Asteroid Impact Mission (AIM)

ESA's NEO Exploration Precursor

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HSF Precursor Missions

Application driven objectives and payload definition
- Science to enable exploration

- Definition in consultation with diverse community – space sciences, planetology, radiation biology, robotics, HSF technologies, human physiology etc.

Lunar Lander (see next slide):
- Lunar Exploration Definition Team – initial objectives
- Topical Teams – Details

- What has to be done to prepare for future human exploration?
- What needs to be done in-situ on the Moon?
- What can be achieved by a precursor mission?
- How does the mission achieve this?

Lunar Lander Objectives

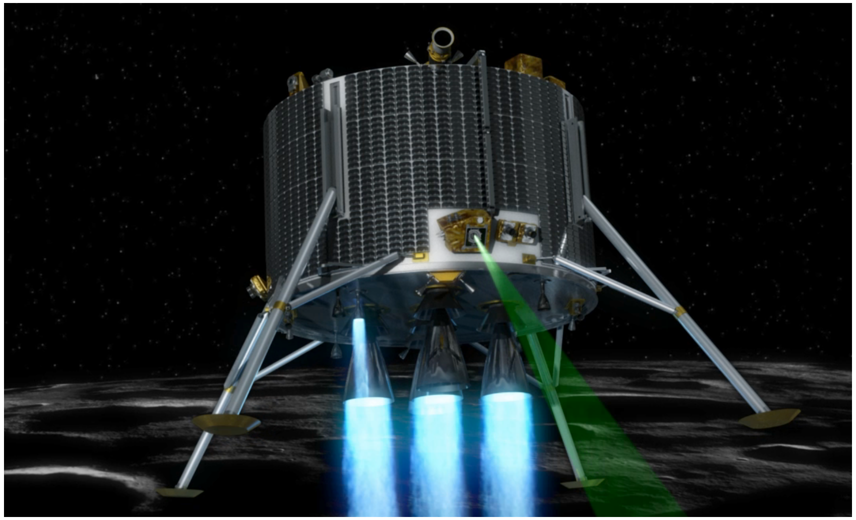
Programme Objective

PREPARATION FOR FUTURE HUMAN EXPLORATION

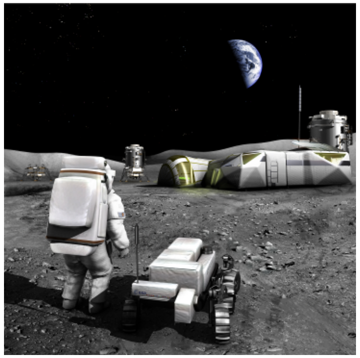
Lunar Lander Mission Objective

ENABLE SUSTAINABLE EXPLORATION

- **Soft Precision Landing with hazard avoidance**

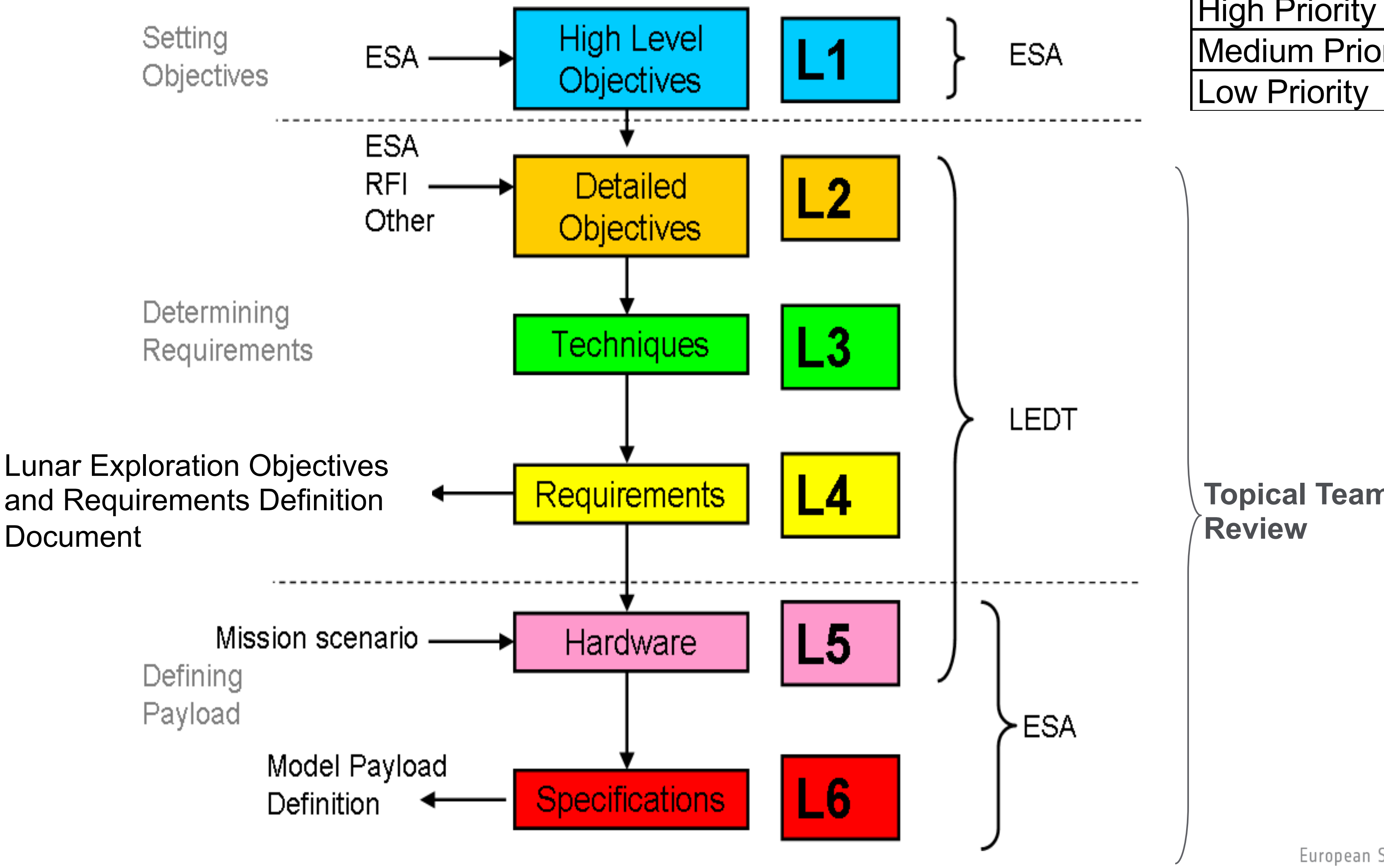


- **Crew health**
- **Habitation**
- **Resources**
- **Preparations for human activities**



Definition Process

High Priority	16
Medium Priority	9
Low Priority	16



High Priority Objectives

Crew health

- Radiation effects on human physiology
  - Dose
  - Particle spectra
  - DNA repair pathway responses
- Dust toxicity
  - “chemical reactivity”
  - nm – µm size distribution
  - Mineralogy and physical properties

Habitation and surface systems

- Landing Site Characterisation
- Dust:
  - Charging and levitation
  - Physical properties (mechanical, electrostatic, adhesive, abrasive, magnetic etc.)
  - System interactions and pathways for entering habitats

Resources

- Volatiles
  - Species, abundance and distribution
  - Solar Wind Implanted
  - H_2O, OH, hydrated minerals etc.
- Regolith
  - Mineralogy and physical properties

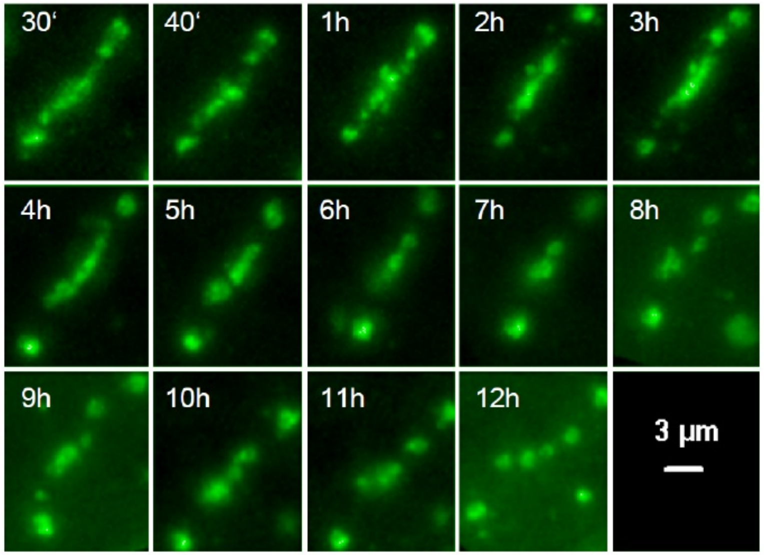
Preparations for future human activities

- Exosphere
- Radio Astronomy Preparation
  - Radio background

Radiation and crew health

Automated Microscope for the Examination of Radiation Effects

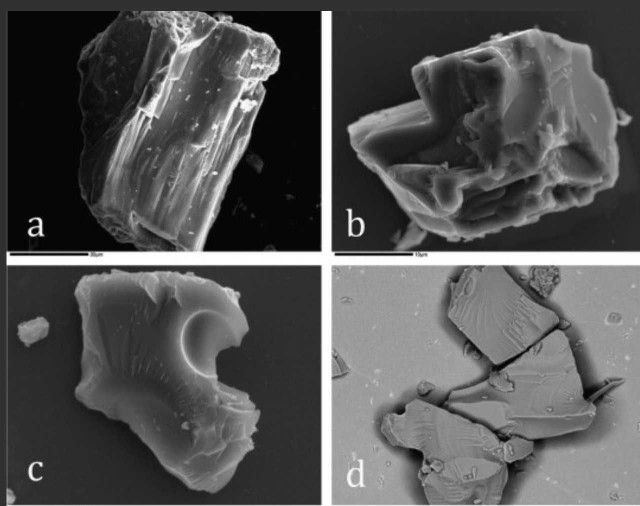
- Experiment concept from TT-IBER
- Radiation effects on human physiology
- DNA repair mechanisms
    - in human cells
    - following damage by HZE-GCR particles
    - in the Lunar environment
- Techniques applied in terrestrial studies
- Feasibility of lunar payload needs determining
- Potential application to other platforms for exploration preparation



From Jakob et al., Proc. Natl. Acad. Sci. USA, 2009

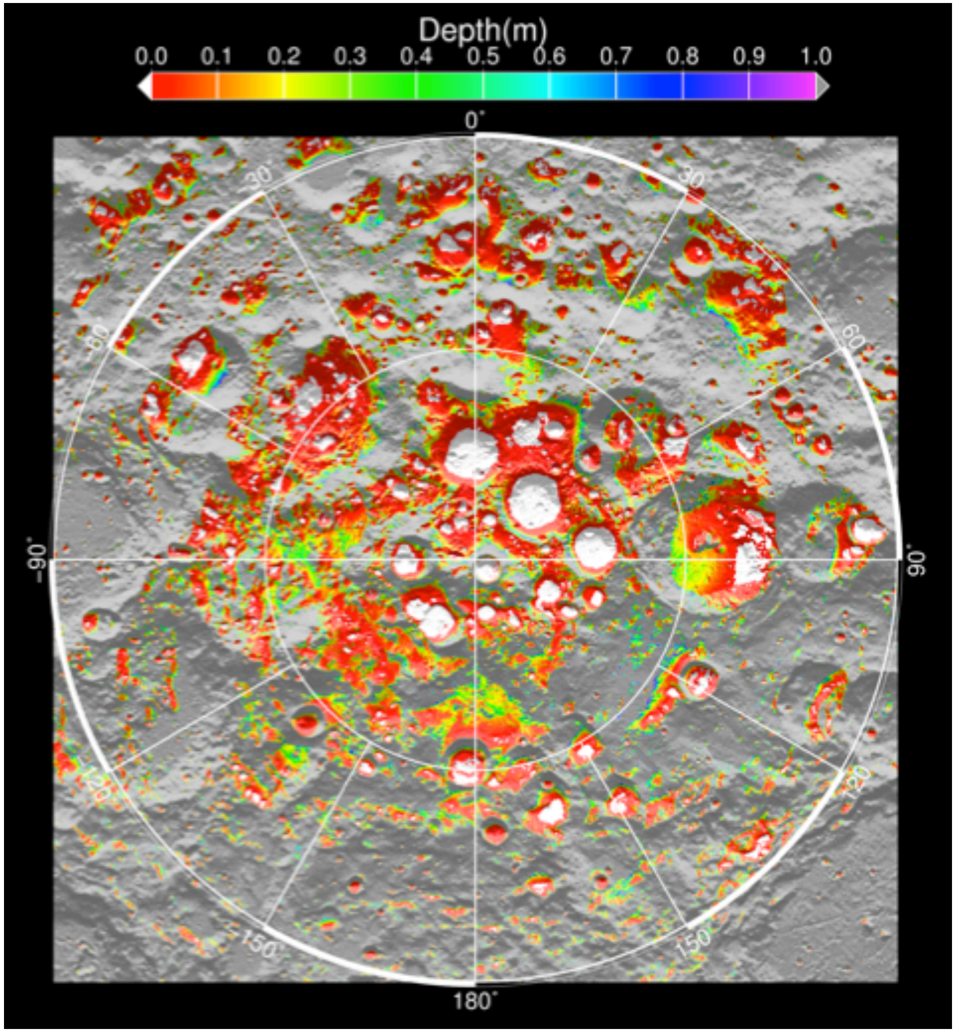
Dust Properties & Toxicity

The astronauts found the lunar dust to be unexpectedly high in its **adhesive characteristics**, sticking to the suits, instruments, and the lunar rover.



Properties of charged dust are to a large amount not understood or fully characterised.

Resources



Measurements

Identify Solar Wind Implanted and other volatiles in the lunar regolith

Extract volatiles from the lunar regolith as a potential resource

Observe exosphere species

Need to understand implications of surface contamination during landing

Potential Instruments for Consideration

Mass spectrometer
(heritage e.g. Beagle 2 GAP)

Starting point is important

For a Lunar Lander

A “human exploration precursor mission” looks very different to a “lunar geophysics mission”, different from a “lunar volatiles” mission, different from a “lunar geology mission”…

Extrapolating to an NEO

A “human exploration precursor mission” is probably different to a “planetary defence preparation mission” is probably different to a “solar system formation chronology mission”… at least in certain ways.

Conclusion

Know what the mission/science is for. This will strongly affect the outcome

Assign levels of priority to different goals

Science definition requires input from a wide range of science and technology communities

Overlapping Goals of NEA Missions

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Planetary Defense

Deflection demonstration and characterization
Orbital state
Rotation state
Size, shape, gravity
Geology, surface properties
Density, internal structure
Sub-surface properties
Composition (mineral, chemical)

Science

Orbital state
Rotation state
Size, shape, gravity
Geology, surface properties
Density, internal structure
Sub-surface properties
Composition (including isotopic)

Precursor

Deflection demonstration & characterization
Orbital state
Rotation state
Size, shape, gravity
Geology, surface properties
Density, internal structure
Collision and Impact Properties

Human Exploration

Orbital state
Rotation state
Size, shape, gravity
Geology, surface properties
Density, internal structure
Composition (mineral, chemical)
Radiation environment
Dust environment

Resource Utilization

Geology, surface properties
Density, internal structure
Sub-surface properties
Composition (mineral, chemical)

Human exploration preparation potential objectives

(no prioritisation attempted)

- Surface Characterisation (regolith, boulders etc.)
- Rotation
- Structure (shallow surface - deep interior) and structural stability
- **Radiation**
  - **Total dose**
  - **Secondary neutron flux**
  - **Human physiology-GCR interaction**
- **Electrostatic environment**
- **Dust**
  - **Dynamics (charging, levitation, transfer)**
  - **Toxicity ("reactivity", size distribution)**
  - **adhesion (charging, "stickiness", size distribution)**
  - **Abrasion (structure, shape, hardness)**
  - **mechanical properties**
- Gravity model
- Porosity (macro/micro)
- Mass distribution
- Temporal variability
- Orbital Debris environment

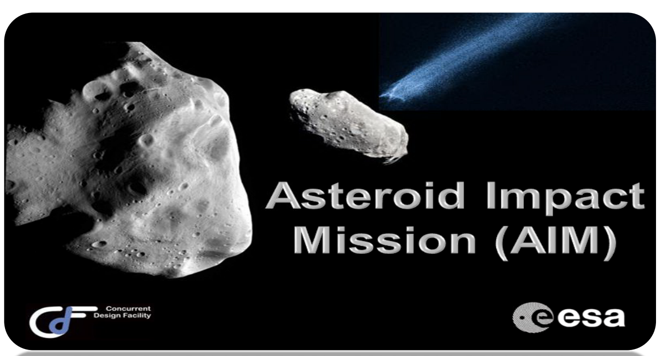
Lunar Objectives Crossover

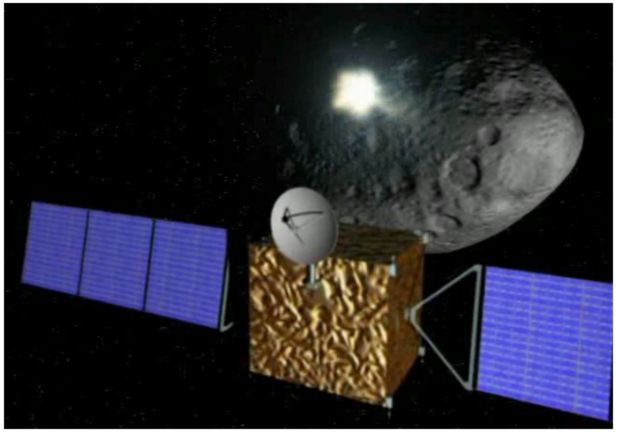
AIM mission goal

AIM (Asteroid Impact Mission) dual spacecraft momentum transfer characterization concept.

Secondary goal: **platform for investigations relevant to HSF**

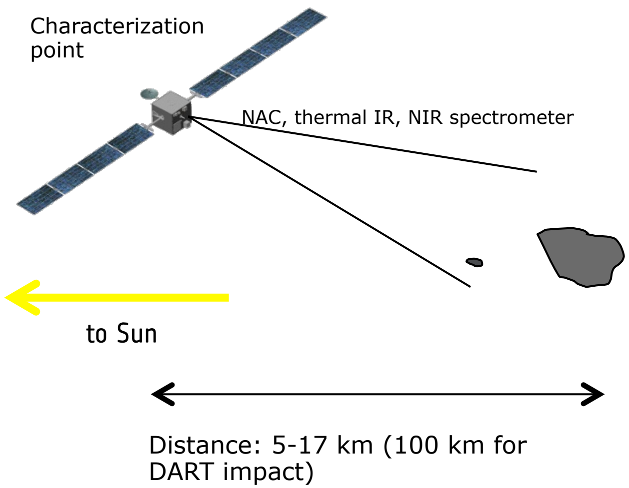
- Self standing spacecraft mission for each spacecraft, **independent** achieving objectives at least in part i.e. characterization, deflection
- Cost 150 M€ per s/c including launch and operations (duration < 3y)
- Ground based measurements provides robustness -> A well characterized radar-observed, binary target (Didymos)
- Focus on impact dynamics





Goals (rendezvous)

AIM 1 target characterization **through a rendezvous s/c,** autonav demo, **characterization also from ground (radar, optical)**



AIM 1

Deflection demonstration and Characterization

Orbital state

Rotation state

Size, Mass gravity

Geology, surface properties,

Density

internal structure

Collision and Impact Properties

Beyond AIM 1:

- ***Deflection demonstration***
- ***internal structure***
- ***Collision and Impact Properties***

Requirements

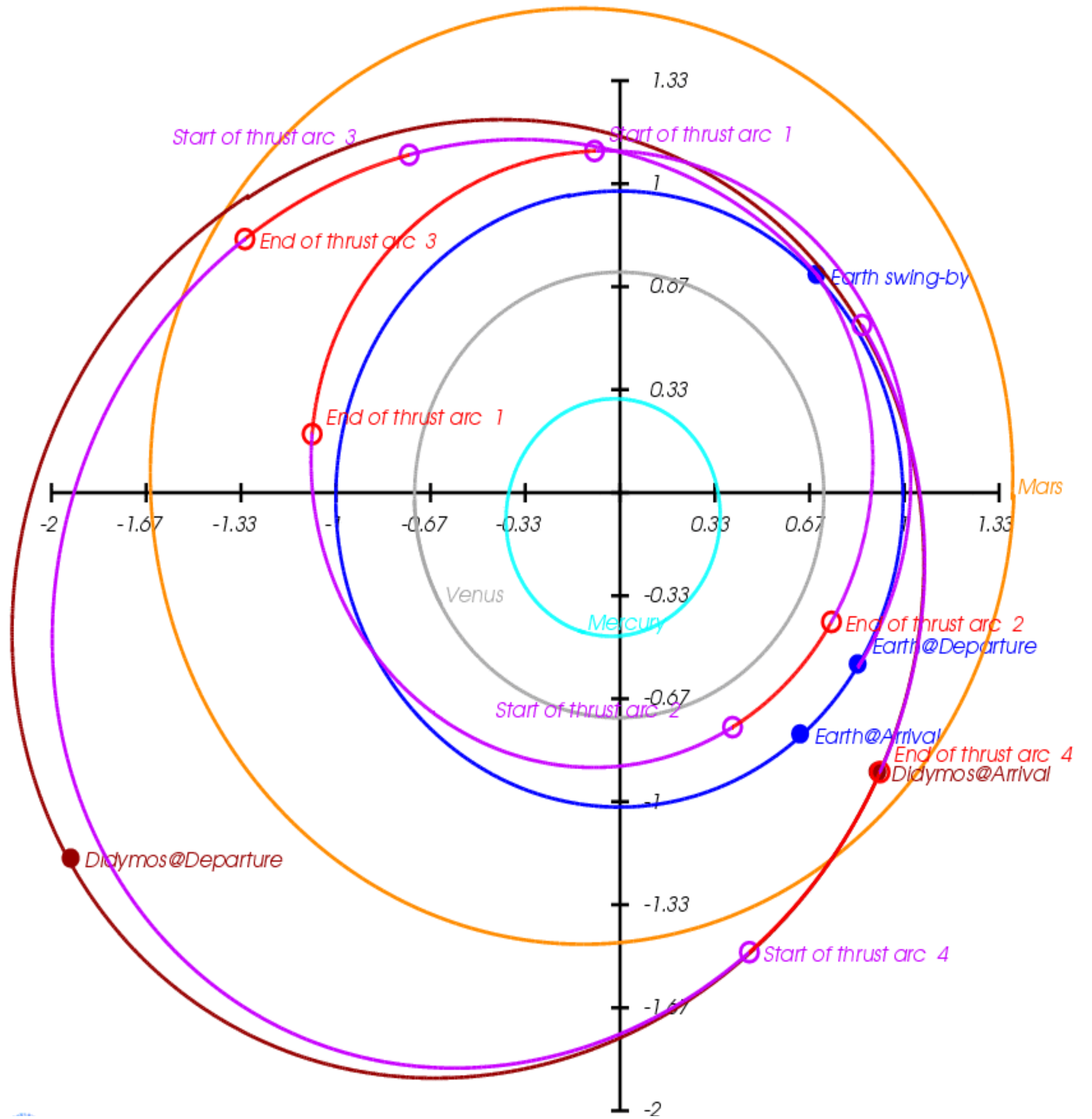
P#	Parameter	Relevance to goal	Possible measurement / is it a must have?
1	Orbital state	Key to determine momentum transfer	• in-space (CAM) – a must , Ground (photometry, radar)
2	Rotation state	Key to determine momentum transfer	• in-space (CAM) – a must, Ground (photometry, radar),
3	Size, Mass, Gravity	Mass key to momentum, size to shape, volume, gravity to internal structure, operations	• Mass from binary orbit, shape model from CAM (or LIDAR), a must gravity field RSE (not a must?)
4	Geology, surface properties	Bulk composition, material mechanical properties, surface thermal inertia	• VIS photometry to derive spectral type (must) IR spectrometer mineralogy (not a must) • TIR for Yarkowski / YORP (not a must if not large source of error)
5	Density, internal structure	• Affects absorption of impact energy, • "data point" for study of asteroid mitigation.	• Bulk values derived from mass, shape model • Radar Tomography, seismic probing. largely increases complexity and not a must (conclusion Don Quijote) = outside scope AIM

Core strawman payload

Instrument	Mass (kg)	Power (W)	FOV (deg)	Aperture (mm)	Dimensions (mm)	Notes
NAC	2.0	0.75	5.3 x 5.3	14.2	200x150x50	Combines navigation and science purposes. Observe impact and impact crater. Measure orbital, rotational state, shape. Heritage: AMIE (SMART-1).
Micro Laser Altimeter	2.5	4	0.003	30	200x150x50	Precise shape model Based on NLR (NEAR). Low TRL in Europe (BELA). Operational range should be higher than 10 km.
Thermal IR Imager	1.5	1	4	40	60x40x40	Study of surface temperature and thermal inertia. Heritage: MERTIS (BepiColombo). Mass estimate assumes further miniaturization.
NIR spectrometer	1.5	7	4	38	100x50x50	Global mapping of the surface mineralogy Heritage from SIR (SMART-1) and SIR-2 (Chandrayaan-1). Mass estimate assumes further miniaturization

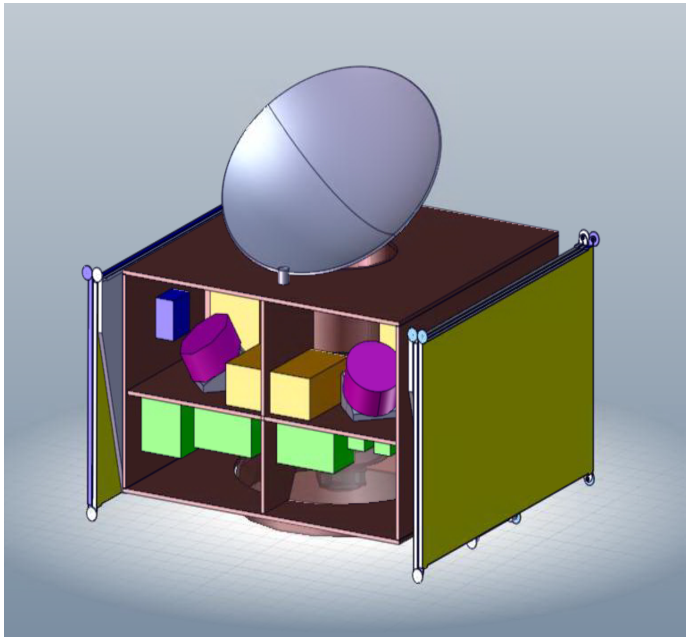
Interplanetary transfer (EP option - longer)

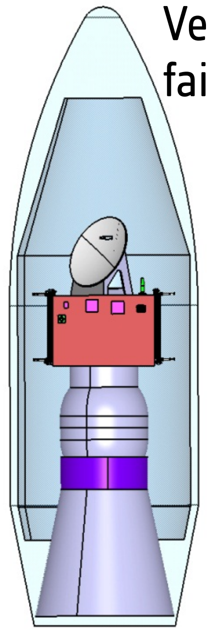
Launch	**19/08/2019**
Escape velocity [km/s]	1.0
Declination [deg]	-14.46
Escape mass [kg]	400
Earth swing-by	**07/11/2020**
Arrival	**01/08/2022**
Final mass [kg]	324
SEP delta-v [km/s]	2.9
Xenon consumption [kg]:	73
Hydrazine consumption [kg]:	5
Thruster on time [d]:	213



Duty cycle: 85% of available thrust actually used

AIM 1 Total Mass Budget





Vega fairing

Rendez-Vous S/C Mass (kg)	
Dry Mass w.o. margin	269.60
Dry Mass + 20% margin	323.52
Propellant Hydrazine	9.00
Propellant Xenon	73.00
Wet Mass	**405.52**

Propulsion Stage Mass (kg)	
Propellant STAR 48	**1222.00**
Structure	**23.21**
Clampbands S/C I/F	6.60
S/C adaptor	16.61
Mechanisms	**35.20**
Clamp Band spin table	14.30
spring set spin table	3.30
Clamp Band prop module	14.30
Spring set prop module	3.30
Propulsion	**137.55**
SRM Star 48	137.55
Dry Mass Propulsion Stage	**195.96**

If there were an impactor… AIM 2

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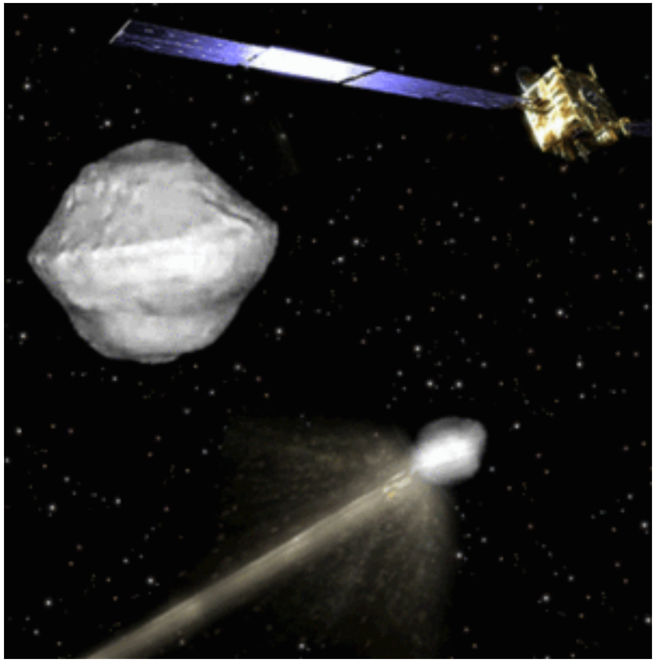
AIM 2 autonav demo and impact experiment; monitored from **ground and from AIM 1**

AIM 2

Deflection demonstration and characterization
Orbital state
Rotation state
Size, shape, gravity
Geology, surface properties
Collision and Impact
Collision and Impact Properties



Short-term focus: seeking international cooperation to augment AIM return

AIDA mission rationale report

esa

- Naomi Murdoch (OCA, Coor.)
- Paul Abell (NASA)
- Ian Carnelli (ESA)
- Benoit Carry (ESA)
- Andy Cheng (JHU/APL)
- Gerhard Drolshagen (ESA)
- Moritz Fontaine (ESA)
- Andrés Gálvez (ESA)
- Detlef Koschny (ESA)
- Michael Kueppers (ESA)
- Patrick Michel (OCA)
- Cheryl Reed (JHU/APL)
- Stephan Ulamec (DLR)
- …

http://www.esa.int/neo

Contributions on payloads ideas compatible with the mission are welcome starting 1st Feb 2013

Conclusions

- Analysis of simple NEA rendezvous demo addressing aspects also relevant to future human exploration
- Short-term focus: seeking international cooperation. Ongoing work with JHU/APL – AIM+ DART = AIDA (Asteroid Impact Deflection Assessment)
- Mission could be an affordable, risk-free cooperation
- A good opportunity to enhance public support and involvement in space research
- Call for Experiment ideas to be release on 1st Feb 2013

Thank you

www.esa.int/neo

www.esa.int/gsp