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Introduction: Comets are, without doubt, extremely valuable scientific targets, as they largely preserve the ices formed at the birth of our Solar System. 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 the its constituent ices' sublimation point for the first time since its formation.

Comet Interceptor follows two highly successful ESA cometary missions: *Giotto* to comets 1P/Halley in 1986 [2] and 26P/Grigg-Skejllerup in 1992 [3], and *Rosetta*, which explored 67P/Churyumov-Gerasimenko at close range for an extended period during 2014-2016. The latter mission also delivered the Philae probe to perform the first soft landing on a comet's nucleus [e.g. 4-6].

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 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, maintained through occasional station-keeping, that is suitable 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 comet, 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, VRO (formerly The Large Synoptic Survey Telescope, 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 VRO performance, based on the best current understanding of the underlying population of Oort cloud comets from the Pan-STARRS survey [12], suggest that ~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 kms^{-1}, 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 provided by ESA, the other by the Japanese space agency, JAXA, will be released from the primary craft. The main spacecraft, which would act as the primary communication point for the whole constellation, would 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 grain 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 is also to 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.

To meet the observational goals, the payload instruments for the main (A) and accompanying (B1 and B2) spacecraft at the time of writing are listed in Table 1. Details of the instrument Principal Investigators and their consortia are provided on the science team website, www.cometinterceptor.space

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References: [1] Snodgrass, C. and Jones, G. (2019) *Nature Comms.* 10, 5418. [2] Reinhard R. (1986) *Nature* 321, 313–318. [3] Grensemann, M. G. and Schwehm, G. (1993) *J. Geophys. Res.* 98, A12, 20907. [4] Taylor, M. G. G. T., et al. (2017) *Philos. Trans. R. Soc. A* 375, 20160262. [5] Filacchione, G. et al. (2019) *Space Sci. Rev.* 215, 19. [6] Groussin, O. et al. (2019) *Space Sci. Rev.* 215, 29. [7] Ivezic, Z. et al. (2008) *Astrophys. J.* 873, 111. [8] Bowles et al. (2020), *LPSC* 51. [9] Shirley et al. (2020) *LPSC* 51.

Table 1: *Comet Interceptor* scientific instrument payload at the time of writing.

Instrument	Purpose
Spacecraft A (ESA)	
CoCa: Comet Camera	To obtain high resolution images of the comet's nucleus at several wavelengths.
MANIaC: Mass Analyzer for Neutrals and Ions at Comets	A mass spectrometer to sample the gases released from the comet.
MIRMIS: Multispectral InfraRed Molecular and Ices Sensor	To measure the heat radiation being released from the comet's nucleus and study the molecular composition of the gas coma. [8, 9]
DFP : Dust, Field, and Plasma	To understand the charged gases, energetic neutral atoms, magnetic fields, and dust surrounding the comet.
Spacecraft B1 (JAXA)	
HI: Hydrogen Imager	UV camera devoted to studying the cloud of hydrogen gas surrounding the target.
PS: Plasma Suite	To study the charged gases and magnetic field around the target.
WAC: Wide Angle Camera	To take images of the nucleus around closest approach from an unique viewpoint
Spacecraft B2 (ESA)	
OPIC: Optical Imager for Comets	Mapping of the nucleus and its dust jets at different visible and infrared wavelengths.
EnVisS: Entire Visible Sky	Coma mapper to map the entire sky within the comet's head and near-tail, to reveal changing structures within the dust, neutral gas, and ionized gases.
DFP: Dust, Field, and Plasma	A subset of DFP sensors on spacecraft A.