Airbus Defence and Space – Space Systems

Penetrator for the Exploration of Europa

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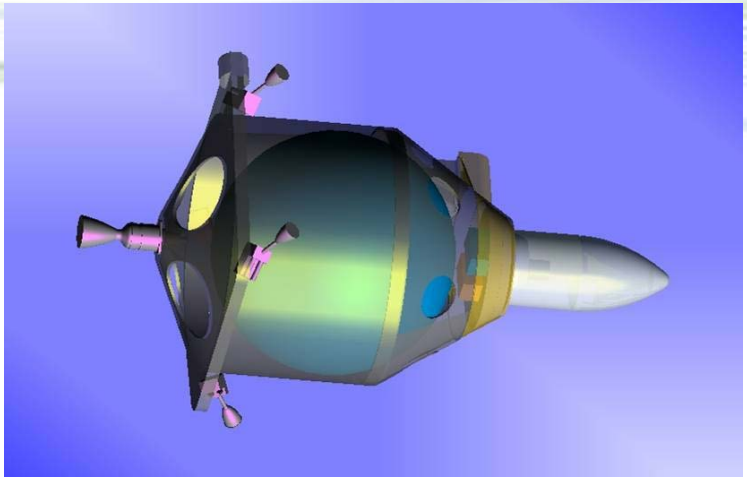
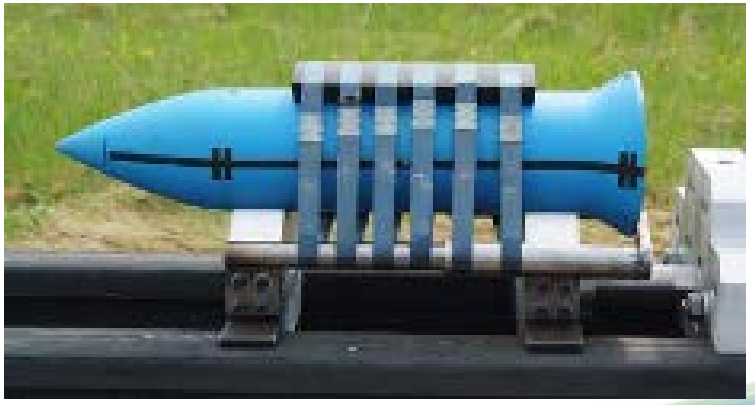
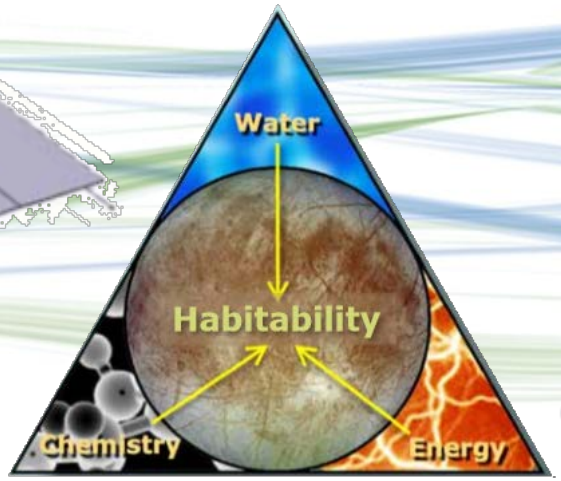
Introduction

- Potential opportunity for a mission to the surface of Europa
  - As part of the NASA Europa Clipper mission
  - Payload focus on astrobiology
- Airbus DS has been building on previous Penetrator development work
  - Early work focussed on instrument selection and penetrator design and concept verification
  - Current activity addresses the delivery via Europa Clipper and the descent vehicle design and penetrator modifications
  - Development of key technologies such as the communications, battery and the drill







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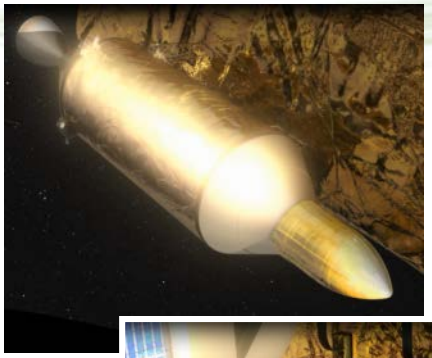
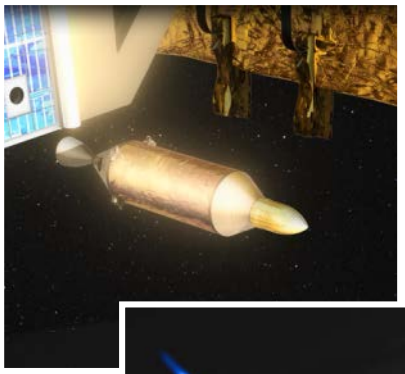
Penetrator Mission Concept

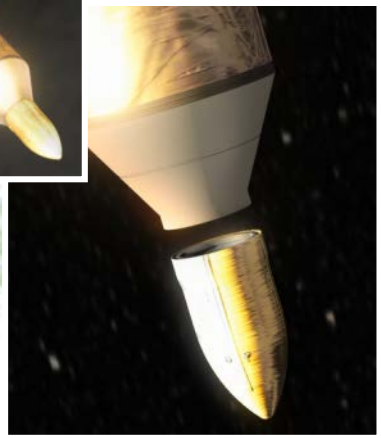


- Journey to Europa on Carrier Spacecraft



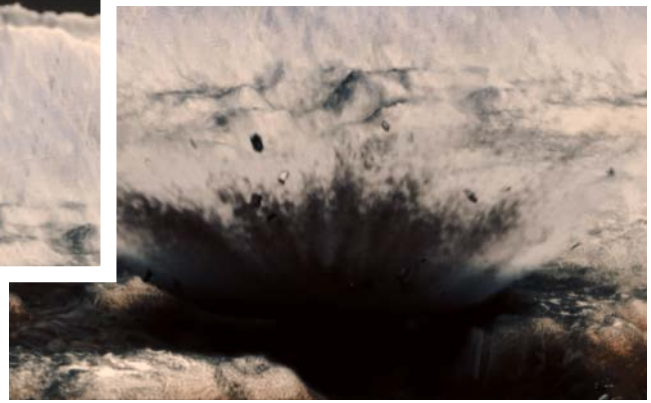
- Release during Europa Fly-by

- Spin up & de-orbit burn of Penetrator Delivery System (PDS)



- Release of penetrator from PDS

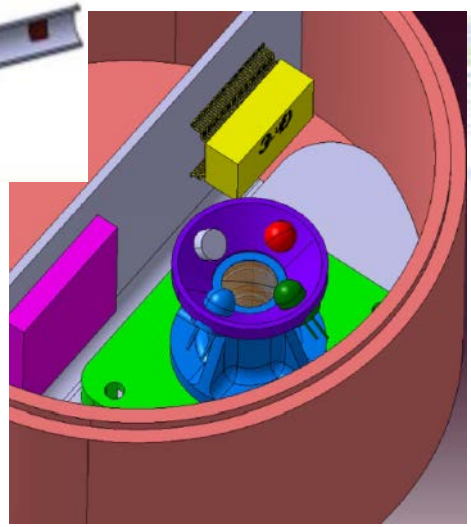
- 300 m/s impact with the surface



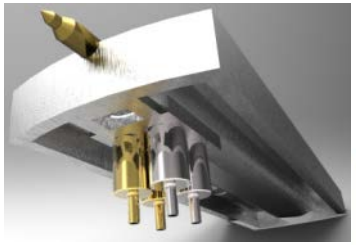
Payloads - E-PAC module

- Key science objective - **Astrobiology**
- E-PAC instrument selection has been performed by ESA and MSSL
  - Instruments selected on both science merit and suitability to penetrator mission (g-loads, low temperatures, PP)
  - Information from previous penetrator related activities (including: penetrator phase-1 and MoonLITE)
  - Sample collection required
- Proposed Instrument Suite
  - Sample Imager (SI)
    - Mineralogy of the sample (by imaging)
    - Biosignatures (by using UV fluorescence and images of cellular and higher lifeform shapes)
  - Habitability Conditions Package (HCP)
    - Test for habitability within the water environment
    - Physical properties e.g. pH, conductivity
  - Biogeochemistry Mass Spectrometer (BMS)
    - To identify and quantify the volatile constituents in the surface and subsurface region

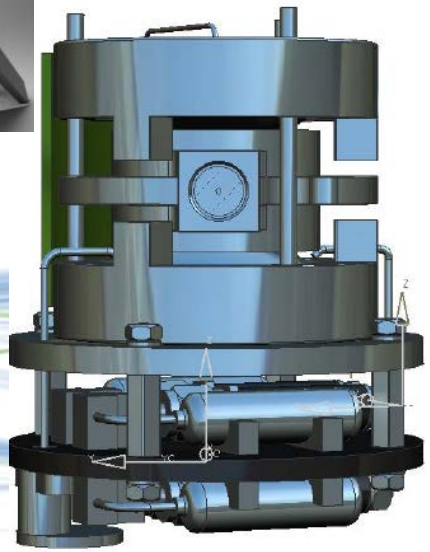
HCP (CAB)



Sample Imager (MSSL)



Material collection mechanism (rapidspace technologies)



BMS (OU)

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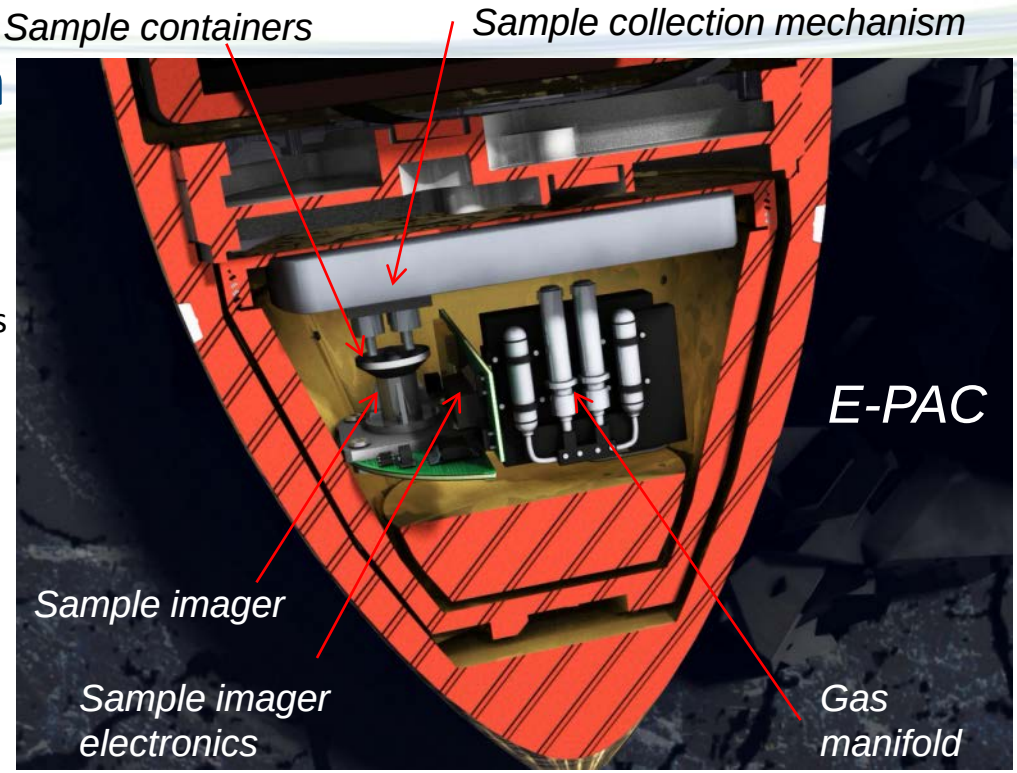
Previous Phase Testing

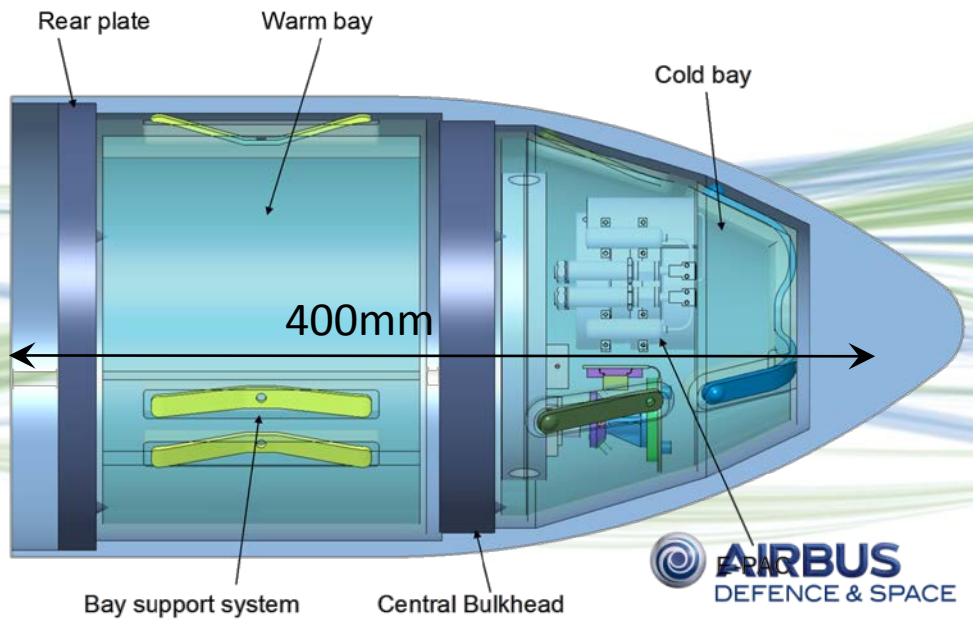
- Mechanical design works well
- Impact conditions survived harsher than expected (340 m/s impact, 25 deg pitch angle)
- Environmental tests before and after impact proved thermal concept was valid
- Some issues identified with internal equipment, drill / mass spectrometer but solutions established

QINETIQ PROPRIETARY

Penetrator Configuration

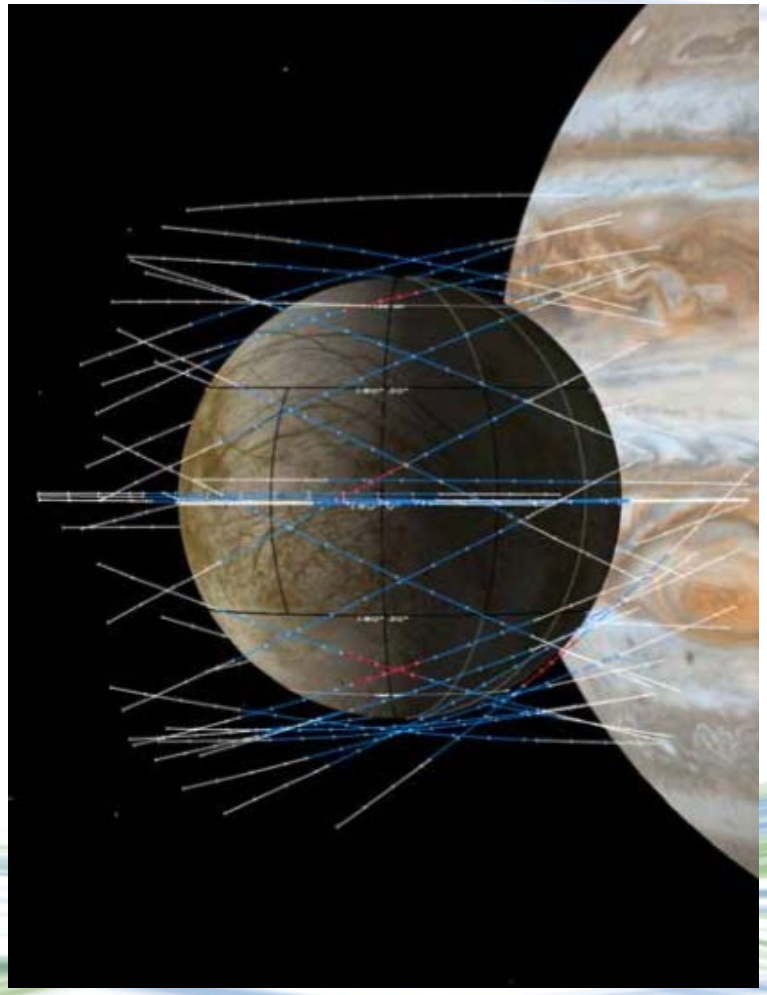
- 80K ice, rapid cool down of instruments
  - Front short lifetime bay houses instruments
  - Rear longer lifetime for data relay
- Bays protected from impact loads
  - Torlon Leaf Springs
  - Provides thermal isolation from shell
- Communications via UHF antenna on the rear plate
- Battery for power until subsequent fly-by by Europa Clipper





Europa Clipper Mission

- Europa Clipper assessment performed by Airbus as part of Penetrator Phase 3 activity
- Penetrator designed for 300 m/s surface impact speed
- Europa Clipper mission:
  - Extended period in a 4:1 resonant orbit with Europa
  - Multiple Europa flybys at 14.2 day intervals
  - “Crank-over-the-top” sequence increases orbital inclination during flybys
  - 4200 m/s hyperbolic speed with regard to Europa
  - Very large DeltaV for the penetrator
    - ~4.6 km/s DeltaV for design impact speed of 300 m/s



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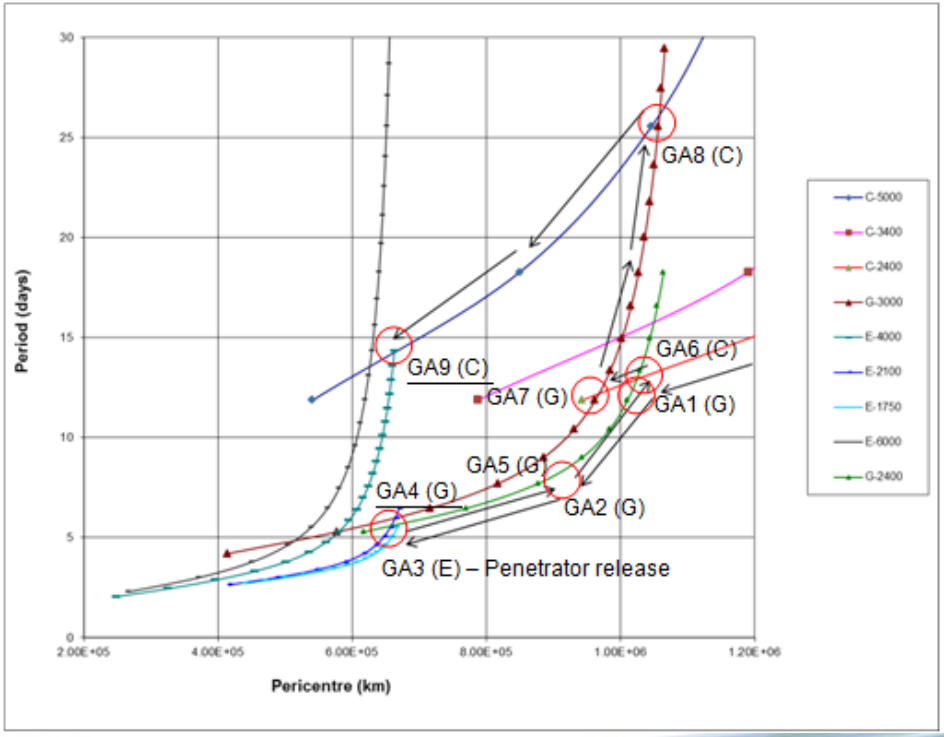
Europa Clipper Penetrator Mission

- Excess hyperbolic speed could be reduced by multiple flybys at Ganymede/Callisto
  - Nominal 4:1 resonant orbit.
  - Flybys to reduce approach speed prior to Europa return (3:2 resonance)
  - Deploy the penetrator as soon as possible to minimise radiation
  - One additional flyby for data downlink
  - Perform additional flybys to return to a 4:1 resonant orbit
- By targeting a temporary Europa 3:2 resonant orbit the excess hyperbolic speed can be reduced to ~1650 m/s
  - The impulsive DeltaV delivered by the penetrator PDS is now ~2.6 km/s
- Modifications to Clipper tour would increase radiation dose – needs assessment



Tisserand plot showing transfer to low speed approach at Europa (3:2 resonance) followed by transfer to 4:1 resonance with Europa

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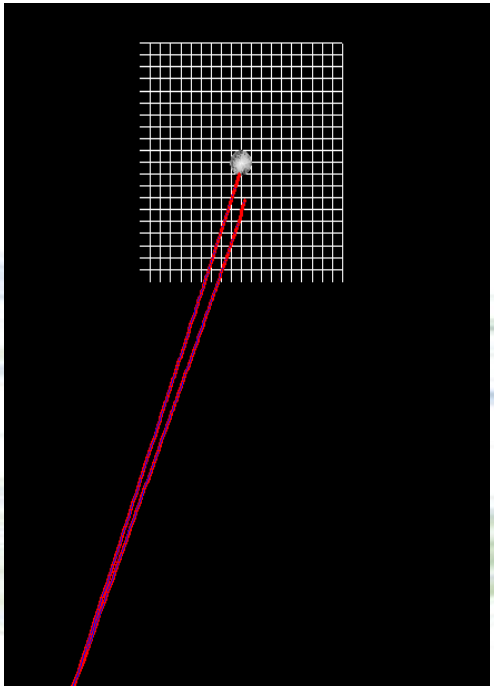
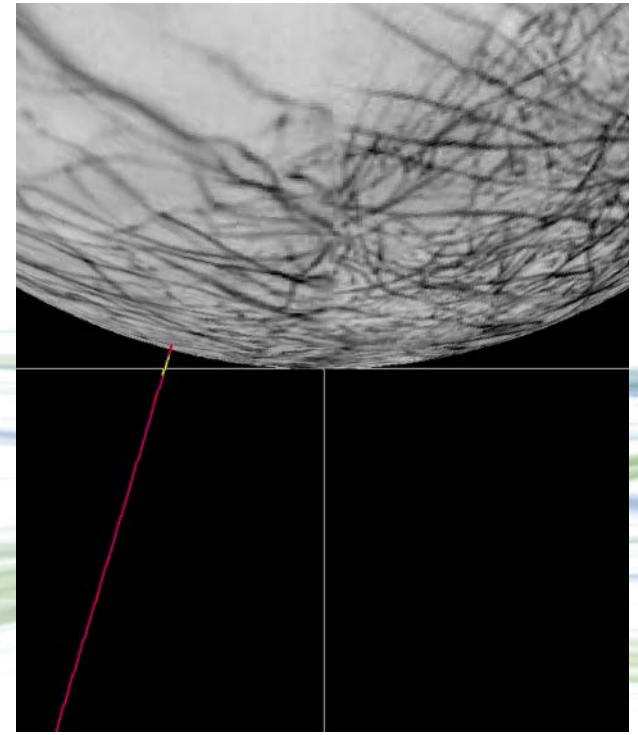
De-orbit Manoeuvre Implementation – Radial approach

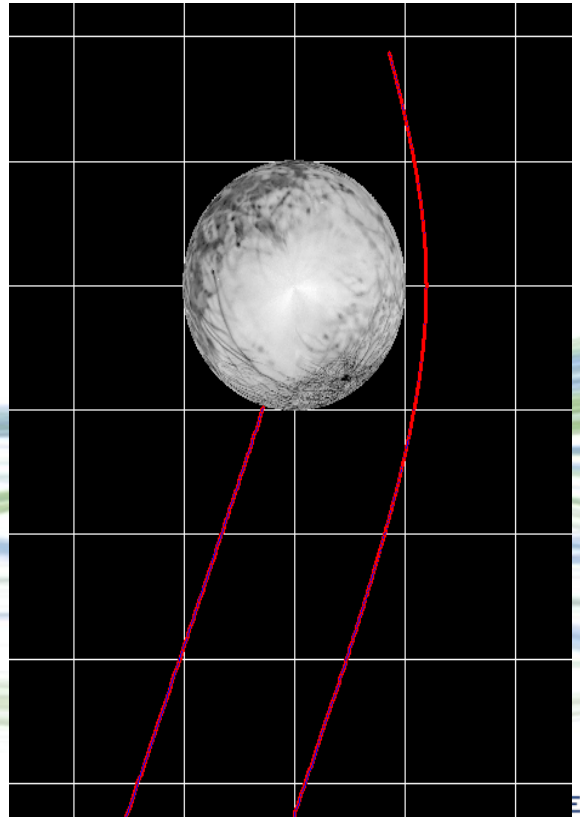
- Penetrator radial approach and Orbiter flyby trajectory (with Penetrator manoeuvre applied to improve visibility – 60 deg achieved at impact)



- PDS retro manoeuvre (yellow) prior to final freefall to surface (red)



- Orbiter flyby trajectory continued after impact, loses visibility until next flyby

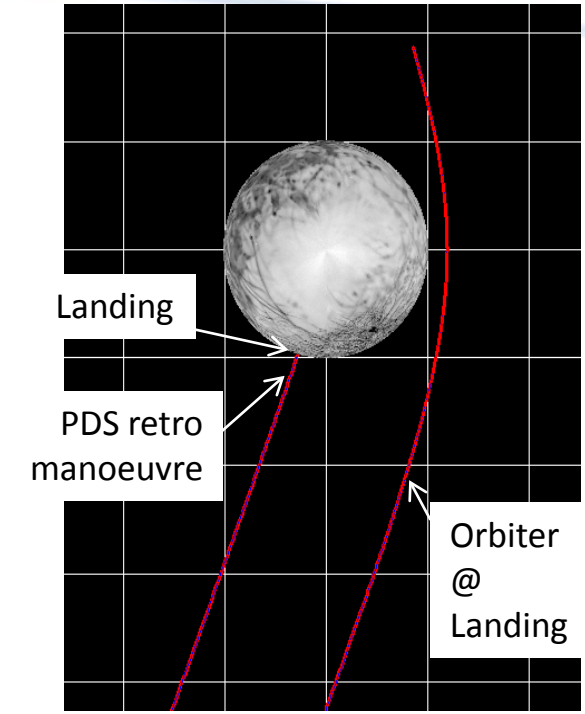


Europa Clipper Penetrator Requirements

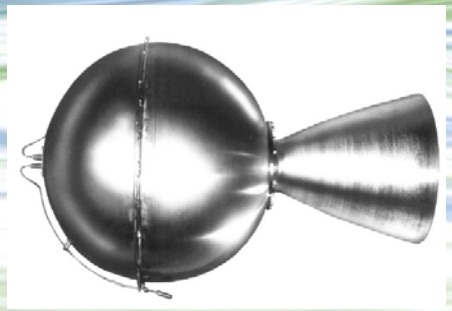
- Impulsive DeltaV delivered by the penetrator
  - 2640 m/s (with 10% margin) – solid rocket motor
  - Additional 80 m/s for targeting – small liquid propulsion system

- Solid rocket motor (SRM) of Penetrator Delivery System (PDS)
  - Quick burn, reduced losses
  - Reduced Isp with respect to bi-prop but low dry mass fraction
  - High reliability over high number of tests and flights
  - Modifications to available off-the-shelf engines to allow mass reduction

- SRM fired shortly before landing to minimise the velocity increase with the freefall to the surface
  - Surface gravity 0.134 g with no air to slow things down
  - Timing is critical!



Separation



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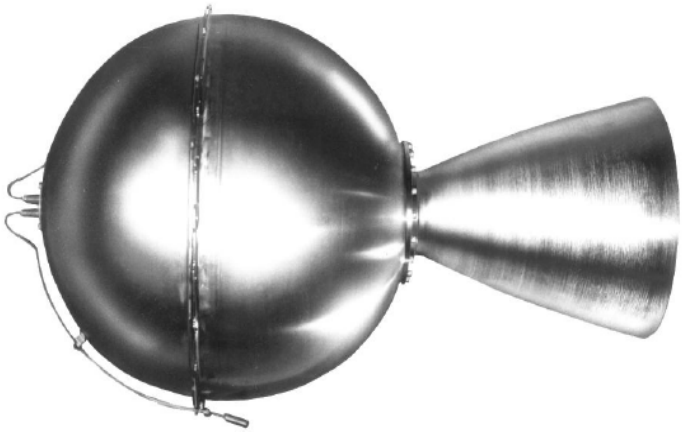
PDS Solid Rocket Motor Selection

- Two options, STAR 24 and STAR 17
- STAR 24 SRM
  - 3442 m/s DeltaV capability
  - 30% over the requirement
- Assumed that reducing the capability of the STAR 24 will be easier than increasing that of the STAR 17
- Off-the-shelf PDS system mass = 295 kg
- Possible mass saving: Reducing the solid propellant from 200 kg to 130 kg matches a DeltaV of 2640 m/s
  - Overall PDS mass = 226 kg
  - In-line with the potential NASA opportunity



Penetrator Europa Clipper - Star 24			
Subsystem	Current Best Estimate (kg)	Design Maturity Margin (kg)	Total CBE + DMM (kg)
Penetrator	20	5	25
Structure	7	1.4	8.4
Reaction Control System	7	0.6	7.6
Command and Data Han	0.4	0.1	0.5
Power	5	0.3	5.3
Harness	0.8	0.2	1
AOCS	0.6	0.1	0.7
Separation Mechanism	3	0.6	3.6
TOTAL	**81.3**	**9.8**	**52**
System Mass Margin		20%	10.4
TOTAL DRY MASS	**81.3**	**9.8**	**62.3**
RCS Propellant			16
Solid Rocket Motor	217.2		217.2
COMPOSITE MASS			**295.5**

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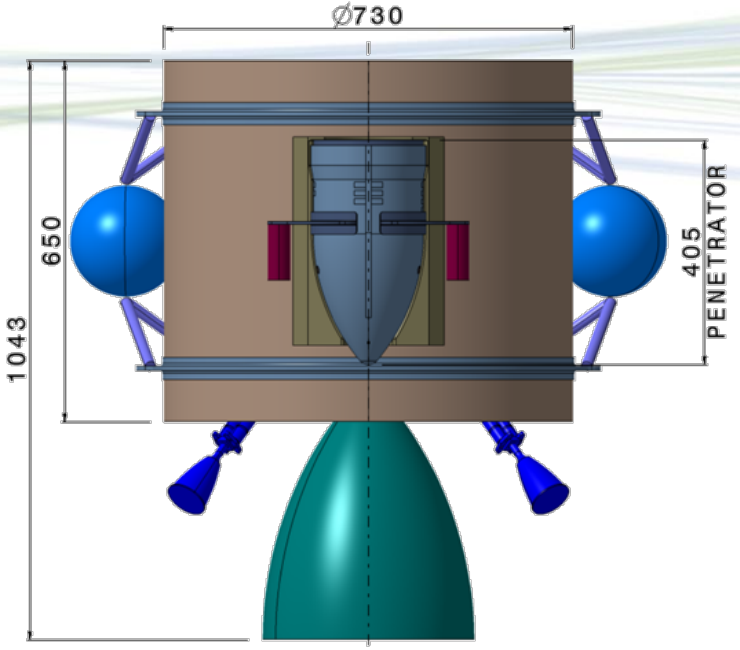
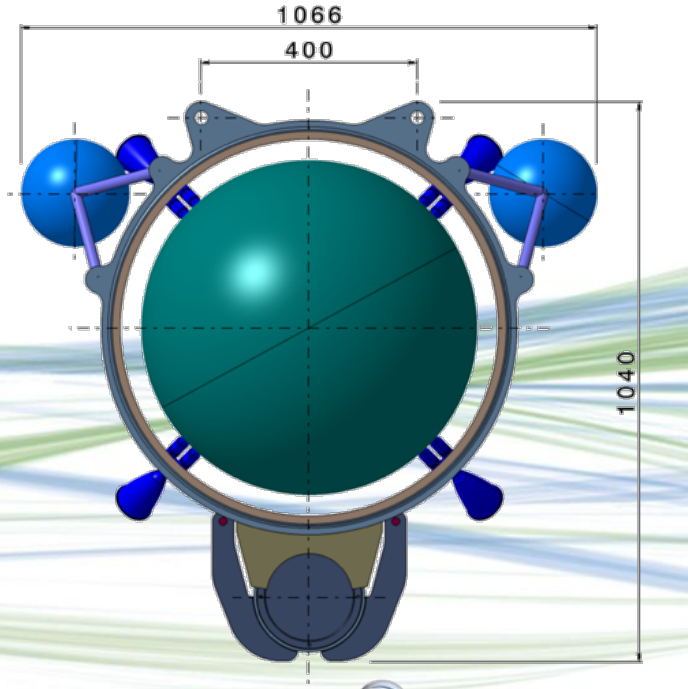
PDS Configuration Concept

- Penetrator delivery system (PDS) provides
  - Large delta-v for de-orbit burn
  - Attitude control via small liquid system
  - Descent timing via small OBC
- Penetrator is passive during descent with natural separation due to PDS spin
- Delivery system provides all functions required
  - Processing
  - Power
  - Propulsion
  - Mechanical system and deployment
- 295 kg system (some scope for mass reduction) and similar volume to Huygens on Cassini





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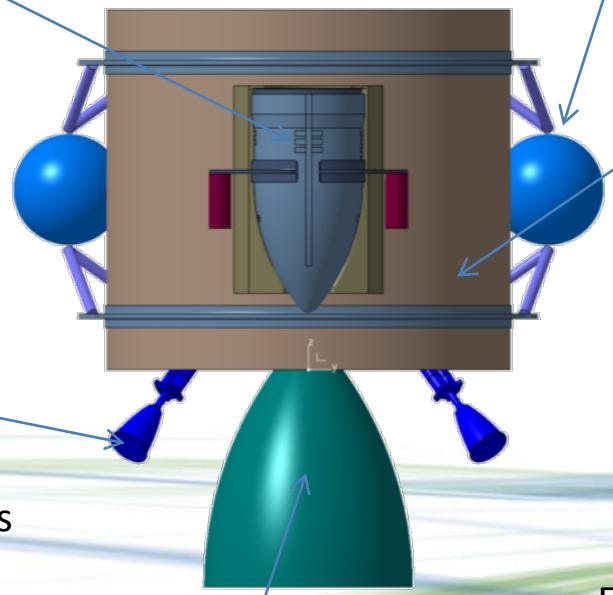
PDS Configuration Concept

Side mounted Penetrator.

- Held in a cradle with release mechanism.
- Penetrator will be imparted with an angular spin rate for stability
- Naturally separates Penetrator and PDS so no dedicated collision avoidance PDS manoeuvre is required post separation

2 x monopropellant tanks, provide balance along the spin axis of the PDS



Main cylinder

- SRM equatorial mounting ring coupling
- Height for RCS thruster tanks, thrusters, penetrator, equipment and orbiter interface points
- Thermally insulated with MLI

4 x 20N monopropellant attitude control thrusters

- Pointing and spin up of the PDS
- Monopropellant thrusters are selected (lower complexity, minimal mass impact)

Equipment (star tracker, gyro, power, OBC and comms)

ATK STAR 24 SRM

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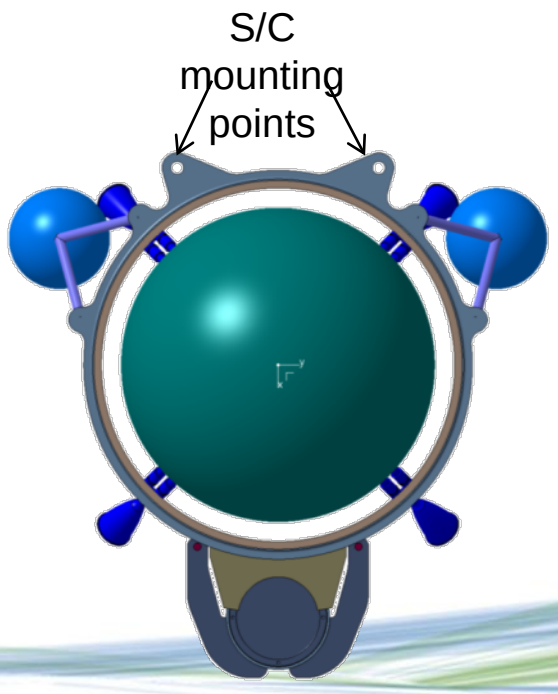
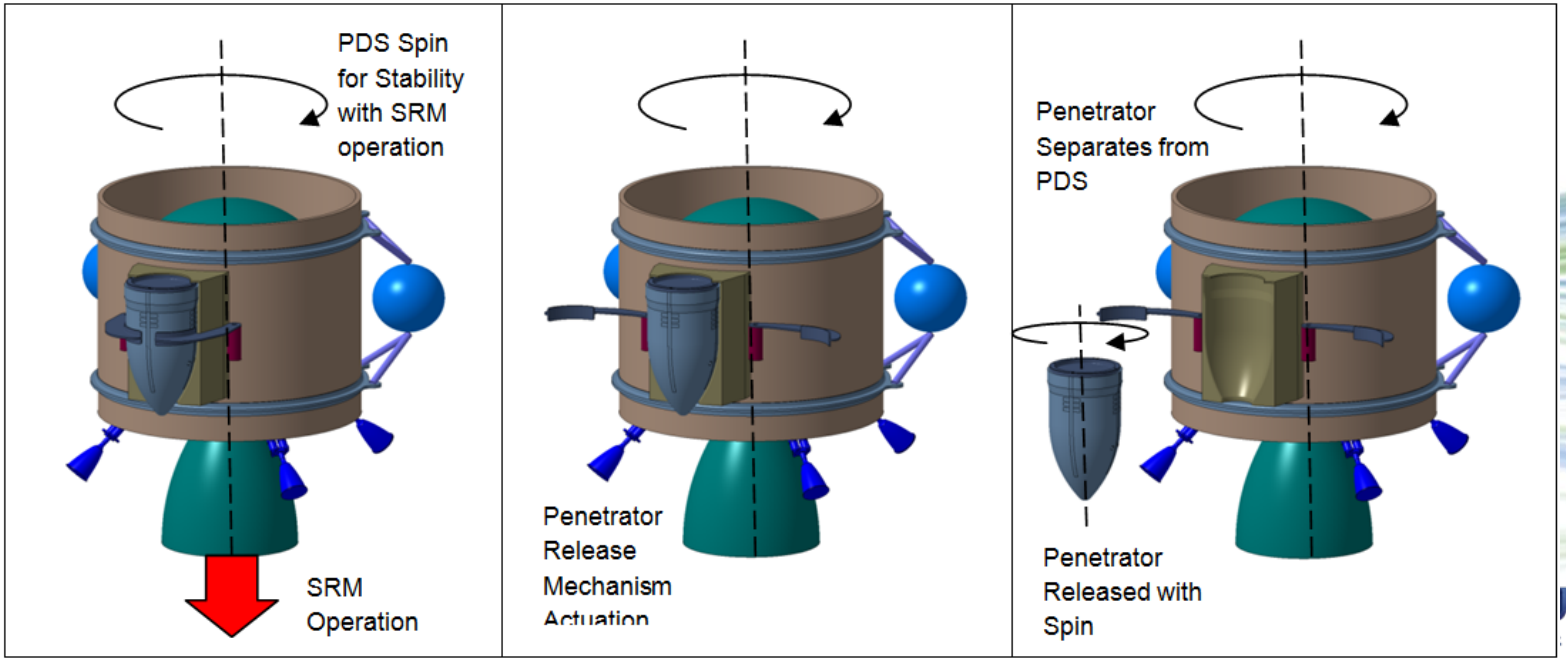
Interfaces to Clipper Spacecraft

- Mechanical configuration keeps one side of Penetrator system free for interface
- Simple hold down and release system (4 x pyros) required to separate from orbiter
- Off-axis mounting required, impact on S/C CoG to be considered
- Electrical interfaces and harness required during transfer, power and communications
- UHF link required post separation
  - Monitor penetrator during descent
  - Collect data from penetrator on next fly-by
- Standard Electra system could be used on S/C



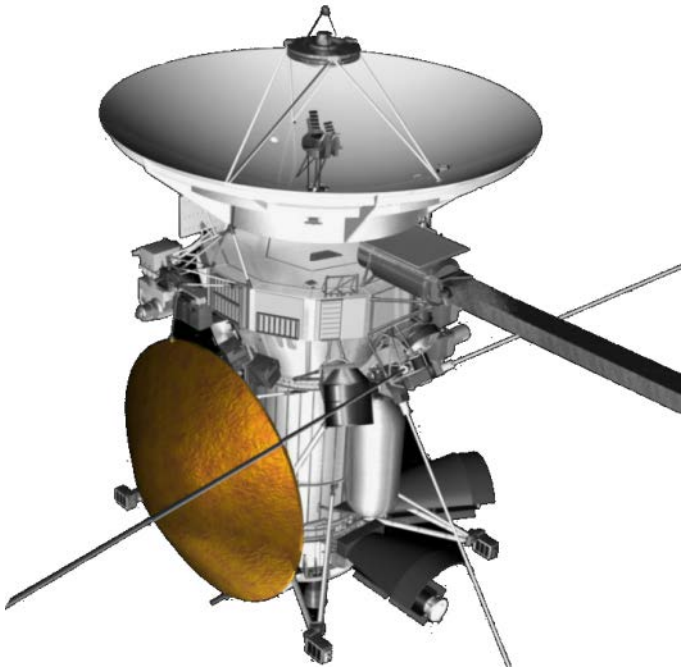
GNC Timeline and Release Sequence

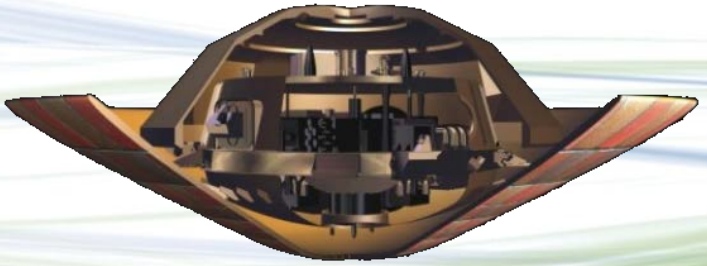
- Release from carrier → 12 hours ahead of impact time
- Rate damping phase → controlling separation tip-off
- Attitude acquisition phase → 3-axis attitude control
- Orbital modification (targeting centre of Europa) → using RCS system
- Spin up phase → using RCS system
- Possible spin-axis direction trimming manoeuvre → using RCS system
- Solid Rocket Motor burn → 30 seconds to terminate at 12 km altitude
- Separation phase → release from spinning PDS passively gives separation
- Impact → at 300 m/s after ~12 km freefall

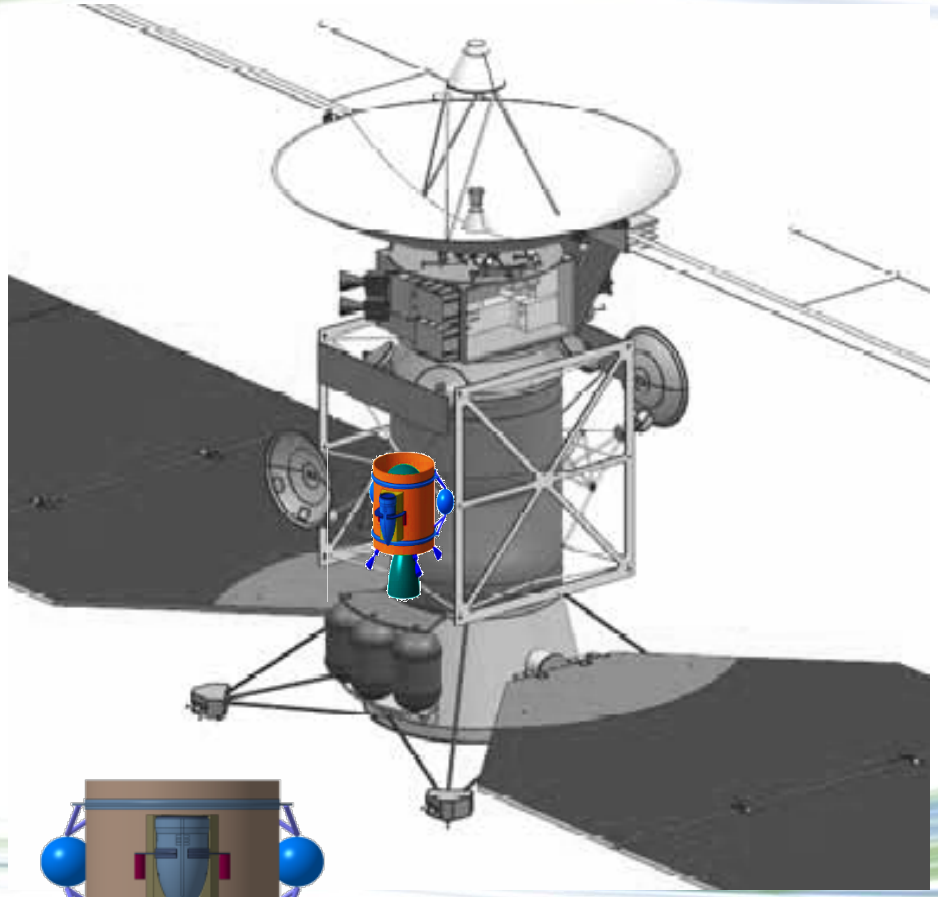


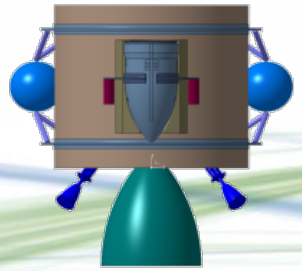
Penetrator Accommodation on Europa Clipper

- Comparison with Cassini Huygens









Huygens: ~2.7 m in diameter, ~0.9m depth
Mass: 320 kg

Penetrator: within ~1m x 1m x 1m box
Mass: Between 200 kg and 300 kg

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Conclusions

- Only limited updates required to Penetrator design for Europa Clipper application
  - Key technology developments underway
  - Angle of attack may be higher than 8 deg, but survivability at higher angles demonstrated during test
  - To minimise the mass a solid rocket motor solution is selected
- A penetrator design for the Europa Clipper mission appears feasible based on our analysis
- Some small alterations to the NASA mission profile and spacecraft are required
- Accommodation on the spacecraft should be feasible provided there is sufficient mass available
- Opportunity for ESA/NASA collaboration