Progress in the Development of the Space Debris Harpoon

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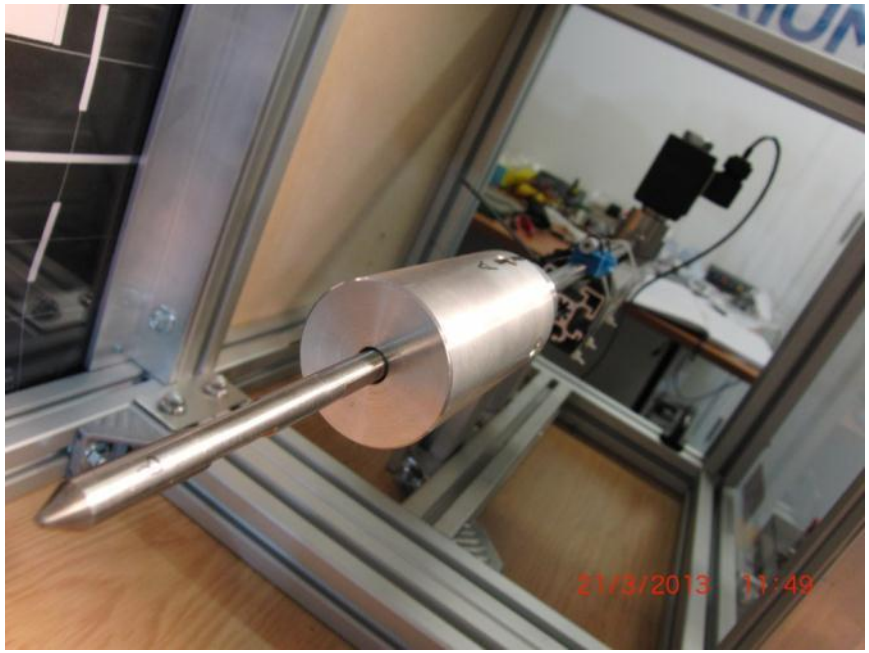
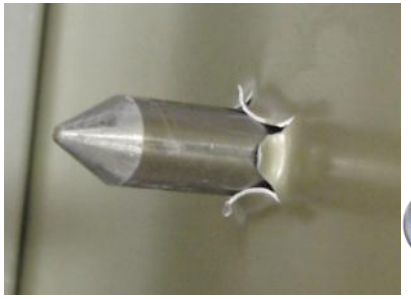
Introduction

- Why the harpoon
- RemoveDebris “mini” harpoon development
- Further development of the harpoon capture system beyond the RemoveDebris demonstration

- Activities to date :
  - *Airbus DS R&D to demonstrate of harpoon concept of panel capture*
    - *Harpoon system concept sizing*
    - *Building up of Stevenage test facility*
    - *Characterisation of the subordnance ballistic properties of structure panels*
    - *Assessment of accuracy of simple system*
  - *Design of RemoveDebris Mini-harpoon & KO of EQM programme*





Why Harpoon?

The harpoon system has several attractive features which led to its study:

- Low mass and volume leading to the possibility of many harpoons on a single host spacecraft
- Relative simplicity leading to high reliability, low development risk and low cost
- High firing speed means compatibility with objects spinning at fast rates
- Short duration from deployment to capture and a safe stand off distance
- Compatible with any object having a suitable surface
- Easy to test on the ground with highly representative targets
- Operational flexibility as the operation plan can be adapted to unforeseen events

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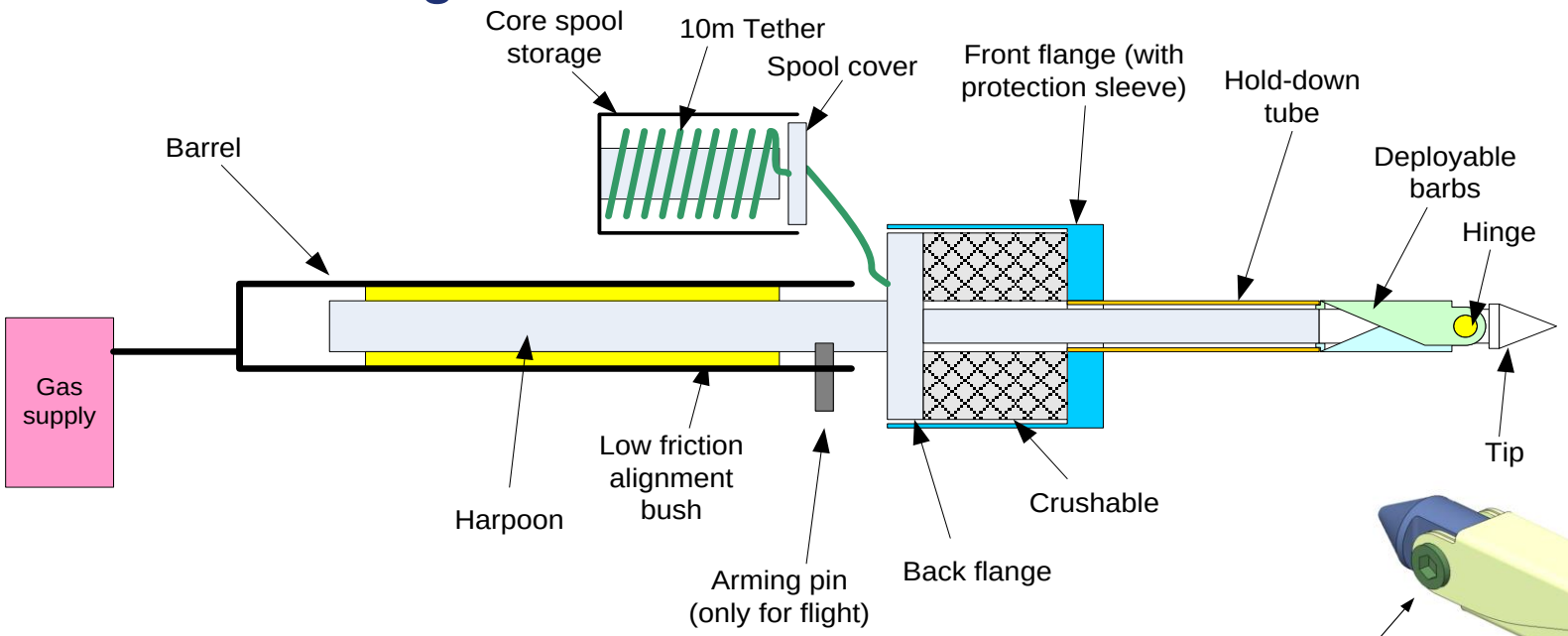
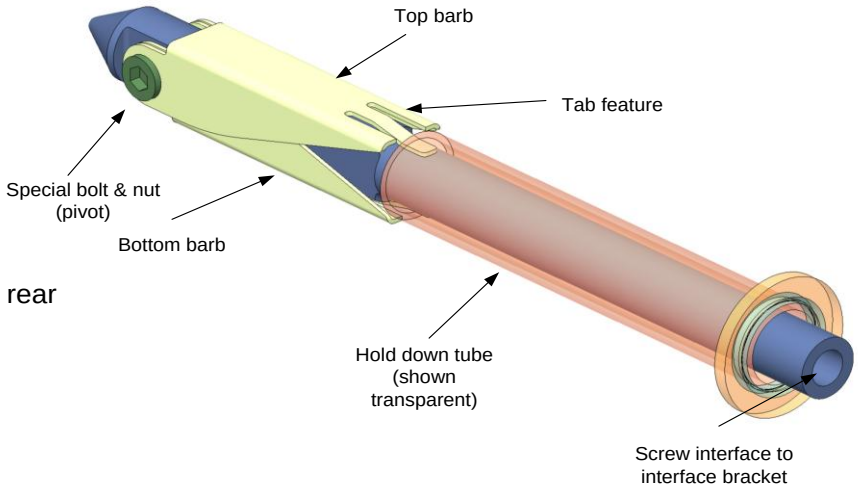
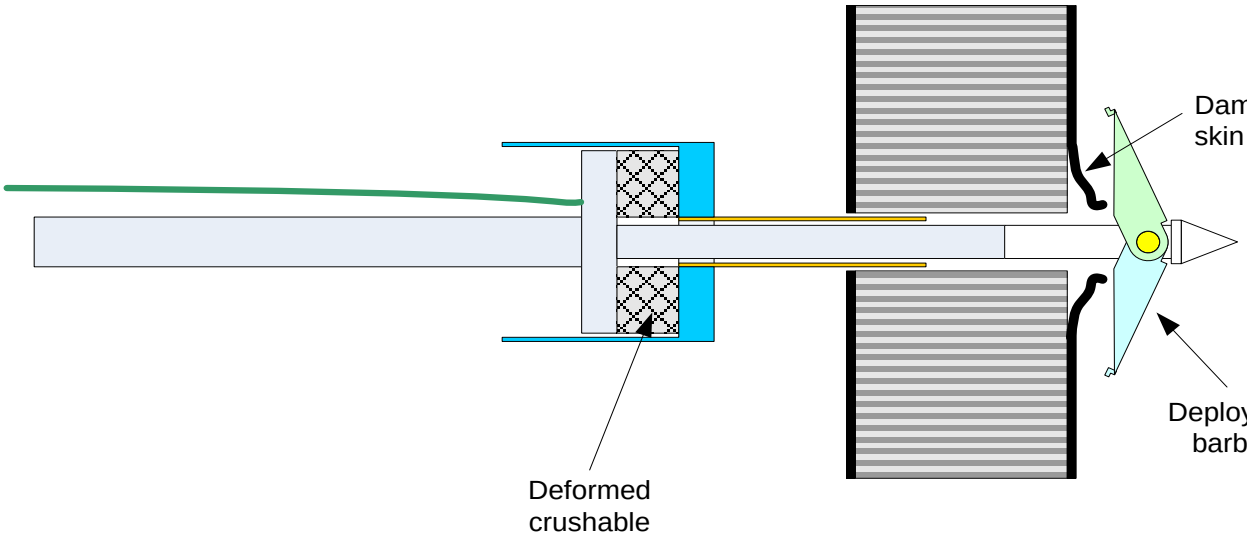
Baseline design schematic







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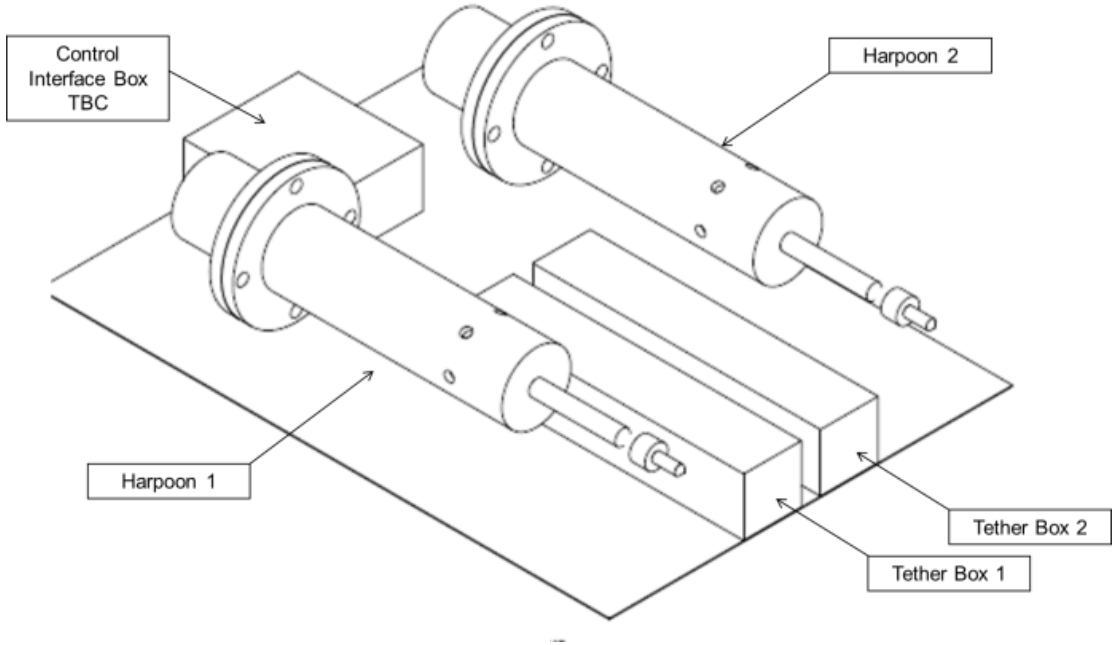
RemoveDebris Harpoon Objectives

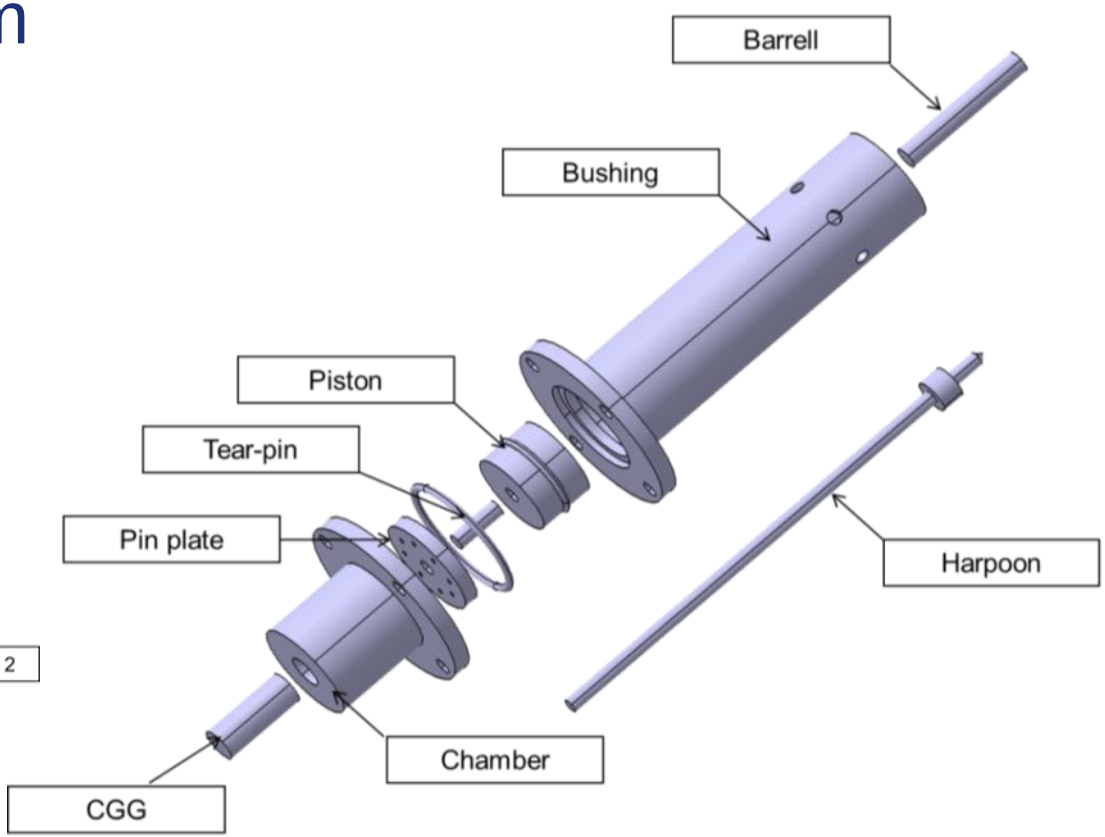
Why test the harpoon in space? – Raise the TRL!

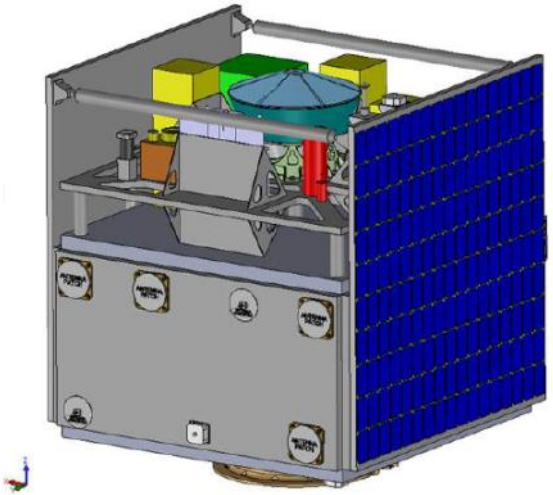
1. Tether deployment mechanism :
   - Tethers historically difficult to deploy successfully in space. Reliable, high speed tether deployment and release mechanism to be developed during project.
2. Firing system :
   - Compressed gas and piston lubricant, characteristics different under vacuum conditions. Characterisation of properties on orbit important for future missions.
3. Targeting :
   - Advantage to harpoon if the nominal harpoon experiment includes targeting in the loop. Demonstrating on orbit of targeting system will reduce a few of the concerns regarding the harpoons pointing requirements.

Achieve TRL 6 for the harpoon system by 2017

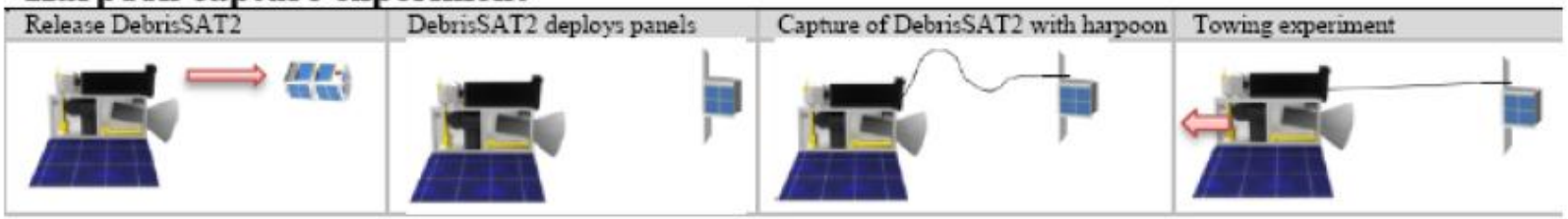
RemoveDebris Harpoon System







Harpoon capture experiment



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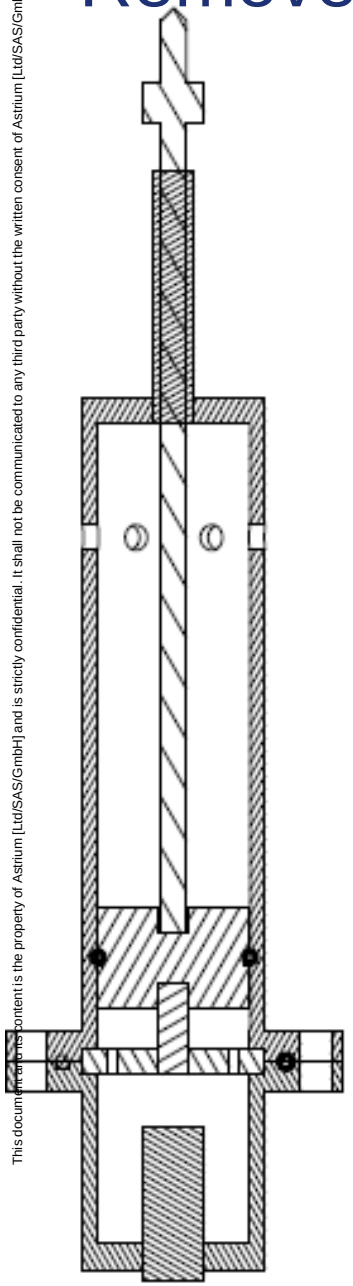
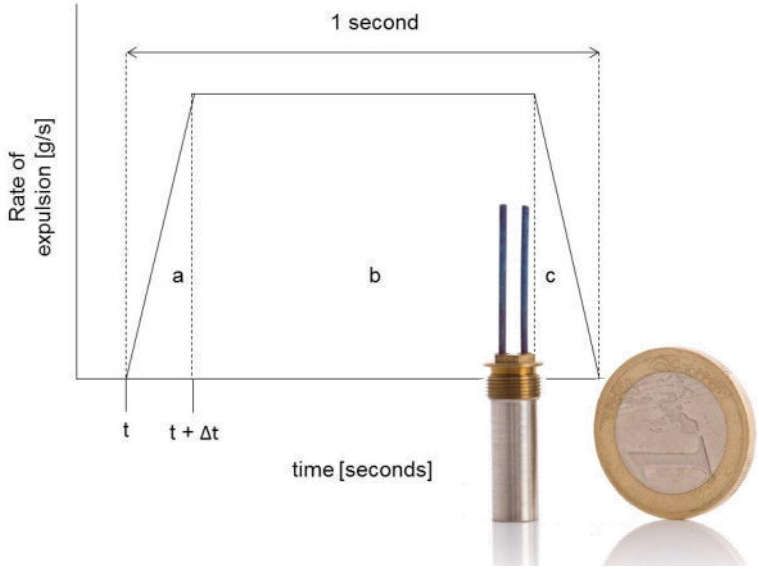
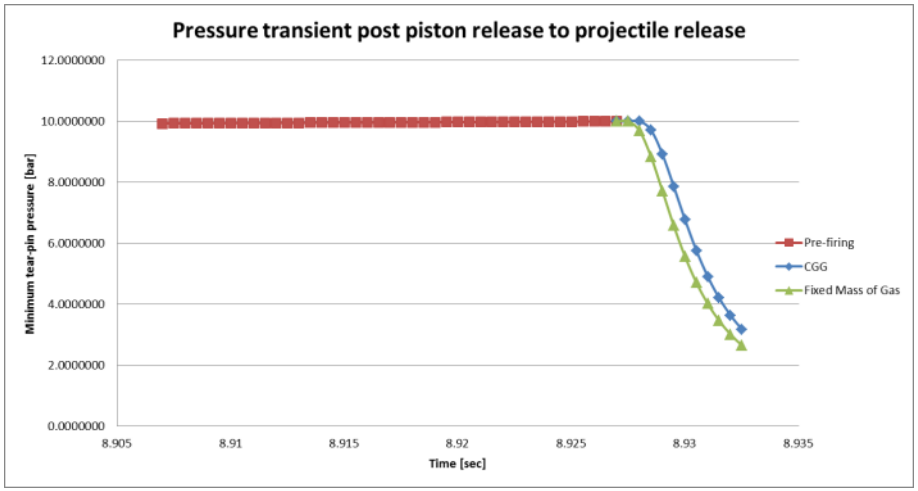
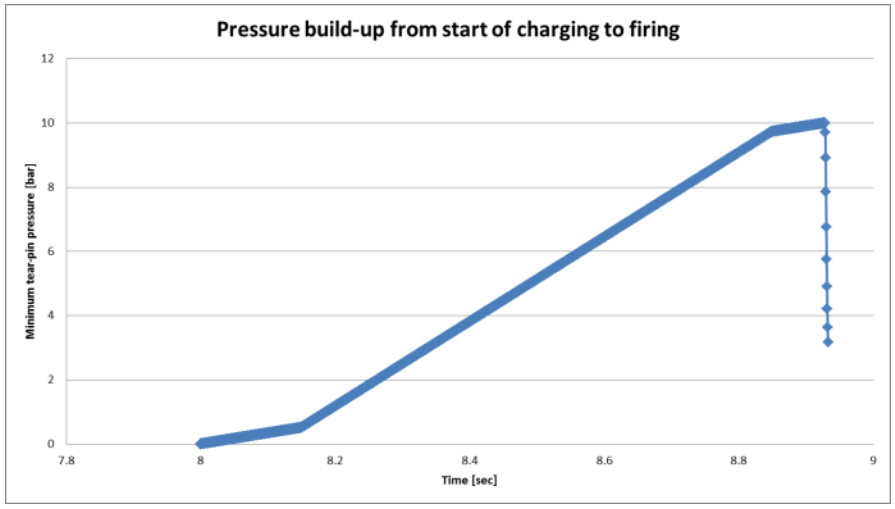
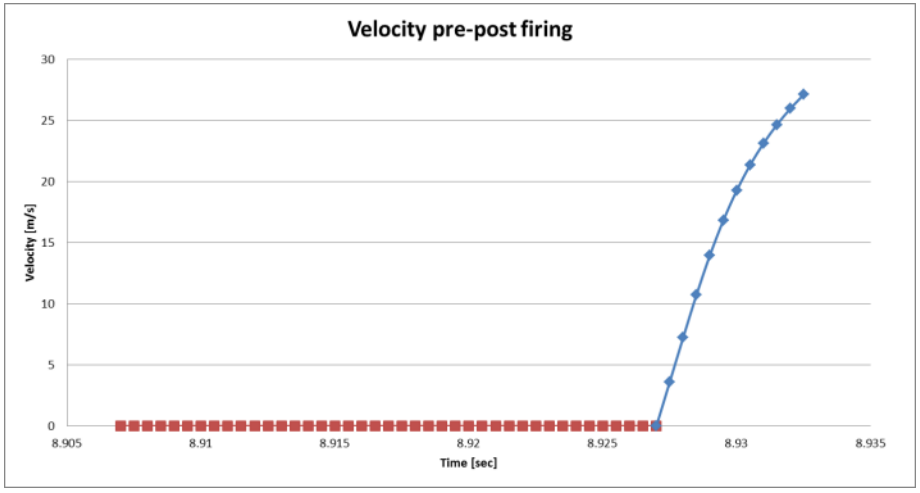
RemoveDebris Firing System – Gas Generator











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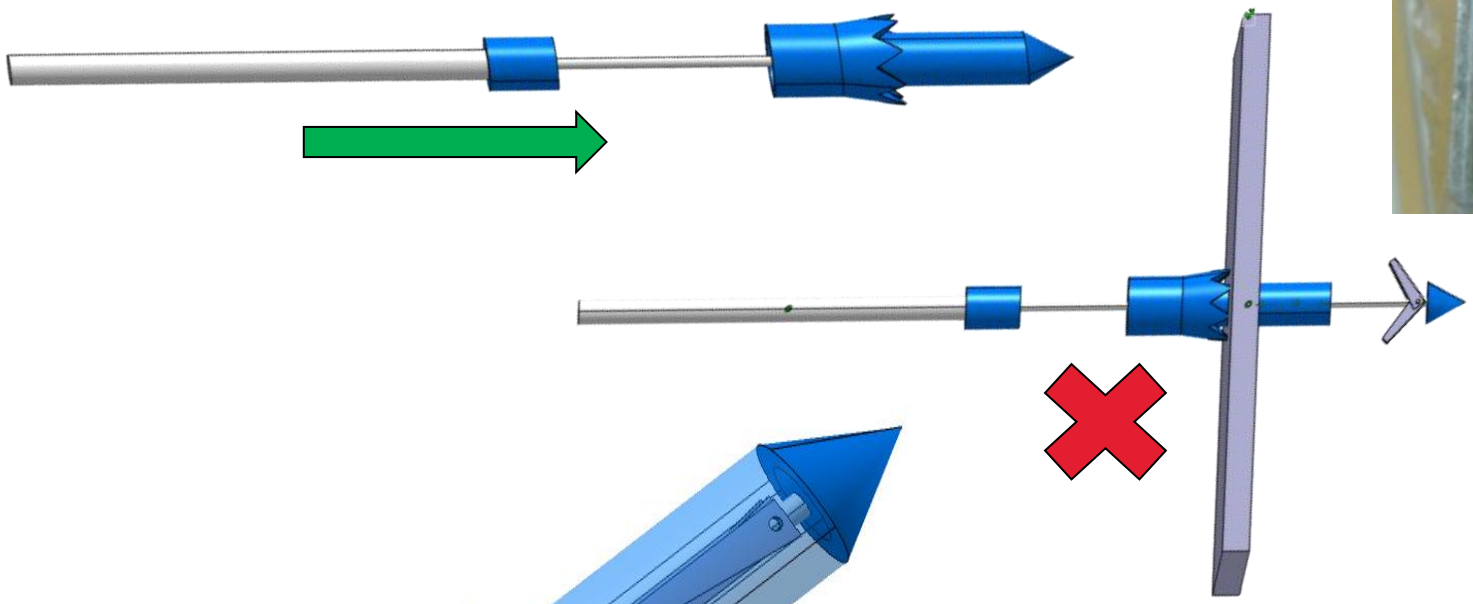
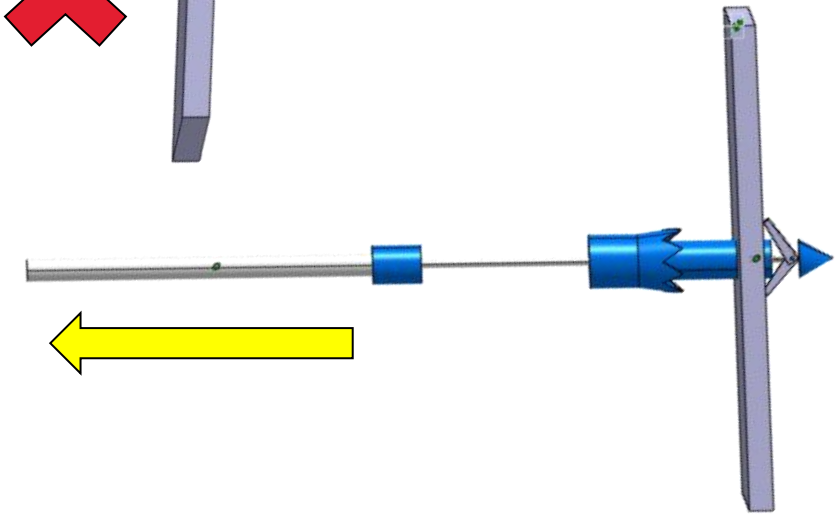
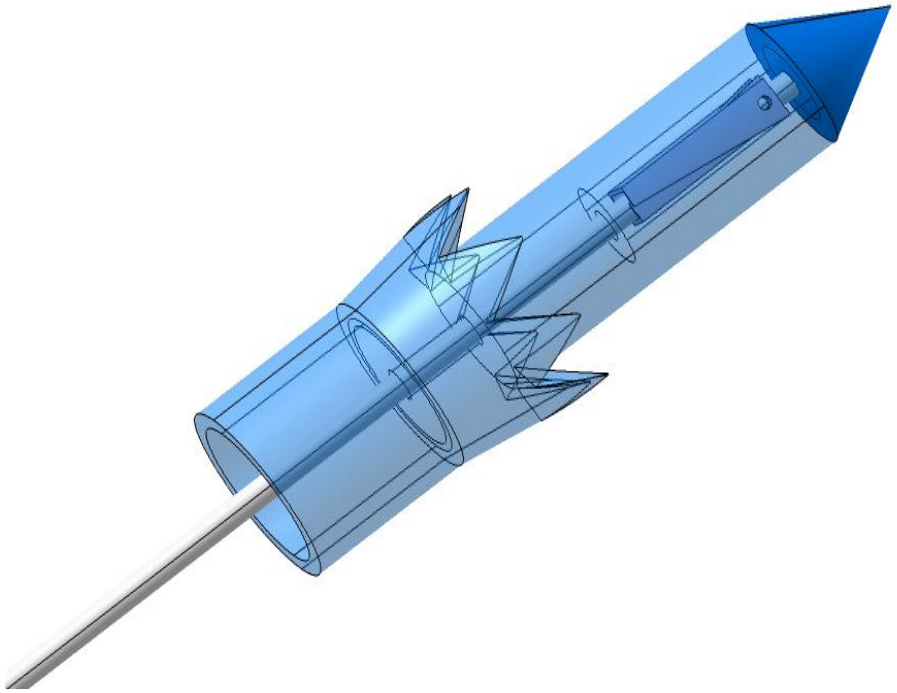
RemoveDebris Projectile







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RemoveDebris Tether

- Tether attached to harpoon, location on projectile.
- Presence of tether is used to demonstrate :
  - Free release of tether at high velocity under microgravity conditions.
  - Allow towing experiment upon successful capture
- Main functional aspects of tether and deployment mechanism :
  - Storage and deployment mechanism (flight approach under test)
  - Tether cutting mechanism to release tether post capture
  - Tether clamp (tether-platform secure attachment upon successful capture, likely timer on projectile release)
- Deployment mechanism has the undergone majority of testing to date, two options selected for further testing :
  - “Figure 8 core” (Rosetta approach)
  - “Cable Tied Feed”

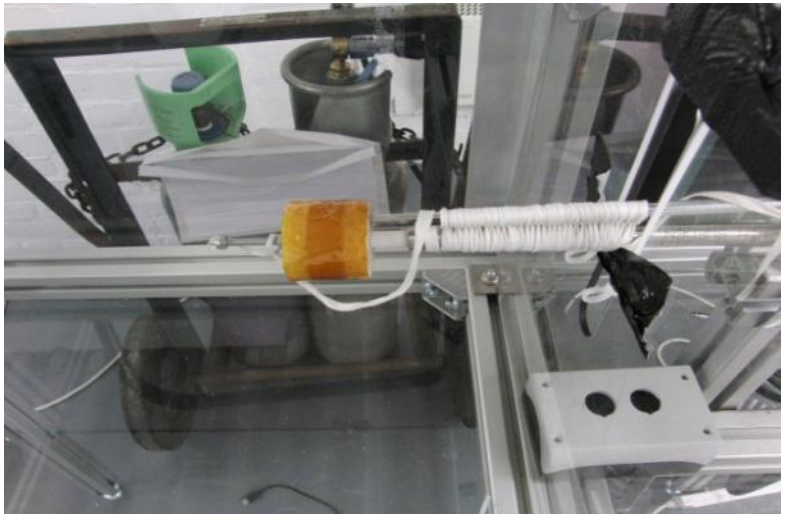
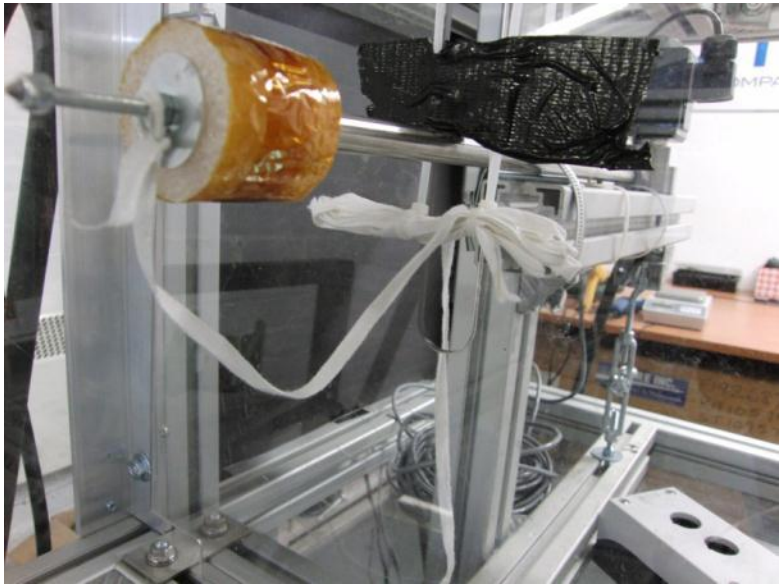


Figure 8 Core



Cable Tied Feed

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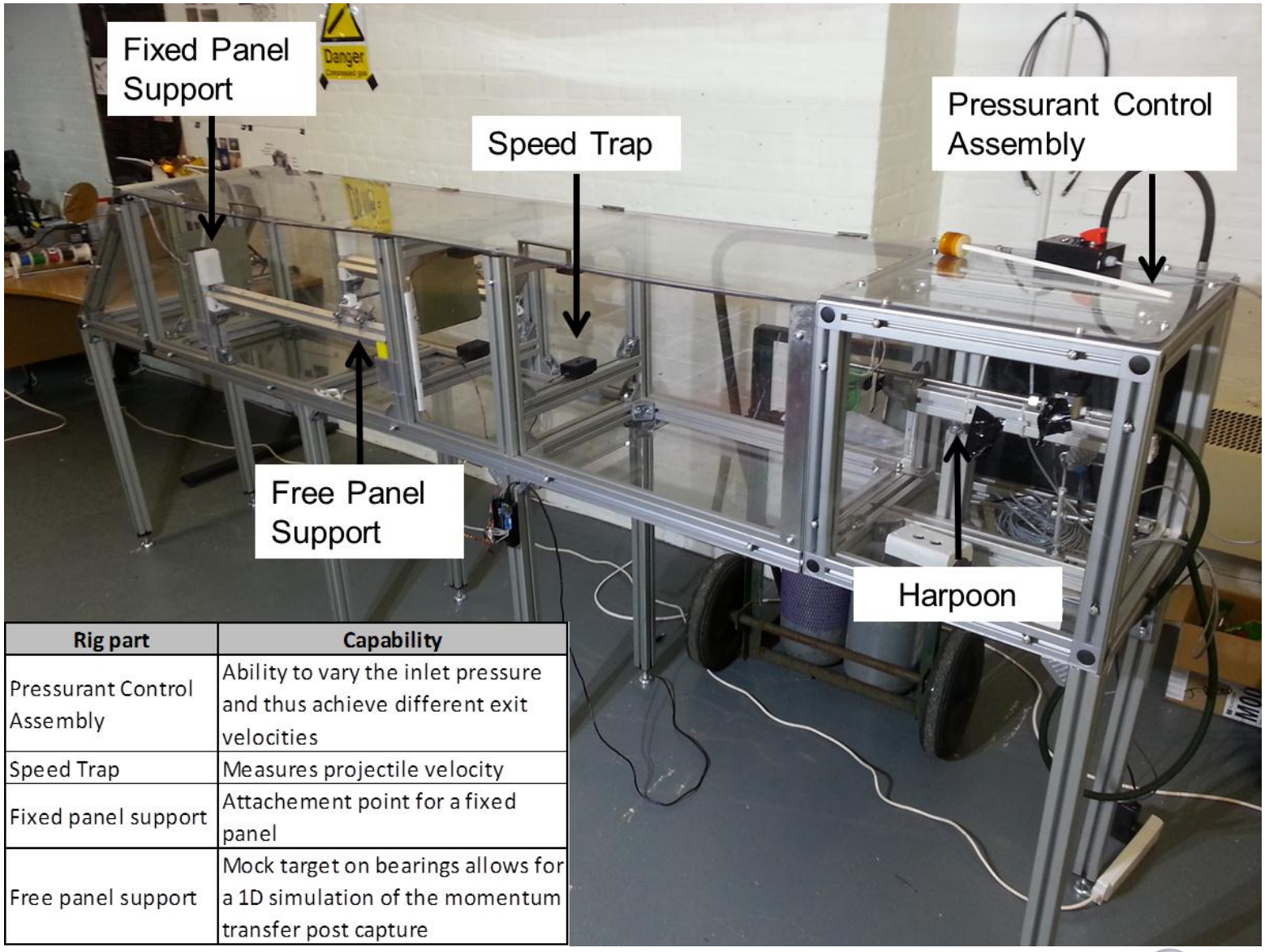
Airbus DS Test Facility for RemoveDebris



Rig part	Capability
Pressurant Control Assembly	Ability to vary the inlet pressure and thus achieve different exit velocities
Speed Trap	Measures projectile velocity
Fixed panel support	Attachement point for a fixed panel
Free panel support	Mock target on bearings allows for a 1D simulation of the momentum transfer post capture

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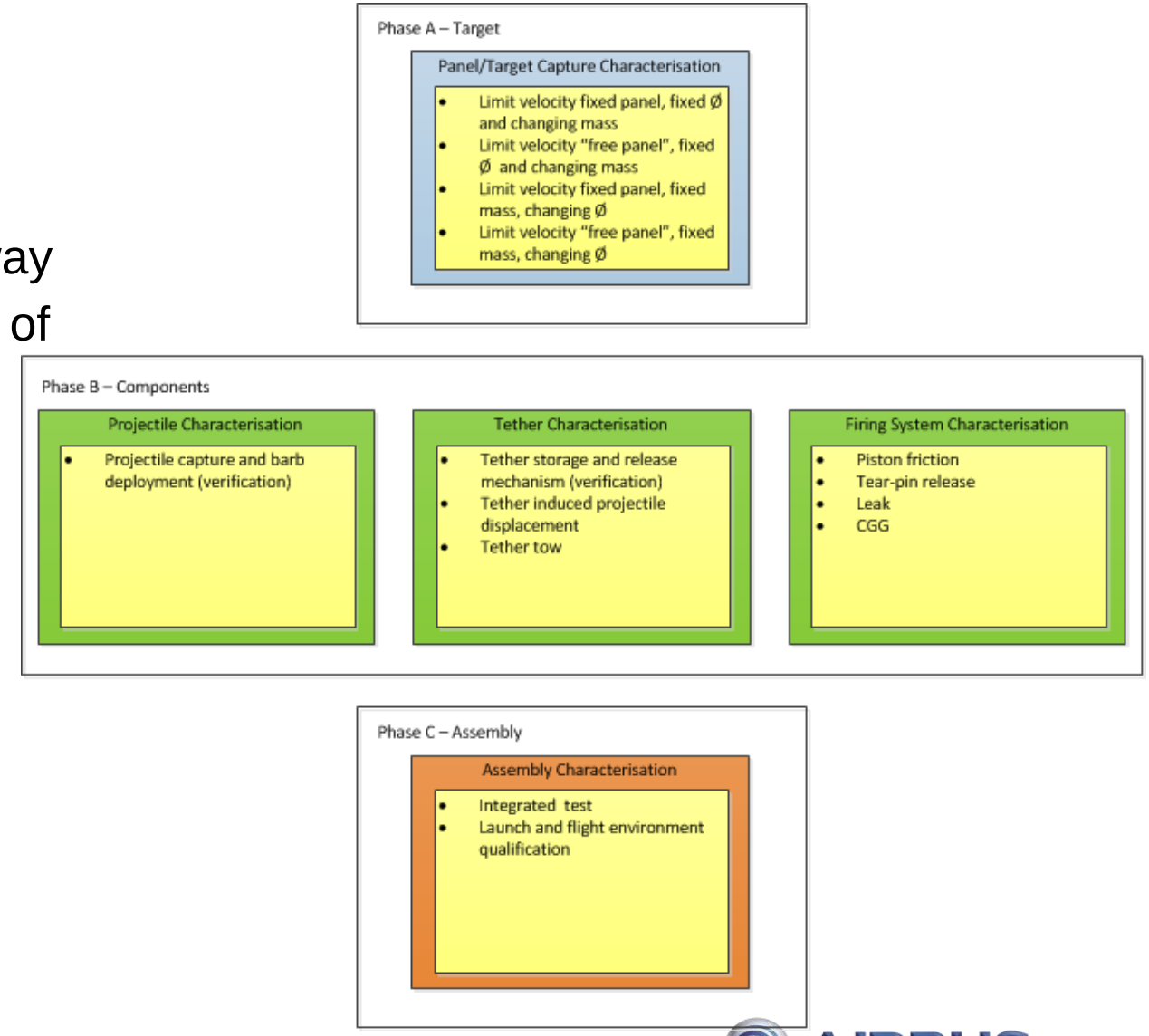
RemoveDebris Next Steps

- EQM kickoff leading to full characterisation of flight design
  - Procurement of EQM h/w underway
  - Testing to support the finalisation of the projectile design
  - GG downselection underway
  - EQM test campaign
- CDR Q4 2014
- FM build up following



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Future Application of Harpoon to ADR Missions
Development for Large Significant Targets

- **Challenges for the Large Harpoon Capture System**
  - Selection and tracking of capture point on target – Harpoon Firing Accuracy
    - *Opening potential targets to heavier structures – potentially reduce pointing accuracy req.*
    - *Ensure generation of secondary debris is controlled with expansion of target envelope*
    - *Compatibility with rotating target and minimising the need for the chaser system to track (on board autonomy)*
    - *Clarify pointing accuracy and design harpoon system to reduced demand on spacecraft system*
  - Towing of target from a single point
    - *Loads on the harpoon and on the structure with a rotating target*
    - *Possible degradation of structures and materials following long exposure*
  - Verification of successful capture
    - *Sensors on harpoon*
    - *Backup approach using chaser sensors (vision based/AOCS)*
  - Redundancy and Failure Tolerance
    - *Multiple harpoon system*
    - *Release of failed harpoon and subsequent deorbit*
    - *Harpoon tether rebound if target is missed*

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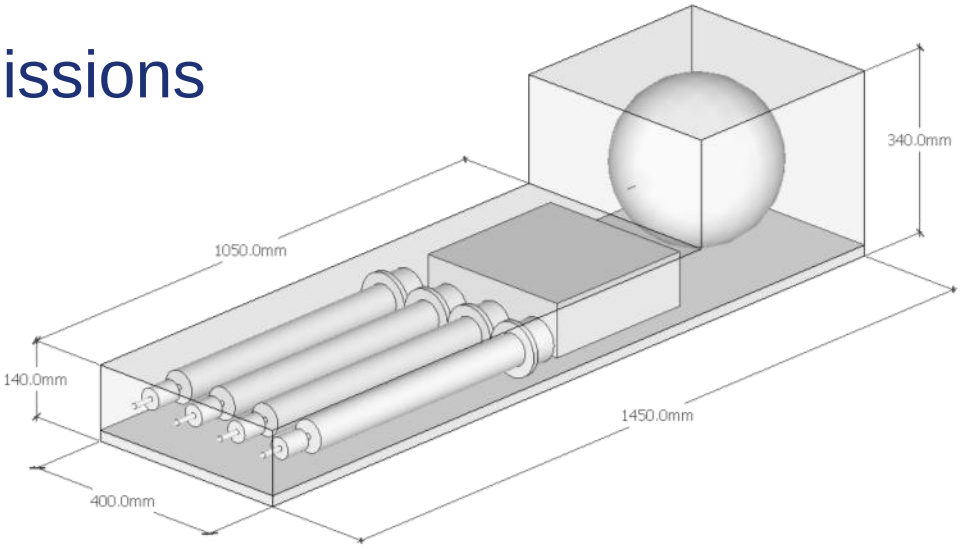
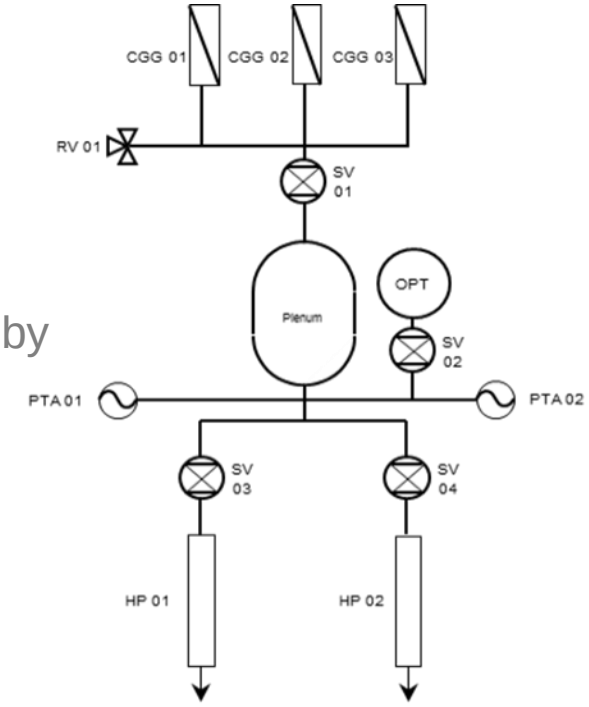
Future Application of Harpoon to ADR Missions
Next Steps

- Large scale harpoon capture system
  - RemoveDebris is to demonstrate the harpoon functionality and is specifically designed for the small target
  - Evolve design into system that can capture significant targets
    - Address the challenges identified
    - Widen envelope of target properties (panel thickness, unit location, attitude)
    - Firing system = greater velocity and responsiveness
      - Possibly pressurised gas system
    - Higher speed Tether deployment
      - dynamics & material partially demonstrated by RemoveDebris
    - Post capture loading on structure/harpoon
    - Integrated capture verification
    - Verification of the complete harpoon system
      - Upgrade of test facility
- *Higher speed/thicker panel projectile design and verification activity underway in collaboration with UNSW Canberra*





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