Comet Interceptor

Science Management Plan

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1. SUMMARY AND SCOPE

Comet Interceptor (CI) is an ESA mission in cooperation with the Japanese Aerospace Exploration Agency (JAXA). It aims to characterise a long period comet, which could potentially be a dynamically new comet, or an interstellar object.
This Science Management Plan (SMP) describes the approach that will be implemented, up to and including the post operational phase, to achieve the mission's scientific objectives and to optimise its scientific return. The SMP provides a mission overview (Section 2), followed by a summary of the mission management scheme (Section 3), including the description of the science and programme management and responsibilities. Section 4 presents the data products and data rights; Section 5 contains a description of the opportunities for participation in the mission and Section 6 outlines the ground segment and operations. Section 7 deals with the science and project management, and Section 8 defines the communication and public outreach plans.
The SMP is approved by the Science Programme Committee following a recommendation by the scientific advisory structure to the Science Programme and may be subject to revisions and updates at a later stage through the same approval loop if needed.

2. MISSION OVERVIEW

2.1. Scientific Objectives

The primary goals of the CI mission are to provide the first-ever in-situ (as opposed to ground-based observation) characterisation of a long period comet, which could be a dynamically-new comet or an interstellar object, and to perform the first simultaneous multi-point exploration of a cometary coma and nucleus.
The science of the mission encompasses two main themes: Comet Nucleus Science and Comet Environment Science. More specifically, the key questions to address are:

1) Comet Nucleus Science - What is the surface composition, shape, morphology, and structure of the target object?
2) Comet Environment Science - What is the composition of the coma, its connection to the nucleus (activity) and the nature of its interaction with the solar wind?

2.2. Mission description

The CI mission consists of the main spacecraft (S/C A) and the two probes (named Probe B1 and Probe B2, respectively).
The Comet Interceptor payload complement includes remote sensing and in situ measurement instruments accommodated on-board the main S/C and the two probes, so as to enable performing multi-point observations of the selected object during the fly-by.
Comet Interceptor will be launched together with the Ariel mission, to the Sun-Earth second Lagrange point, L2.
Following a waiting phase at L2, used to select the actual target object and to optimise the related transfer orbit, CI will cruise to the encounter and release the two probes shortly before performing the fly-by. The duration of the waiting phase depends on the actual target and its length is estimated to be four years.
After their release, the two probes will perform autonomous operations, relaying the scientific data back to the main spacecraft. Following the encounter, the main spacecraft will downlink to Earth the data

acquired during the fly-by. The maximum duration of the CI mission, from launch to the end of the post-encounter phase, is six years.

3. OVERVIEW OF THE MISSION MANAGEMENT SCHEME

The overall CI mission management scheme is summarised in Figure 1. The ESA ground segment includes the Mission Operation Centre (MOC), the Science Operation Component (SOComp) and a number of Ground Stations (G/S) used in the different mission phases. The Science Ground Segment (SGS) is formed by the SOComp (which includes the Planetary Science Archive), and the Comet Interceptor Science Data Centre (CISDC), which is part of the Belgian User Support and Operations Centre (B.USOC) (see Section 6.2 for further details).

The overarching responsibility for the Comet Interceptor mission rests with ESA's Directorate of Science. ESA responsibilities cover the mission architecture, the development and procurement of S/C A and Probe B2, the satellite integration and test activities, the launch services procurement (dual launch with Ariel), the mission and science operations.

During the development and commissioning phases, an ESA-appointed Project Manager will be responsible for implementing and managing ESA's activities. After a successful Near-Earth commissioning review, a Mission Manager will take over the responsibility for the mission throughout its nominal and any extended phases.

The CI mission relies on the cooperation with JAXA, providing the Probe B1 and associated payload, within the remit of an ESA-JAXA Memorandum of Understanding (MoU).

The payload for spacecraft A and B2 is provided by ESA Member States, within the remit of a Multi-Lateral Agreement (MLA[1]), including ESA and the national Funding Agencies. Member States are also responsible to support payload safety, maintenance and operations throughout the mission and to provide contributions to the SGS, including the CISDC.

[1] In case of conflicting provisions, precedence will be given to the MLA, over the present SMP.

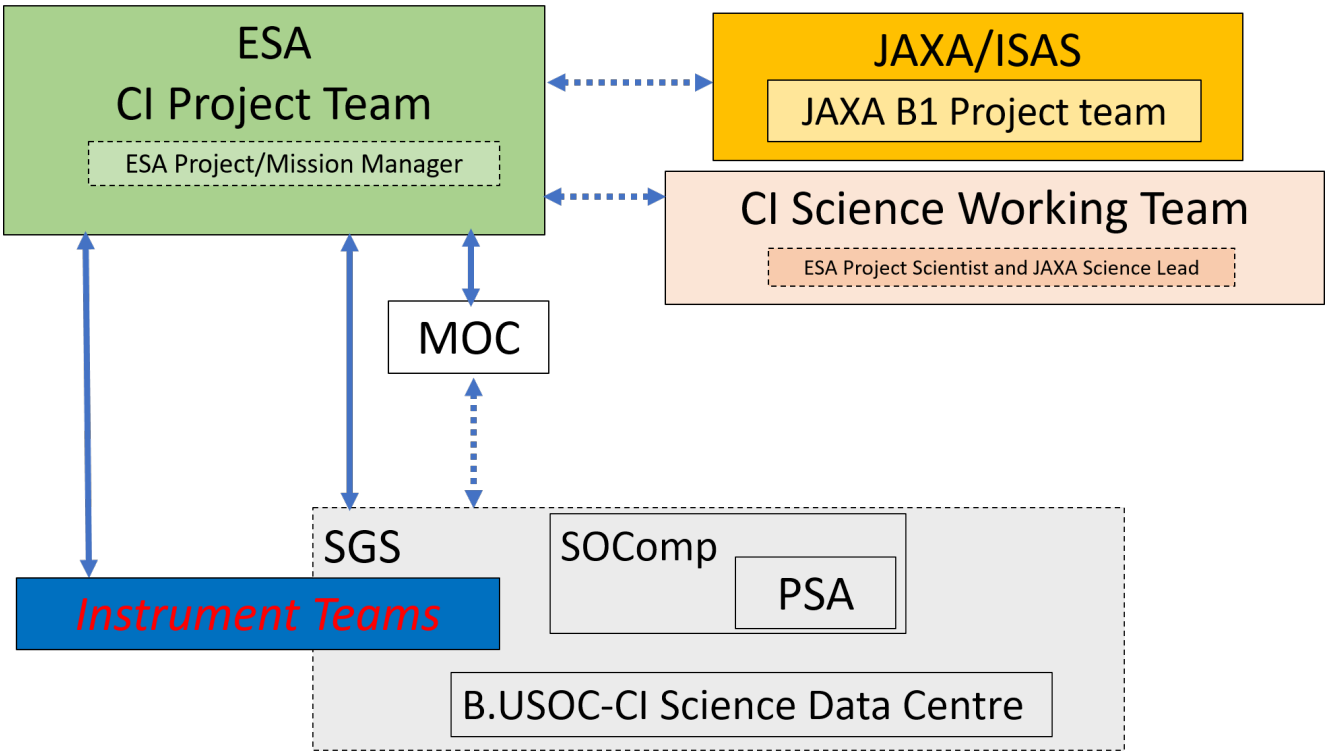

Figure 1. Overview of the Comet Interceptor mission management scheme

Note: Arrows indicate reporting (solid line) and coordination (dashed line) relations.

4. DATA PRODUCTS AND DATA RIGHTS

4.1. **Data products**

Data products are classified according to their processing status and are defined as follows:

- **Level 1**: Raw data. Telemetry data as received at the ground station.
- **Level 2**: Edited raw data (e.g., raw voltages, counts) at full resolution, time ordered, with duplicates and transmission errors removed.
- **Level 3:** Level 2 data that have been located in space and have been transformed (calibrated, rearranged) in a reversible manner and packaged with needed ancillary and auxiliary data (e.g., radiances with the calibration equations applied).
- **Level 4**: Irreversibly transformed (e.g., resampled, remapped, calibrated) values of the Level 3, or possibly Level 2, instrument measurements (e.g., radiances, magnetic field strength).
- **Level 5:** High-level science data products, derived from images (e.g. maps) and/or multi-instrument products.

Reduction of science data is under the responsibility of ILSs, supported by the CISDC.
Instrument teams will deliver final, science grade pipelines for processing Level 1 data to Levels 2-4 to the CISDC before launch. Pipelines will be well documented and produce user friendly data products,

compliant to the relevant standard. Validation of standard compliance will be supported by the SOComp. Instrument teams will also be responsible for any subsequent delta calibration/fixes during the archiving process.

4.2. **Data release and rights**

All Level 1 data will be provided by ESA to the Instrument Lead Scientists (ILSs) and to the CISDC, as soon as they will be received to ground, together with the trajectory, attitude and relevant spacecraft status information; these data will be archived in the CISDC.
After reception of the Level 1 data, the ILSs, supported by the CISDC, will have the responsibility to calibrate and validate the data and create the Level 2 – 4 data, within six months. Immediately after, the CISDC will make the Level 2 – 4 data publicly available, together with Level 1 data. To facilitate analysis of multi-instrument data, all data will be shared among the ILSs and through them with the instrument Co-Investigators (Co-Is) (see Section 5), and with the members of the Science Working Team (SWT) (see Section 7.1) upon creation by the pipeline. Any use of data for publication before the end of the six months period needs agreement by the respective ILS and requires immediate public release of the relevant data. During the calibration and validation period, selected data products will be released for outreach purposed by ESA, in coordination with JAXA and the relevant ILSs and data providers.
Level 5 data are high-level science data produced by the instrument teams, the CISDC, members of the SWT and/or other scientists. Once published, Level 5 data may also be archived in the CISDC.
By the end of the post-operations phase, the CISDC will deliver all data and associated documentation to the European Science Data Centre (ESDC) for long-term archiving in the Planetary Science Archive (PSA).
Comet Interceptor data will be made publicly available in compliance with the established ESA Rules on Information, Data and intellectual Property (ESA/REG/008).

5. PARTICIPATION IN THE MISSION

The possible modes of participation in the Comet Interceptor mission are:

(1) Instrument Lead Scientist (ILS), the scientific lead of a consortium providing an instrument.

(2) Co-Instrument Lead Scientist (Co-ILS), may be appointed if a major development is carried out in a country or institution different from the one of the ILS; A Co-ILS will have similar rights as the ILS, but the ILS will be the scientific interface to ESA.

(3) Co-Investigator (Co-I), a member of an instrument consortium.

(4) Interdisciplinary Scientist (IDS).

5.1. **Instrument Lead Scientist**

Within the remit of the MLA, under the responsibility of the Lead Funding Agency (LFA) for each instrument, the Instrument Lead Scientist (ILS) will have the following responsibilities in science, science management, and science operation matters:

(i) Establish an efficient and effective managerial scheme, which will be used through all phases of the instrument programme.

(ii) Organise the activities, assign tasks and guide other members of the instrument team.

(iii) Ensure that plans are timely established and implemented such that the status reporting complies with the ESA requirements.

(iv) Comply with the management requirements (e.g. progress and programme reviews, change procedures, product assurance, etc.) defined in the Experiment Interface Document (EID).

(v) Ensure the compliance of the instrument design to the scientific requirements defined in the Science Requirement Document (Sci-RD).

(vi) Be member of and attend the meetings of the Science Working Team (SWT) (see Section 7.1) and other delegated entities/groups, as appropriate, and take an active part in their work; report on instrument development and provide summaries of the main scientific results.

(vii) Provide the formal scientific interface of the instrument team with ESA.

(viii) Provide adequate calibration of all parts of the instrument, both on the ground and in space. This includes the provision of all required calibration data and software, along with a full instrument technical and science user manual for use by the general science user community.

(ix) Support the definition of and participate in the science, mission and instrument operations and data handling up to the end of the mission in accordance to the EID Part A requirements.

(x) Exploit the scientific results of the mission and assure their diffusion as widely as possible.

(xi) Provide the scientific data, in line with the CI data rights and delivery plan (see Section 4), including relevant calibration software and/or products, and associated documentation, in a format that will be agreed, for application by the general science community.

(xii) Support science communications and public relations activities of ESA and JAXA, and provide suitable information and data in a timely manner, as outlined in Section 8.

The financial support to the activities mentioned above will be provided by the relevant LFA, within the remit of the MLA (and the MoU between ESA and JAXA as applicable). Other national Funding Agencies supporting Co-ILS and Co-I teams are required to seek agreement with the LFA on financial matters related to the Co-ILS and Co-I team contributions.
The technical and programmatic management of each instrument for its design, production and delivery of hardware, software and ground segment elements will be detailed in the MLA (and the MoU between ESA and JAXA as applicable) and will be performed under the responsibility of the LFA providing financial support for the relevant instrument. Other national Funding Agencies providing contribution to (part of) these activities will seek agreement with the LFA on related financial matters; such contributions will be spelled out in the MLA.

5.2. **Co-Instrument Lead Scientist**

For instruments composed of more than one unit and for suites of instruments, one or more Co-ILSs can be appointed if a major development is carried out in a country or institution different from the one of the ILS.
The financial support to the activities for which the Co-ILSs are responsible will be provided by their national Funding Agencies and will be supported by formal interagency agreements with the LFA, which

holds overall responsibility with respect to instrument development and delivery to ESA. The relevant contributions will be spelled out in the MLA.

5.3. **Co-Investigator**

Members of each ILS-led consortium may be appointed as Co-Investigators (Co-Is). Each Co-I should have a well-defined role either with regard to hardware/software delivery or with regard to scientific support of the investigations within the instrument consortium. The ILS-led consortium may review the status of its members regularly and implement changes if required.
Each Co-I is required via the respective national Funding Agency to seek agreement on financial matters with the LFA of the instrument.

5.4. **Interdisciplinary Scientist (IDS)**

To ensure a top-level oversight of mission science, up to four Interdisciplinary Scientists (IDS) will be selected through an open Announcement of Opportunity (AO) process. IDSs should not be affiliated to or reflect instrument specific domains, but rather cover mission-related science themes, take part in the analysis of data from different CI instruments. IDSs will have the same data rights as all science team members. An IDS may also undertake specific tasks in areas such as modelling of the comet environment, science operation planning, hazard assessment and similar activities that may be required during the course of the mission. It is foreseen to select at least one Interdisciplinary Scientist each for nucleus science and for coma science. The selection will be done jointly by ESA and JAXA.
The proposals submitted by IDS candidates in response to the AO must describe clearly their scientific case, the relevance of their contribution to the mission and the instrument data sets needed to carry out their research programme. Financial endorsement by the relevant national funding agencies and/or other supporting institutions, should they require funds for their activity, is also required. The IDSs will be selected three (TBC) years before launch and will be part of the SWT. Scientists leading or involved in the (programmatic, scientific, or technical) management of the instruments or being responsible for hardware or software development and procurement activities, as well as other SWT members, are not eligible, while Co-Is of instrument teams may apply to become IDSs. The IDSs, like the ILSs, are expected to provide adequate support to the communications activities of ESA.

6. GROUND SEGMENT AND OPERATIONS

As indicated in Section 3, ESA is the mission lead and will be responsible for the launch, early operations, commissioning and operations of the spacecraft.
The CI Ground Segment provides the means and resources with which to manage and control the mission via telecommands, to receive and process the telemetry from the satellite, and to produce, disseminate and archive the generated products. Responsibility for and provision of the CI Ground Segment is split between ESA, JAXA, and the CISDC.

6.1. **Mission Operations**

The overall responsibility for the design and implementation of the Comet Interceptor Mission Operations rests with ESA. JAXA is responsible for the autonomous operations of satellite B1, after separation from the main spacecraft.

The Mission Operations Centre (MOC) is responsible for the operations of the Comet Interceptor spacecraft, and, in particular for the following tasks:

- monitoring and ensuring the spacecraft (including payload) safety and health;
- providing mission analysis, flight dynamics support including determination and control of the satellite's orbit and attitude, and intervention in case of anomalies;
- implementing the agreed spacecraft operations plan, from LEOP to S/C and probes disposal.
- handling of telemetry/telecommands for both the CI spacecraft and payload through the ESA tracking station network;
- ground station planning and collection of the CI raw telemetry science and auxiliary data and for making them available to the SOC for further processing.

ESA-provided ground station(s) will ensure the necessary telecommanding and telemetry capabilities.

6.2. **Science Ground Segment**

The science ground segment consists of the ESA SOComp, the CISDC, and the instrument teams (see Section 5.1).
The SOComp will be closely associated with the MOC, to guarantee science operation support to the MOC, and will manage the science operations.

6.2.1 SOComp

The main tasks of the SOComp are:

- Responsibility for the scientific operations of the mission;
- Interface with MOC for reception of spacecraft data and auxiliary files;
- Support in the coordination of the CI payload operations plan, as well as support to the scientific community;
- Support of CISDC and Instrument teams in creating standard compliant archive data;
- Reception and validation of data delivered by CISDC for ingestion into the long-term archive at the PSA at ESAC;
- Support in payload commanding during the science operations phase.

6.2.2 Comet Interceptor Science Data Centre

The Belgian User Support and Operations Centre (B.USOC) will host the Comet Interceptor Science Data Centre (CISDC). During the mission phase C and D, the CISDC will iterate with SOComp and Instrument teams to define interfaces and set up data management and visualisation tools. In Phase E, the main focus of CISDC will be interfacing with Instrument teams, to ensure completeness and validity of data and calibration pipelines. By the end of the mission, the CISDC will deliver these data, in an agreed Planetary Data System (PDS) archive format, to the PSA. During the operation and post-operation of the mission, the CISDC will ensure data are validated, formatted and calibrated in coordination with the teams of all instruments, for subsequent distribution and delivery, according to the data policy of the mission (see Section 4).

7. SCIENCE AND PROJECT MANAGEMENT

7.1. Science Working Team

The Comet Interceptor Science Working Team (SWT) will be appointed by ESA after the mission has been adopted. The ESA Project Scientist (PS), in coordination with the JAXA Science Lead (SL), will chair the SWT.
The SWT will advise ESA on all aspects of the mission potentially affecting its scientific performance. It will assist the ESA PS and the JAXA SL in maximising the overall scientific return of the mission within the established boundary conditions. It will act as a focus for the interests of the scientific community in Comet Interceptor.
The SWT members will have the data access and rights as indicated in Section 4.
The SWT may be asked to review and endorse top-level requirements that impact science return.
Members of the SWT are expected to contribute to monitor and to give advice on all aspects of the Comet Interceptor mission which affect its scientific performance. They may perform specific scientific and/or technical tasks, as needed during development and operations.
The SWT will consist of the following members:

- Instrument Lead Scientists (see Section 5.1).
- One Instrument Co-Lead Scientist per instrument team and up to three Co-Lead Scientists for the Dust, Field and Plasma (DFP) suite (see Section 5.2).
- Interdisciplinary Scientists (see Section 5.4) will be added to the SWT following a joint ESA – JAXA competitive selection.

The SWT may invite Co-ILSs who are not members of the SWT, Co-Is and other scientists to participate in the SWT meetings.
In case of decisions requiring a vote, there will be one vote for each of the following instruments: Comet Camera (CoCa), Modular InfraRed Molecules and Ices Sensor (MIRMIS), and Mass Analyzer for Neutrals and Ions at Comets (MANiaC), accommodated on S/C A; Entire Visible Sky (EnVisS) instrument, and OPtical Imager for Comets (OPIC), accommodated on Probe B2; Dust, Field and Plasma (DFP) suite, accommodated on S/C A and Probe B2; Hydrogen Imager (HI), Plasma Suite (PS), and Narrow and Wide Angle Camera suite (NAC+WAC), accommodated on Probe B1.
The operations timeline for the flyby will be recommended by the SWT. Final approval and responsibility for the mission operations remains with ESA.
The SWT will advise ESA on the target selection as well as on related target navigation aspects. In case no long period comet or interstellar object that is reachable with CI will be found by the planned waiting time in L2, the SWT will recommend target object(s) from a list of pre-defined backup (short period comets) targets. Final responsibility for the target selection remains with ESA.
The SWT may be supported by working groups, which will be established by the SWT as needed. They will generally be chaired by a SWT member.

7.2. Steering Committee

A Multi-Lateral Agreement (MLA) will be established between ESA and the Funding Agencies to formalise the commitments, responsibilities and deliverables of all parties. In case of conflicting provisions, the MLA will prevail over the present SMP. A Steering Committee with representatives from the national Funding Agencies will be set up to oversee the timely fulfilment of the obligations of all parties to the MLA and address any issues that may arise in that context.

8. Communication and Public Outreach

ESA will have overall responsibility for the science communications, educational and outreach activities related to Comet Interceptor. ESA and JAXA will have the right to use any data acquired by Comet Interceptor for outreach purposes, in coordination with the holders of the data rights as applicable, as covered by the ESA Rules on Information, Data and intellectual Property (ESA/REG/008).

Approximately one year before the satellite Qualification and Acceptance Review, a public outreach coordination group will be established in close collaboration between ESA, JAXA, the relevant bodies funding the provision of the scientific payload in the Member States and other institutions involved in the mission. Interactions between these parties will have to coordinate the outreach effort and to guarantee consistency between all applicable documents and policies.

Until launch, outreach activity will be focussed on key hardware deliveries, the launch campaign, and possibly the detection of potential target objects. After launch, and in particular after the comet flyby, a regular flow of science results from the mission will be prepared in a manner suitable for communication and public outreach purposes. Such outreach activity necessitates the timely availability of suitably processed data and the full involvement of the instrument teams.

Formal dedicated agreements regarding public outreach activities will be established between ESA, the relevant funding authorities, and other institutions involved in the mission. The terms and conditions contained in these agreements will be applicable on the relationships between the funding authorities and the various scientific investigators. These agreements will take account of any necessary project-specific science-to-public-outreach balance. The implementation of such agreements will be tracked by the SWT and as part of the standard project reviews.