Comet Interceptor: A mission to an ancient world

Cecilia Tubiana¹, Geraint Jones²,³, Colin Snodgrass⁴, and the the Comet Interceptor Team*¹

¹Max Planck Institute for Solar System Research, Goettingen, Germany (tubiana@mps.mpg.de)
²Mullard Space Science Laboratory, University College London, Surrey, UK
³The Centre for Planetary Sciences at UCL/Birkbeck, London, UK
⁴Institute for Astronomy, University of Edinburgh, Royal Observatory, Edinburgh
*¹A full list of authors appears at the end of the abstract

Comets are the most pristine objects in our Solar System. Having spent most of their life at large distance from the Sun, where they remained mostly unaffected by solar radiation, comets are the most unaltered remnants from the era of planet formation. In June 2019, a multi-spacecraft project – Comet Interceptor – was selected by the European Space Agency (ESA) as its next planetary mission, and the first in its new class of Fast (F) projects [1]. The mission’s primary science goal is to characterise, for the first time, a long-period comet – preferably one which is dynamically new – or an interstellar object. An encounter with a comet approaching the Sun for the first time will provide valuable data to complement that from all previous comet missions: the surface of such an object would be being heated to temperatures above its constituent ices’ sublimation point for the first time since its formation.

A mission to an unknown target: As a comet’s trajectory needs to be very well known in order to send a spacecraft to it, past missions to comets (e.g. Giotto to comets 1P/Halley in 1986 [2] and 26P/Grigg-Skjellerup in 1992 [3] and Rosetta to 67P/Churyumov-Gerasimenko in 2014-2016 [4]) have, by necessity, been sent to short-period comets with well-characterised orbits. A consequence of this is that all past missions have encountered comets that have evolved from their original condition during their time orbiting near the Sun. Comet Interceptor will take a different approach: it will be delivered to Sun-Earth Lagrange Point L2 with the ESA Ariel mission, planned for launch in 2028. At L2, it will be in a relatively stable location in space, where a ‘parking’ orbit can be maintained through occasional station-keeping, waiting for later injection onto an interplanetary trajectory to intersect the path of its target. This allows a relatively rapid response to the appearance of a suitable target, which will need to traverse the ecliptic plane in an annulus which contains Earth’s orbit. In addition to having a spacecraft capable of being targeted at relatively short notice, this mission to a “new” comet is possible because large sky survey observatories are now finding incoming comets with greater warning times, of a few years at least. With the advent of powerful facilities such as the Vera Rubin Observatory’s Legacy Survey of Space and Time, LSST, under construction at the time of writing in Chile [5], the prospects of finding a suitable dynamically new comet nearing the Sun for the first time are very promising. The enticing possibility also exists for the spacecraft to encounter an interstellar object if one is found on a suitable trajectory. Simulations of LSST performance, based on the best current understanding of the underlying population of Oort cloud comets from the Pan-STARRS survey, suggest that about 5 years between discovery and interception is likely, and the target comet may be found before the mission is
launched. A short period comet will serve as a backup destination in case a suitable target is not found within a period of approximately 3 years post-launch. An important consequence of the mission design is that the spacecraft must be as flexible as possible, i.e. able to cope with a wide range of target activity levels, flyby speeds, and encounter geometries. This flexibility has significant impacts on the spacecraft solar power input, thermal design, and dust shielding that can cope with dust impact speeds ranging from around 10 to 80 km/s, depending on the target comet’s orbital path.

A Multi-Spacecraft Architecture: Comet Interceptor will comprise three spacecraft. When approaching the target, the two sub-spacecraft – one (B2) provided by ESA, the other (B1) by the Japanese space agency, JAXA, will be released from the primary craft. The main spacecraft, which will act as the primary communication point for the whole constellation, will be targeted to pass outside the hazardous inner coma, making remote and in situ observations on the sunward side of the comet. The two sub-spacecraft will be targeted closer to the nucleus and inner coma region. These two platforms will perform valuable complementary observations to those of the primary spacecraft, venturing into a region of the coma that presents a higher risk to their safety. Data will be transmitted from the two sub-spacecraft to the primary spacecraft in real time, for later transmission to Earth. Dust shields are included on all three spacecraft, to protect them from high speed dust impacts.

Scientific Goals and Observations: Measurements of the target include its surface composition, shape, and structure, its dust environment, and the composition of the gas coma. A unique, multi-point 'snapshot' measurement of the comet-solar wind interaction region will also be obtained, complementing single spacecraft observations made at other comets. The mission’s instrument complement will be provided by consortia of institutions in Europe and Japan.

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the Comet Interceptor Team: Team members are listed at www.cometinterceptor.space