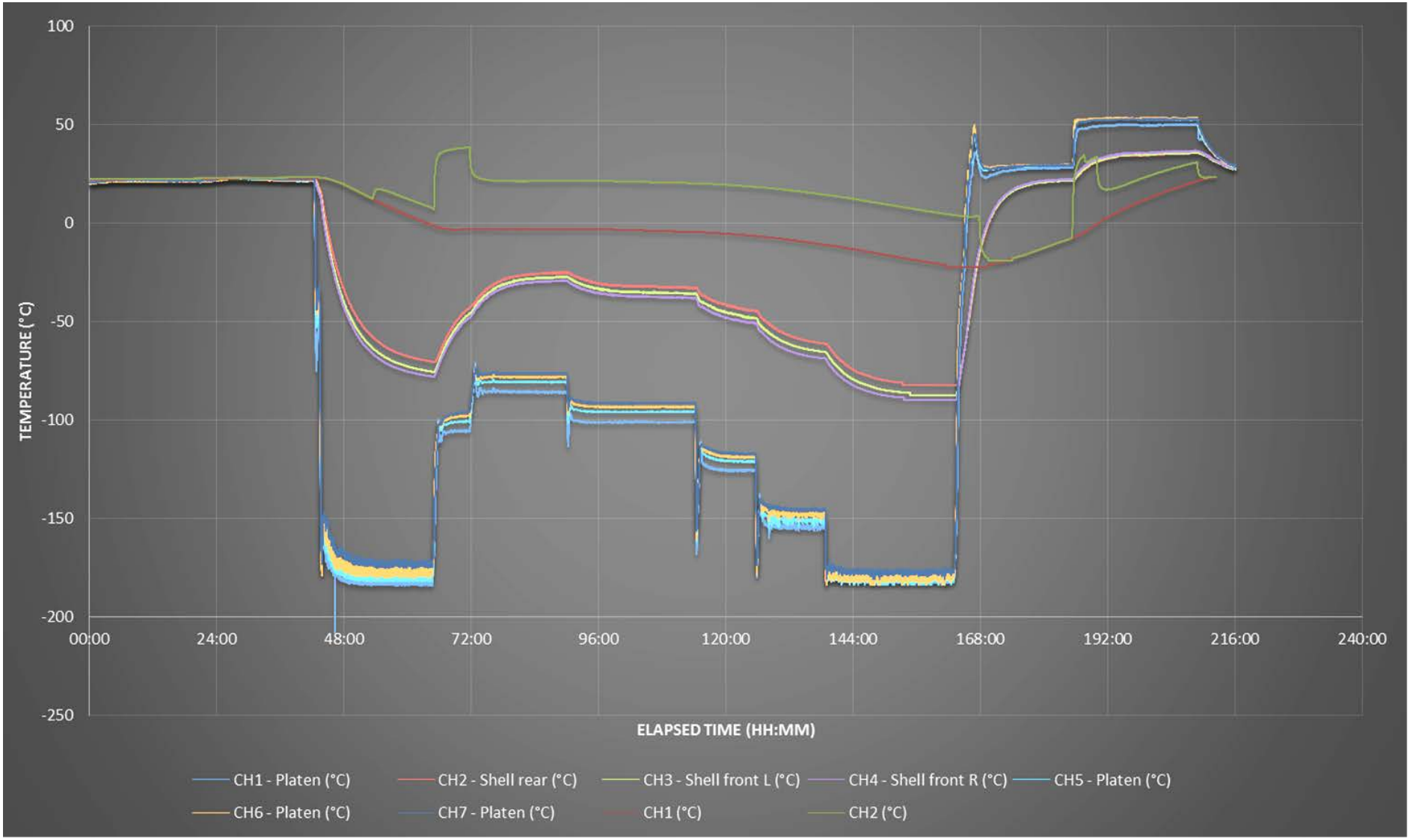
I know its hot but you can't stay in there – we're about to fire the penetrator!

Test Results

Shock Loads Recorded



Environmental Test Results



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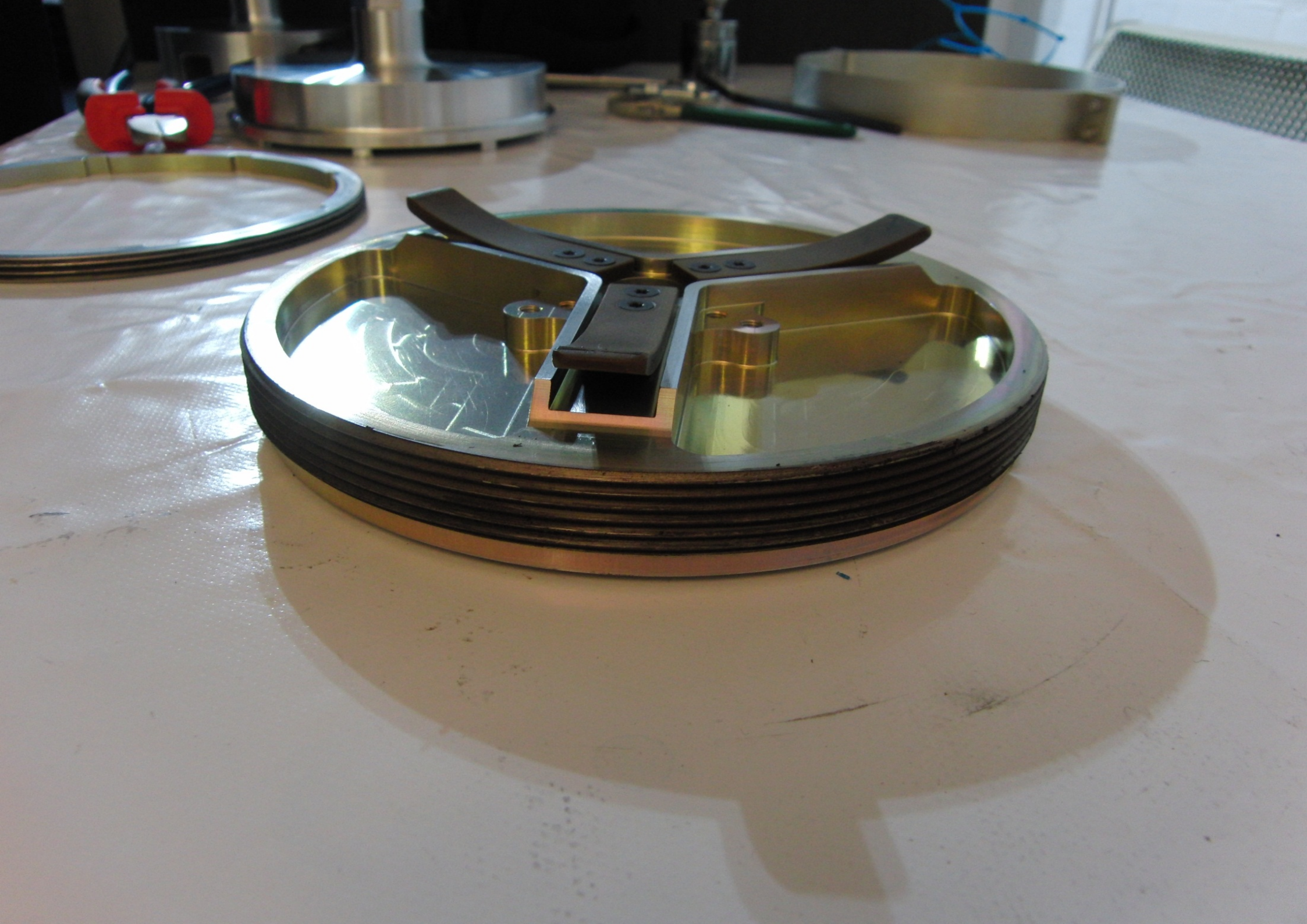
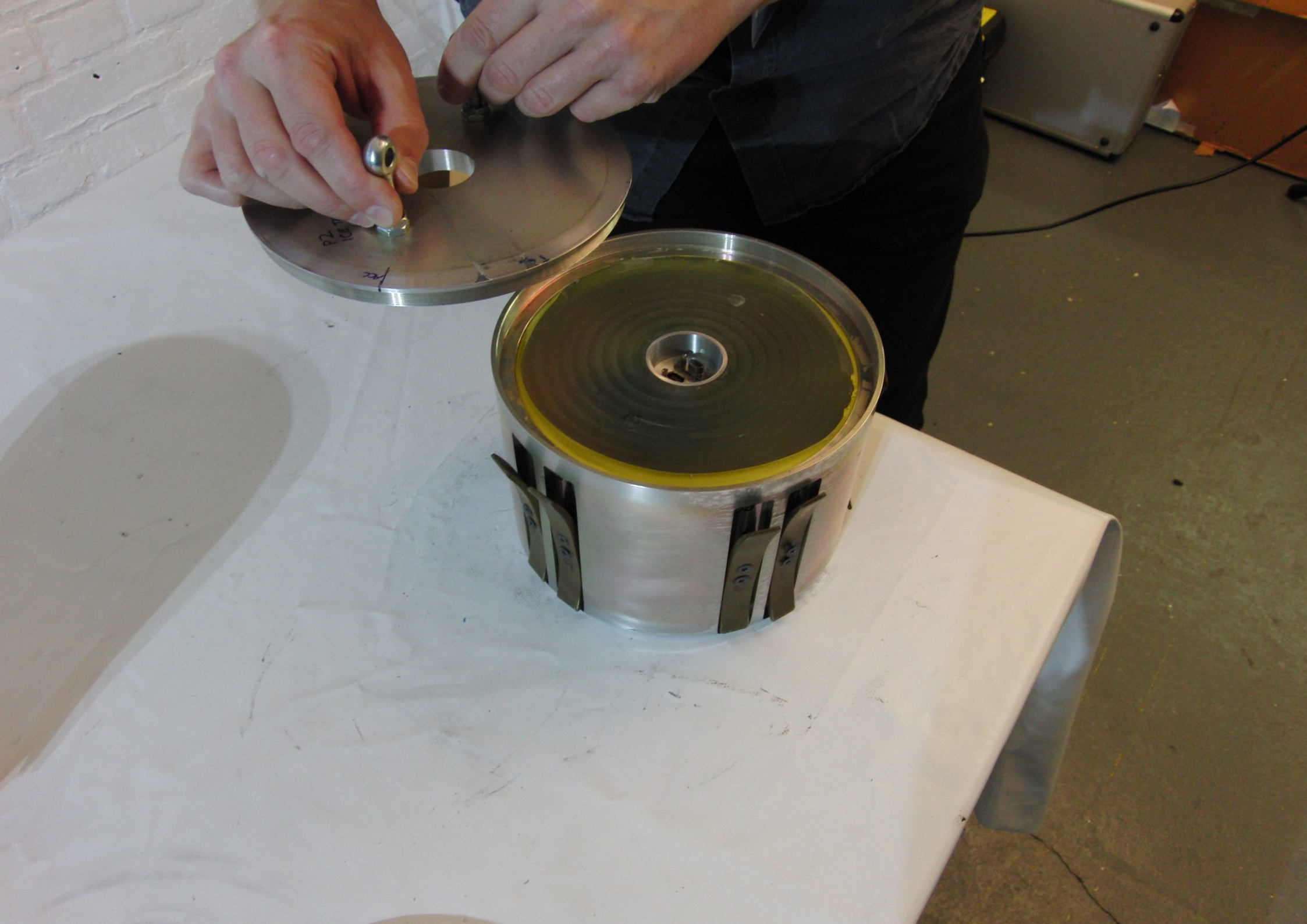
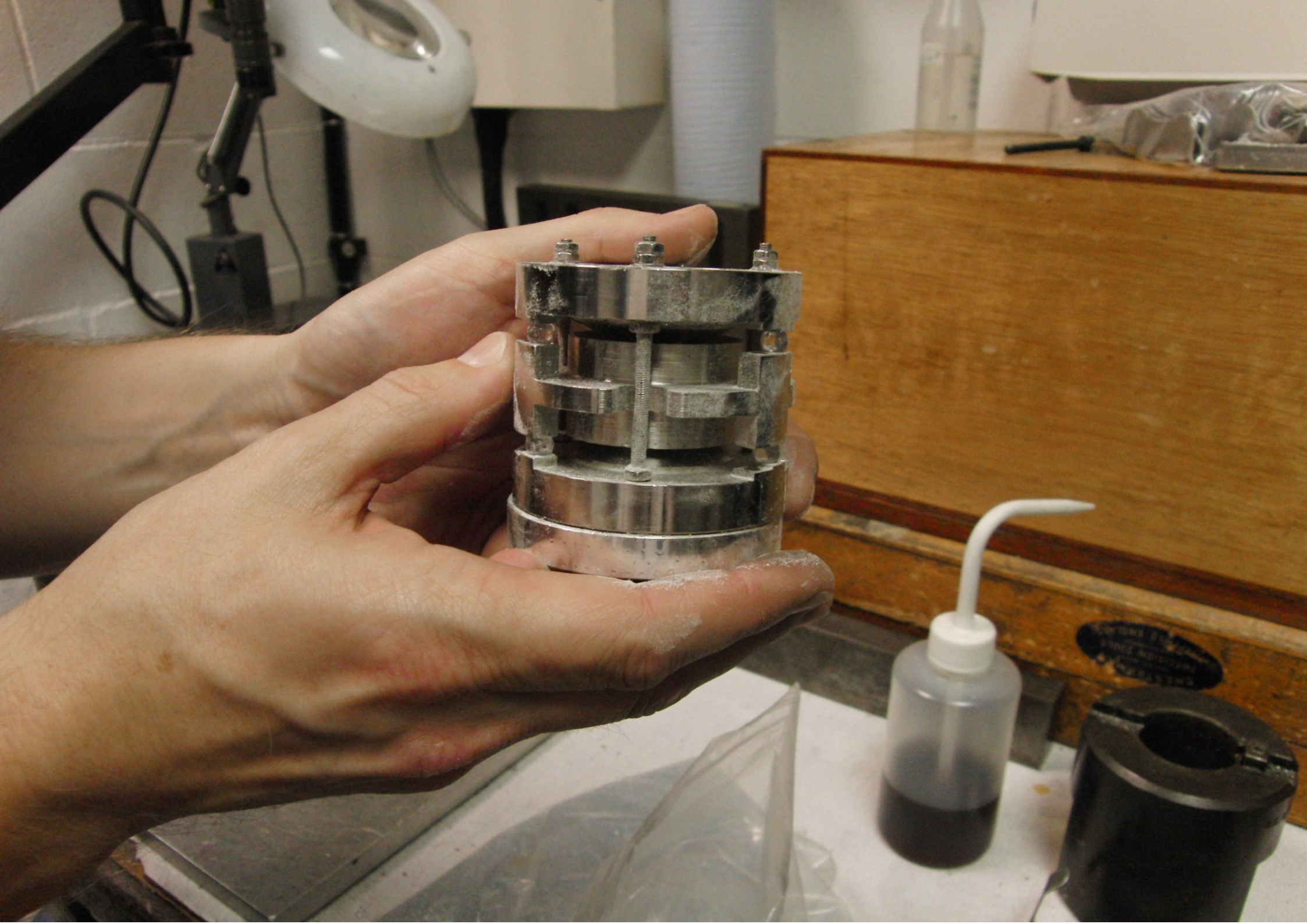






Testing conclusions & Next Steps

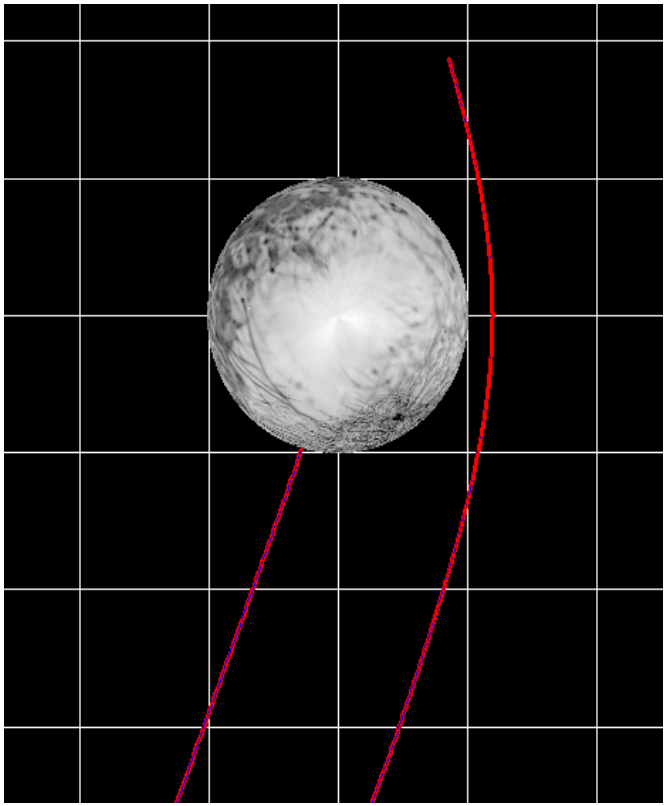
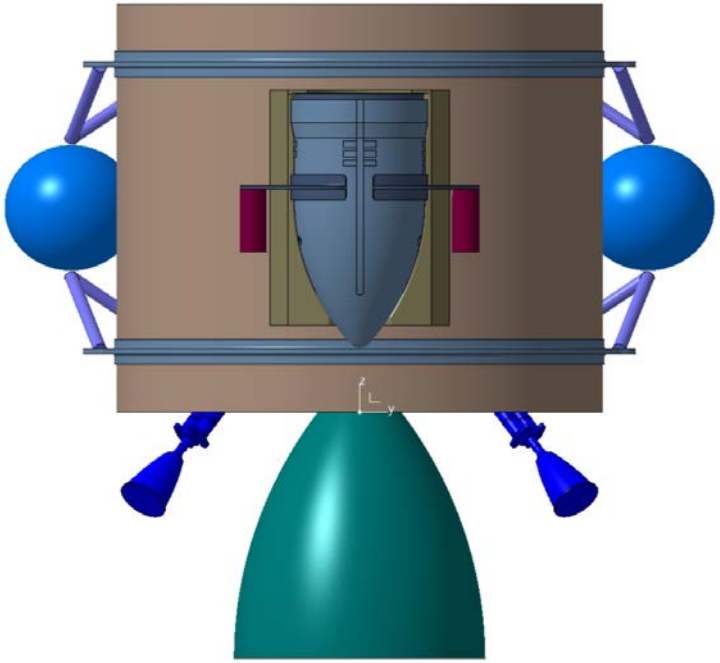
- Mechanical design works well
- Impact conditions survived harsher than expected (340m/s impact, 25 deg pitch angle)
- Environmental tests before and after impact proved thermal concept was valid
- Some issues identified with internal equipments, drill / mass spectrometer but solutions established

- Negotiating next phase of the activity
  – Battery and UHF technologies to be addressed
- Application to higher delta-v missions being assessed

Fly-by Mission Option

- For a Europa fly-by mission the delta-v is higher than the orbital case
- For a typical mission profile the excess hyperbolic speed wrt Europa is 4200 m/sec
- A very large delta-v for the penetrator ~4600m/s
  - Dry mass fraction for this level of delta-v too low to deliver penetrator
- Alternative strategies can make Penetrator delivery feasible
  - The excess hyperbolic speed wrt Europa can be reduced by making multiple flybys at Ganymede and Callisto
  - A more efficient strategy (less flybys) is to approach Europa initially with a lower speed before performing flybys to enter the nominal sequence
- By using a lower approach speed the excess hyperbolic speed can be reduced to approx. 1650 m/s
  - The impulsive DeltaV delivered by the penetrator PDS is now approx 2600 m/s
  - Delta-v impact on flyby mission < 70m/s

Penetrator Descent Module Design



- The PDM is separated from the Orbiter 12 hours before Europa fly-by
- A relatively small manoeuvre (~50m/s) achieves the required pericentre
- After spinning up a solid rocket motor is used to deliver the main braking burn
  - The burn reduces the velocity to ~240m/s 12km above the surface
- Separation of the penetrator and freefall of ~40 s provides ground separation
- Overall mass of 295kg to deliver a 25kg penetrator
- Delta-v capability 3442m/s
  - 30% over requirement
  - Excess delta-v can be used to reduce the delta-v needed on the flyby mission