Report on the discussion of the “1-Spacecraft-1-Probe” (1S1P) option during the Comet Interceptor Far Environment Working Group (FEWG) Telecons held on 10 May and 29 June 2021.

Background

During the Comet Interceptor (CI) Full Team Meeting on 15 April 2021, the team was informed by Nicola Rando of ESA that ESA is currently considering the option to descope one of the two probes (B1 and B2) on Comet Interceptor to increase the available ΔV. Given mass constraints that are tighter than initially expected, a situation is envisioned where with two probes, the available ΔV might not be sufficient to reach a dynamically new comet (DNC) or an interstellar comet (IC) in the available time, forcing CI to investigate one of its backup targets, a short-period comet (SPC).

During the FEWG telecons held on 10 May and on 29 June 2021, we, as a group, assessed the implications of the 1S1P scenario for the expected scientific outcome of the mission. We considered separately the two cases where either probe B1 or B2 was missing from the original payload. The discussion was structured following the level-2 payload requirements of the Science Requirements Document (SciRD), version 3.

One question that arose during the telecon is, if it is not possible to keep both probes, whether having only one probe would enable it and the main s/c to acquire more data in total, hence whether there is a critical limit in data storage volume on s/c A and whether the descope of one probe might enable the remaining probe to transmit more data to s/c A during the flyby, i.e. if the data receiving rate of A is the limiting factor here.

In the following, the results from this discussion are summarised.

We note that during the FEWG discussion we assumed EnVisS (without the narrow band filters) to be part of the payload of B2. However, for the individual science requirements a potential contribution of EnVisS is identified explicitely.

Far Environment Gas coma (Science Objectives R0-C-10 and R0-C-20)

Option A+B1 (descoping B2):

<u>Losses:</u> All science requirements in these categories are expected to be met, also without B2.

Comment: none.
Mitigation strategy: irrelevant.

Option A+B2 (descoping B1):

<u>Losses:</u>

- Without the Hydrogen Imager (HI) on B1, the coma observations in the Lyman-α line would not be possible. Hence SciR R1-C-15 would not be met.
- The lack of HI would also negatively affect R1-C-30, the measurement of the H_2O isotopic ratios D/H with B1/HI. This ratio would then only be measurable by MANiaC on s/c A, which means it would be measured only with a single method instead of two complementary ones that provide redundancy e.g. in the case of low activity.
- Partial loss of information is expected for R1-C-05 and R1-C-10, that require measuring the absolute and relative densities of volatiles and detect minor species and distributed sources, respectively. Without the PS-CIMS instrument on B1, this measurement would rely only on A/MANiaC. Hence a measurement at the theta angle of B1 would be lost, and, with that, information on the heterogeneity of the coma at different solar zenith angles.

Comment: none.
Mitigation strategy: none so far.

Far Environment Dust coma (Science Objectives R0-C-30 and R0-C-40)

Option A+B1 (descoping B2):

Losses:

- The most severe loss in this scenario would be the complete loss of polarimetric information (R1-C-75) due to the loss of EnVisS on the light scattering process by dust and its phase dependence on phase angle and location in the coma. Such a measurement has not yet been carried out by any spacecraft visiting a comet (Giotto measured the degree of polarisation only for a single phase angle). In addition, comet observations and hence polarimetry at phase angles >60° can hardly be carried out from Earth except for measurements from solar observatories. This phase angle range contributes to diagnose especially the composition, structure and monomer size of the dust particles. Polarisation measurements at phase angles <60° will enable linking large-scale ground-based measurements to the small near-nucleus scales accessible to Comet Interceptor. The instruments on board s/c A and B1 will measure the total intensity scattering phase function only, which provides less specific diagnostics of the dust properties.
- Partial loss is expected for R1-C-55, as in-situ density structures in the dust coma would be detectable only at the comparatively far flyby distance of s/c A, not any more at the closer distance of s/c B2 due to the loss of B2-DISC. 2D in situ information on local structures would therefore be lost. Remote sensing information on local dust structures would be reduced from a 3-line to a 2-line measurement, and in particular the roughly along-trajectory viewing direction of B2-OPIC would not be covered. Hence a valuable constraint to a 3d model of the dust density distribution would be lacking.
- Partial loss is also expected for R1-C-60, targeting the mass and fluence of dust in the 1-200μm sensitivity range of DISC. Without B2, these quantities would only be measured along the trajectory of s/c A, hence information on their evolution with nucleus distance would not be available. This would prevent the direct discrimination of particles stemming directly from the nucleus and those returning under the influence of solar radiation pressure. This will make the derivation of the dust mass distribution, especially for small particles, highly model-dependent. It would also prevent the detection of potential deviations from pure radial outflow e.g. by dust fragmentation. In the case of a distant fly-by at a low-

activity target A-DISC may not be able to measure a statistically significant amount of particles, such that without B2-DISC there may not be any such measurement at all, resulting in complete loss of R1-C-60. That said, A-COMPLIMENT may still detect nano-dust in this case.

- Major loss for R1-C-65 would be induced by OPIC not searching for cm-dm-sized refractories. CoCa expects to provide only upper limits on their abundance due to its larger distance from the nucleus.
- Partial loss is expected for R1-C-40 (large scale dust coma) because wide-scale imaging from the perspective of B2-EnVisS and B2-OPIC would not be available.

Comment: It is expected that A-DISC will be able to measure a statistically sufficient abundance of particles as long as the flyby distance scales with the activity of the comet.

Possible partial mitigation: it may be possible to derive or at least constrain the dust density along the trajectory of s/c B1 and s/c A from impacts on the s/c evident from the reconstructed attitude. However, the sensitivity and relevant mass range of such detections need to be assessed.

Option A+B2 (descoping B1):

Losses:

- Partial loss is expected for R1-C-40 (large scale dust coma) because wide-scale imaging from the perspective of B1 would not be available.
- Partial loss is also expected for R1-C-55 (local dust structures) as the remote sensing constraints on local dust structures would be reduced from 3 to 2 trajectories, yielding less information on the 3d distribution of such structures due to the lack of extended theta-angle coverage from B1.

Comment: none.
Mitigation strategy: none so far.

Far Environment Plasma Science (Science Objective R0-C-60)

Option A+B1 (descoping B2):

Losses:

Partial loss is expected for all four science requirements related to objective R0-C-60. All measurements would be reduced to 2-point simultaneous measurements instead of 3-point ones, with the data point obtained closest to the nucleus and information on the 3d structure of the B-field both lacking.

- Partial loss for R1-C-90 would result in lack of a measurement of the B-field close to the nucleus by B2-FGM. B-field and ion measurements at intermediate range will be provided by B1-PS.
- Partial loss for R1-C-95 as without B2-DISC and B2-FGM, no measurement of dust and B-field close to the nucleus would be possible.

- Partial loss for R1-C-100 because without B2-FGM, no simultaneous 3-point measurements close to the nucleus would be possible and hence it will be harder to build a 3d picture of the boundaries and their structure. A and B1 are more likely not to cross some of the boundaries due to their larger distance, while B2 has the best chance to cross all boundaries.
- Partial loss to R1-C-105 would be induced as without B2-FGM part of the information on the energy and momentum transfer across the coma would be missing. This could in part be recovered by B1-PS. However, the information on wave propagation can only be 1d with two measurement points.

Comment: see below.
Mitigation strategy: none.

Option A+B2 (descoping B1):

Losses:

Partial loss is expected for all four science requirements related to objective R0-C-60. All measurements would be reduced to 2-point simultaneous measurements instead of 3-point, with the data point at intermediate range lacking. All four science objectives may be in part covered by B2-DFP-FGM.

- Partial loss for R1-C-100 because building the 3d structure of the boundaries will be more limited and require more assumptions.

Comment: see below.
Mitigation strategy: none.

Comments for both options:

Both options are heavily linked: losing one measurement point may affect the plasma science as a whole.

There are several advantages of 3-point measurements over 2-point measurements:

- A+B1 and A+B2 are not necessarily symmetric in losses, e.g. because of their different distances to the nucleus and theta angles.
- Especially for a non-DN comet and for phenomena with associated time-scales that are short compared to the flyby duration (such as high-frequency waves), the third measurement would bring a real advantage over previous missions (e.g. Rosetta).
- Plasma processes cannot be constrained too well along a single line A-B, because plasma waves have many scales and preferential directions. A measurement at a third point would support the discrimination between wave modes.
- 3-point-measurements allow to constrain the wave vector in a plane while 2-point-measurements cannot constrain the wave vector, which would be a real improvement over past missions.
- Crossing boundaries along three independent lines would allow to start building a large-to-medium scale 3d picture of the boundary structures.

The FEWG notes that – with existing constraints – numerical plasma and neutral atmosphere models, built from the lessons learned during the Rosetta and other past missions, may help characterise and reconstruct some of the boundaries from 2-point measurements. These models can partially, but not solely, address the possible lack of a 3rd measurement point.

Far Environment linking plasma-dust-gas (Science Objective R0-C-50)

Option A+B1 (descoping B2):

Losses:

Both requirements related to R0-C-50 would be fully missed.

- R1-C-80 (mapping of ion rays through wide field mapping) primarily relies on EnVisS and would therefore be gone without B2. Mapping of the ion tail and its separation from the dust dust depends on a favourable approach geometry from outside the orbital plane of comet, and on a sufficient level of comet activity to support an ion tail surface brightness that can be detected in broad-band filters. B1-WAC and CoCa may also be able to image a bright ion tail.
- R1-C-85 targets the correlation of in-situ data with wide field maps obtained in R1-C-80 and cannot be fulfilled without R1-C-80 being fulfilled. In addition, part of the related in situ measurements (those by B2-FGM and B2-DISC) would be missing.

Comments: none

Possible mitigation: B1-WAC and A-CoCa may be able to measure the ion rays. SciRD v3 needs to be changed to reflect this point, if correct.

Option A+B2 (descoping B1):

Losses:

- Without B1-PS-MAG, a measurement from a second theta angle would be lacking for R1-C-85.

Comment: none.

Mitigation strategy: none.