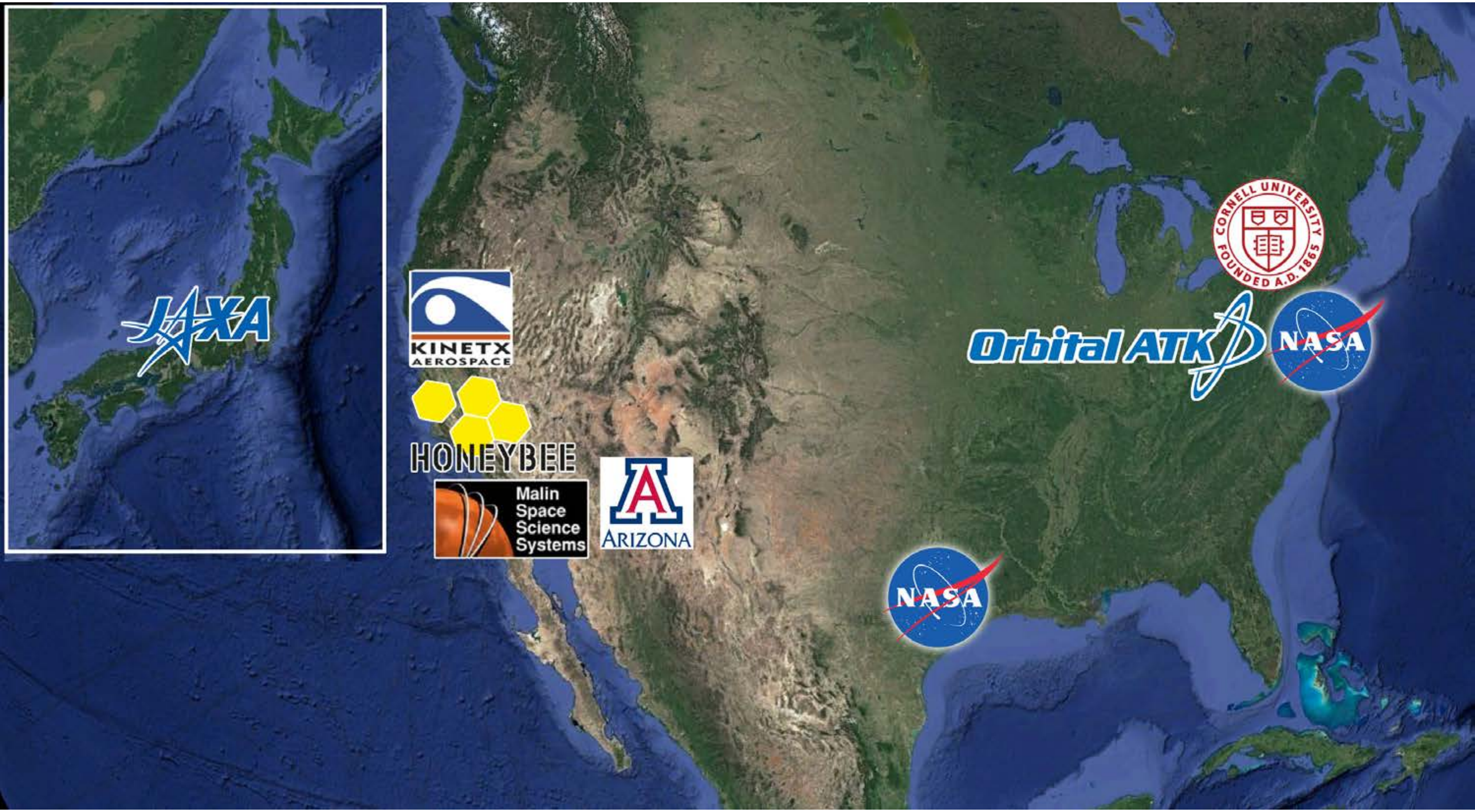
CAESAR

Project Overview

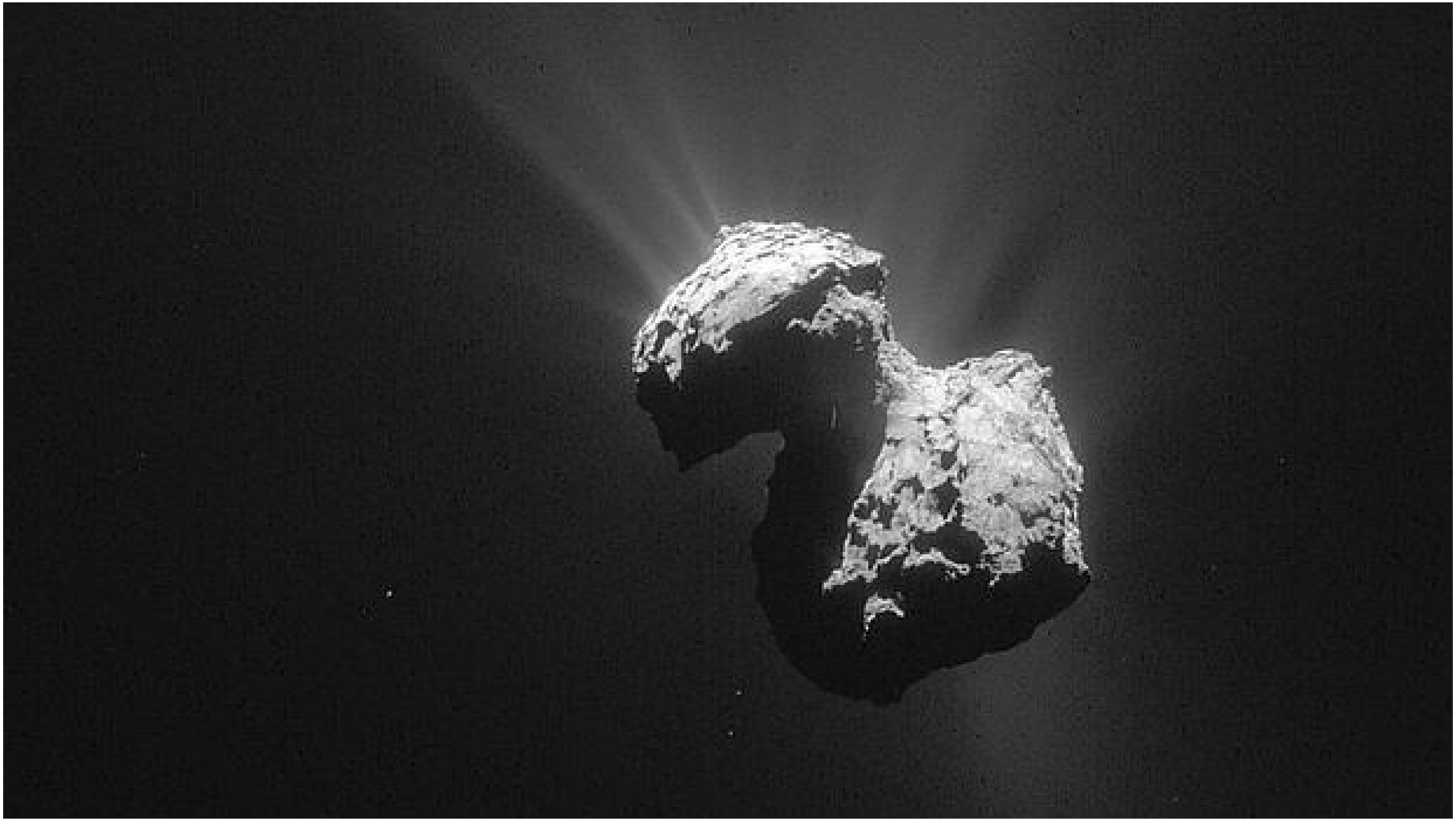
Steve Squyres
Principal Investigator

Goddard Space Flight Center
Orbital ATK
JAXA
Honeybee Robotics
Malin Space Science Systems
Arizona
KinetX Aerospace
Lyndon B. Johnson Space Center

Key Partner Organizations



Churyumov-Gerasimenko



CAESAR Sample Science

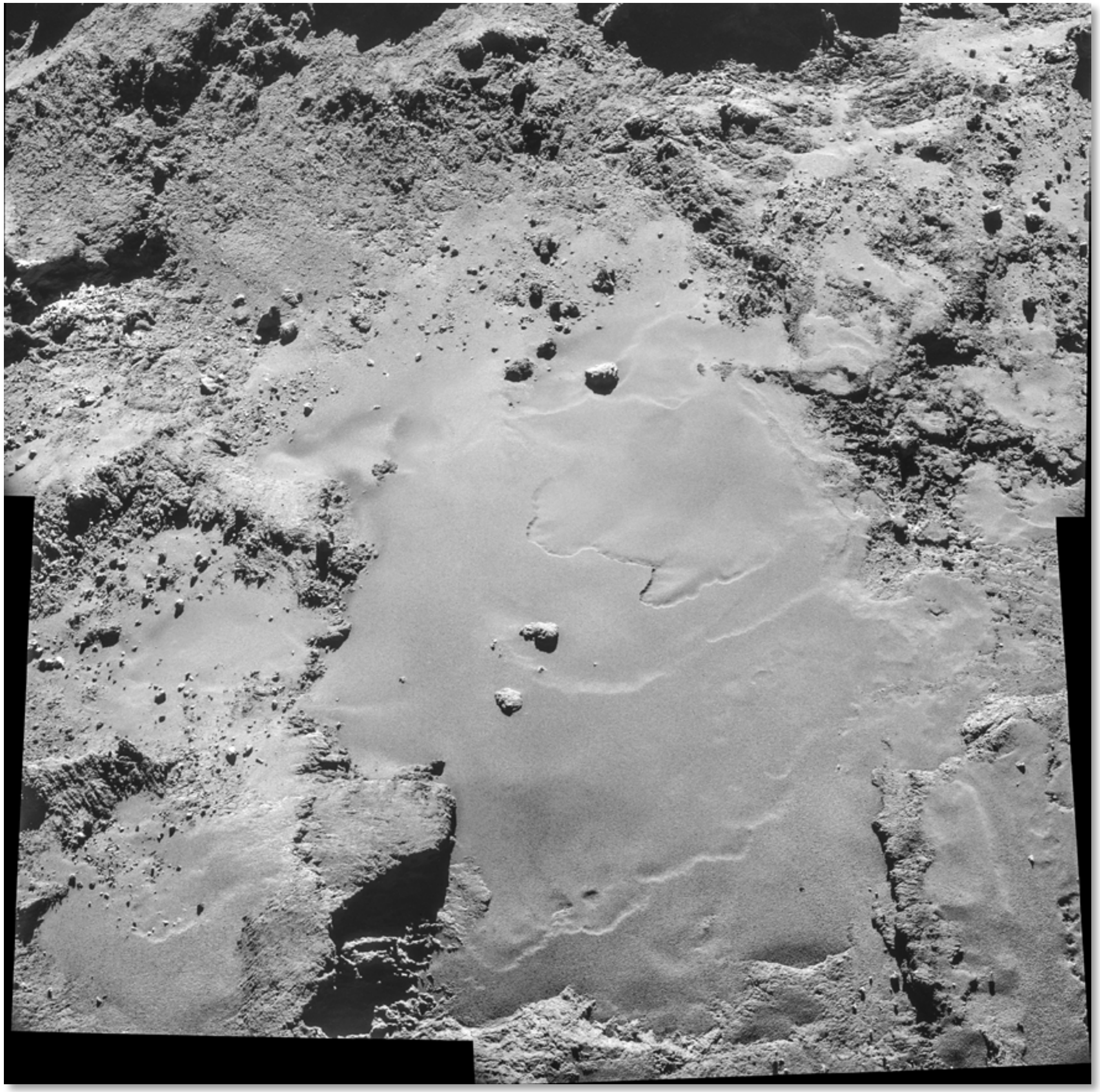
Testable Hypotheses	Observables from Solid Sample in SCS and Volatile Sample in GCS	Observables from Solid Sample in SCS
Interstellar Medium to Protoplanetary Disk Transition (D.2.1.3.2)		
67P contains a greater abundance and diversity of circumstellar grains and molecules than asteroids sampled by meteorites.	Crystallography, elemental and isotopic compositions of mineral and organic grains; molecule-specific isotopic ratios; noble gases	
67P contains volatile elements, ices and organic molecules that were trapped during formation of grain mantles in the ISM or outer protoplanetary disk.	Isotopic and chemical compositions of volatile elements, organics, and noble gases (GCS). Isotopic compositions of noble gases in non-volatile samples	
67P contains refractory organic compounds that formed in cold molecular clouds and the outermost protosolar disk.		Isotopic and chemical compositions of refractory organic molecules & carbonaceous grains; Isotopic, chemical and structural properties of macromolecular material.
H_2O and CO in 67P retain evidence of O isotopic fractionation from photochemical self-shielding.	Oxygen isotopic compositions of H_2O and CO	
Protoplanetary Disk (D.2.1.3.3)		
67P contains high-temperature materials, such as chondrules, CAIs, and silicates that formed across the Solar System.		Mineralogy, chemistry, and isotopic compositions of chondrules, CAIs, metals, sulfides, crystalline and amorphous silicates
67P contains complex refractory organics from the hot, inner regions of the protoplanetary disk.		Textures, chemistry, and isotopic compositions of refractory organics
67P is a primordial fossil that retains largely unaltered signatures from the protoplanetary disk epoch.	Textures, mineralogy, crystallography, and isotopic compositions of grains and organics. H and O isotopic ratios of hydrated minerals and H_2O	
Geological and Dynamical Evolution (D.2.1.3.4)		
67P is a collisional remnant of a larger planetesimal that underwent internal heating, partial differentiation, sublimation and recondensation, outgassing, and hydrothermal alteration.	Crystallography, petrology, mineral textures, labile element abundances, mineralogy, trace element profiles, H and O isotopic measurements of hydrated minerals and H_2O	
Jupiter family comets delivered a substantial fraction of water to Earth.	H and O isotopic measurements of H_2O, H isotopic measurements of organics	
67P contains prebiotic organic compounds that may have contributed to the origin of life on Earth.	Volatile and non-volatile organic molecule abundances, isotopic ratios, and chirality, mineralogical constraints for aqueous alteration	
67P surface materials record processes of tidal disruption and reaccumulation, resurfacing, and mass wasting.	Space weathering rims, mineral microstructures, IR spectra, noble gas abundances and isotopes	

CAESAR Sample Science

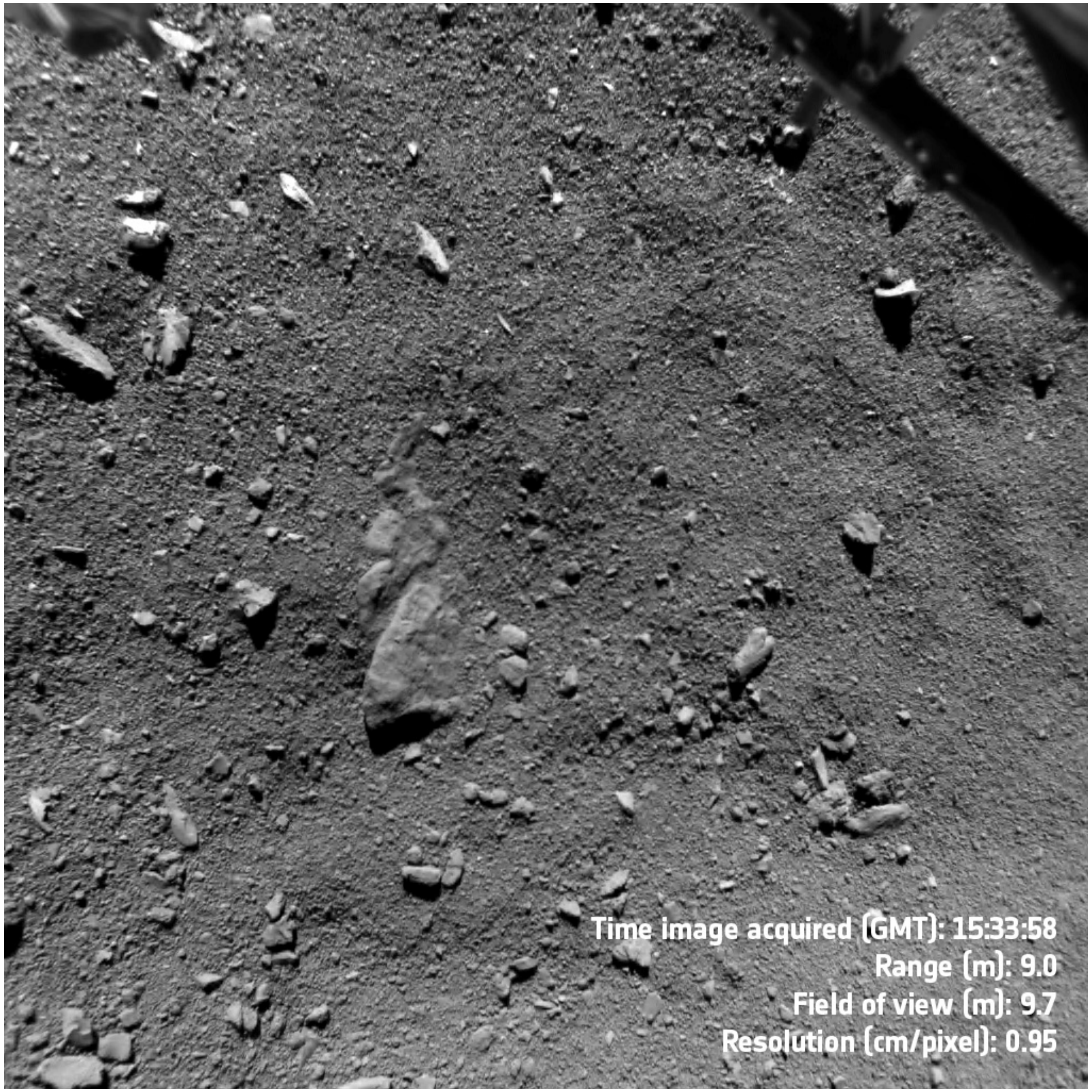
	Bulk Sample Return			CBE	30% Test Contingency	Sub total		CBE
	CAESAR Science Team Instrument Capabilities	Responsible Team Members	Test Objective	g	g	g	Total # of analyses	g
Baseline Analysis	ICP-OES	Lauretta	Bulk major/minor element abundances	0.01	0.003	0.013	10	0.13
Baseline Analysis	HR-ICP-MS	Lauretta	Bulk trace element abundances	0.1	0.03	0.13	10	1.3
Baseline Analysis	EPMA, SEM, UVF/ Optical microscopy	Takigawa	Sample mineralogy/petrology organic textures and mineral associations	0.5	0.15	0.65	10	6.5
Baseline Analysis	SPM, CT-Scan	Kimura	3D structure, grain size distribution					
Baseline Analysis	EA-IRMS	Glavin	Bulk H, C, N isotopic abundances	0.05	0.015	0.065	10	0.65
Baseline Analysis	CF-IRMS	T. Nakamura	Bulk O isotopes	0.01	0.003	0.013	10	0.13
Nanoscle-coordinated analysis	NanoSIMS	Messenger, Nguyen	Presolar grain and organic grain isotopic compositions and abundances	$2x10^{-6}$	$6x10^{-7}$	$3x10^{-6}$	10	$3x10^{-5}$
Nanoscle-coordinated analysis	NanoSIMS/ LA-MC-ICPMS	Nguyen, Lauretta	O isotopes, Al-Mg, Mn-Cr, Pb-Pb chronology, micro-scale trace elements	0.01	0.003	0.013	10	0.13
Nanoscle-coordinated analysis	µL2MS	Clemett	In-situ organic distributions	$<10^{-6}$	$<10^{-6}$	$<10^{-6}$	10	$<10^{-6}$
Nanoscle-coordinated analysis	UV-Visible-NIR Spectroscopy	Gerakines	Organic molecular structure and abundances	$<10^{-6}$	$<10^{-6}$	$<10^{-6}$	10	$<10^{-6}$
Nanoscle-coordinated analysis	Synchrotron-XRD, S-XRF, S-CT	T. Nakamura	Nanoscale bulk chemistry, structure, mineralogy	$<10^{-6}$	$<10^{-6}$	$<10^{-6}$	10	$<10^{-6}$
Nanoscle-coordinated analysis	TEM/EDS, EELS	Zega, Kimura	Nanoscale chemistry/minerology	$<10^{-6}$	$<10^{-6}$	$<10^{-6}$	10	$<10^{-6}$
Nanoscle-coordinated analysis	Synchrotron XANES	Furukawa	Nanoscale organic structure	$<10^{-6}$	$<10^{-6}$	$<10^{-6}$	10	$<10^{-6}$
Nanoscle-coordinated analysis	SS-NMR	Furukawa	Organic macromolecular structure	0.1	0.03	0.13	10	1.3
High precision/High sensitivity Analysis	GC/LC-MS	Dworkin, Furukawa	Organic molecular structure, abundances, and chirality	0.1	0.03	0.13	10	1.3
High precision/High sensitivity Analysis	GC-C-IRMS	Glavin	C, N, and H compound specific isotopes of volatile and non-volatile organics	0.25	0.075	0.325	10	3.25
High precision/High sensitivity Analysis	CF-IRMS	T. Nakamura	O isotopes of H_2O	0.05	0.015	0.065	10	0.65
High precision/High sensitivity Analysis	NIR-CRD	Blake	O isotopes of volatiles (H_2O, CO, CO_2)	$2x10^{-4}$	$6x10^{-5}$	$3x10^{-4}$	10	0.003
High precision/High sensitivity Analysis	Static Gas MS	T. Nakamura	Noble gas abundances and isotopic ratios	0.05	0.015	0.065	10	0.65
							Total	14.56

Nanoscale coordinated analysis will be performed on sample used for Baseline Analysis and therefore do no contribute to the total mass budget.

Churyumov-Gerasimenko

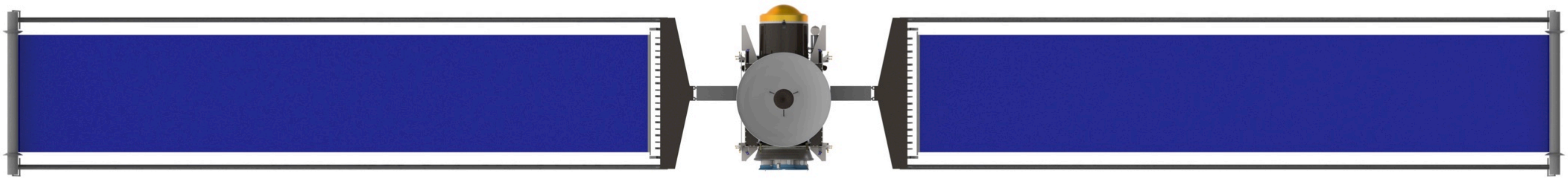


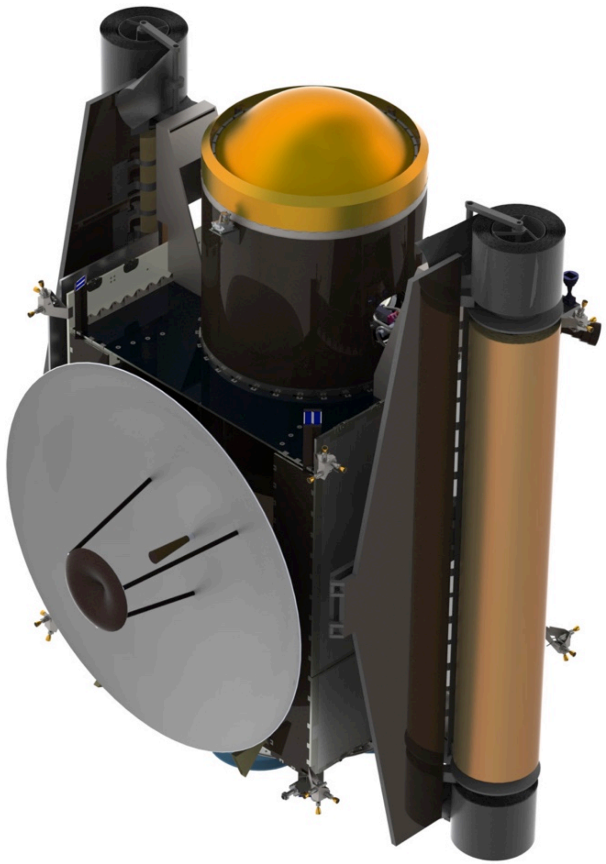
Churyumov-Gerasimenko

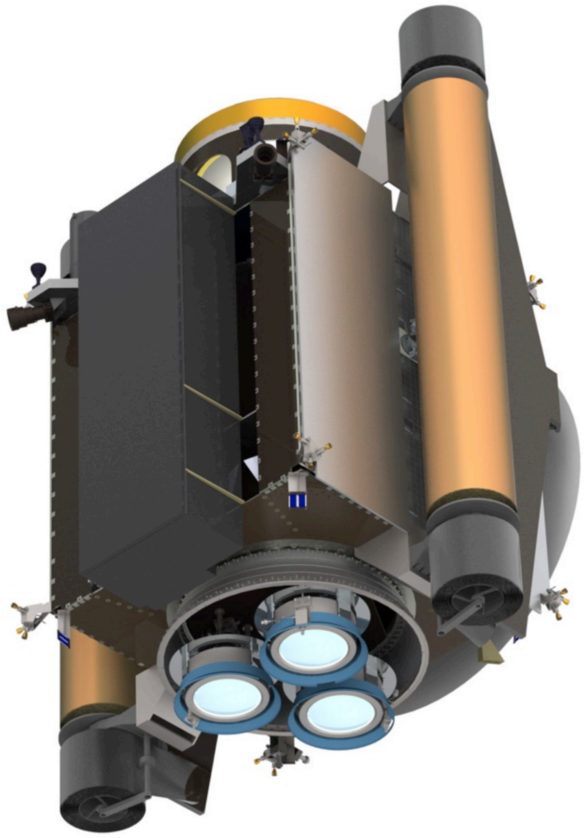


CAESAR

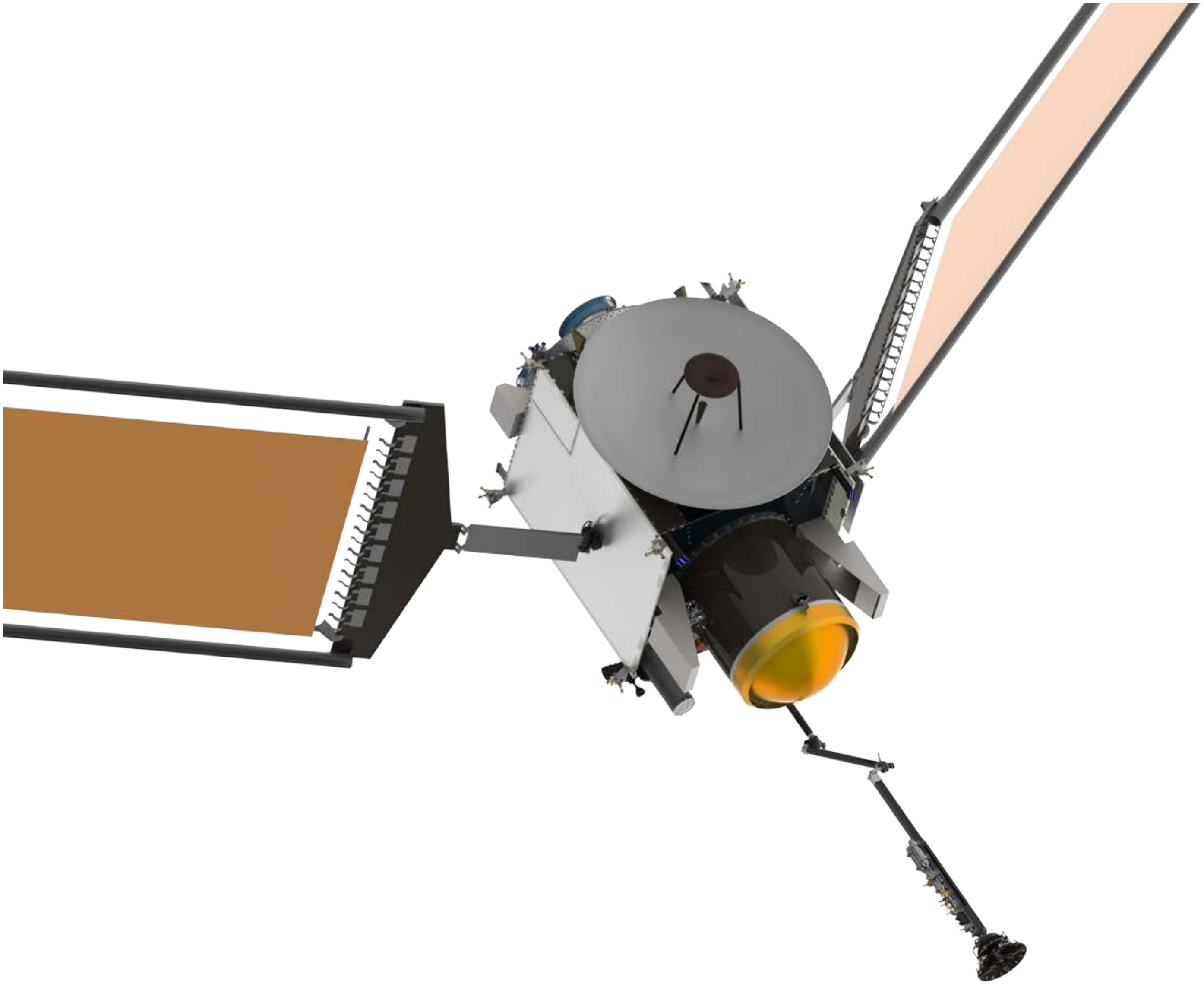
The Spacecraft



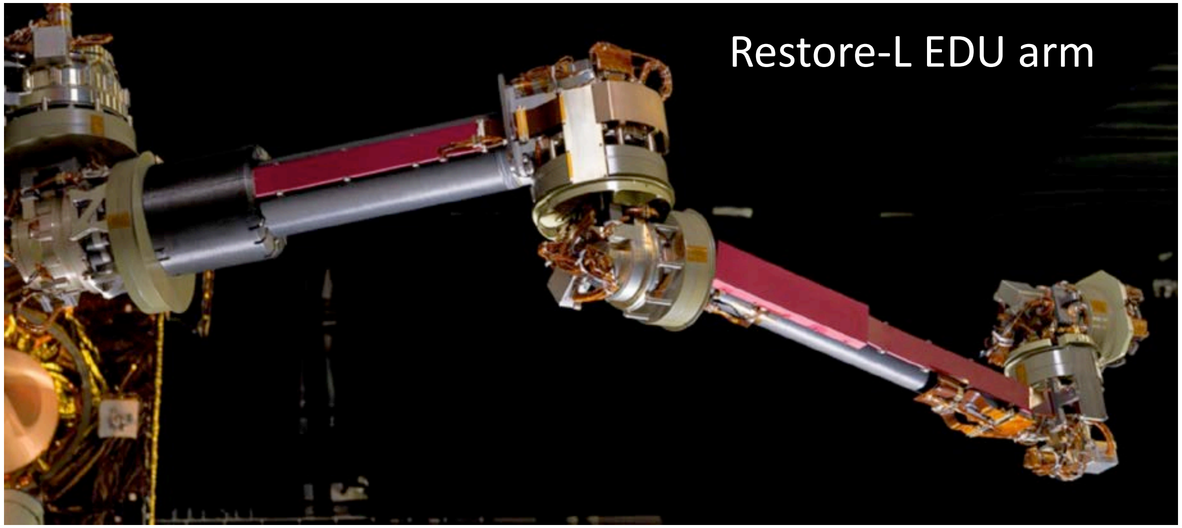




The Spacecraft



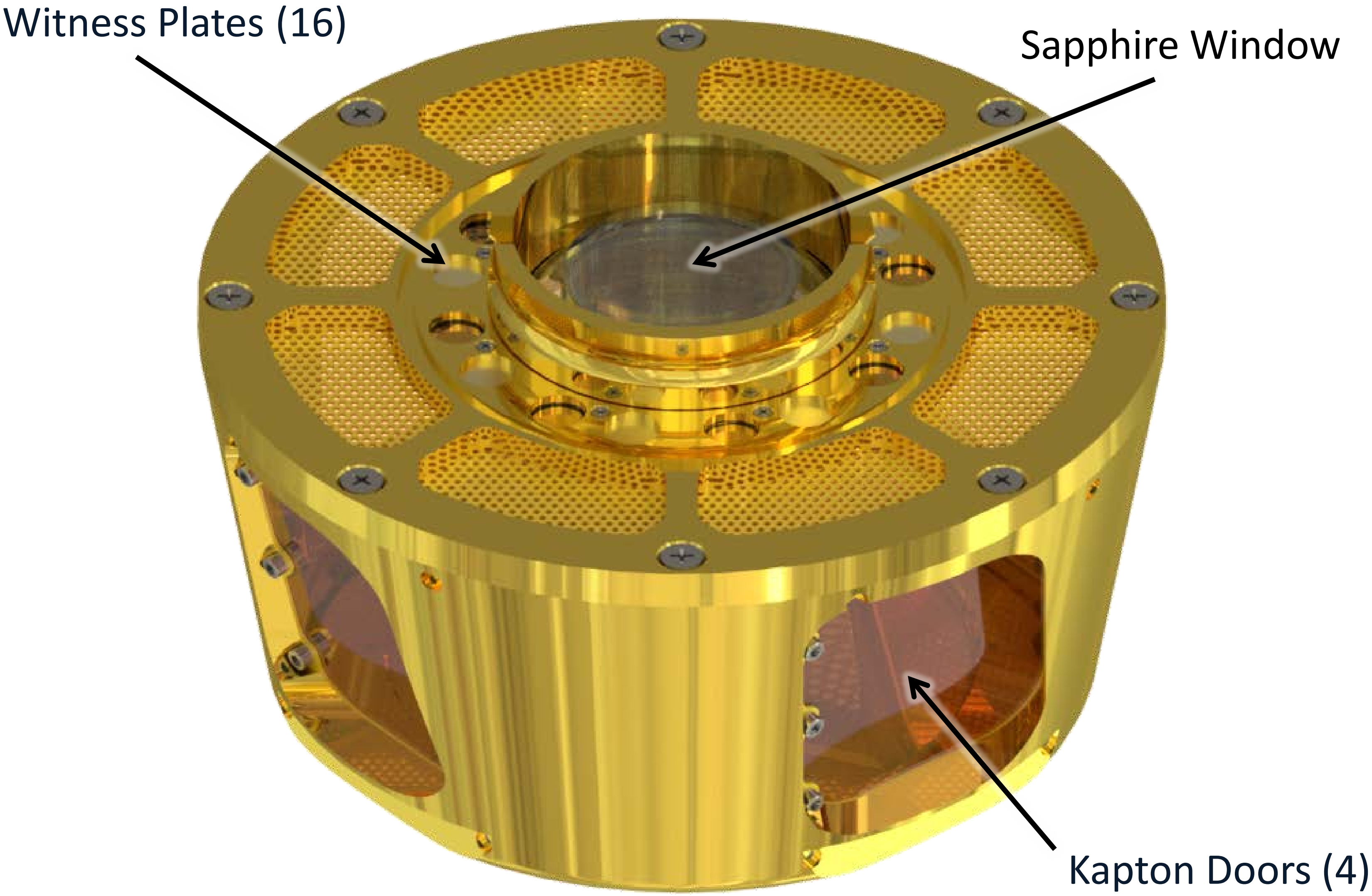
TAG Arm



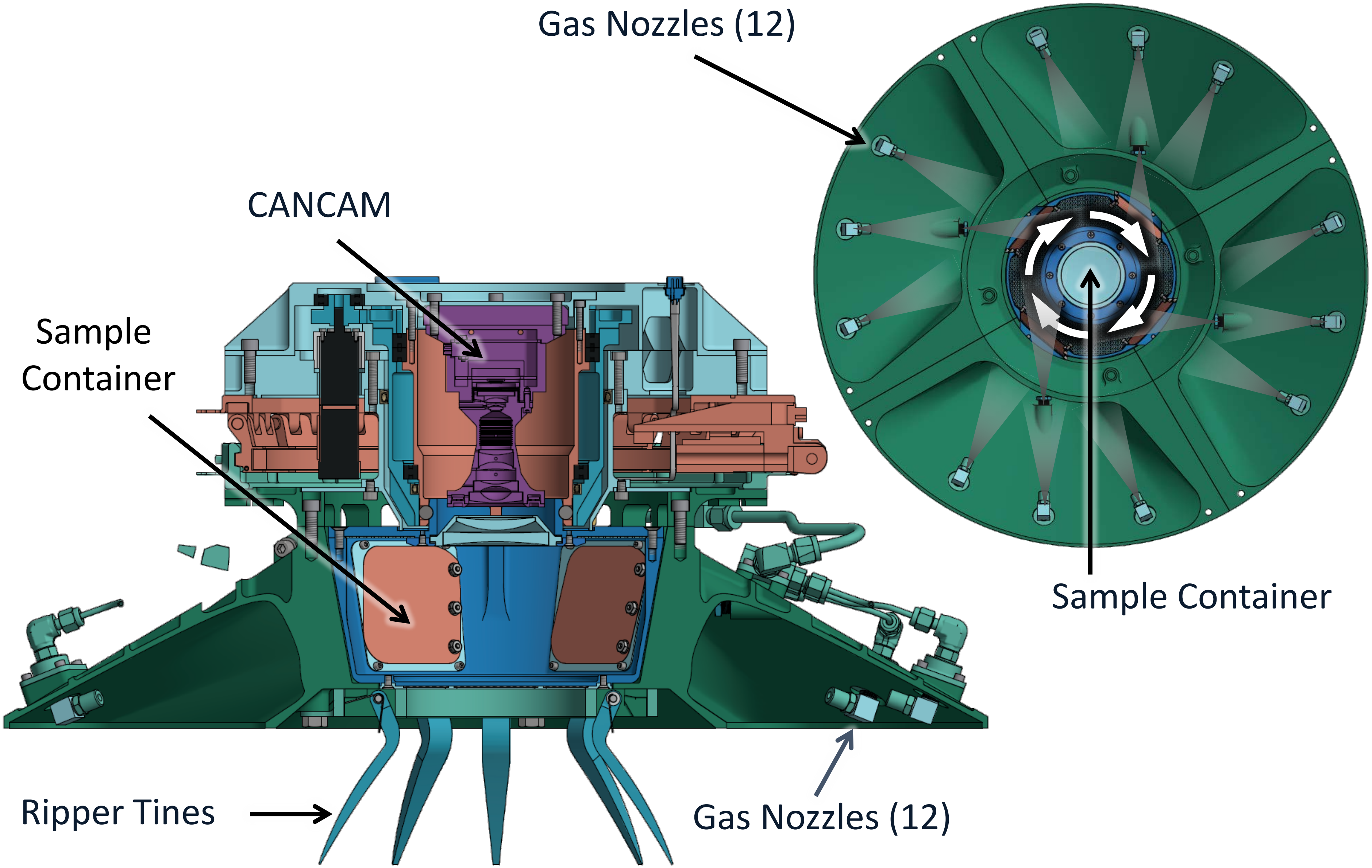
Sample Acquisition System

Sample Acquisition System

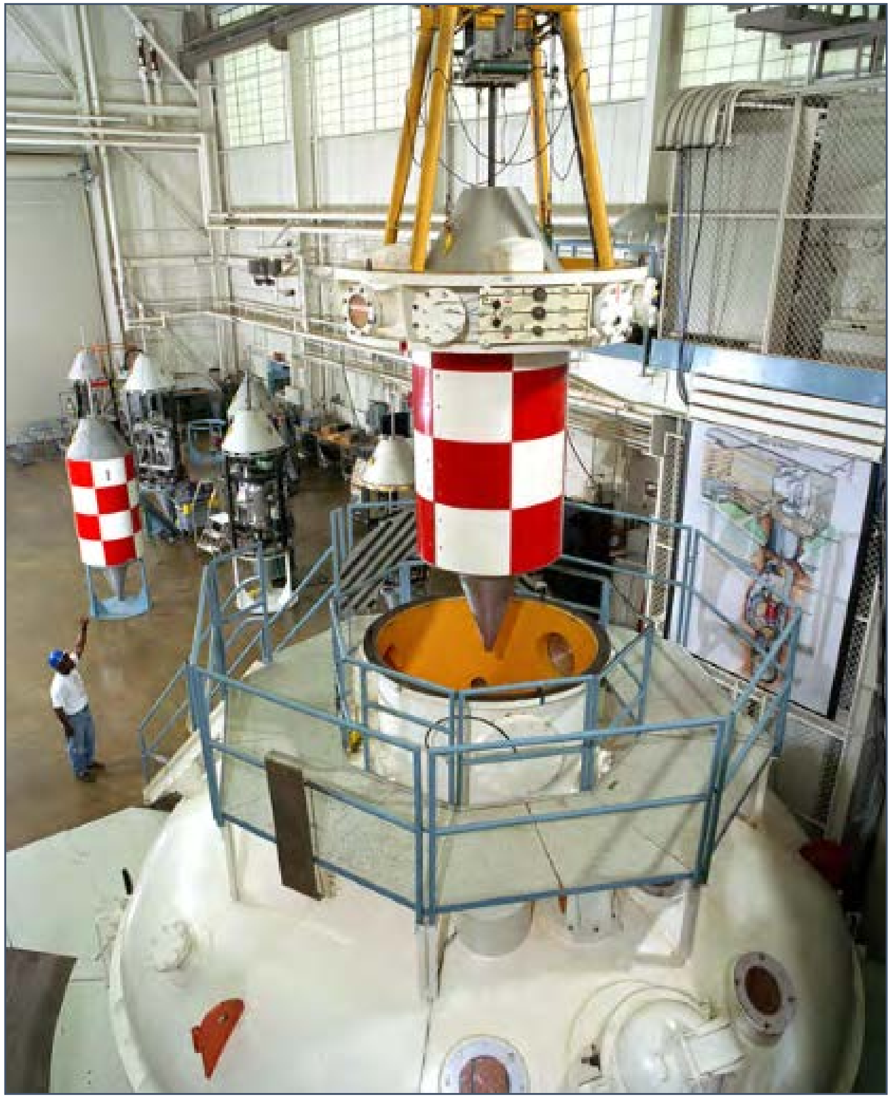
Sample Container



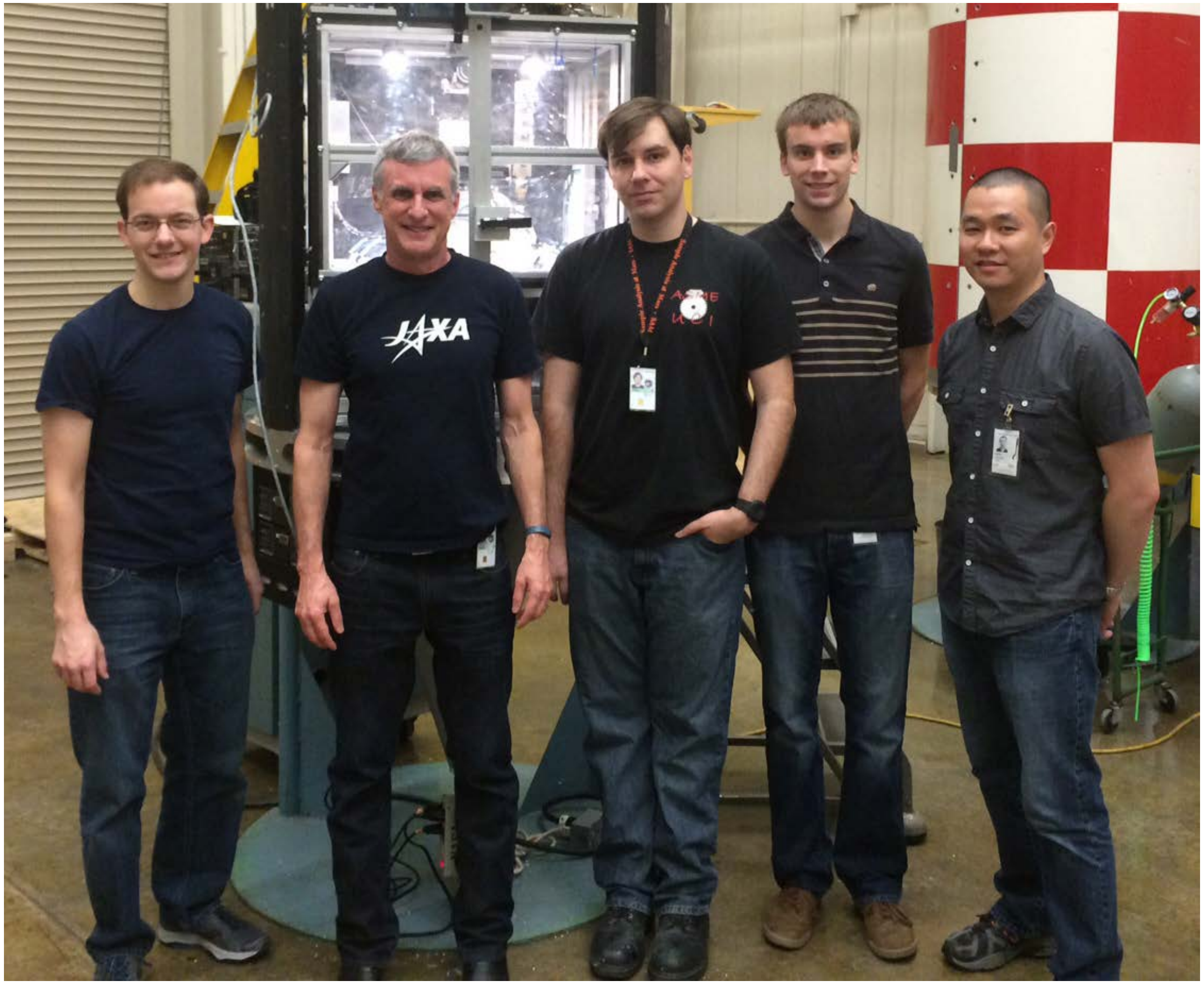
SAS Operations

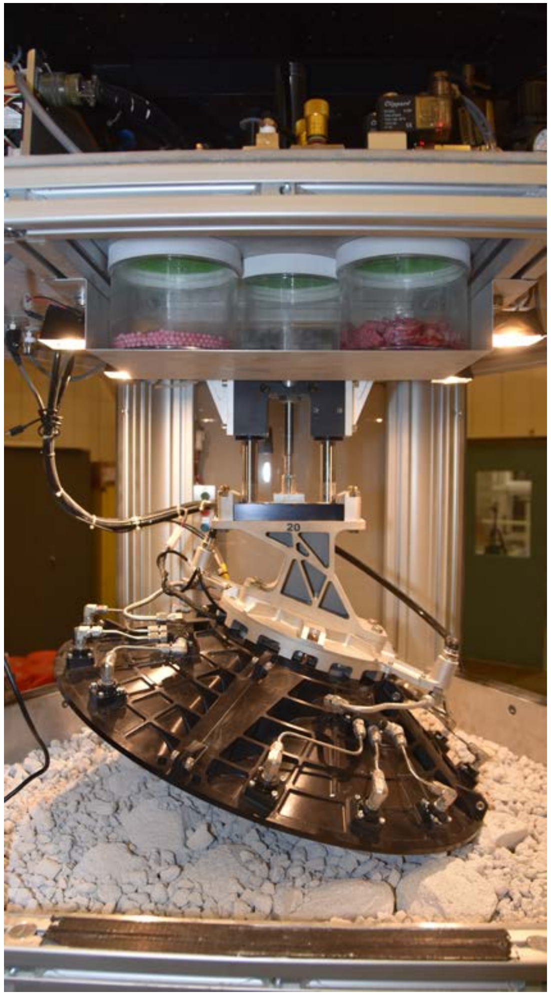


GRC Zero-G Test Facility



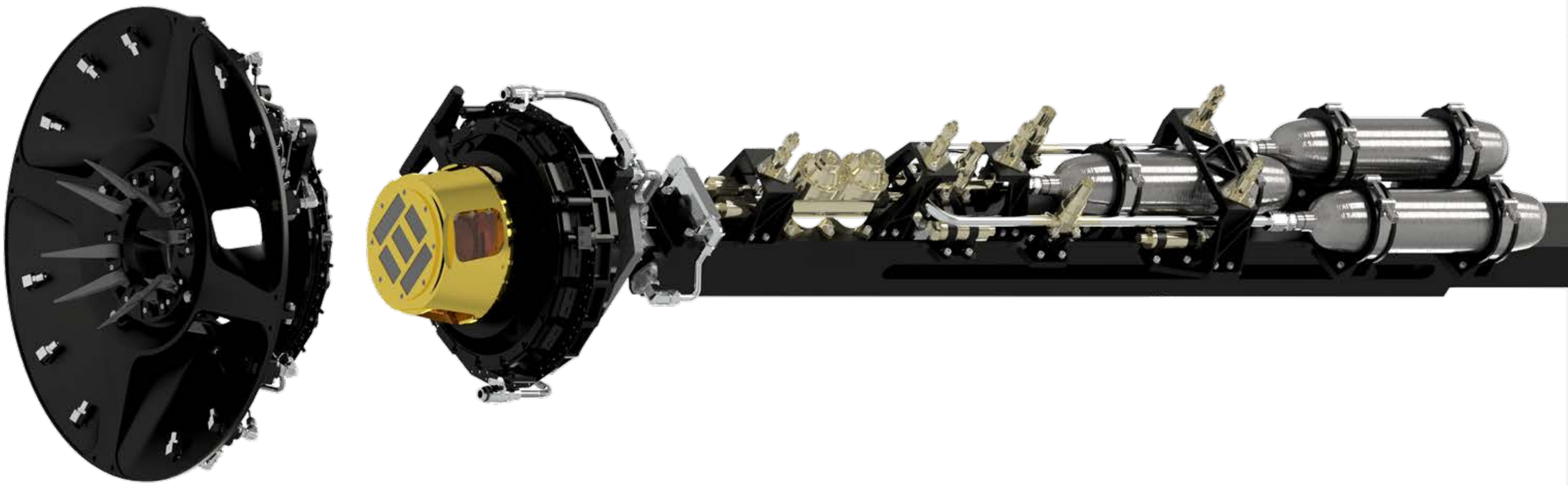
Zero-G / Vacuum Testing



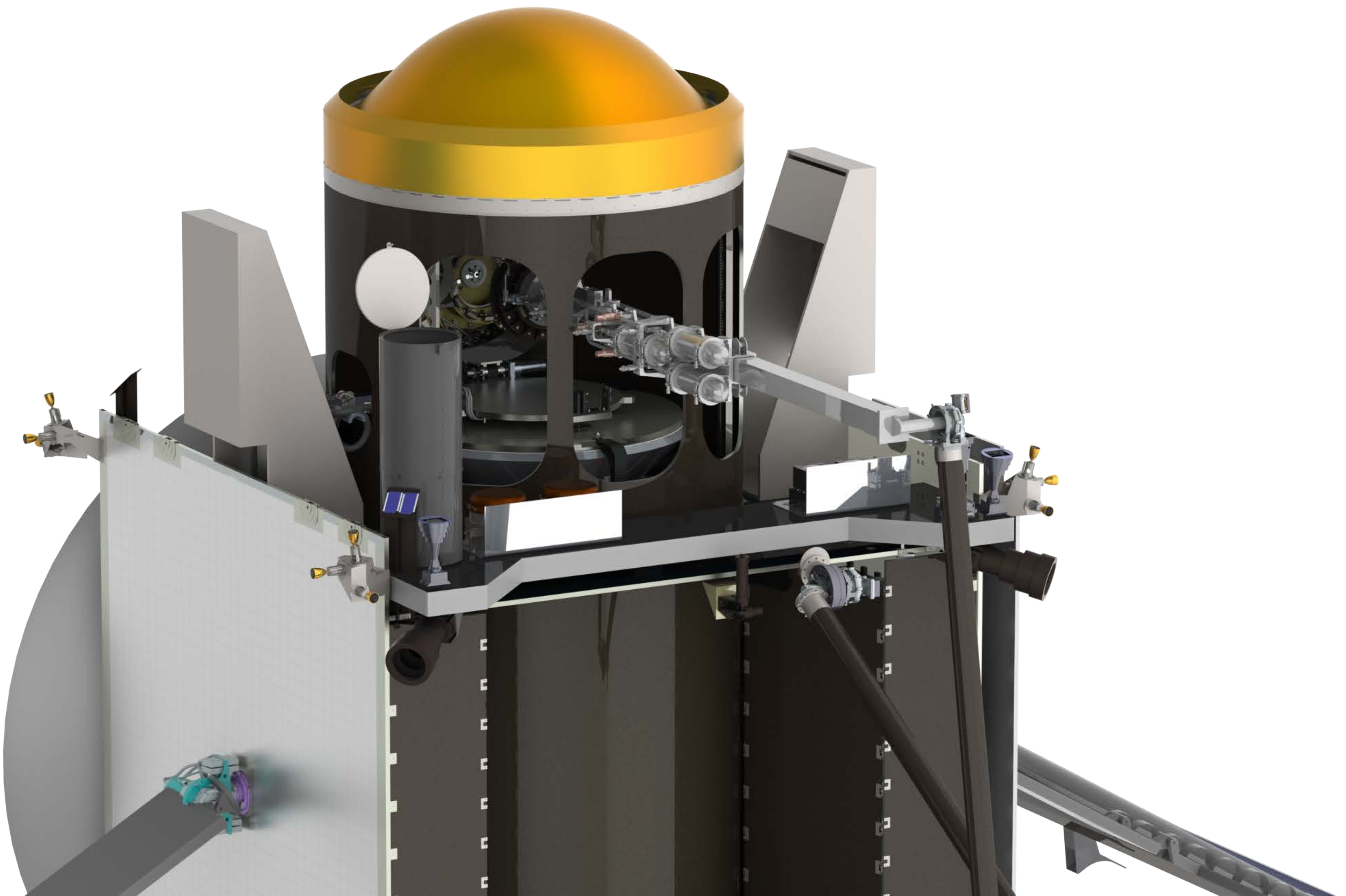


Test Results

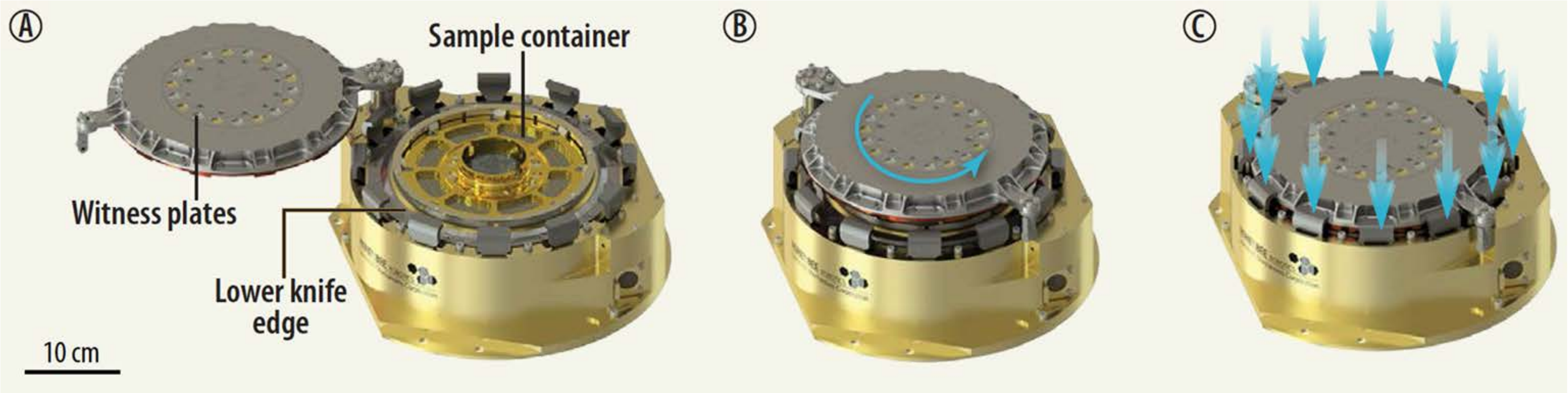
Eject Sample Cone

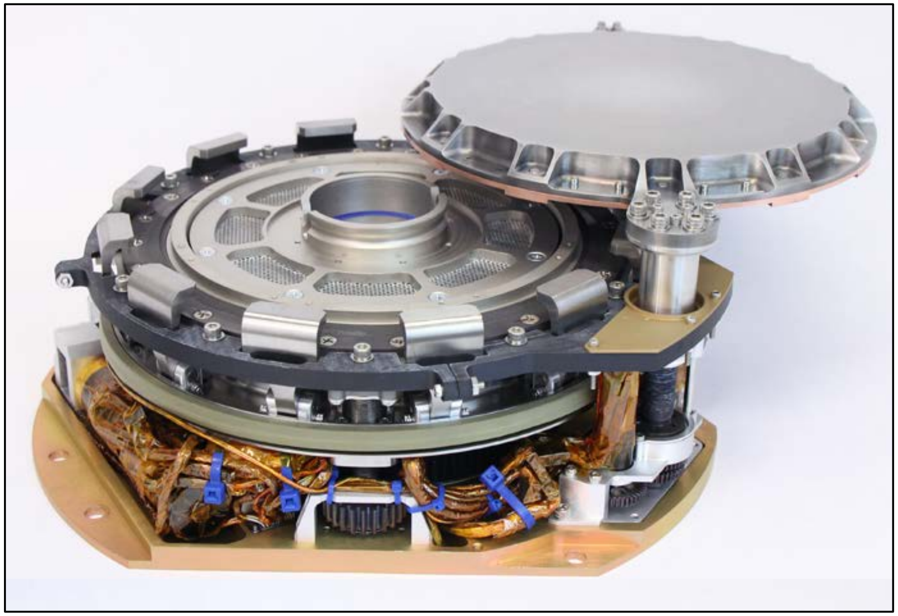


Stow Sample Container

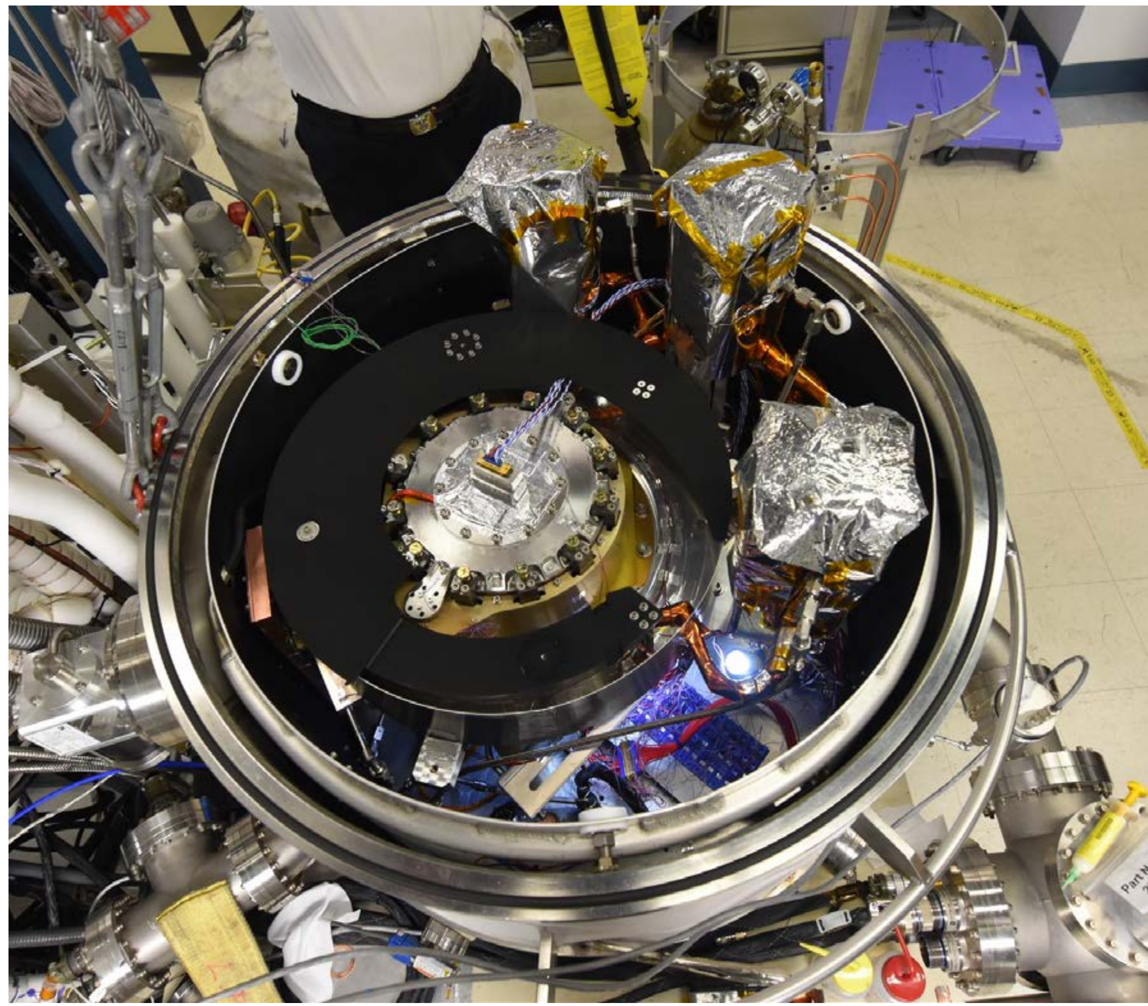


Sample Containment System

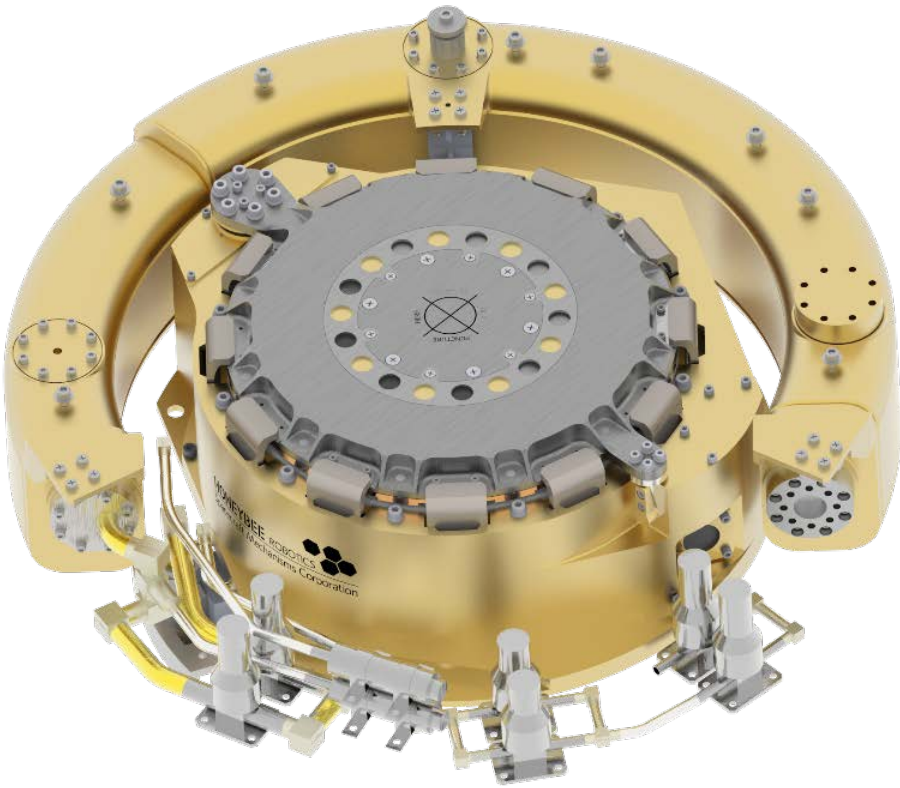




Gas Containment System

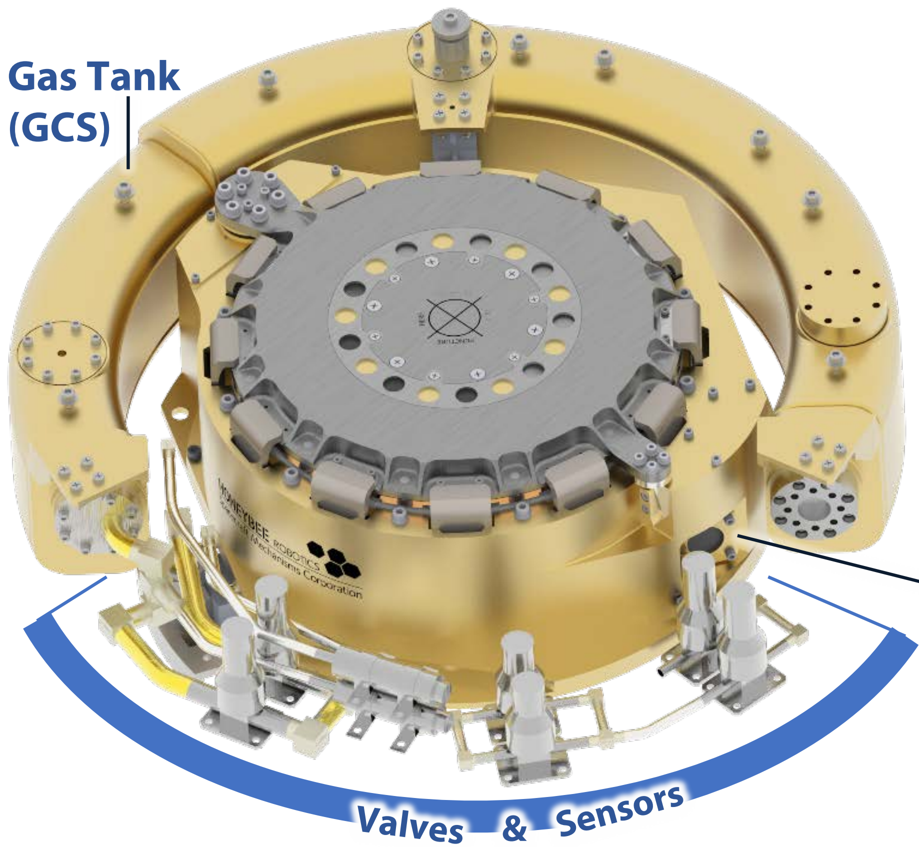


Sample Preservation

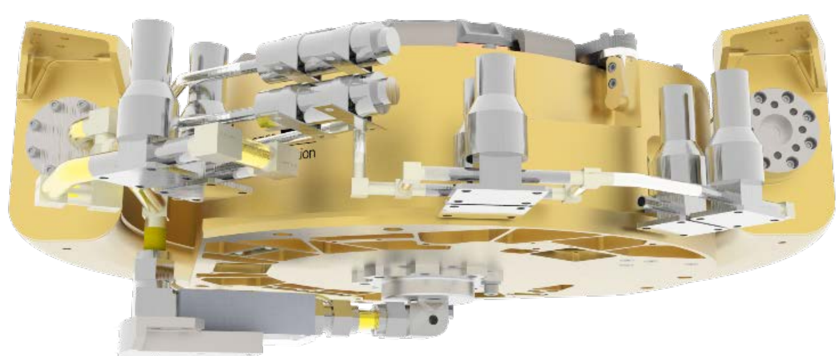


Sample Preservation

Top View

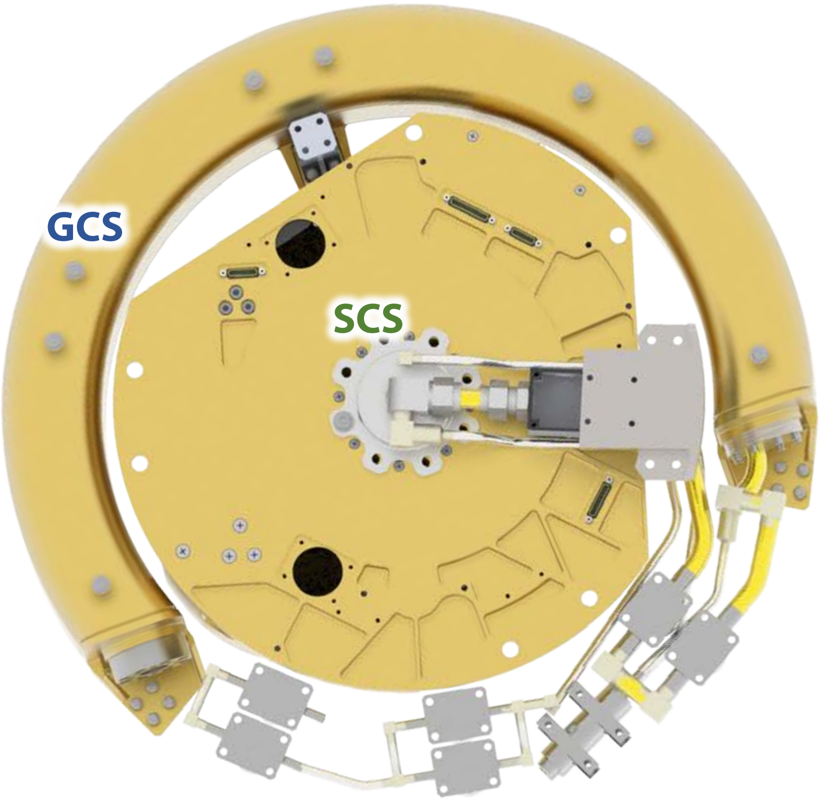


Side View



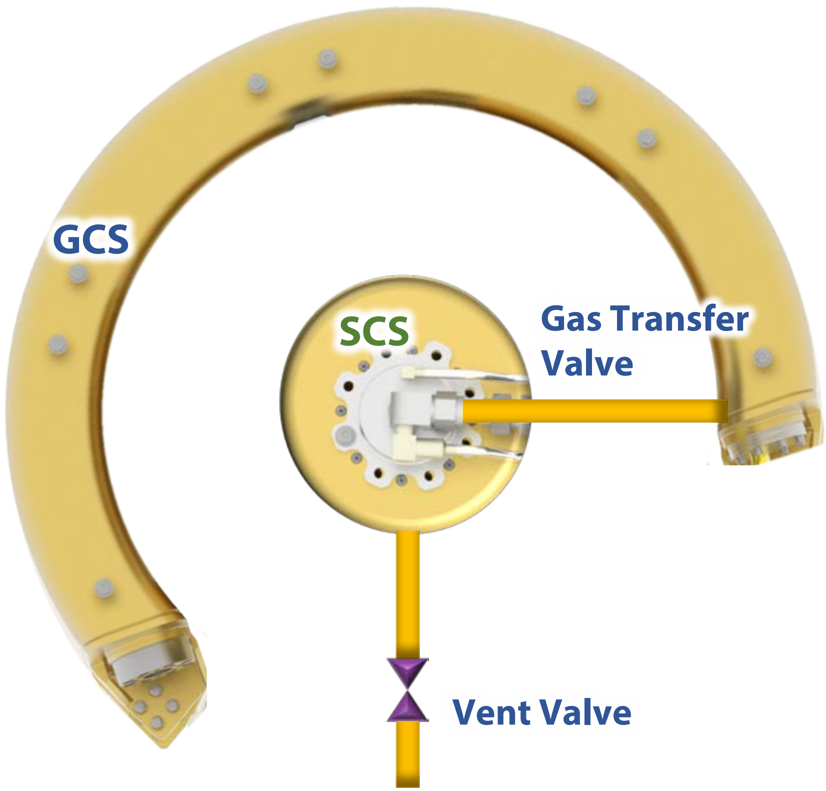
Sample Preservation

Bottom View

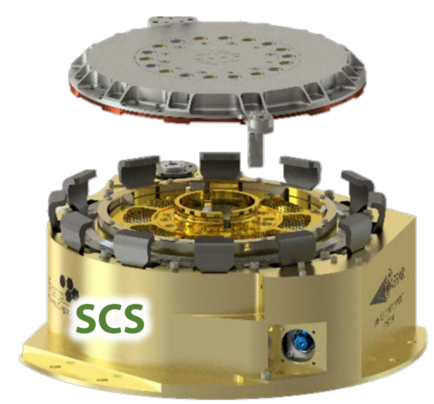


Sample Preservation

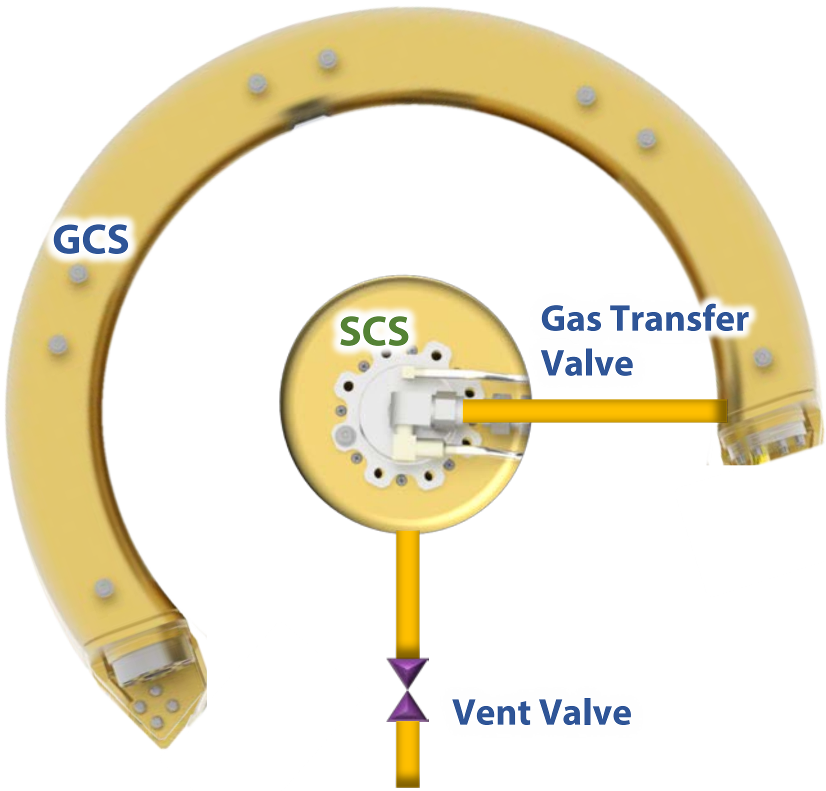
Simplified View



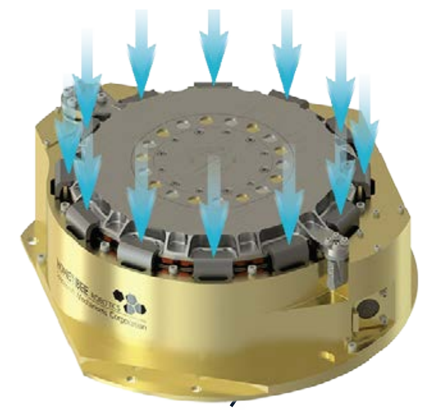
Solid sample stored in SCS



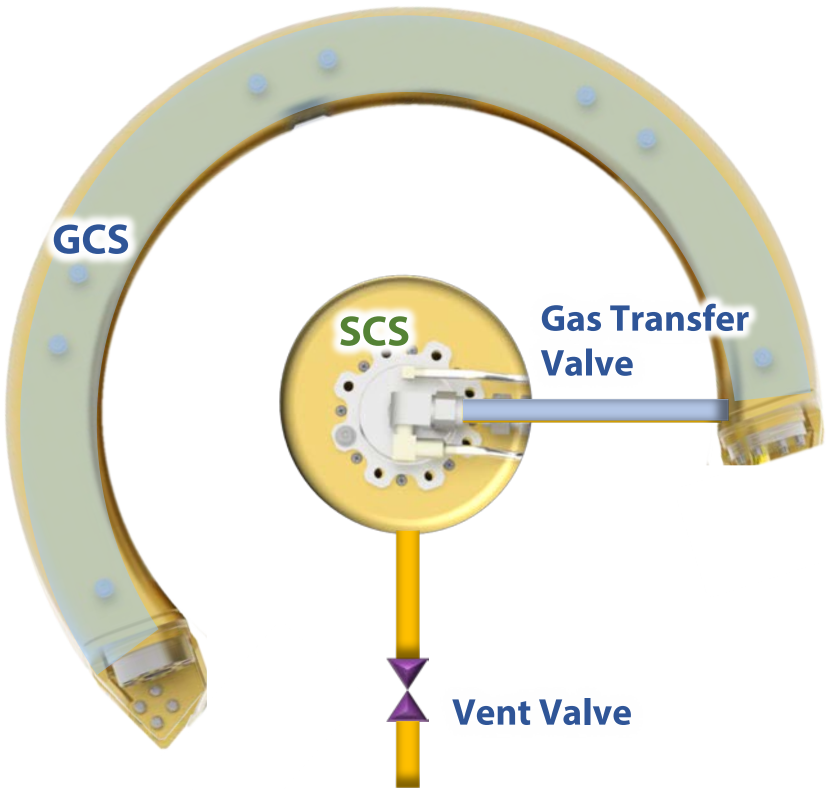
Sample Preservation



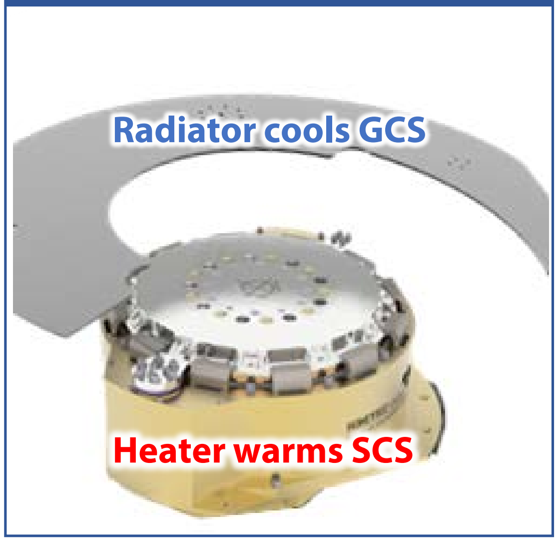
SCS hermetically sealed



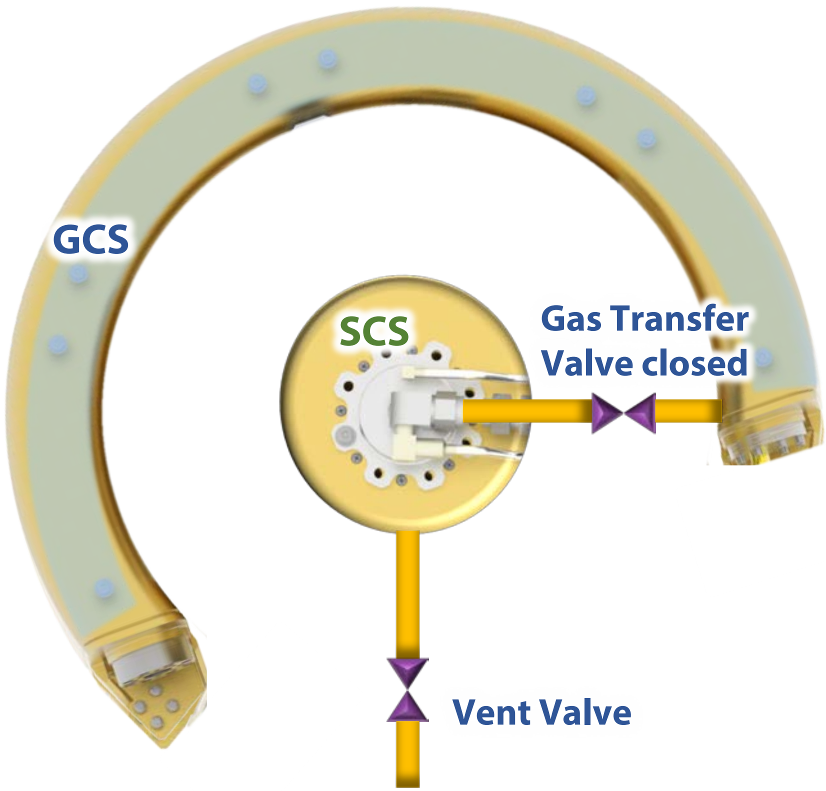
Sample Preservation



Gas transfer to GCS



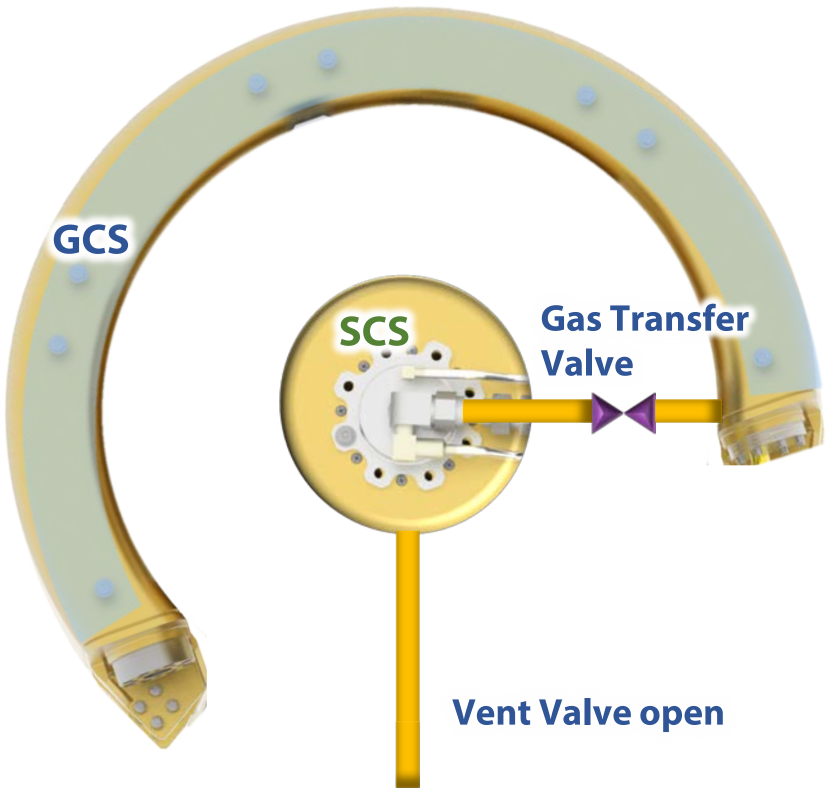
Sample Preservation



Gas transfer completed

Gas Transfer Valve is closed when P and PH_2O sensors indicate gas transfer is complete.

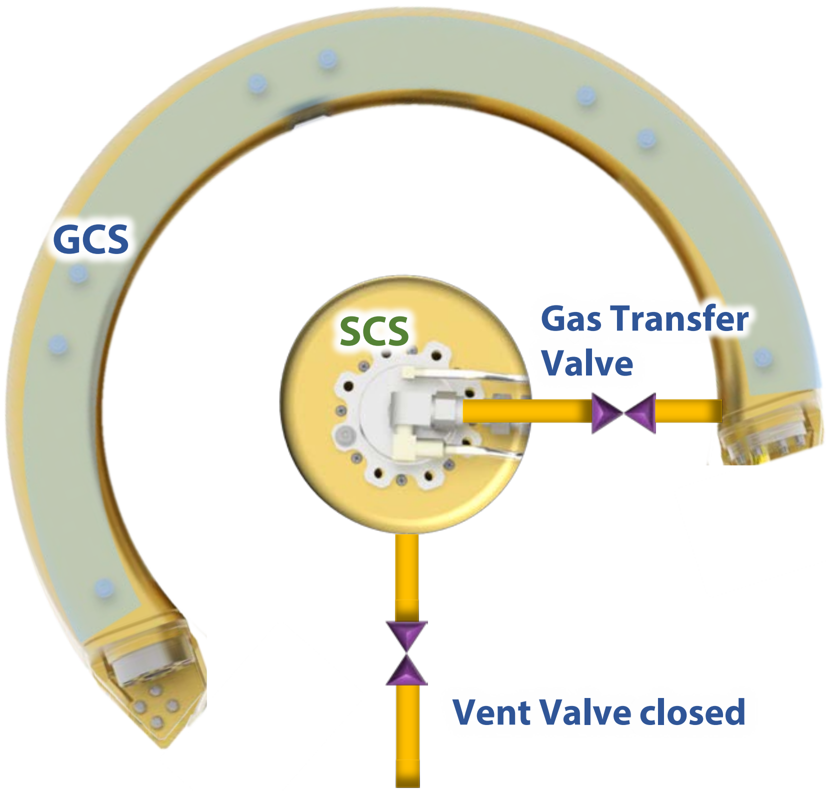
Sample Preservation



SCS evacuated

SCS is vented to space, and remains vented throughout return cruise, preventing sample alteration.

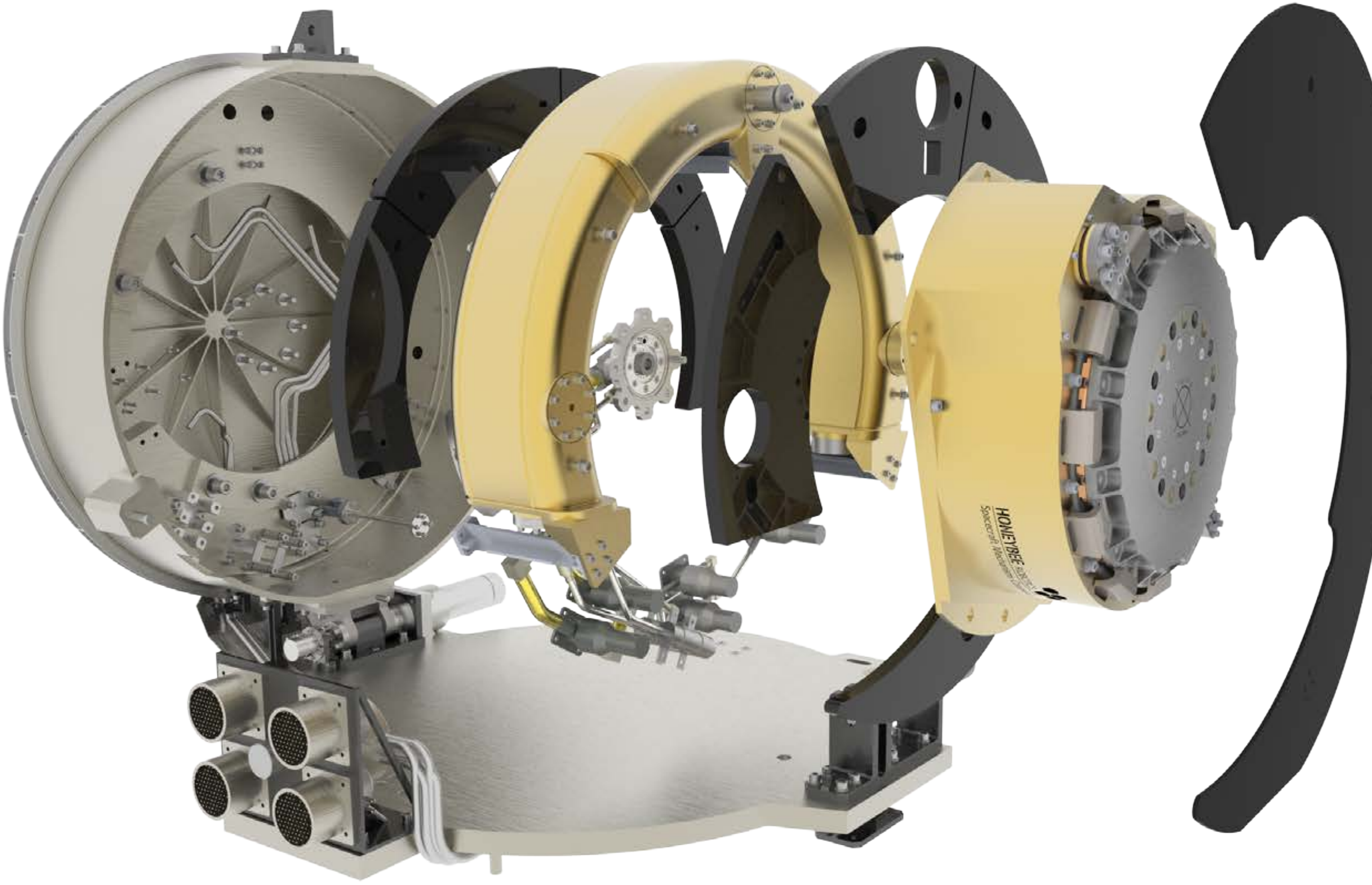
Sample Preservation



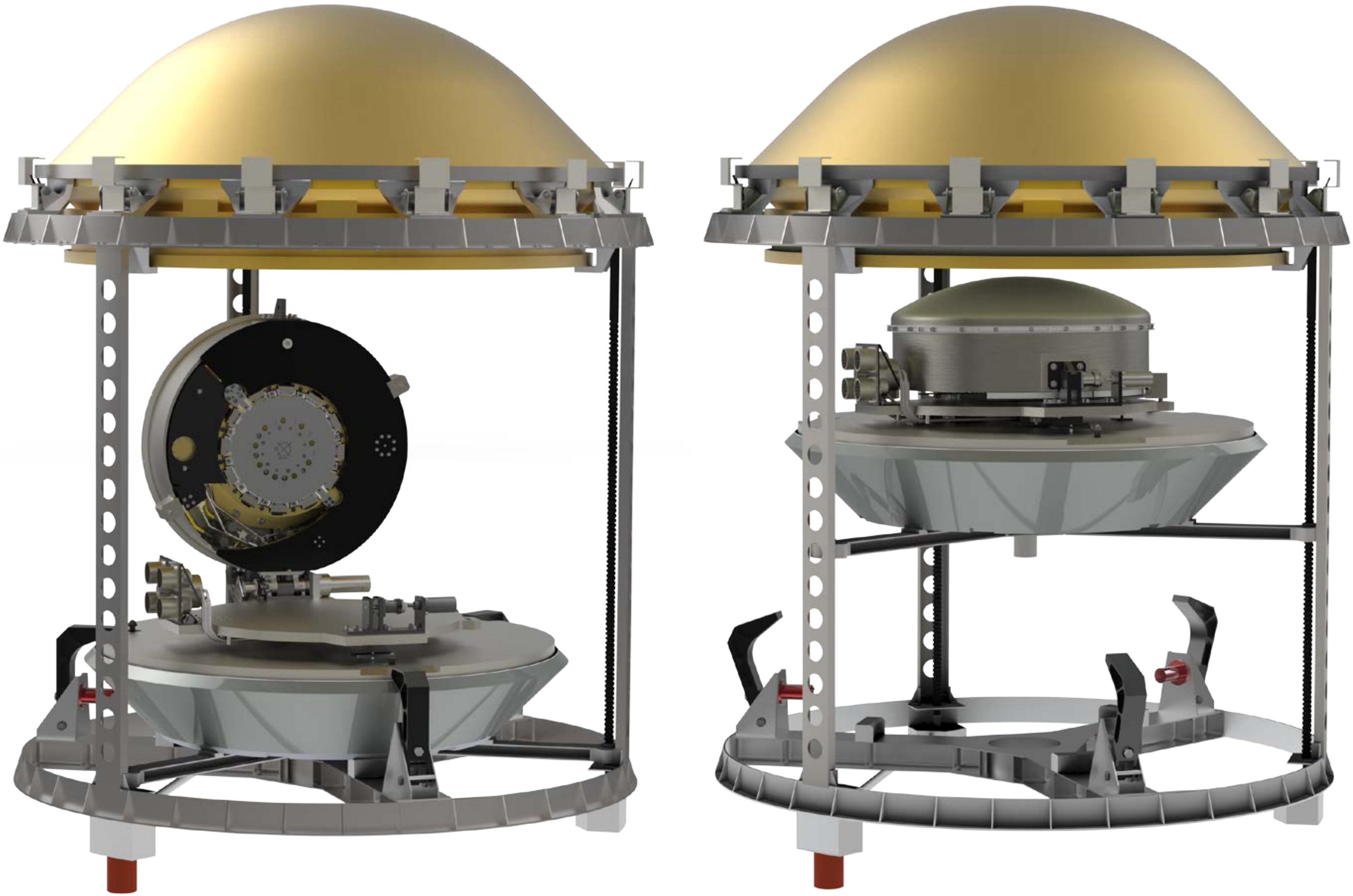
SCS sealed

Vent Valve is closed just before Earth entry, preventing sample contamination.

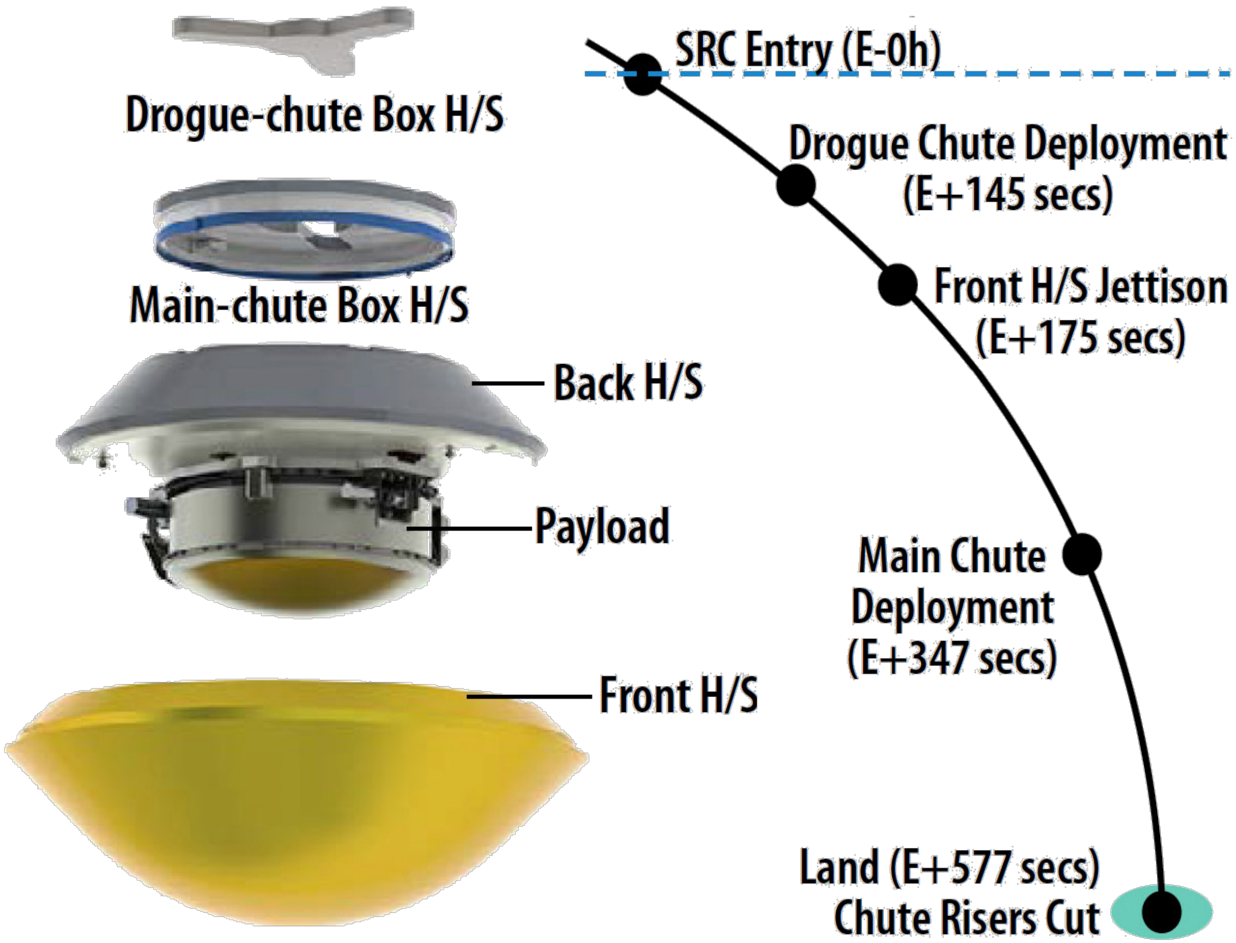
Gas Containment System

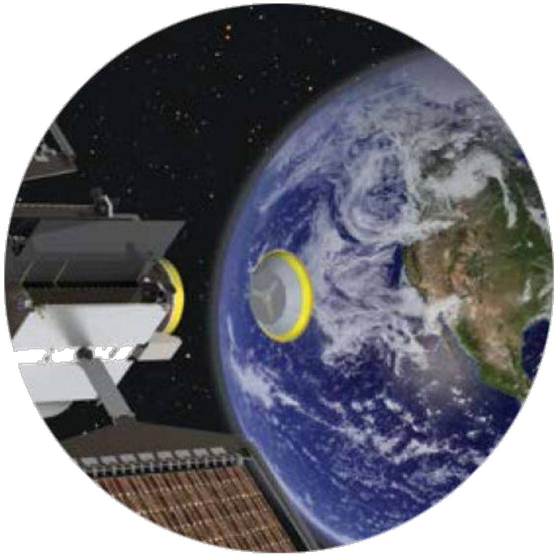


Sample Return Capsule

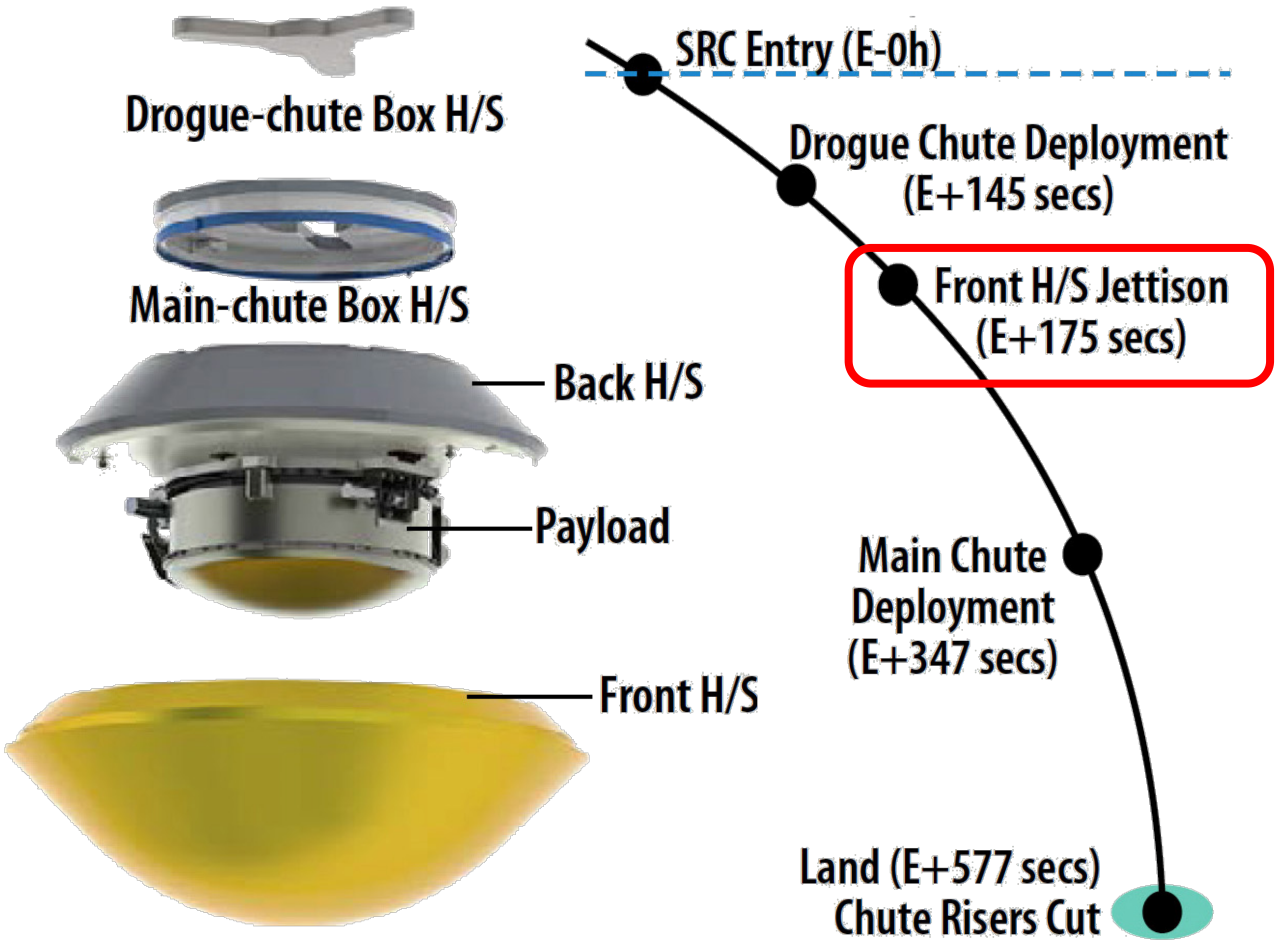


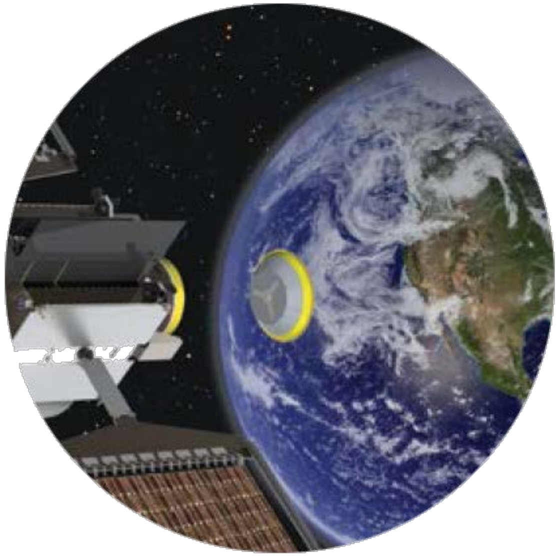
Sample Return Capsule



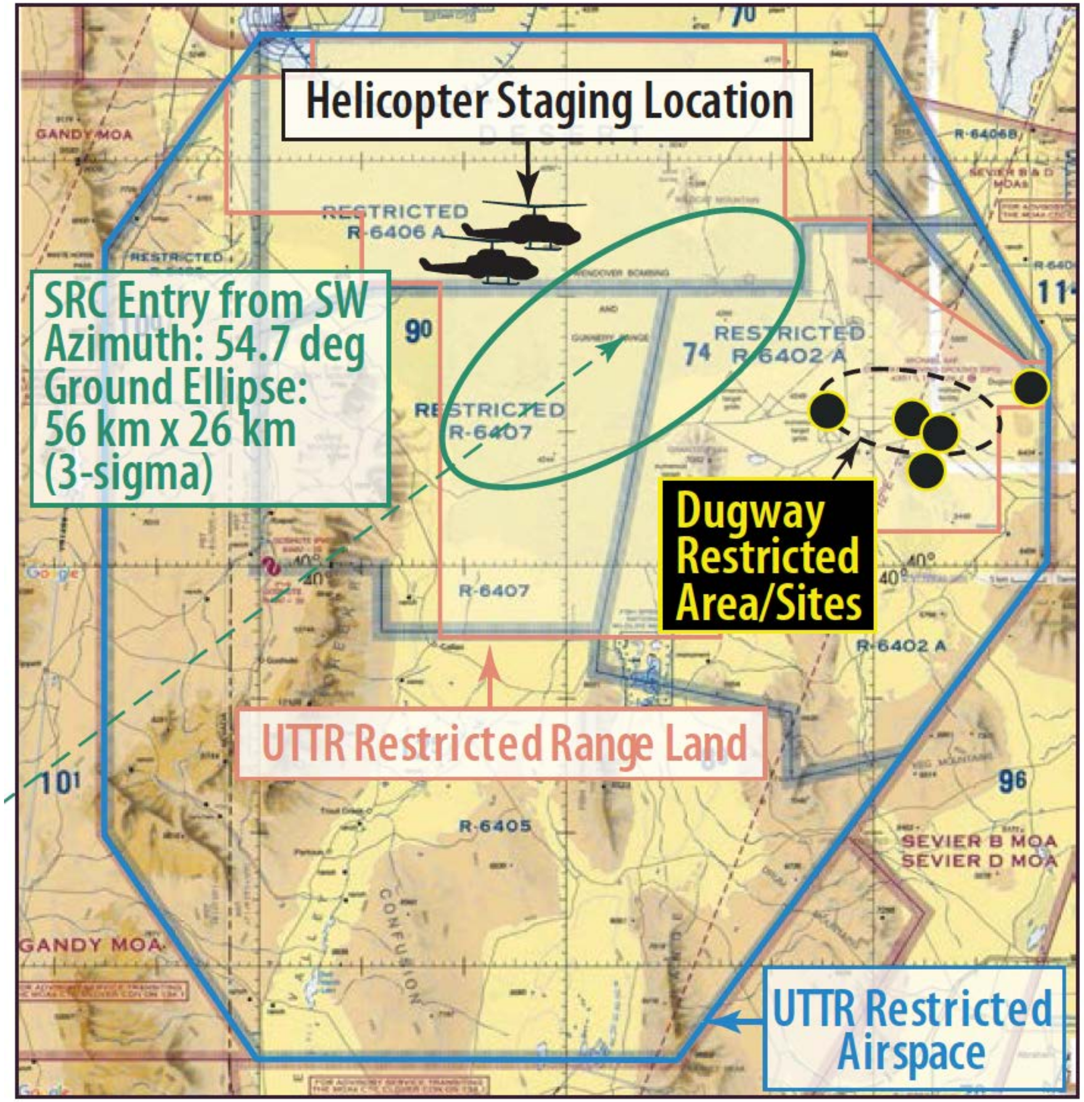


Sample Return Capsule

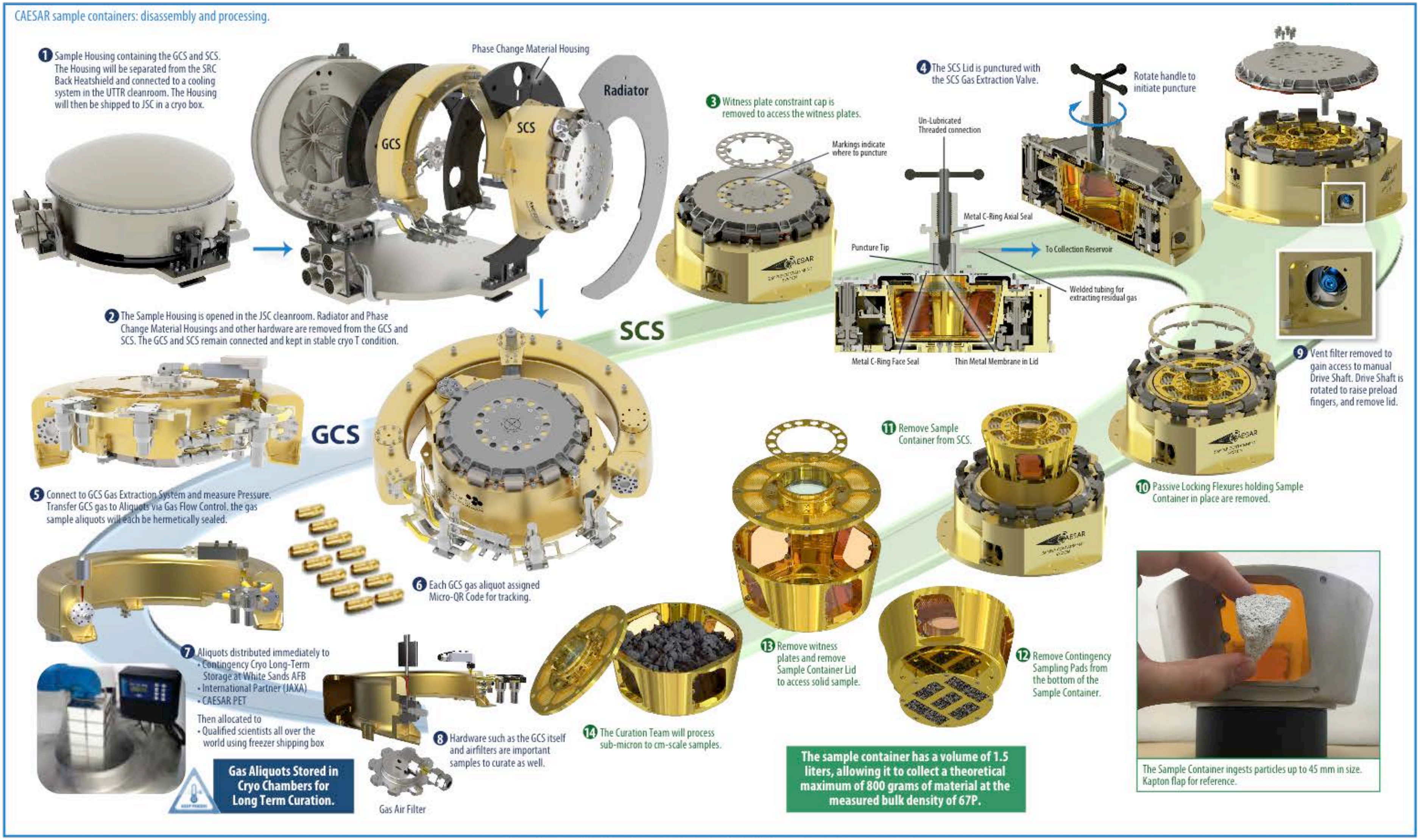




SRC Recovery



Sample Curation



Thank you!

More details in our LPSC abstracts:

- **Abstract 1332:** The CAESAR New Frontiers Mission: 1. Overview
- **Abstract 1334:** The CAESAR New Frontiers Mission: 2. Sample Science
- **Abstract 1336:** The CAESAR New Frontiers Mission: 3. TAG Site Selection and Camera Suite
- **Abstract 1337:** The CAESAR New Frontiers Mission: 4. Sample Acquisition and Preservation
- **Abstract 1339:** The CAESAR New Frontiers Mission: 5. Contamination, Recovery and Curation

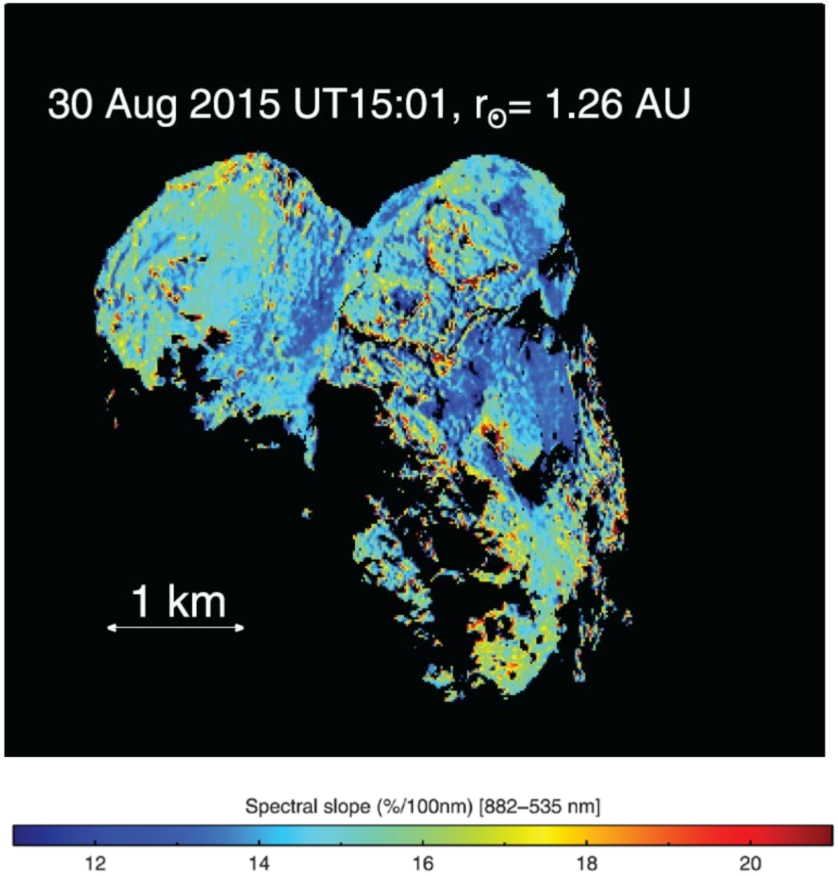
Backup

Ice Distribution on 67P

Rosetta's comet 67P/Churyumov-Gerasimenko sheds its dusty mantle to reveal its icy nature

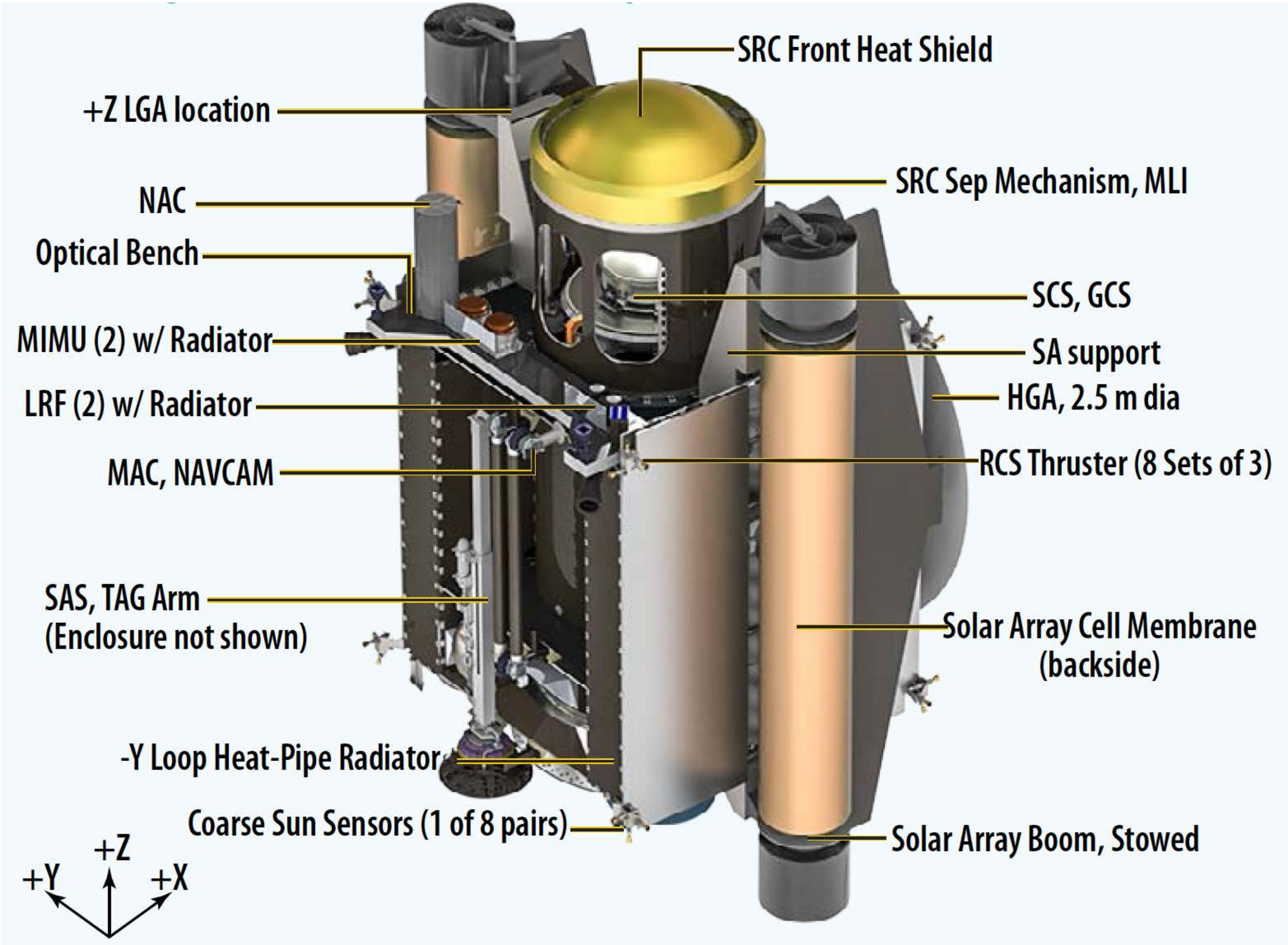
S. Fornasier,[1*] S. Mottola,[2] H. U. Keller,[2,3] M. A. Barucci,[1] B. Davidsson,[4] C. Feller,[1] J. D. P. Deshapriya,[1] H. Sierks,[5] C. Barbieri,[6] P. L. Lamy,[7] R. Rodrigo,[8,9] D. Koschny,[10] H. Rickman,[11,12] M. A'Hearn,[13] J. Agarwal,[5] J.-L. Bertaux,[14] I. Bertini,[6] S. Besse,[15] G. Cremonese,[16] V. Da Deppo,[17] S. Debei,[18] M. De Cecco,[19] J. Deller,[5] M. R. El-Maarry,[20] M. Fulle,[21] O. Groussin,[22] P. J. Gutierrez,[8] C. Güttler,[5] M. Hofmann,[5] S. F. Hviid,[2] W.-H. Ip,[23,24] L. Jorda,[22] J. Knollenberg,[2] G. Kovacs,[5,25] R. Kramm,[5] E. Kührt,[2] M. Küppers,[15] M. L. Lara,[8] M. Lazzarin,[6] J. J. Lopez Moreno,[8] F. Marzari,[6] M. Massironi,[26,27] G. Naletto,[28,27,17] N. Oklay,[5] M. Pajola,[29,27] A. Pommerol,[20] F. Preusker,[2] F. Scholten,[2] X. Shi,[5] N. Thomas,[20] I. Toth,[30] C. Tubiana,[5] J.-B. Vincent[5]

"The increase in water-ice visibility is observed on the whole surface, indicating that the composition in terms of dust-to-ice ratio must be similar at large scales all over the nucleus. This means that even the smooth areas commonly thought to be covered with material that fell back on the surface (18) must be water-ice rich."

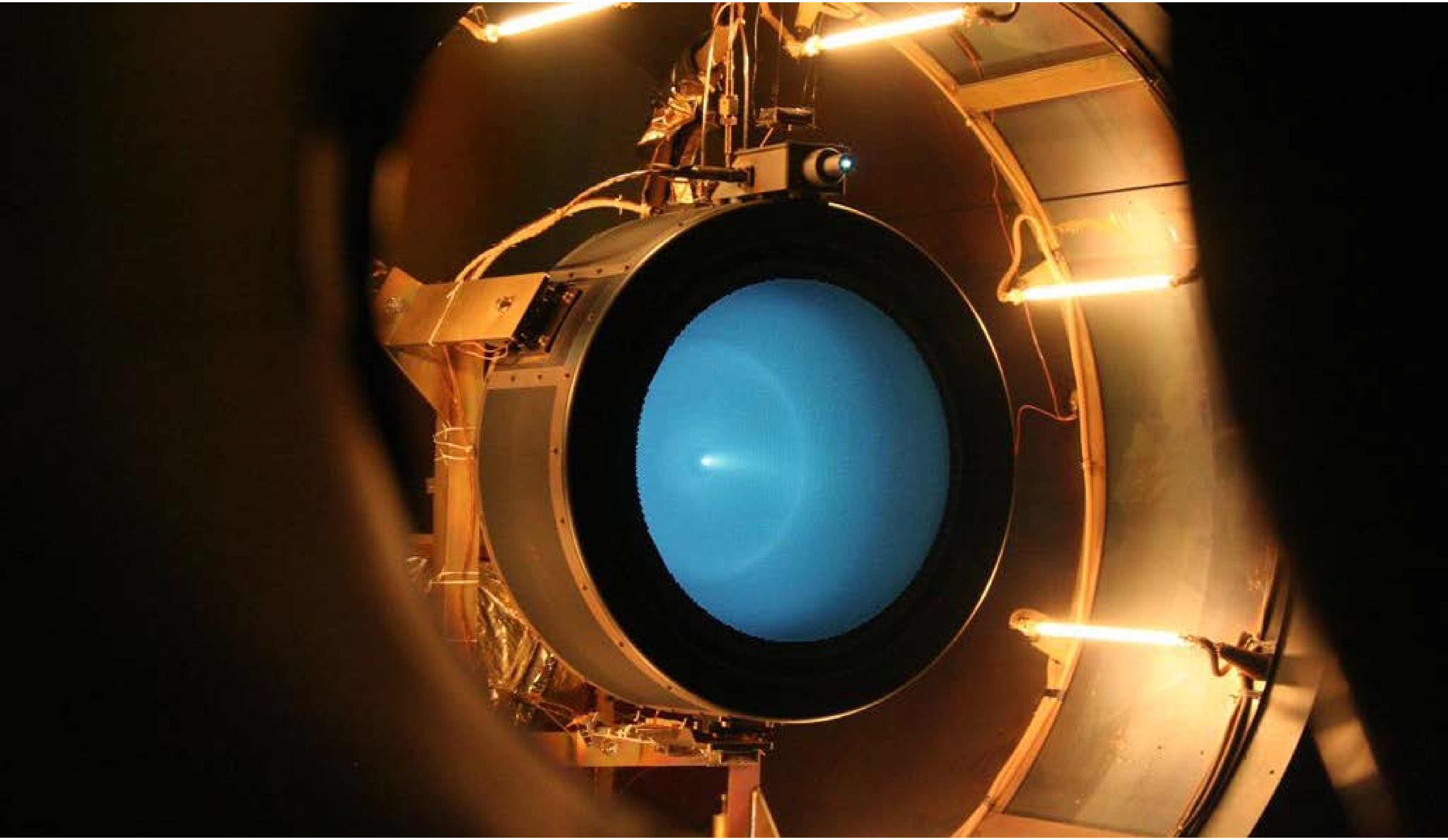


CAESAR

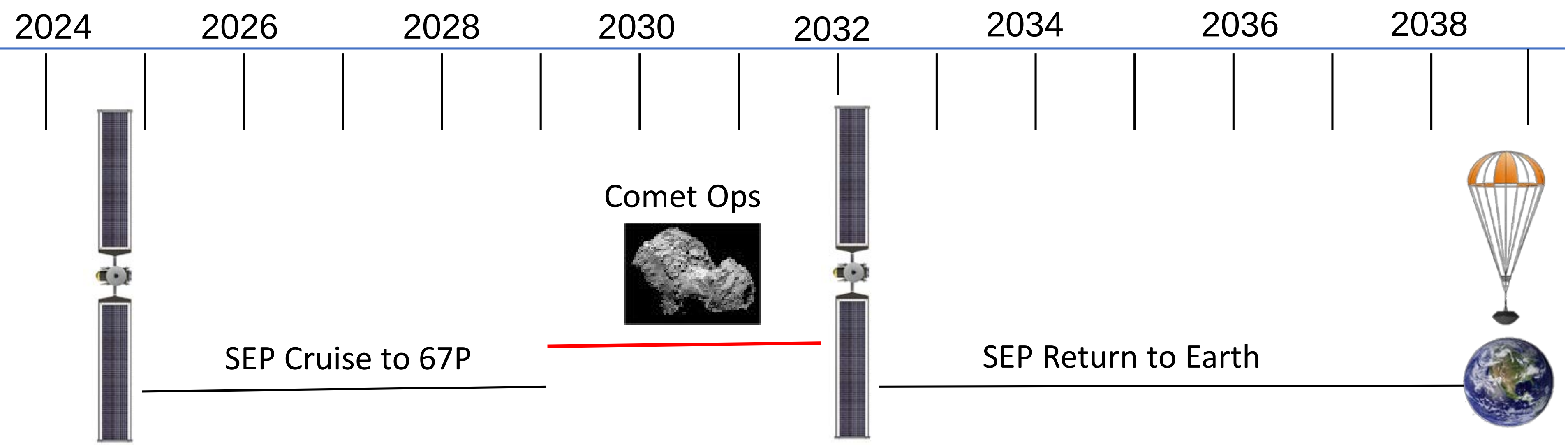
The Spacecraft



NEXT-C Ion Thruster

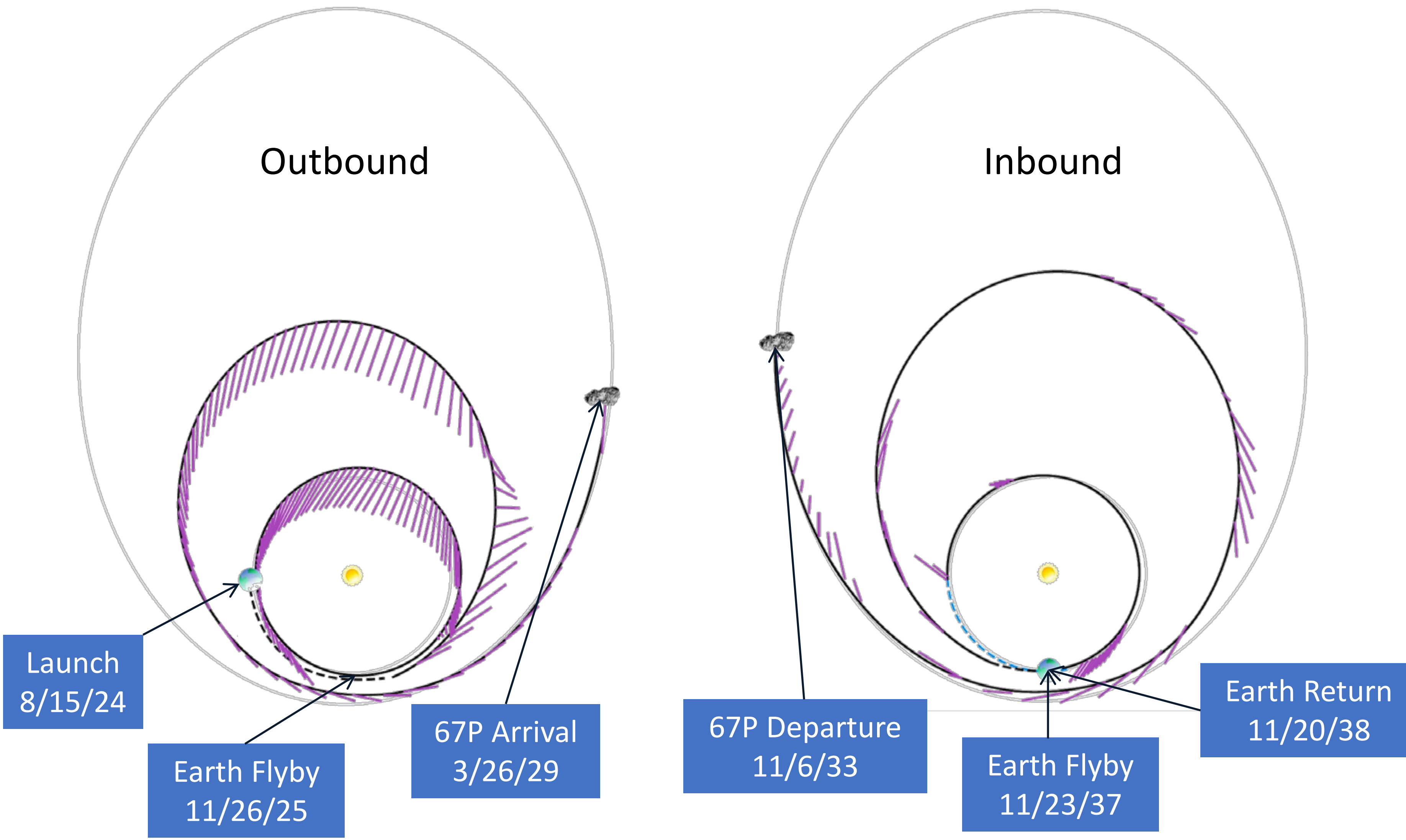


Mission Timeline



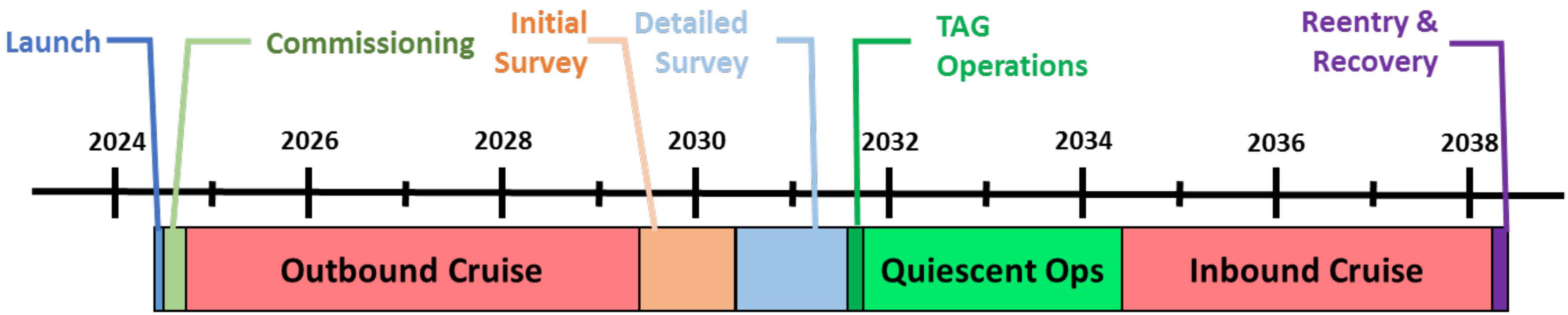
Launch	August 2024
Arrive at Comet	January 2029
Depart Comet	February 2032
Earth Return	November 2038

Trajectory



Outbound
Inbound
Launch 8/15/24
Earth Flyby 11/26/25
67P Arrival 3/26/29
67P Departure 11/6/33
Earth Flyby 11/23/37
Earth Return 11/20/38

Mission Operations Phases

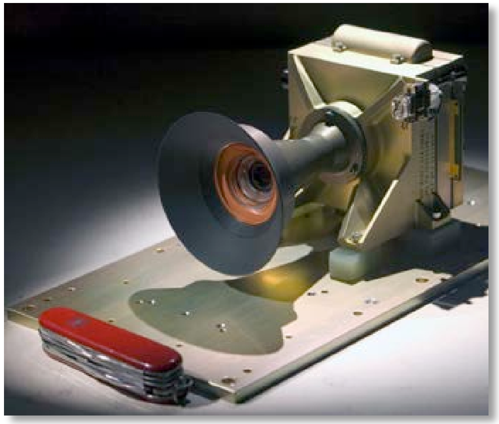


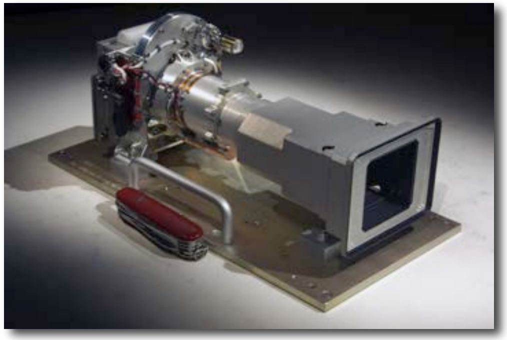
Phase	Duration	Sub-Phase	Duration
Launch	1.1 day	Pre-Launch	1 day
		Launch & Ascent	~1 hr
Commissioning	2 months	Activation	2 weeks
		Checkout	6 weeks
Outbound Cruise	5 years	SEP	1 week/1 day
		Coast	
		Comet Acquisition/Arrival	~1 year
Initial Survey	15 months	Remote Imaging	1 year
		High Mapping Orbit	1 month
		Medium Mapping Orbit	2 months
Detailed Survey	9 months	Low Mapping Orbit	2 months
		High Altitude Recon	5 months
		Low Altitude Recon	2 months

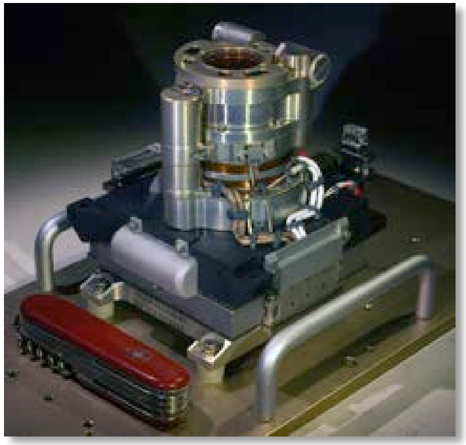
Phase	Duration	Sub-Phase	Duration
TAG Operations	2 months	TAG Rehearsals	1 month
		TAG Event	2 weeks
		Sample Verification/Handling	2 weeks
Quiescent Ops	~3 years	Quiescent Ops	~3 years
Inbound Cruise	3.5 years	SEP	1 week/1 day
		Coast	
Reentry & Recovery	2 weeks	S/C EDL Preparation	1 week
		SRC Prep & Release	1 day
		EDL, Recovery & Transport	3 day

Camera Suite

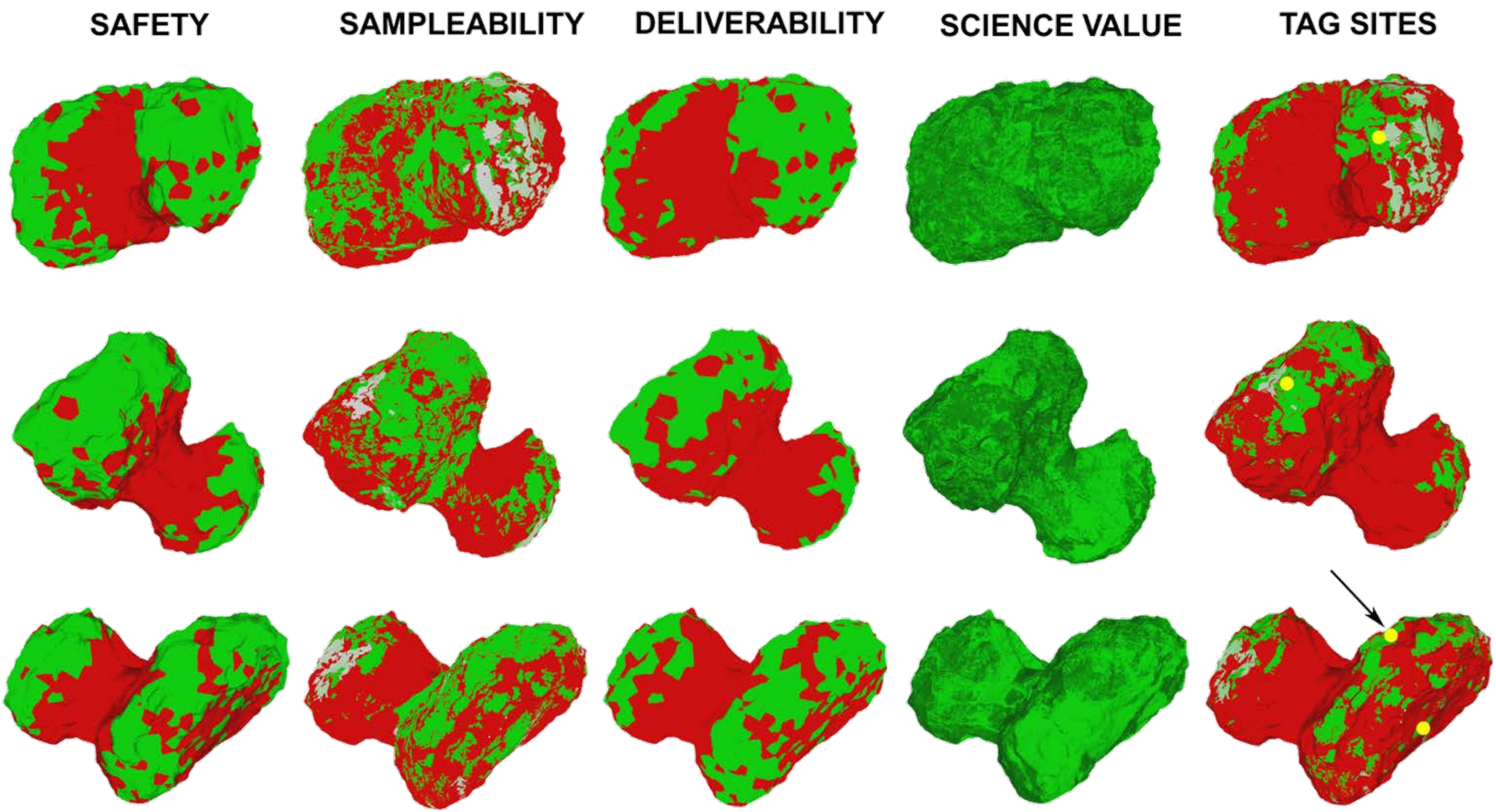
- **Wide-angle navigation cameras and sample canister camera based on the OSIRIS-Rex TAGCAMS.**
- **Narrow-angle mapping camera based on the Lunar Reconnaissance Orbiter Narrow Angle Camera.**
- **Mid-angle mapping camera is based on the Mars Science Laboratory Mastcam M100.**
- **Arm-mounted TAG camera is based on the Mars Science Laboratory MAHLI instrument.**







Preliminary TAG Site Selection



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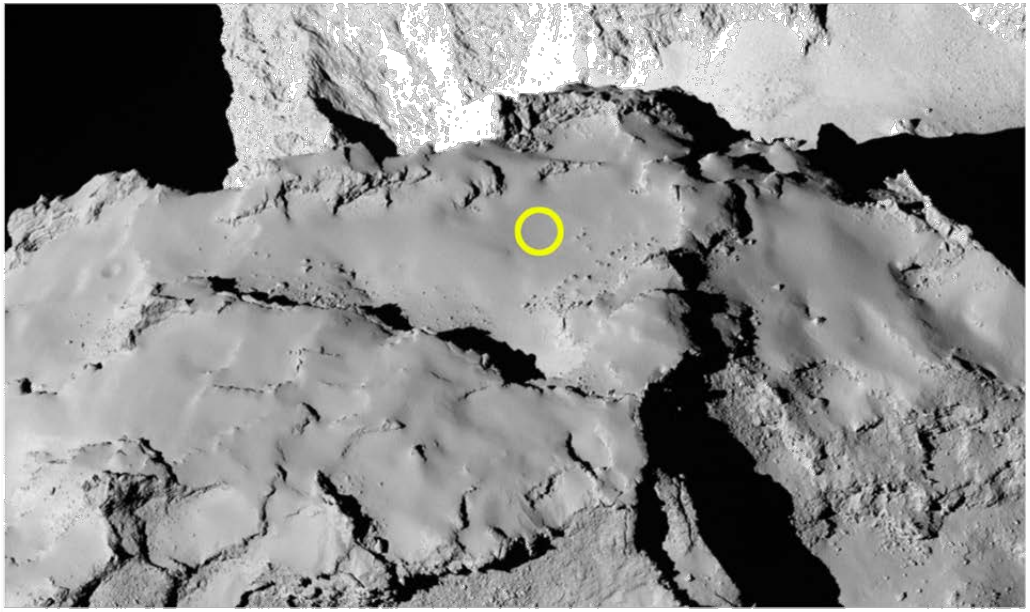
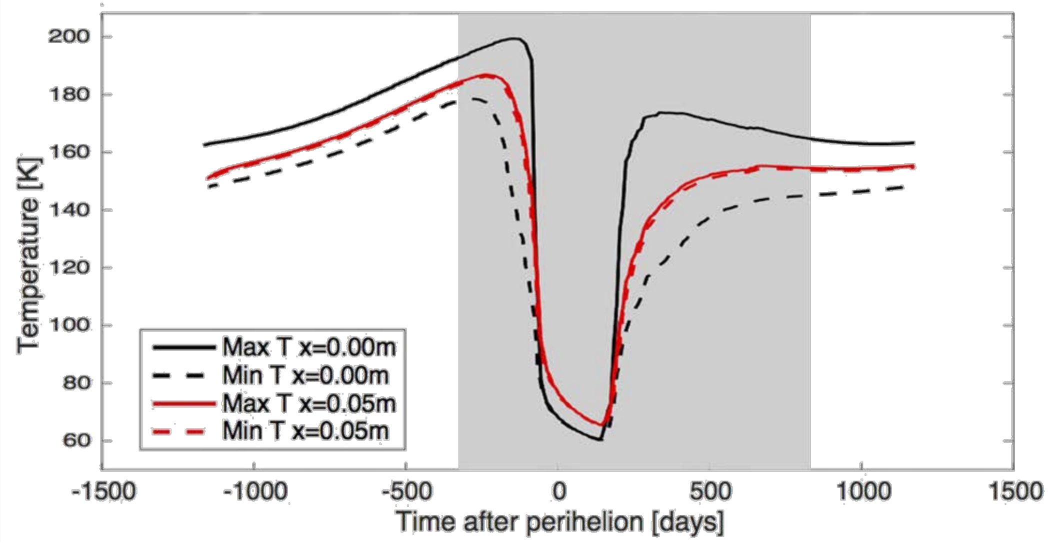
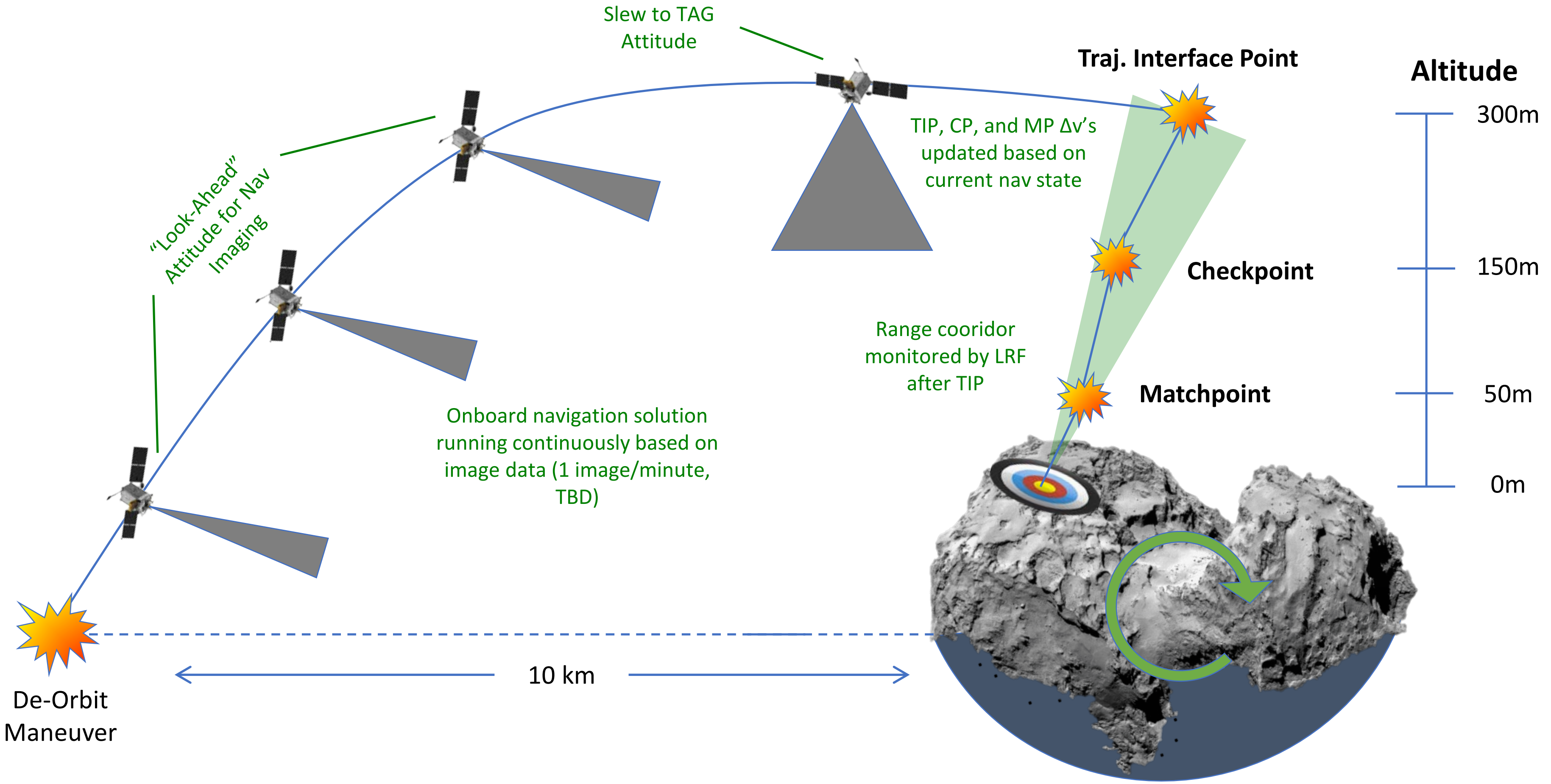




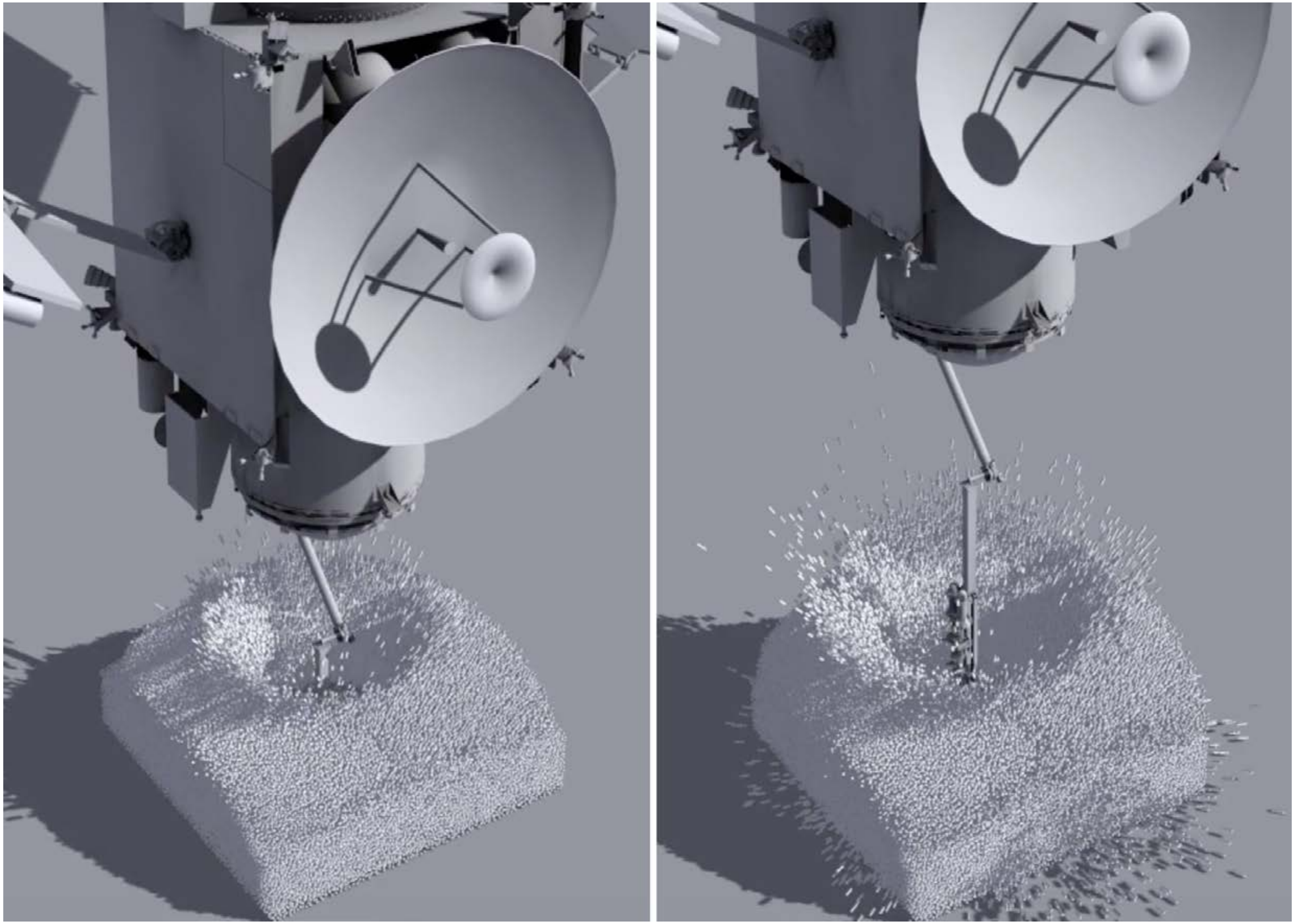
TAG



TAG Timeline

TAG

TAG



TAG Arm