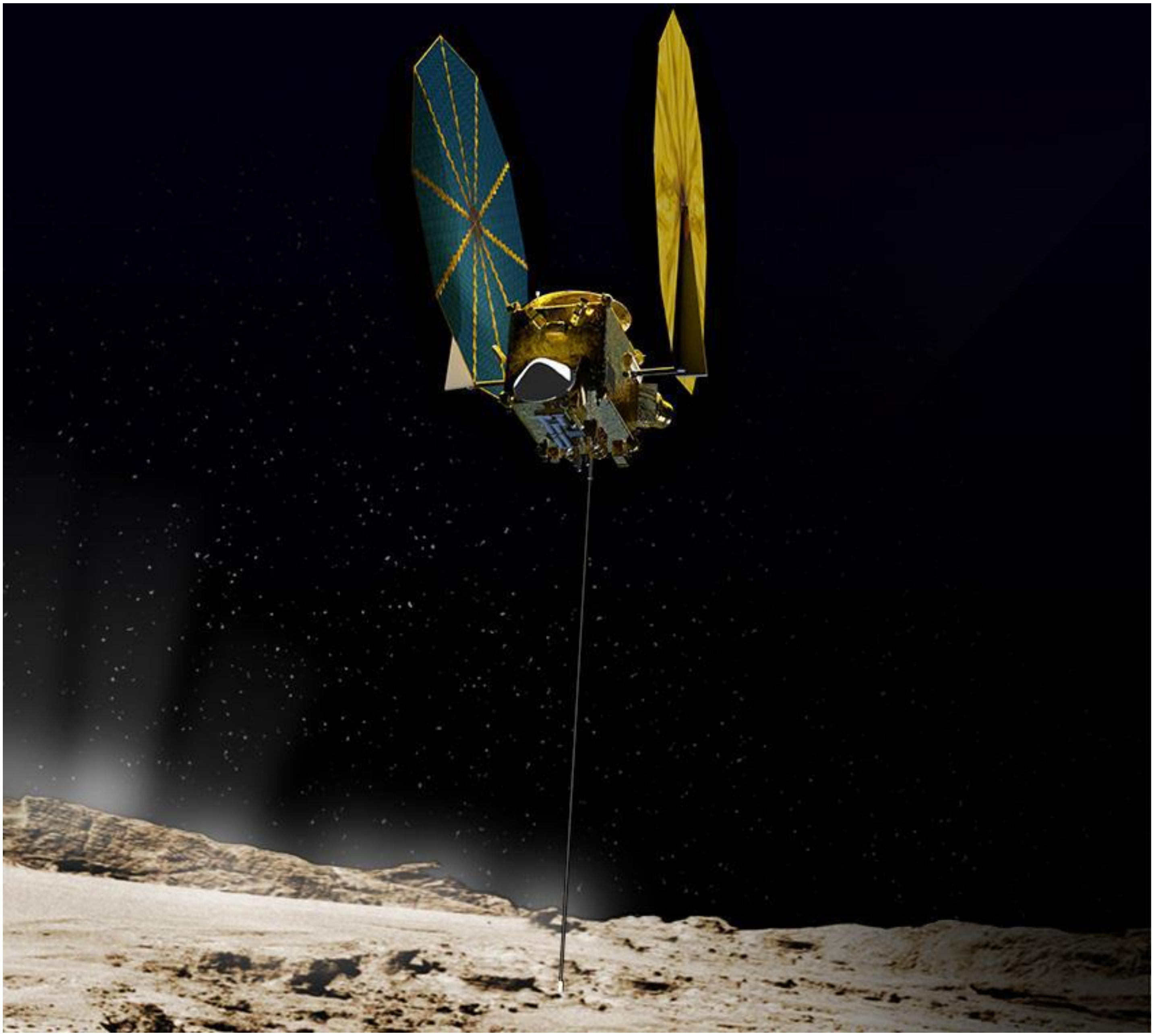
Safe Sample Collection using a Tethered Harpoon



Deployment: SARP launch and sample collection at a comet. The CORSAIR spacecraft commands the launch of the SAS at 10 m. The Launcher accelerates the SARP to penetrate >10 cm into the surface. The SARP Outer Sheath bears the impact forces and breaks up material for ingestion. Under-dense material is compressed to fill the cartridge. The SARP comes to rest through comet resistance, retraction system braking, or both.

CORSAIR

COmet Rendezvous, Sample Acquisition, Investigation, and Return

Larry Nittler (PI, ASU)
Jamie Elsila Cook (DPI for Sample Science, GSFC)
Jessica Sunshine (DPI for Comet Rendezvous, APL)
Neil Dello Russo (PS, APL)
Adrienn Luspay-Kuti (DPS, APL)
James Leary (MSE, APL)

MISSION OVERVIEW: Comets are invaluable time capsules that preserve materials from the dawn of the Solar System. *CORSAIR*'s proposed mission is straightforward: to return to Earth for analysis these early Solar System relics from a comet nucleus. (Organic analysis will be done at Goddard.)

If selected, *CORSAIR* would return the first macroscopic comet samples directly from the nucleus of **comet 22P/Kopff**, as well as coma dust samples. Volatile ices would be sublimated from the samples and chemically characterized before samples are returned for analysis on Earth. 22P/Kopff is ideal for *CORSAIR*'s proposed mission because it is a highly accessible, regularly observed, active Jupiter-family comet that will provide new discoveries from this first exploration.

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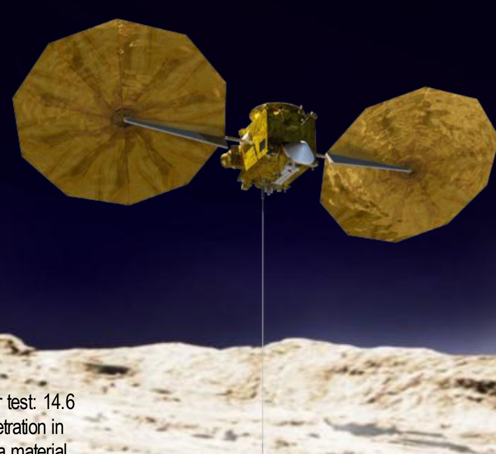
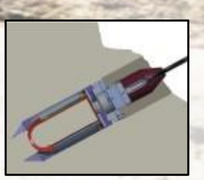
COmet Rendezvous, Sample Acquisition, Investigation, and Return

CORSAIR's Rugged Sample Acquisition System

- *CORSAIR's* proposed sampling system is the culmination of years of hardware development and testing.
- Sampling would be safely conducted without landing, using a tethered probe, while the spacecraft remained 10 m above the surface.
- *CORSAIR*'s proposed sampling system is designed to collect material down to depths of at least 10 cm, and possibly up to a meter, to access more primitive material that may be below the alterred surface.
- The system is designed to sample over an extensive range of surface strengths and local topographies, from loose regolith to solid material.





Sampler schematic: 9-cm outer diameter

Sampler test: loose material

Sampler test: 14.6 cm penetration in 2.4 MPa material

Exhibit A. Stage 1 – Deployment: SARP Launch and Sample Collection (T=0; Launch). *The SC commands the SAS at 10 m. The Launcher accelerates the SARP to penetrate >10 cm into the surface. The SARP Outer Sheath bears the impact forces and breaks up material for ingestion. Under-dense material is compressed to fill up the cartridge. The SARP comes to rest through comet resistance, retraction system braking, or both.*

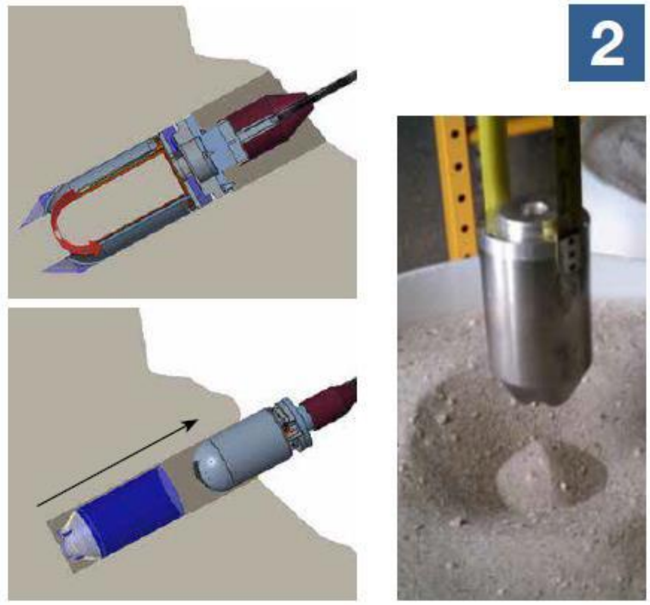


Exhibit B. Stage 2 – Acquisition: SARP Door Close and Decouple (T=1–2 s). *A timer closes the Cartridge door, cutting through material and fully encapsulating the sample. Another timer separates the Outer Sheath from the Inner Sheath, providing a well-understood friction force for removal. (Right figure shows SARP testing.)*

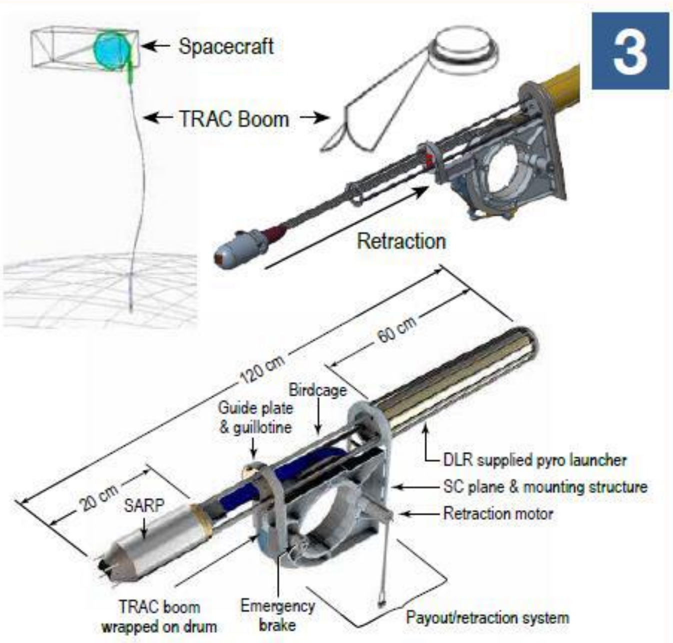


Exhibit C. Stage 3 – Retraction: SARP Return (T=2–11 s). *The Boom Retraction and Deployment (BRAD) controls the SARP return to the end of the Launcher to avoid buckling. The SARP is mechanically grounded at the end of the launcher. The ADAMS model was used to analytically verify buckling margins.*

Exhibit D. Stage 4 – Preparation: SARP Rotation (T=21 s). *A final timer actuates the flip hinge, rotating the Cartridge and Inner Sheath away from the TRAC boom decoupler plate and exposing the KINEE interface.*

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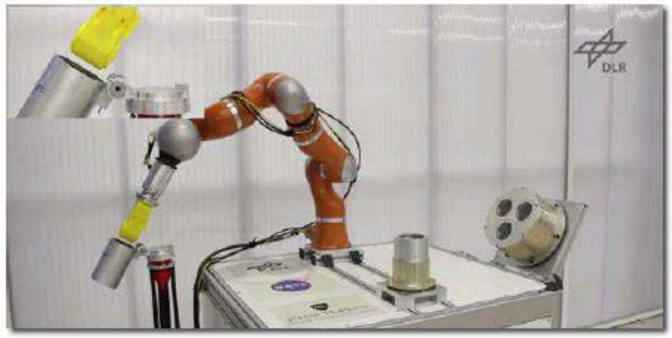


Exhibit E. Stage 5a – Handling: SARP Inspection and Removal (Ground Command). *A ground-commanded sequence takes a set of inspection images. Once downlinked and reviewed, a ground-commanded sequence has the RA grasp the KINEE interface and remove the SARP from the Inner Sheath. The STS is robust to multiple failures. (Above figure shows the DLR prototype arm removing the SARP during end-to-end testing [§J.10.6.2.2].)*

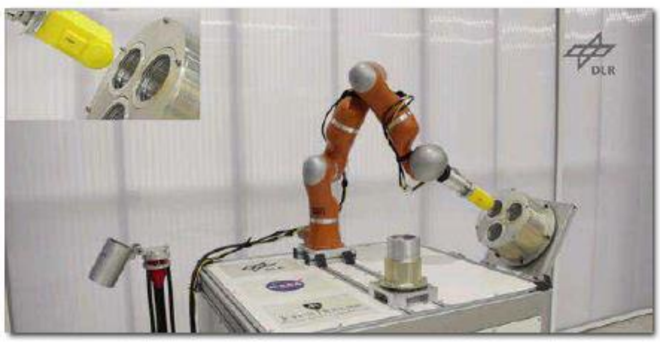
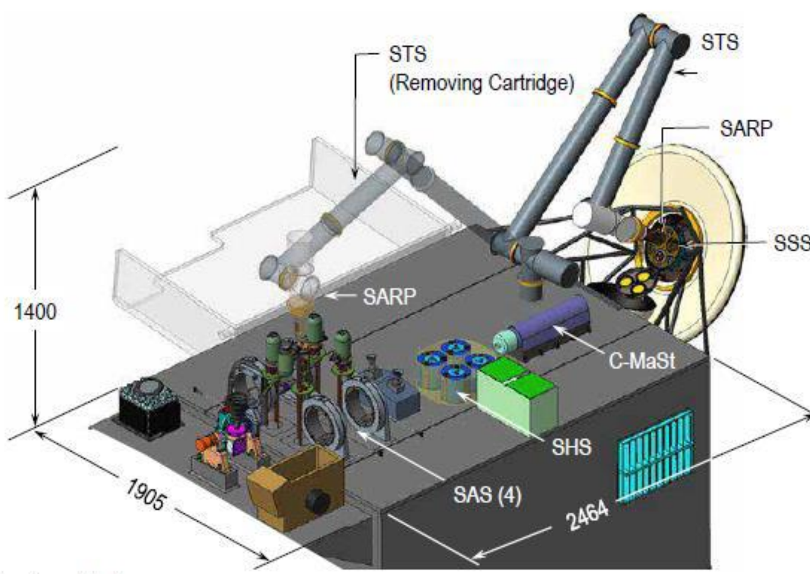
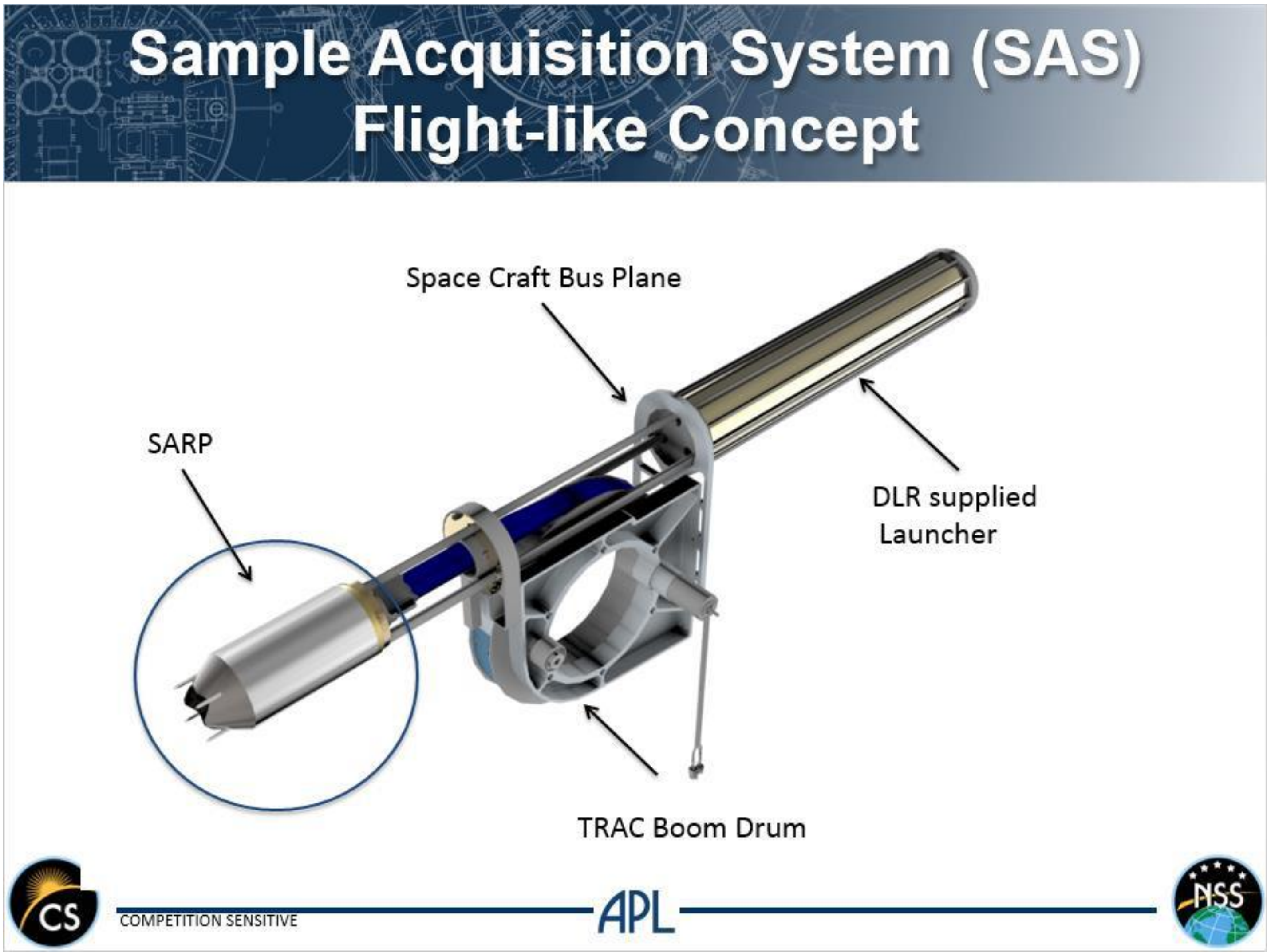


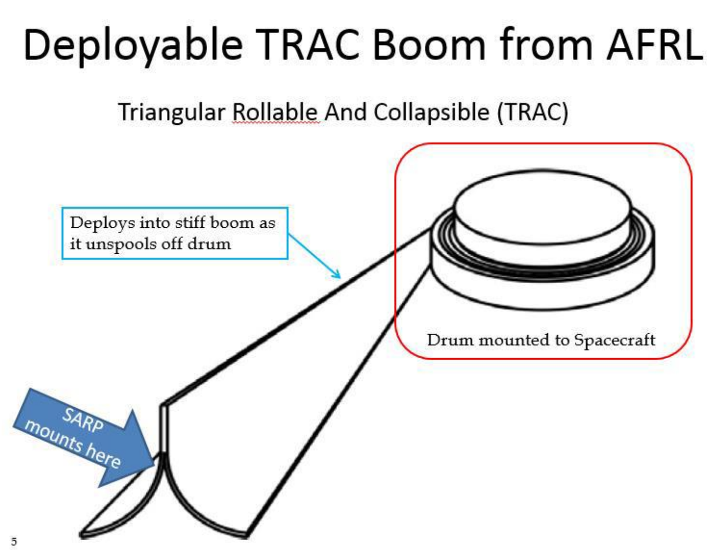
Exhibit F. Stage 5b – Handling: SARP Transfer and Storage (Ground Command). *A ground-commanded sequence continues by moving the SARP to the SHS (and later to the SSS after devolatilization [shown]). The RA releases the SARP once torque feedback verifies SHS (SSS) insertion. A final ground-commanded sequence takes a set of inspection images and returns the RA to the home position. (Above figure shows the DLR prototype arm stowing the SARP in the SSS simulator during end-to-end testing [§J.10.6.2.2].)*



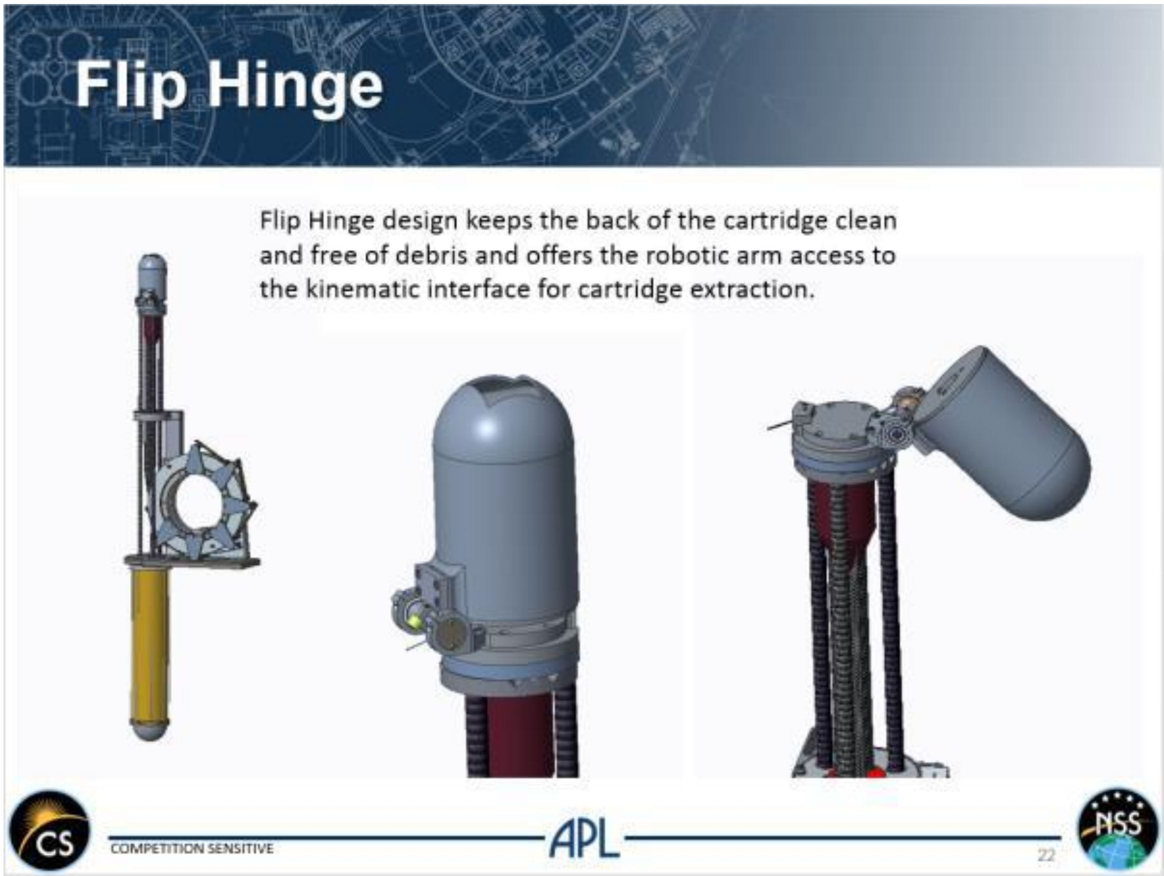
dimensions in centimeters



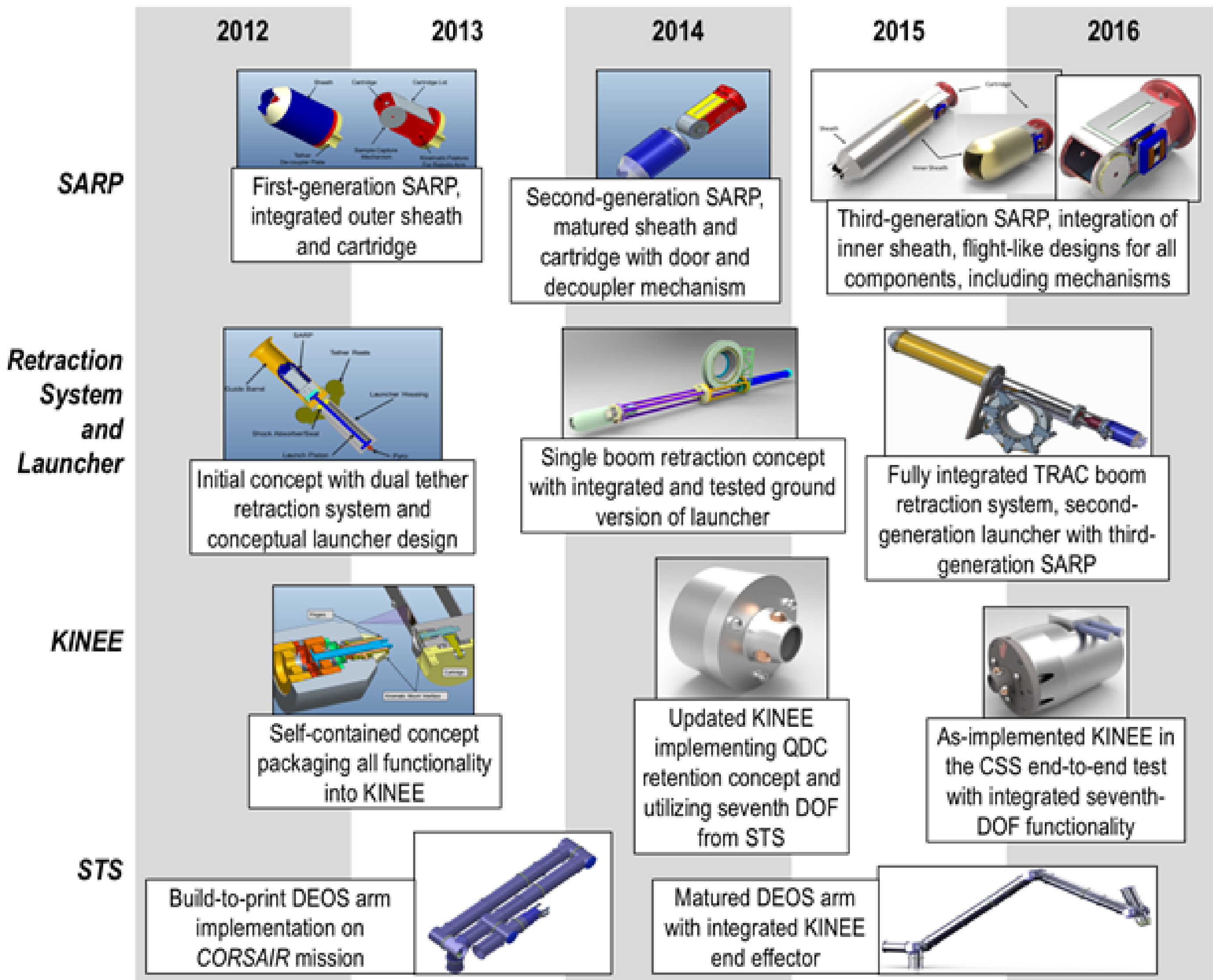
A schematic diagram of the SAS including the DLR-provided launcher.



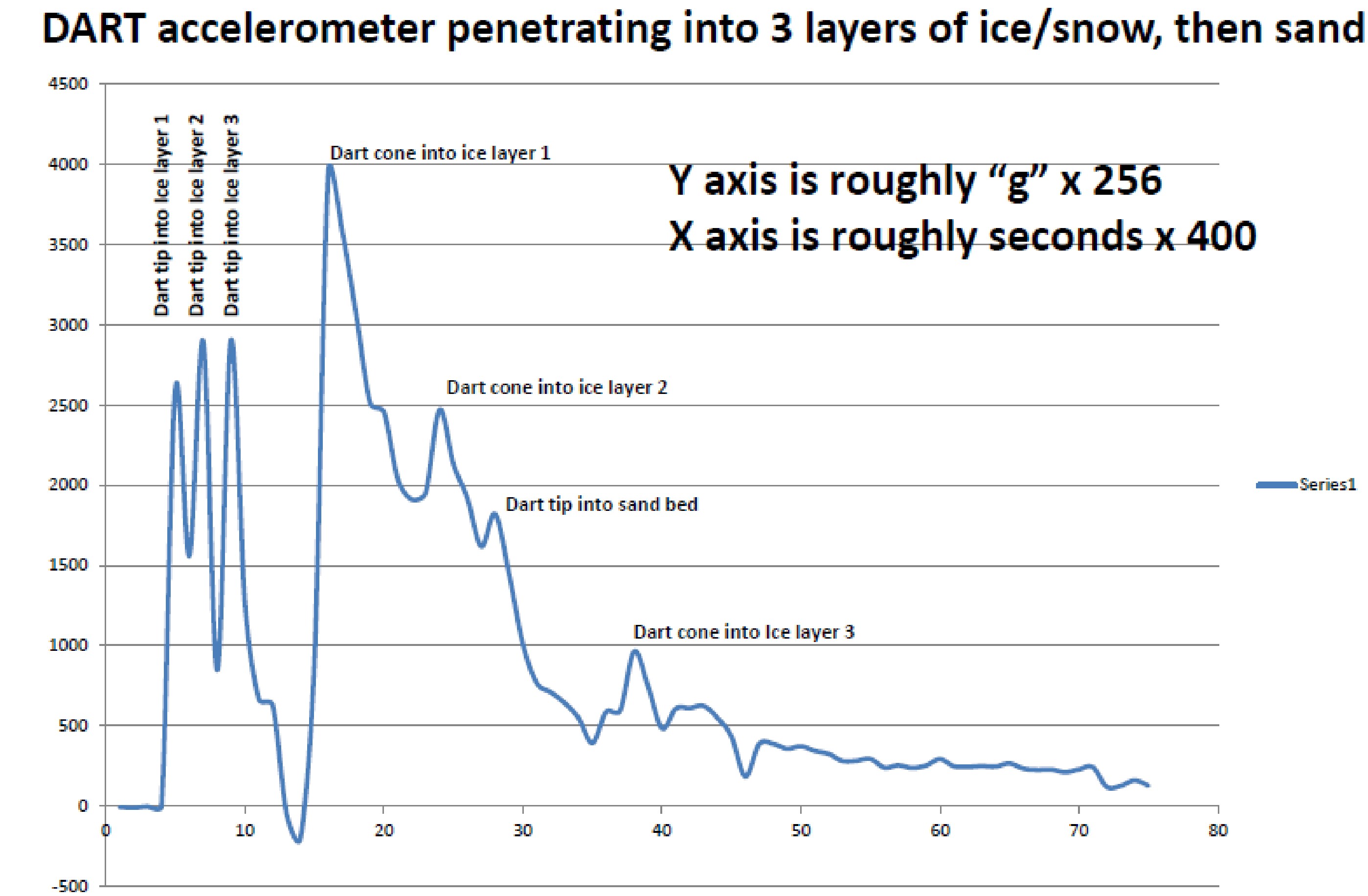
Visualization of the TRAC boom rolling flat on the reel but deploying to generate a more rigid cross sectio



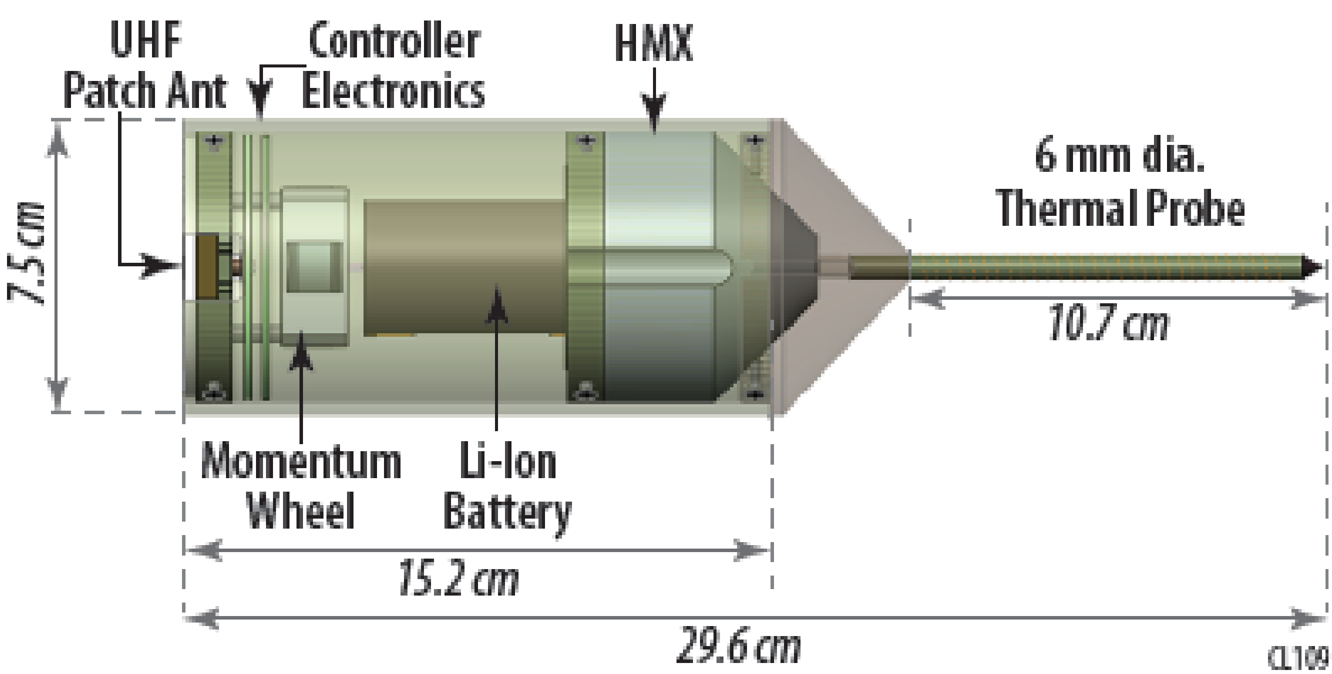
The SARP is reeled back to a firm mechanical ground, locked against the birdcage. The frangebolt releases the flip hinge exposing a clean interface for the KINEE. The clean sample cartridge is extracted from the SARP by the robot arm.

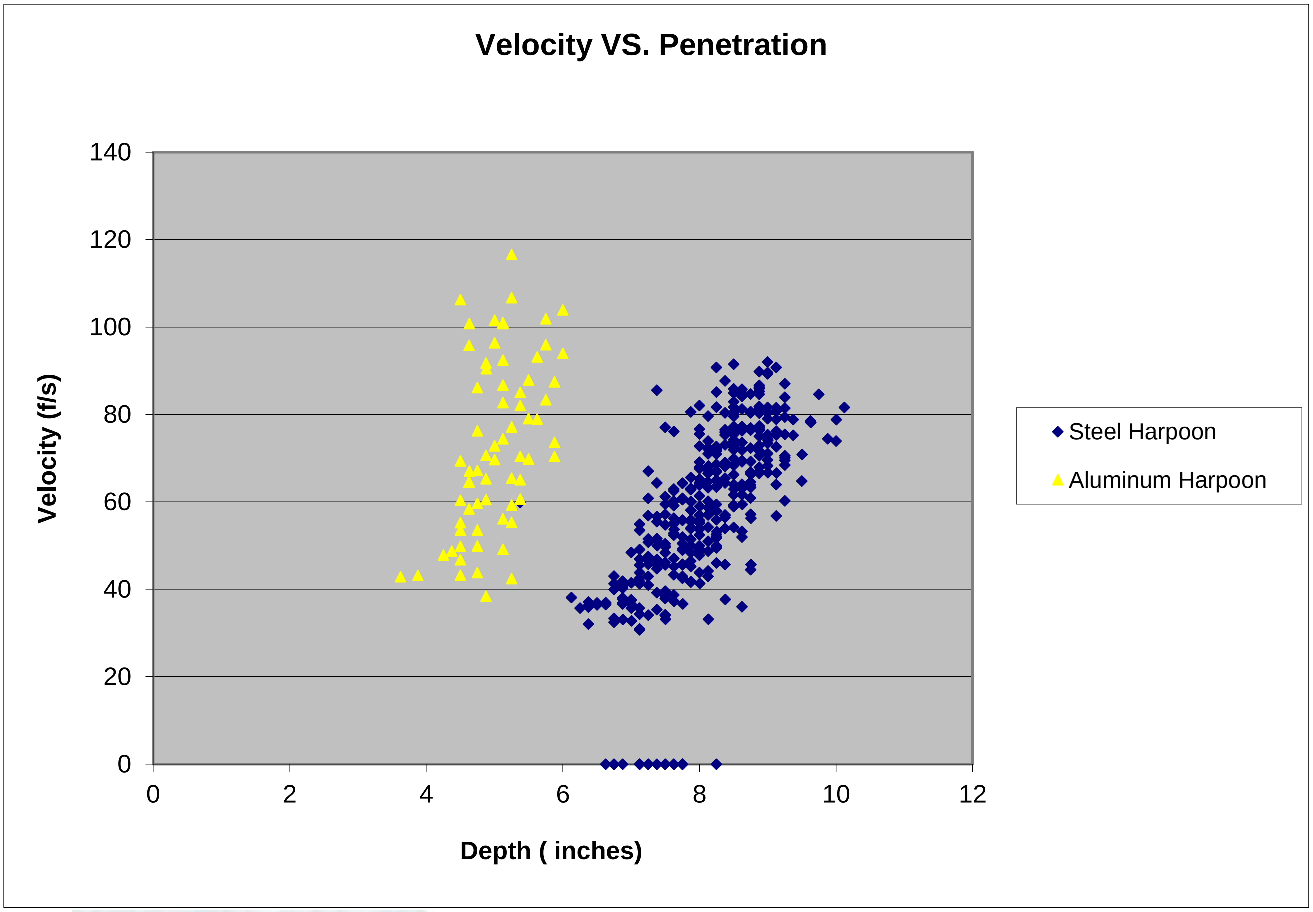


The CSS development includes multiple design iterations and refinements.



Test results from a Dart dropped from a height of 5m into a layered target at the GSFC Tower Test Facility. The target consisted of a stack of three, 1cm thick, ice sheets separated by 1 inch thick layers of snow resting on a bed of sand. We identified the signals as the Dart tip penetrated each ice layer and then the sand as well as a more degraded signal as the wider conic section of the probe also penetrated these layers.





Ballistic Testbed