EPSC Abstracts
Vol. 12, EPSC2018-122, 2018
European Planetary Science Congress 2018

The CAESAR New Frontiers Mission: Returning a Sample of a Cometary Nucleus

J.I. Lunine (1), K. Nakamura-Messenger (2), D.F. Mitchell (3), V.E. Moran (3), M.B. Houghton (3), D.P. Glavin (3), A.G. Hayes (1), D.S. Lauretta (4), S. W. Squyres (1) and the CAESAR Project Team.
(1) Cornell University, Ithaca NY USA, 14850, (2) NASA Johnson Space Center, Houston TX, USA, 77058, (3) NASA Goddard Space Flight Center, Greenbelt MD, USA 20771, (4) University of Arizona, Tucson AZ USA 85721
(jlunine@astro.cornell.edu)

Abstract

The Comet Astrobiology Exploration Sample Return (CAESAR) mission will acquire and return to Earth for laboratory analysis a sample of surface material from the nucleus of comet 67P/Churyumov-Gerasimenko (67P). CAESAR will characterize the surface region sampled, preserve the collected sample in a pristine state, and return evolved volatiles by capturing them in a separate gas reservoir.

1. Introduction

Comet sample analyses can provide unparalleled knowledge about presolar history through the initial stages of planet formation to the origin of life. Returning a sample of a cometary nucleus can uniquely address questions regarding the nature of Solar System starting materials and how these fundamental components came together to form planets and give rise to life.

The Comet Astrobiology Exploration Sample Return (CAESAR) mission will acquire and return to Earth for laboratory analysis a minimum of 80 g of surface material from the nucleus of comet 67P/Churyumov-Gerasimenko (67P). CAESAR will characterize the surface region sampled, preserve the collected sample in a pristine state, and return evolved volatiles by capturing them in a separate gas reservoir.

The sample CAESAR will return will allow laboratory analyses on Earth to determine the nature and abundances of interstellar dust grains and molecular cloud materials, and characterize the origins and ages of refractory solar nebula condensates. It will trace the history of volatile reservoirs, delineate the chemical pathways that led from simple interstellar species to complex and prebiotic molecules, and constrain the geological and dynamic evolution of the comet. And it will evaluate the potential role of comets in delivering water and organics to the early Earth. CAESAR will achieve these goals by carrying out coordinated sample analyses that will link macroscopic properties of the comet with microscale mineralogy, chemistry, and isotopic studies of volatiles and solids.

2. Implementation

Launched from Cape Canaveral, the solar powered CAESAR spacecraft conducts an outbound cruise, equipped with a solar electric propulsion system. After a flyby of the Earth and possibly the 12-km B-type asteroid 2809 Vernadskij, it arrives at 67P in December 2028. CAESAR enters orbit around 67P, lowering its orbital altitude slowly and sequentially over a period of months.

Collection of a sample from the surface of comet 67P is enabled by the CAESAR Camera Suite provided by Malin Space Systems. During an initial survey, the color Narrow Angle Camera is used to search for natural satellites, determine changes that have occurred since Rosetta, and produce a global topographic map. Images of increasing resolution are used to downselect to 16 and then 8 candidate touch-and-go (TAG) sites. A subsequent detailed survey phase provides images that are used to down-select to the final 4 candidate TAG sites. These sites are documented with 7-color stereo images, and higher resolution monochromatic stereo images. The team selects a primary TAG site. At least three TAG campaigns can be conducted.

Data for TAG guidance is provided by both optical navigation and laser ranging. After a deorbit burn, three deterministic propulsive maneuvers refined by a closed-loop linear correction from an onboard navigation system deliver the spacecraft to the selected TAG site. The sample is collected by the Sample Acquisition System (SAS), which has been specifically designed for the surface properties of comet 67P observed by the Rosetta/Philae mission. It contacts the comet surface during a brief touch-and-go maneuver, mounted on a three-degree-of-freedom TAG Arm. During surface contact, pneumatic jets direct the sample into a 1.5-liter sample container. Sample collection is verified by direct imaging of the sample container interior, and a load cell in the TAG Arm measures sample mass. An engineering model of the SAS has been tested in zero gravity and vacuum at the NASA Glenn Zero Gravity Research Facility, over a range of adverse surface strength properties, slopes, and particle size distributions. Honeybee Robotics provides the SAS.

After sample collection, the spacecraft automatically executes a back-away burn. The TAGCAM camera, mounted on the spacecraft, images the SAS and surface at five frames/s during TAG, documenting TAG at high resolution. The CANCAM camera, mounted within the SAS, images inside the sample container, documenting sample collection. Once successful sample collection has been verified, and while the sample is still cold, the TAG Arm inserts the sample container into the Sample Containment System (SCS), mounted inside the Sample Return Capsule (SRC). The SCS immediately seals the sample, preventing material from escaping into space. The SCS seal uses a stainless-steel knife edge driven into a copper gasket, and has been shown via test to substantially exceed leak rate requirements after having been sealed under a range of cold and dirty conditions. Honeybee Robotics also provides the SCS.

The SCS then slowly warms the sample from the cold temperatures at which it was collected to typical comet surface temperatures near perihelion. As gases evolve from the solid sample, they pass from the SCS into a 5-liter passively cooled gas reservoir in the Gas Containment System (GCS), also mounted in the SRC, separating them from the solid sample and thereby protecting the solid sample from alteration. Once H_2O has sublimated from the solid sample, the GCS is sealed to capture the volatiles it contains, and the SCS is vented to space to maintain the solid sample under vacuum. The SCS vent is closed before Earth entry to prevent atmospheric contamination. Continuous records of sample temperature, pressure, and H_2O vapor partial pressure are collected from sealing at the comet until opening on Earth. The interiors of the SCS, GCS, and associated plumbing are coated with high-purity gold to minimize surface reactivity and catalysis. Goddard Space Flight Center (GSFC) provides the GCS.

The pristine nature of the sample is preserved using stringent cleaning protocols during fabrication, and careful mission design during spacecraft operations. Ground and flight witness materials thoroughly document any contamination. The team follows rigorous cleanliness and documentation protocols through all mission phases. The CAESAR SRC is provided by the Japanese Aerospace Exploration Agency (JAXA). Its design is based on the SRC flown on the Hayabusa and Hayabusa2 missions. Like its predecessors, the CAESAR SRC drops its heat shield during parachute descent, greatly simplifying thermal control of the comet sample. The aerodynamic stability in the transonic regime of the Hayabusa SRC design allows use of a subsonic drogue parachute, providing ease of flight testing.

The SRC lands at the Utah Test and Training Range (UTTR) and is immediately placed in cold storage. Phase change material sealed in aluminum housings mounted on the GCS assures that no melting of H_2O will occur even if SRC recovery is delayed for hours. All recovered hardware is transported to the Johnson Space Center, where the samples are removed and delivered to the dedicated CAESAR curation facility. After preliminary examination, samples are made available to the worldwide scientific community.

3. Summary

CAESAR will return the first sample from a comet nucleus. The payload has been designed to maximize the scientific value of the sample, including both its non-volatile and volatile components. The choice of comet provides substantial risk reduction, achieving the mission within a constrained New Frontiers budget. Most of the sample ($\geq$75%) will be set aside for analysis by generations of scientists using continually advancing tools and methods, yielding an enduring scientific treasure that only sample return can provide.