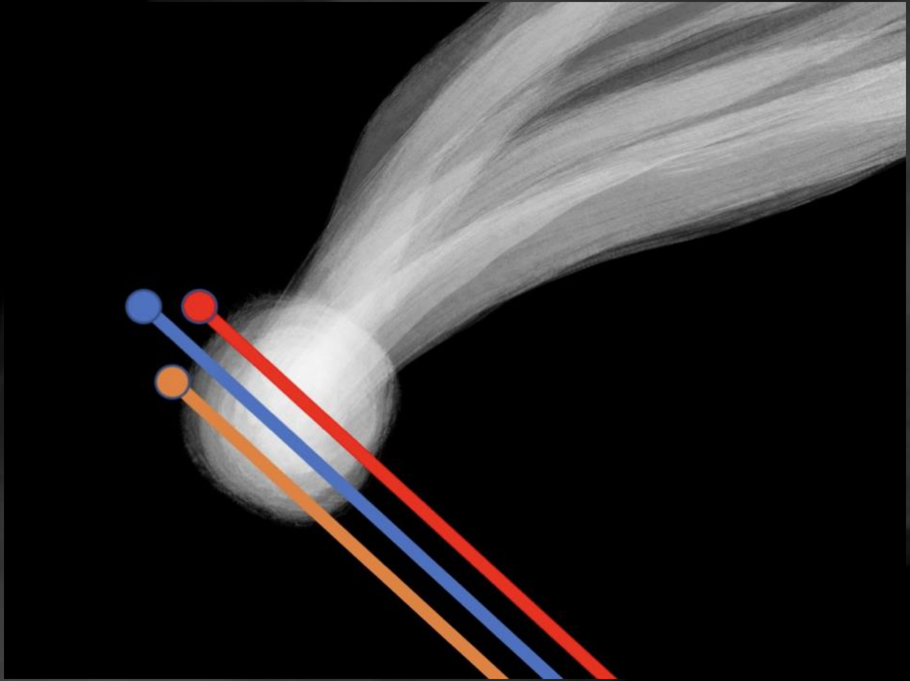
DISC (Dust Impact Sensor and Counter) il misuratore di polvere per Comet Interceptor la nuova missione ESA ad una cometa.

Vincenzo Della Corte
INAF-IAPS

Comet Interceptor

An ESA mission to an ancient world



Geraint Jones
UCL Mullard Space Science Laboratory, UK

@einionyn

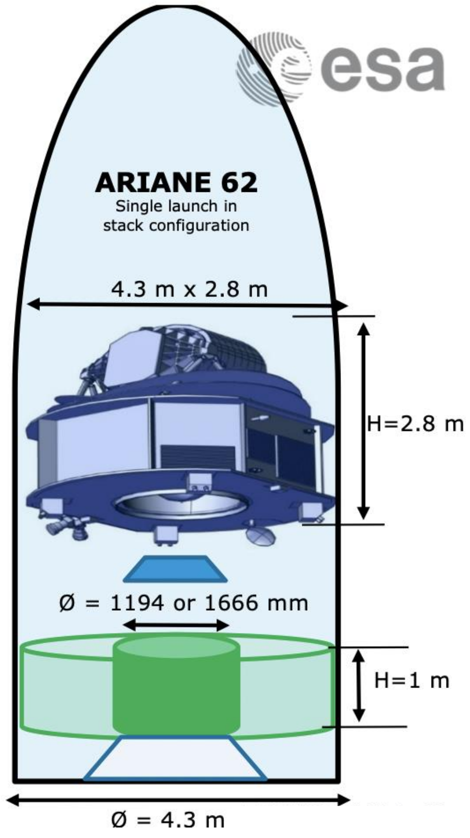
Colin Snodgrass
University of Edinburgh, UK

@colinsnodgrass

and the Comet Interceptor Team

OVERVIEW

- On June 20 2019, Comet Interceptor was selected by ESA as its first F-class mission.
- Maximum cost to ESA at completion, excluding launch: €150M.
- ESA member states and other collaborating agencies generally fund instruments and the science teams.
- Shared launch with Ariel exoplanet telescope, to Sun-Earth L2 point, in 2028
  - Limits on mass (originally 1000 kg, now 800 kg)
  - Must fit underneath Ariel, and be designed to support it during launch



Comet Interceptor is a mission targeting a dynamically-new comet, or an interstellar object.

Why?

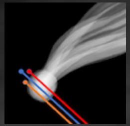
- All previous comet missions have been to objects that have passed the Sun many times

- Targets were relatively evolved, with thick coatings of dust on their surfaces

- A dynamically-new comet (**DNC**) is one that is probably nearing the Sun for the first time

- A mission to a DNC would encounter a **pristine** comet, with surface ices as first laid down at the Solar System’s formation

Multiple Spacecraft Architecture



- To separate time and space variations in coma
- Simultaneous coma + nucleus + particles & fields studies at different distances
- Separating safe / distant measurements and high risk / high gain close approaches

- A: main spacecraft
    - Passes sunward of comet at ~1000 km ('safe' distance)
    - Data relay for other spacecraft
    - Propulsion + communication
    - Minimum payload to ensure results even if other spacecraft fail

- B1: inner coma
    - Targeted to pass through inner coma
    - In-situ sampling, coma imaging
    - 3 axis stabilised

- B2: nucleus + coma
    - Targeted at nucleus (but unlikely to actually hit it)
    - In-situ sampling, nucleus + coma imaging
    - Spin stabilised, no AOCS

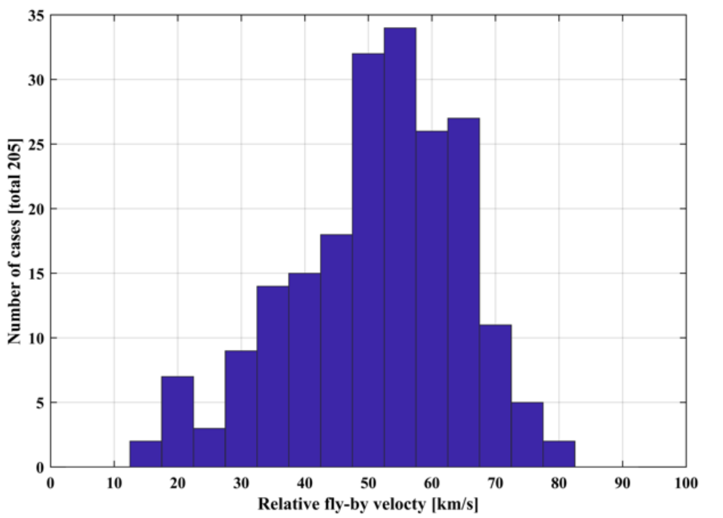
CHALLENGES

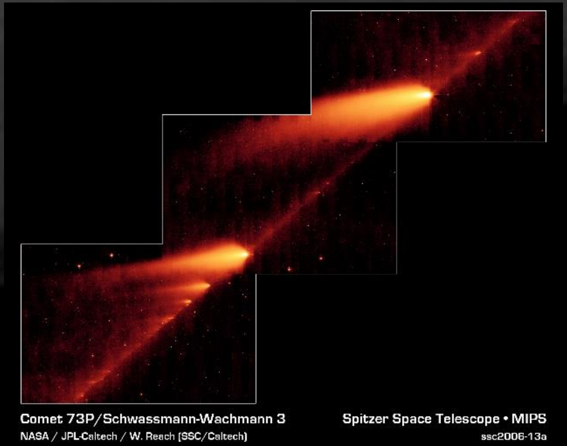
- Mission has to be designed to encounter comets on a wide range of possible trajectories and encounter speeds
- Retrograde orbits could mean flyby speeds > 70 km/s in worst case
- Cost means that entire mission should be < 5 years

SOLUTIONS

- Spacecraft design can cope with range of different encounter geometries – no HGA to Earth at encounter. Dust shielding equivalent to that used on Giotto
- Wait at L2 limited to ~3 years
- If no suitable target found, backup short period comets identified, including 73P.

A mission to short period comet will carry out new science: not repeat of previous missions.

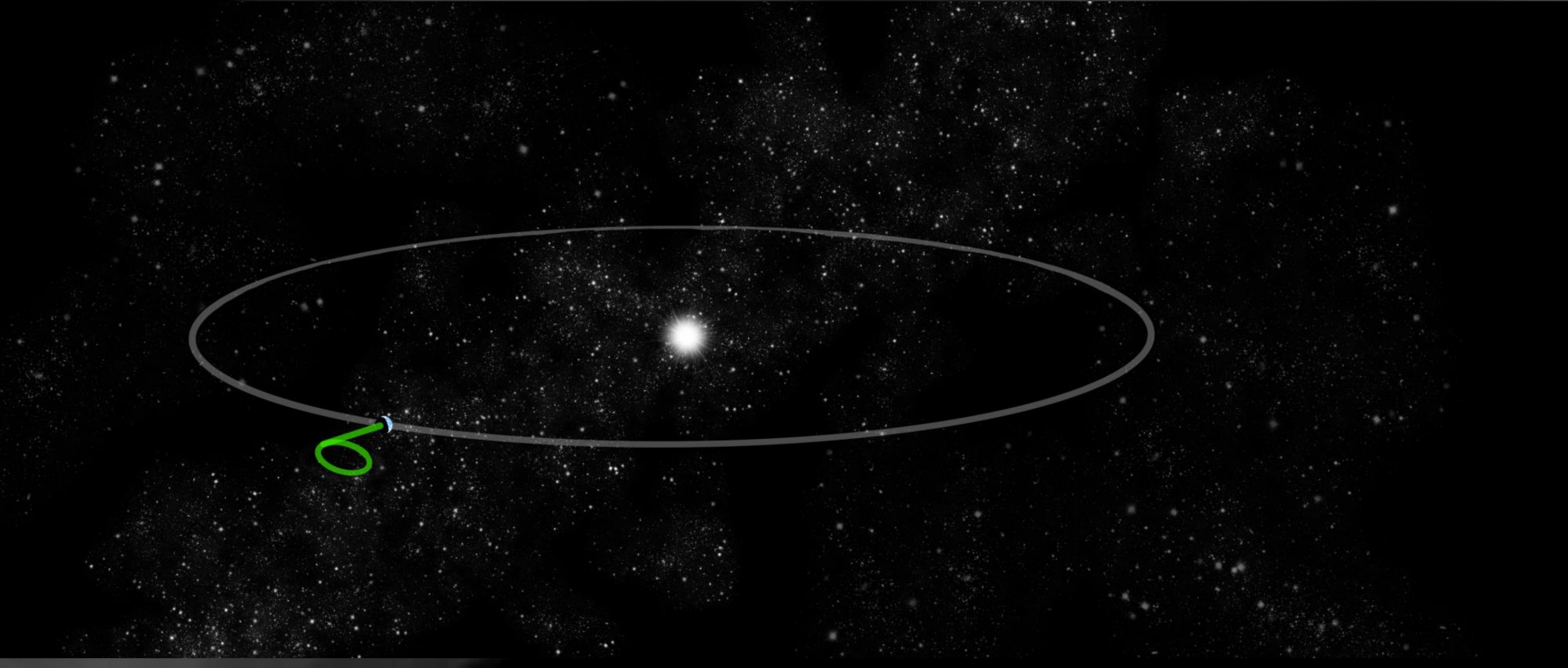




Comet Interceptor Mission Profile

- Mission ‘parked’ at stable Lagrange point L2 after launch with Ariel

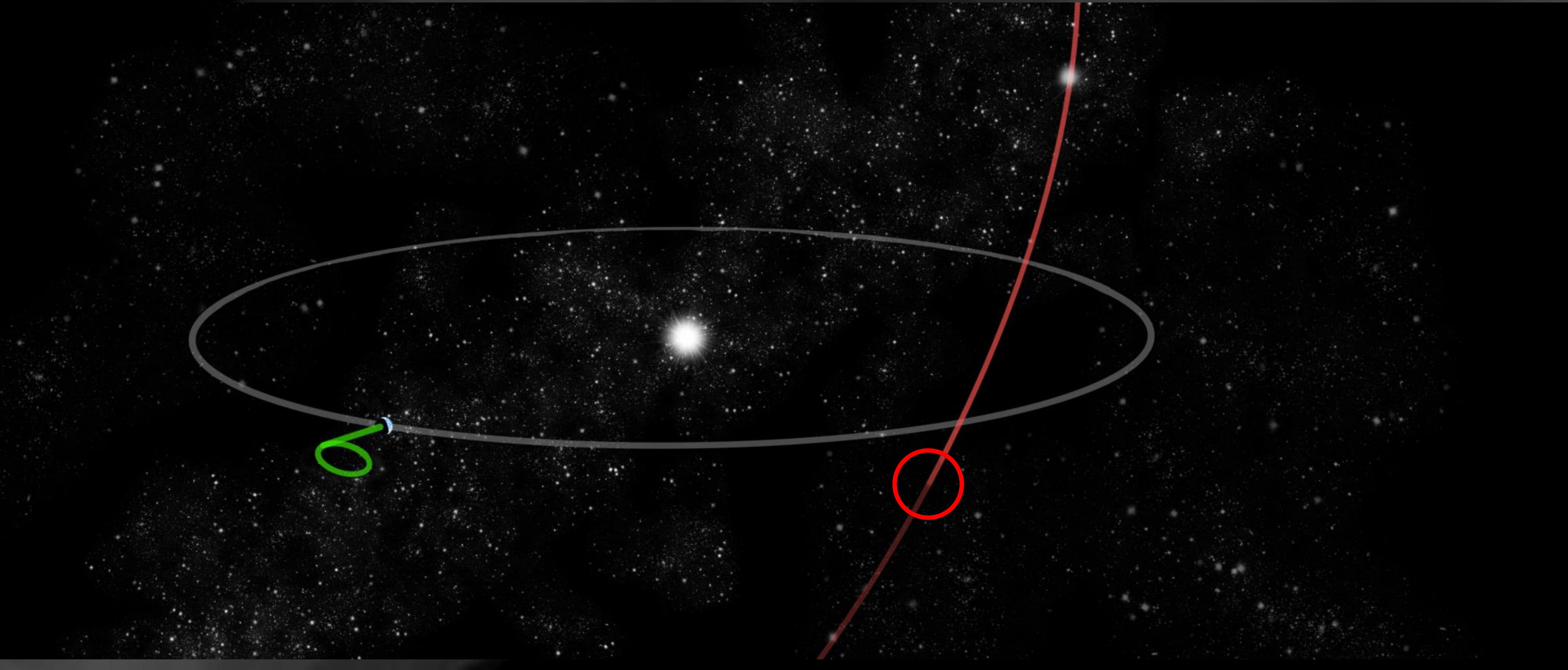
- Waits for up to 2-3 years for new target discovery



Comet Interceptor

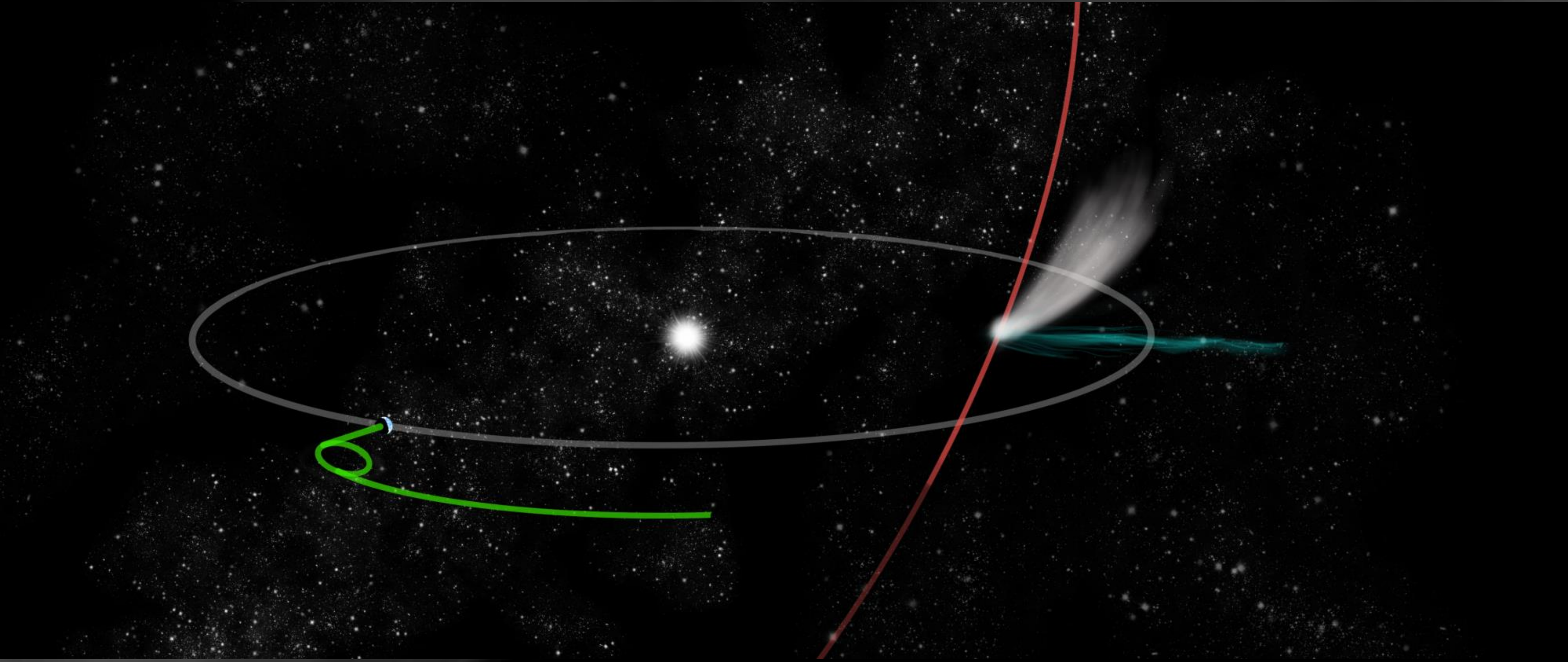
Comet Interceptor Mission Profile

- Orbit computed and ecliptic crossing point predicted



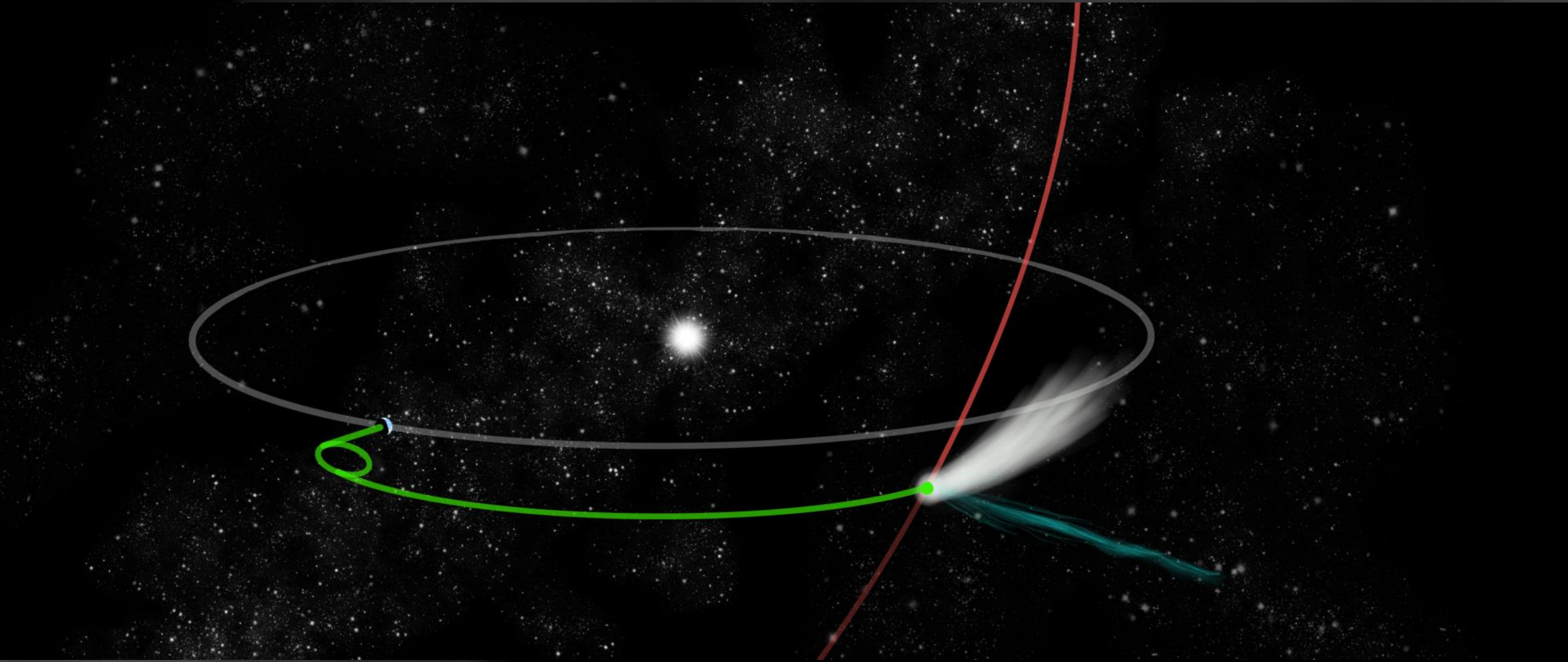
Comet Interceptor Mission Profile

- Comet Interceptor leaves L2 to intercept comet's path



Comet Interceptor Mission Profile

- Encounter with comet close to the ecliptic plane



Proposed payload

<table>
<tr><th>Spacecraft</th><th>Instrument</th><th>Description</th></tr>
<tr><td rowspan="3">A
ESA</td><td>CoCa</td><td>Visible/NIR imager</td></tr>
<tr><td>MIRMIS</td><td>NIR/Thermal IR spectral imager</td></tr>
<tr><td rowspan="2">DFP</td><td rowspan="2">Dust, Fields & Plasma (similar on A and B2)</td></tr>
<tr><td rowspan="4">B2
ESA</td></tr>
<tr><td>MANIaC</td><td>Mass spectrometer</td></tr>
<tr><td>EnVisS</td><td>All-sky multispectral visible imager</td></tr>
<tr><td>OPIC</td><td>Visible/NIR imager</td></tr>
<tr><td rowspan="3">B1
JAXA</td><td>HI</td><td>Lyman-alpha Hydrogen imager</td></tr>
<tr><td>PS</td><td>Plasma Suite</td></tr>
<tr><td>WAC</td><td>Wide Angle Camera</td></tr>
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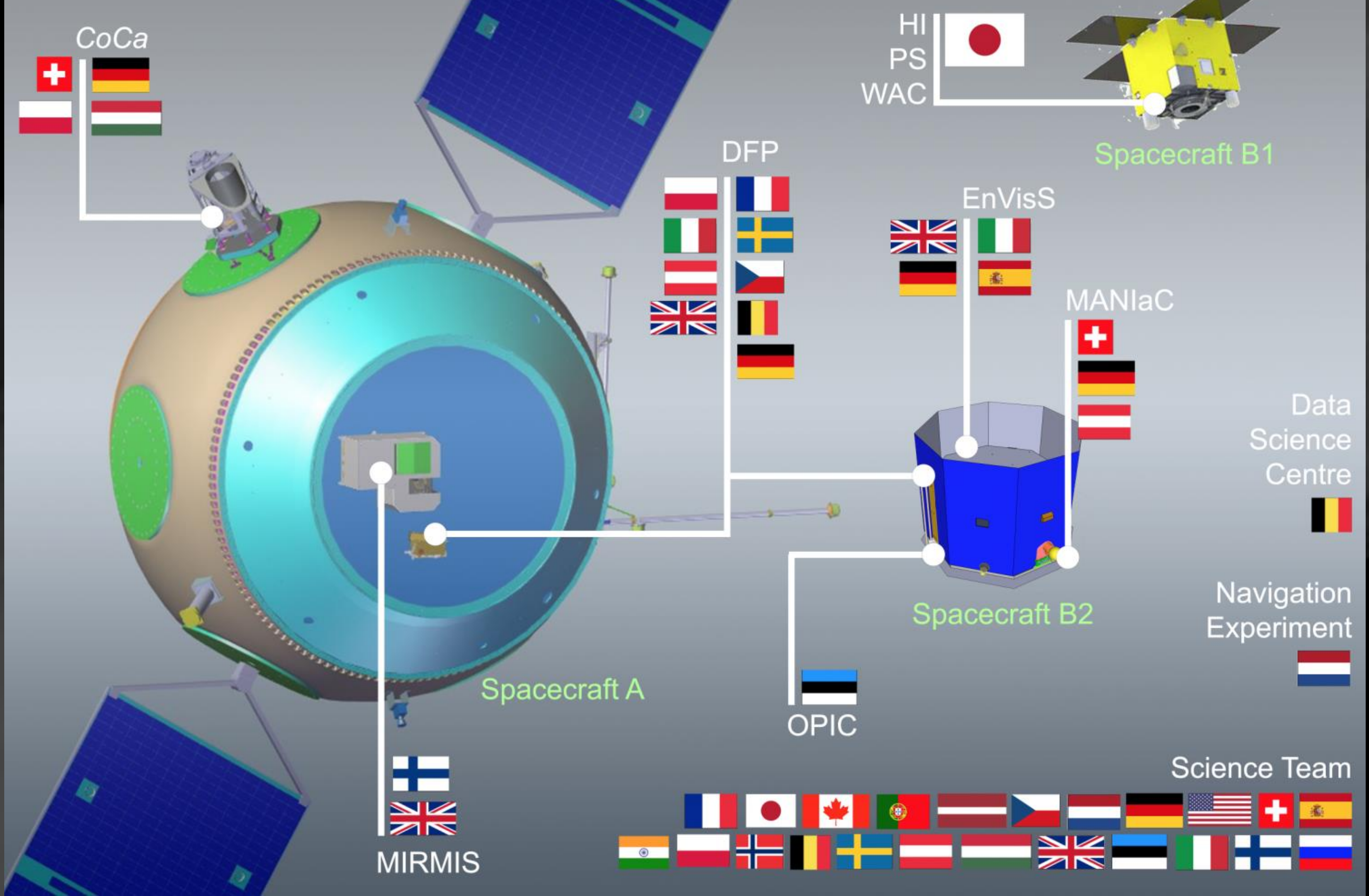
Comet Interceptor

National Contributions



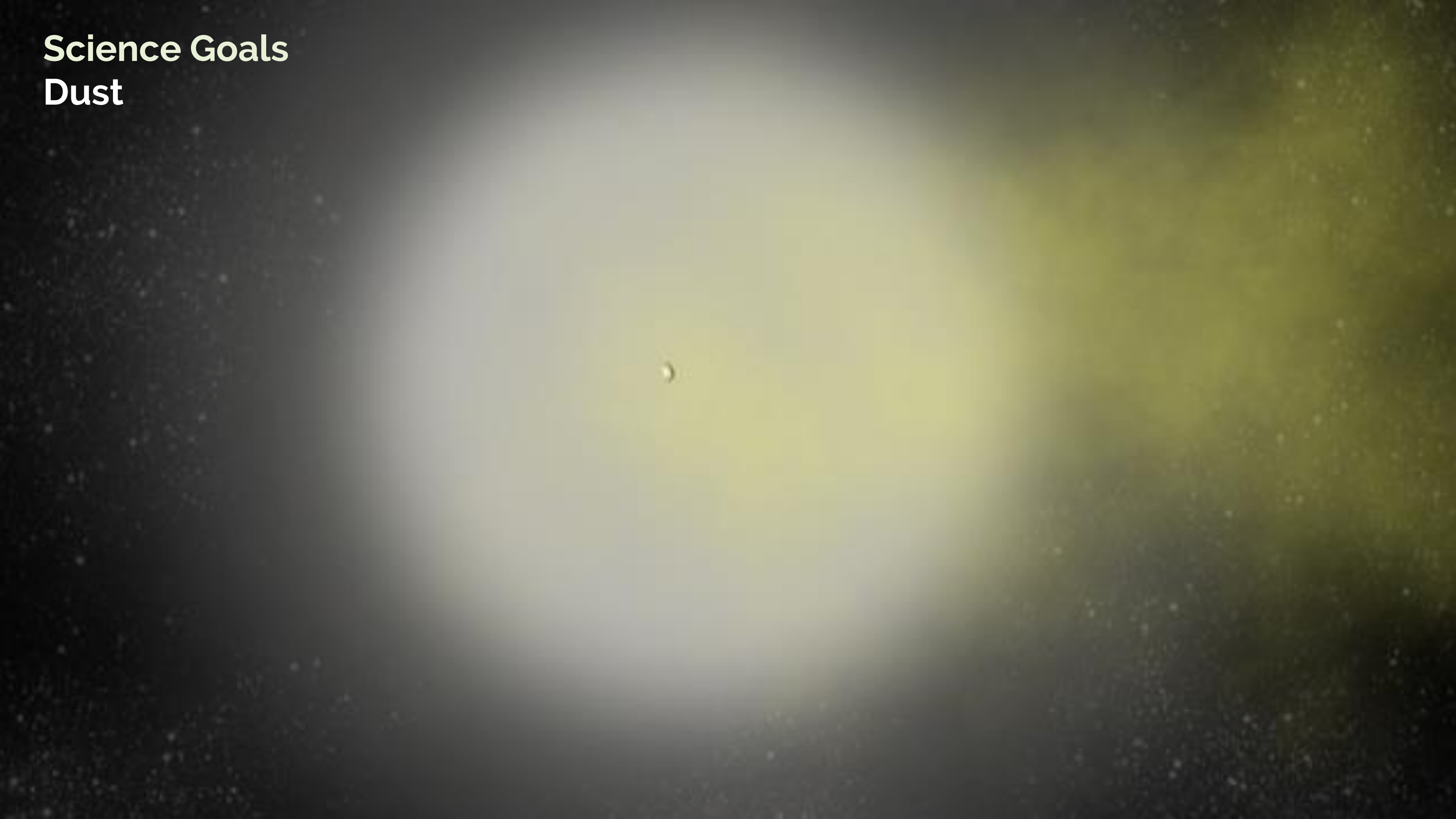
Comet Interceptor

Science Goals
Nucleus

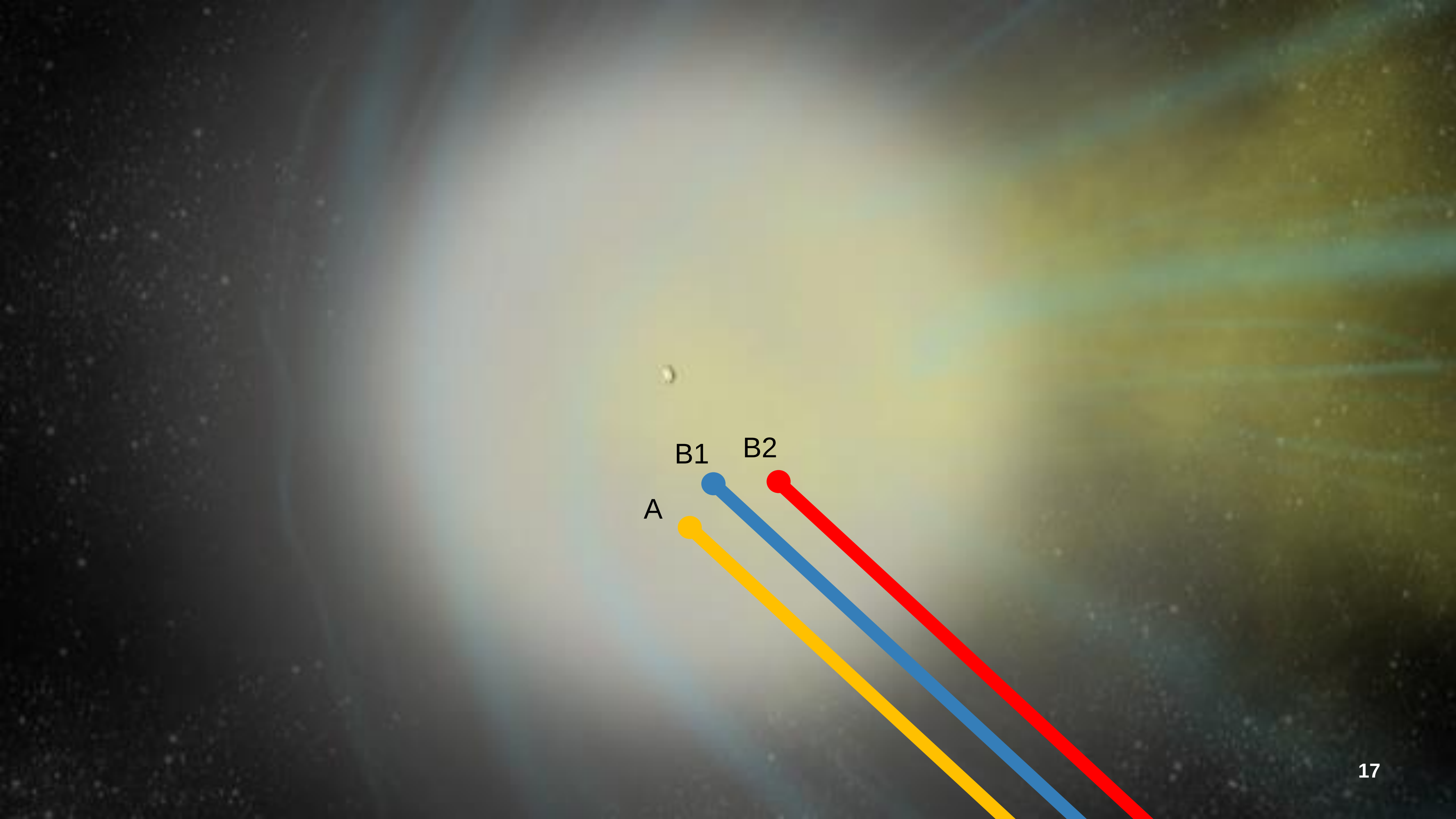
Science Goals

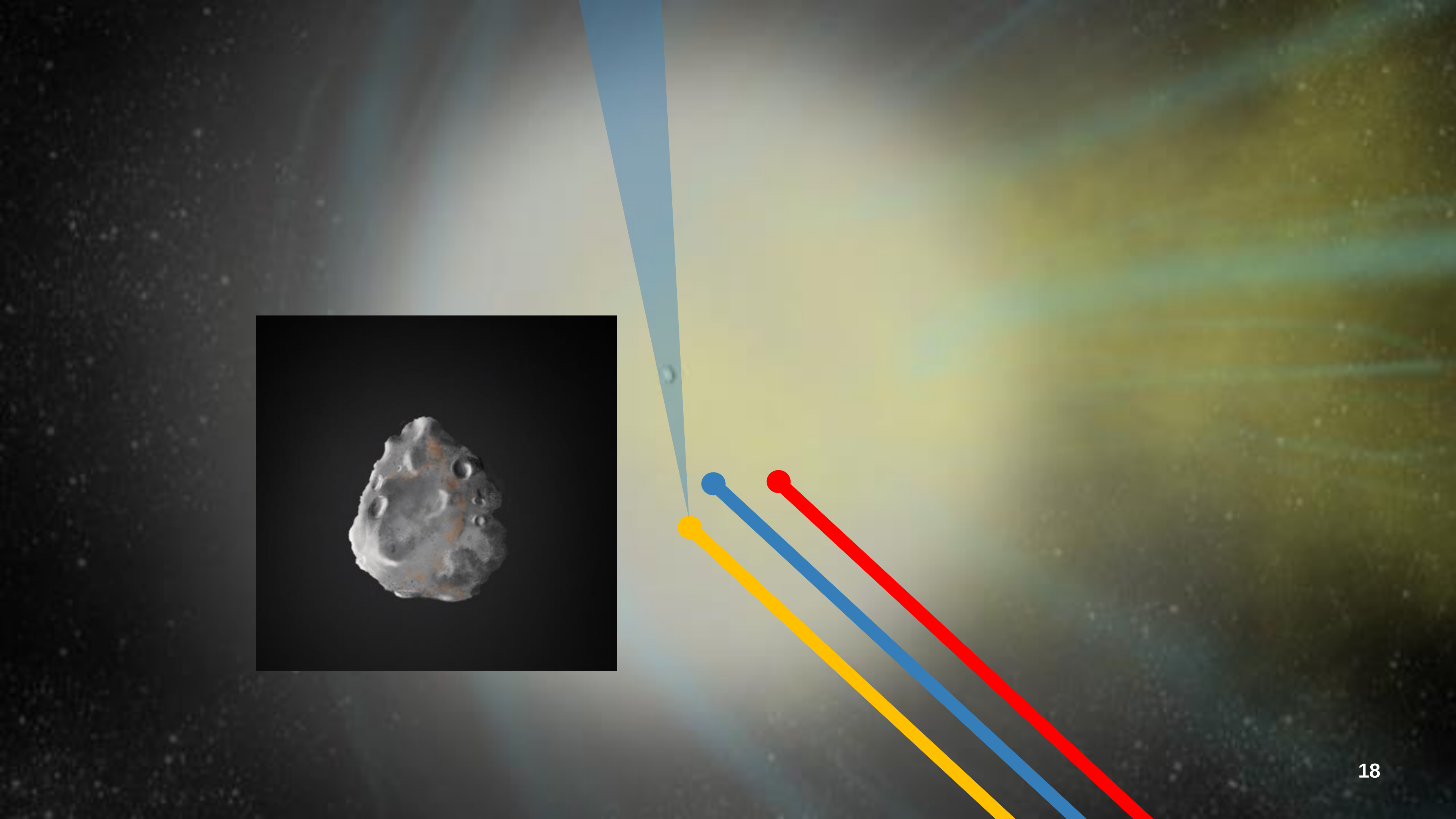
Neutral Coma

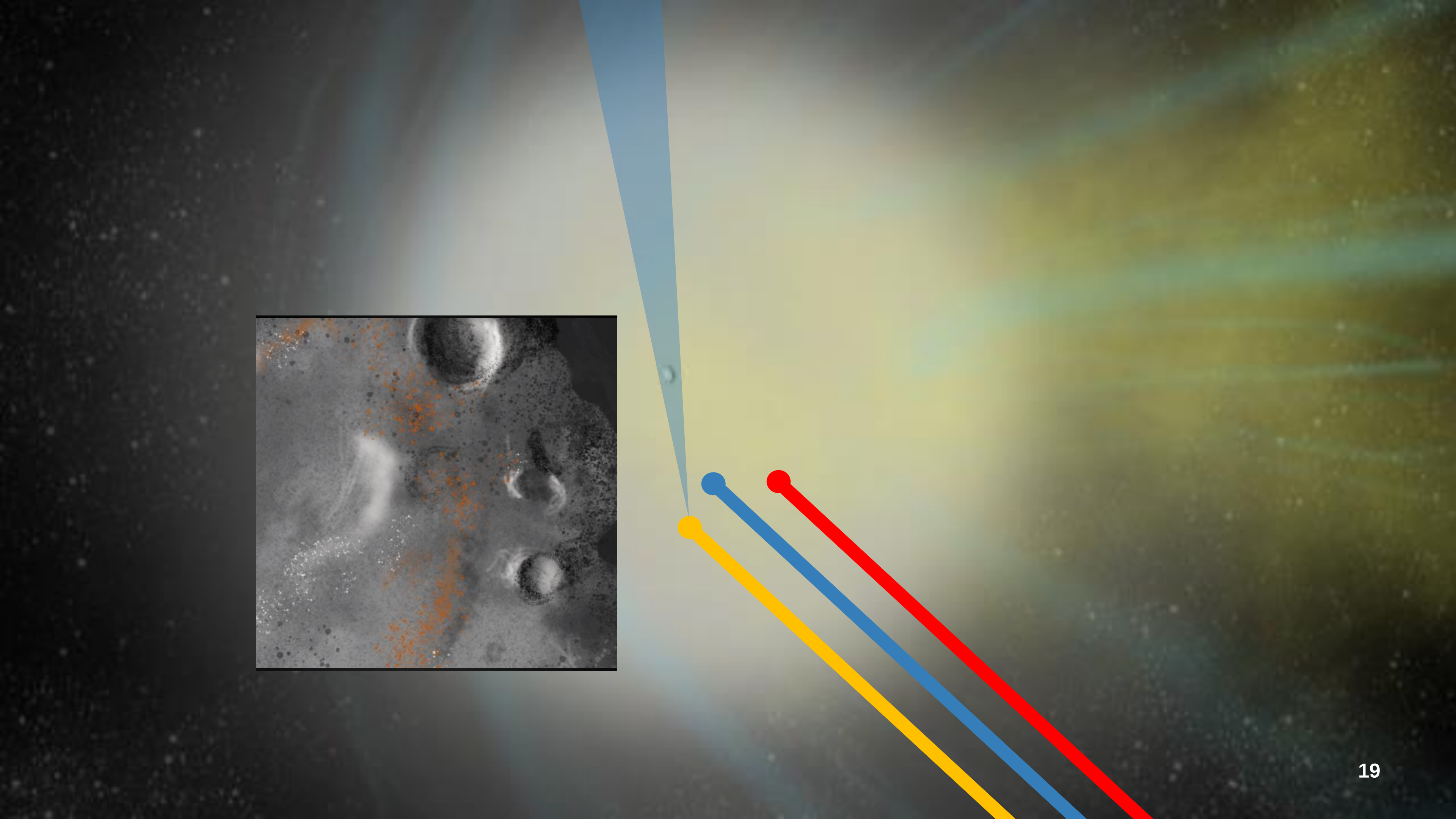
Science Goals
Dust

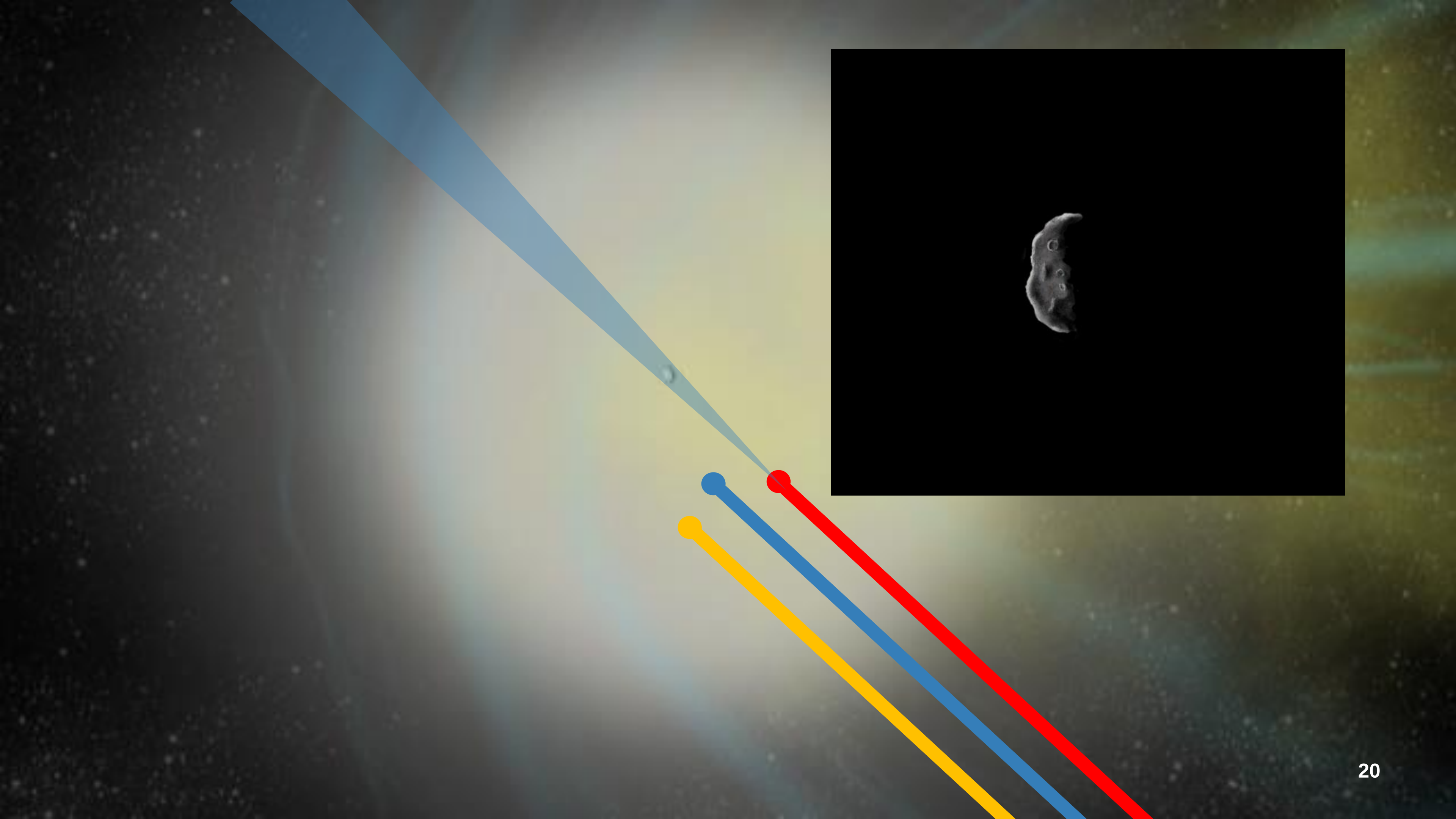


Science Goals
Plasma

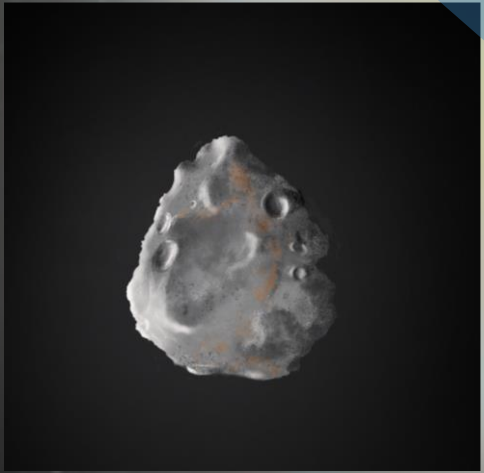

B1
B2
A



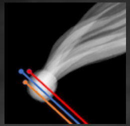




Multiple views of cometary nucleus: views from three spacecraft reveal 3D structure of nucleus and coma from a single flyby



New Science

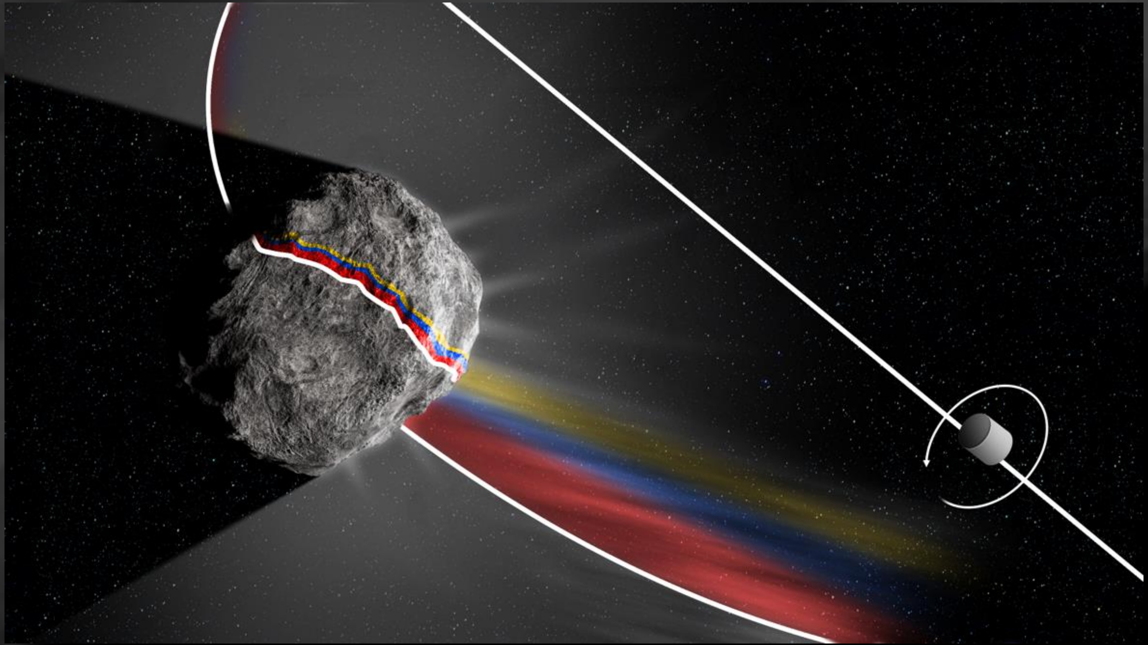


Comet Interceptor

- **Entire Visible Sky** (EnVisS): Multispectral and polarimetric mapper All-sky view of dust, including polarimetry, neutral gas, and ion features

Multi-point measurements of cometary environment, including plasma

- **Energetic Neutral Atoms**: first observations of solar wind-neutral charge exchange processes at a comet



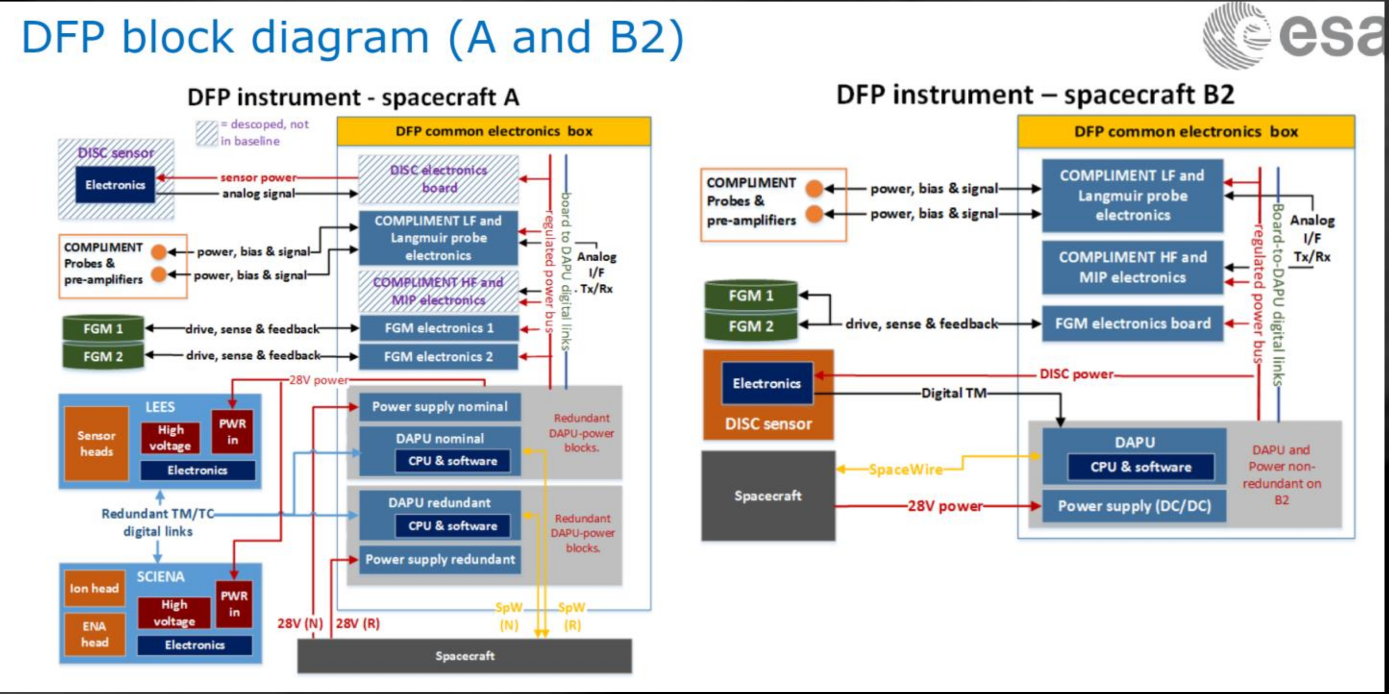
DFP-DISC

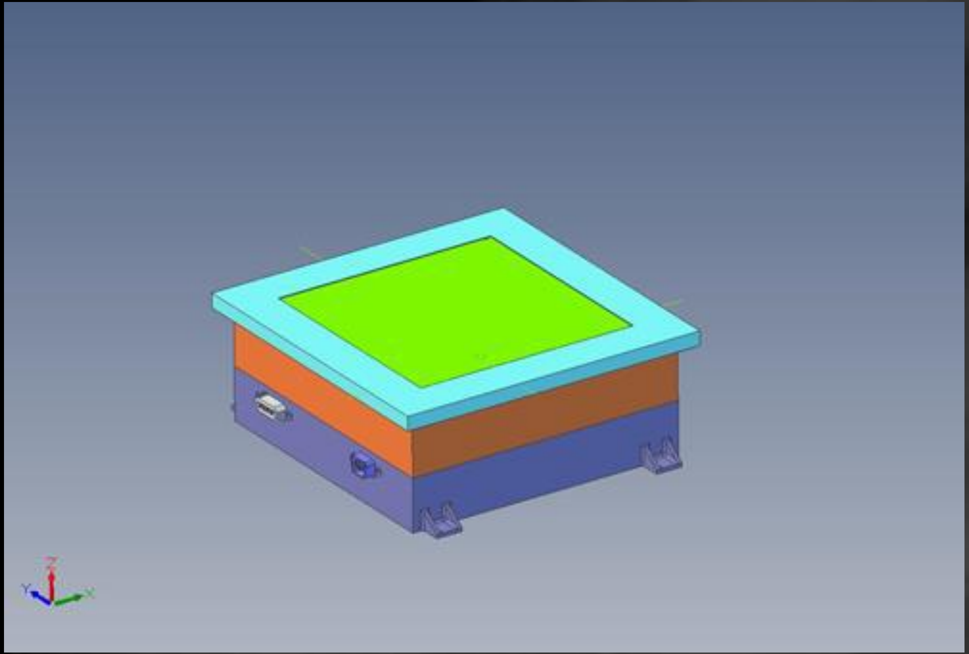
DFP-Dust Impact Sensor and Counter

The Dust Field and Plasma (DFP) package is a combined experiment dedicated to the in situ, multi-point study of the multi-phased ionized and dusty environment in the coma of the target dynamically new comet and of its interaction with the surrounding space environment and the Sun.

The DFP will measure magnetic field, electric field, plasma parameters (density, temperature, speed), the distribution functions of electrons, ions and energetic neutrals, spacecraft potential and the cometary dust impacts,

DFP-Dust Field and Plasma Package



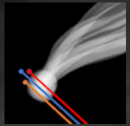


DISC optim S/C A and B2	
Mass	0,370 kg(*)
Volume	125x120x50 mm

The aim is to characterize the dust environment in the coma of the target dynamically new comet. For each dust particle detected its momentum is measured. From the momentum, knowing the speed of the S/C, the particle speed is retrieved.

DISC, if mounted on both S/C B2 and S/C A, will be able to determine dust mass distribution; particles count; particle impact duration; dust particle density/structure; dust maps,around the nucleus.s.

DFP-DISC Science



- Measurement of individual dust particle physical properties:
  - Size 1 – 200 micron
  - Momentum $10^{-4} – 10^{-10}$ kg m/s
  - Mass distribution
  - Particle tensile strenght

DFP-DISC Description & Working principle

- DISC sensing element: a thin (0.5 mm) aluminium squared plate equipped with piezoelectric (PZTs) sensors underneath.

- A particle impact on the sensing plate induces flexural waves on the Al plate that are detected by the PZTs.

- The maximum displacement of the PZT crystals produces a potential that is directly proportional to particle momentum/kinetic energy.

DFP-DISC
Heritage and development

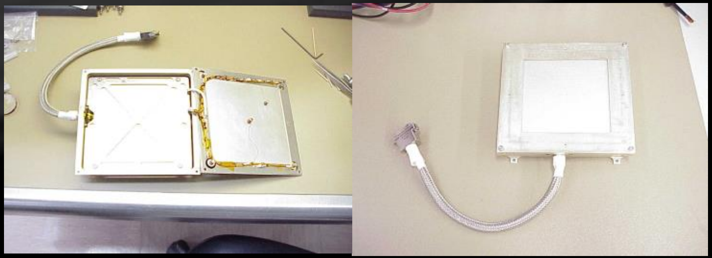
Comet Interceptor

DISC: a direct heritage of the Rosetta/GIADA Impact Sensor (GIADA-IS).

Sensitive element & reading technique can be improved wrt GIADA-IS:

- No impact on detector design and qualification.
- Improvements tailored taking into account mission development time constraints.

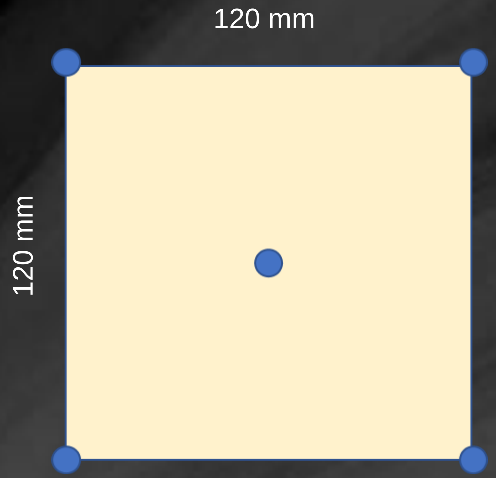
GIADA Flight Spare

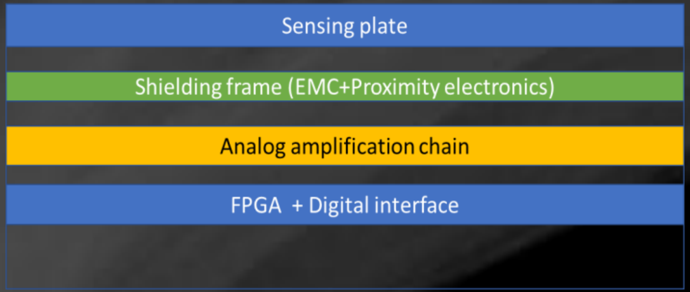


GIADA-IS Development Model

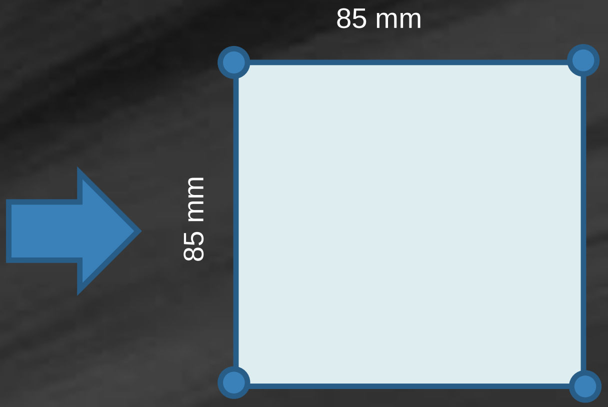
Comet Interceptor

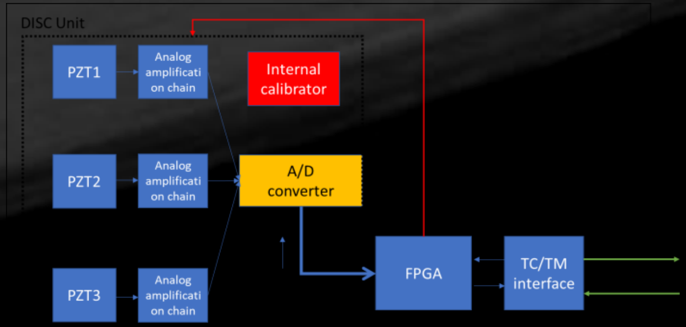
IS GIADA configuration





DISC configuration

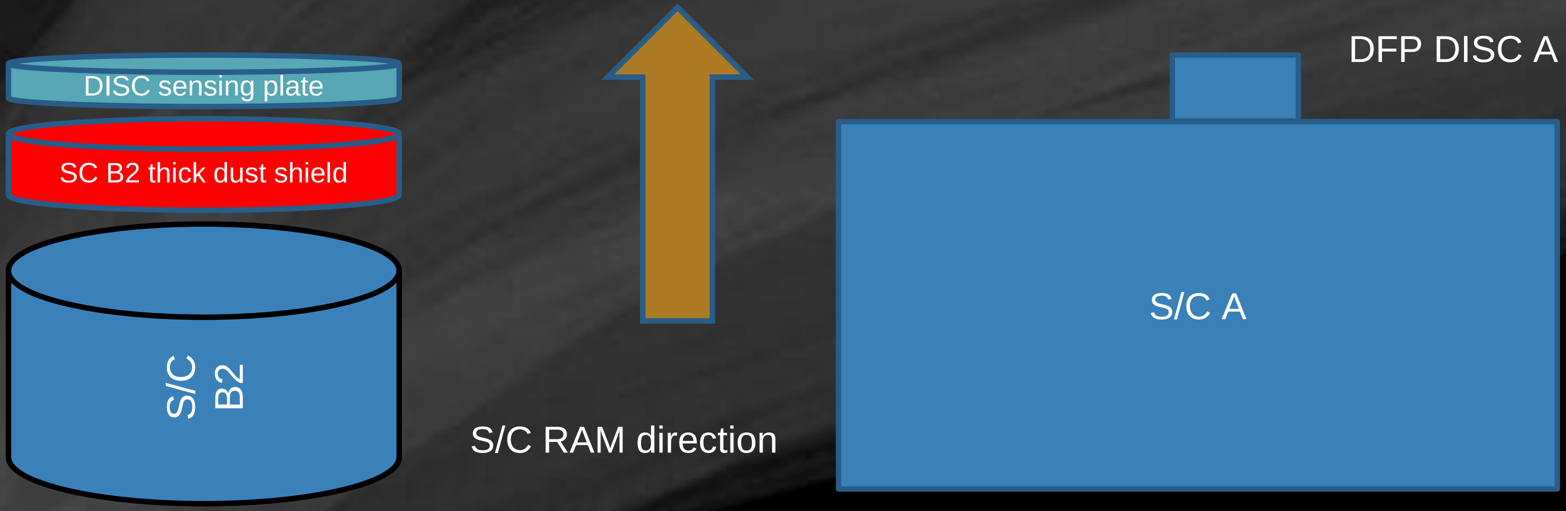




DFP-DISC ACCOMODATION

Comet Interceptor

Optimal DFP-DISC design/accommodation



DFP-DISC
Hyper Velocity Impacts (HVI)

Liu et al, 2016 (Journal of Applied Mechanics): as the shock waves propagate the HVI-induced pressure drops dramatically as a consequence of the wave attenuation and diffraction distance; subsequently, shock waves convert to the bulk waves and are guided by the plate by taking the formality of "lamb waves".

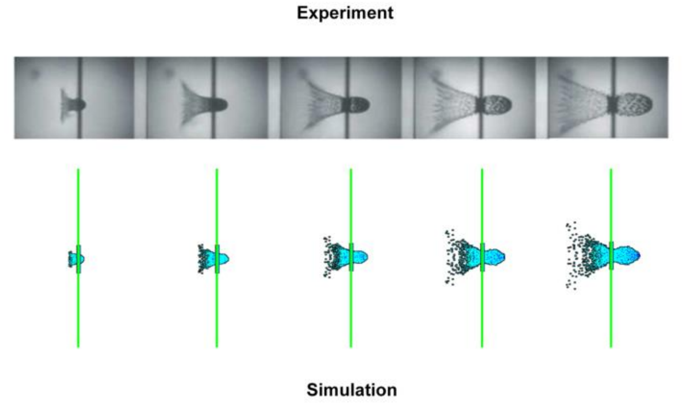
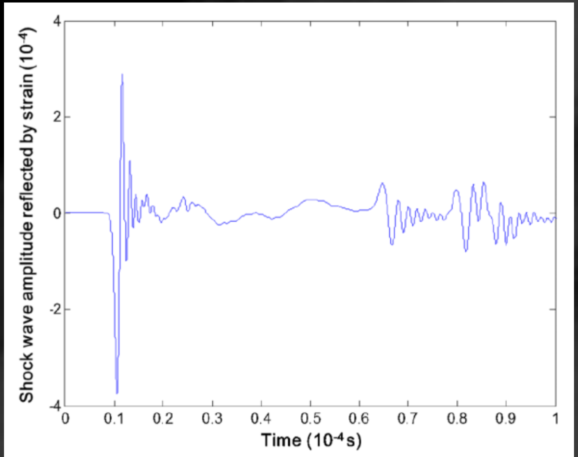


Fig. 2 Comparison of simulation and experiment results in normal HVI (frame interval: 2 μs) [34]

Therefore, in the areas distant from the HVI spot, propagation of the waves can be described using the plate wave theory.

The IS GIADA and DISC design is capable to retrieve all information from the plate wave generated also by HVI impact



Signal registerd by Liu et al 2016
During HVI impact experiments

- Signal analysis shows that the shock wave converts to “lamb wave” quickly as propagation from HVI spot.
- A minimal distance it is necessary to obtain this modification in the shockwave (few mm)
- The sensing PZTs on the DISC plate will be placed only at the corners

- GIADA-IS and DISC are fully capable of detecting and register the “lamb waves” propagating in the sensing plate.

The analysis of the full signal registered by the PZT allows to retrieve information on sensing plate damage and on impacting particle characteristics.