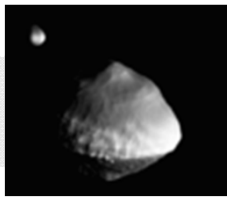
# Asteroid Impact Mission AIM-D$^2$, la componente ESA de la misión AIDA al NEA binario (65803) Didymos

Adriano Campo Bagatin DFISTS – IUFACyT. Universidad de Alicante
*and the AIM team*

# AIDA = AIM + DART



AIDA: Asteroid Impact and Deflection Assessment
AIM: Asteroid Impact Mission
DART: Double Asteroid Redirection Test

**Target:**
**binary NEA Didymos in 2022**

- ESA AIM rendezvous spacecraft
  - Orbiter payload to characterize Didymos dynamical system and study impact results
  - Asteroid proximity operations
  - Lander release on secondary asteroid: deep-interior analysis
  - Deep-space optical communication demonstration

- NASA DART interceptor and Earth-based observing
  - Perform kinetic impact on Didymos' satellite
  - Measure asteroid deflection to within 10%
  - Return high resolution images of target prior to impact
  - Autonomous guidance with proportional navigation to hit center of 150 meter target body

# AIDA: Asteroid Impact & Deflection Assessment

| AIDA Coordination Committee: | |
|---|---|
| **Patrick Michel**, AIM Advisory Team chair | Obs. de la Cote d'Azur |
| **Andy Cheng**, DART Science Definition Team chair | APL |
| **Derek Richardson** | Univ. Maryland |
| **Adriano Campo Bagatin** | Univ. Alicante |
| **Kleomenis Tsiganis** | Univ. Thessaloniki |
| **Olivier Barnouin** | APL |
| **Stephan Ulamec** | DLR |
| **Andy Rivkin** | APL |
| **Petr Pravec** | Charles Univ. Prague |
| **Paul Miller** | LLNL |
| **Steven Schwarz** | Obs. de la Cote d'Azur |
| **Angela Stickle** | APL |

| | |
|---|---|
| **Ian Carnelli** | **ESA** |
| **Lindley Johnson** | **NASA HQ** |
| **Cheryl Reed** | **APL PM** |

| AIM Advisory Team | |
|---|---|
| Patrick Michel | Obs de la Cote d'Azur |
| Simon Green | Open University |
| Jean-Baptiste Vincent | MPS |
| Petr Pravec | CUP |
| Gareth Collins | Imperial College |
| Marco Delbo | Obs de la Cote d'Azur |
| Pascal Rosenblatt | Royal Obs Belgium |
| Juergen Blum | TU Braunschweig |
| Kleomenis Tsiganis | Aristotle Univ. Thessaloniki |
| Stephan Ulamec | DLR |
| Jens Biele | DLR |
| Alain Herique | IPAG |
| Valerie Ciarletti | Université Versailles |

| DART Science Definition Team | |
|---|---|
| Andy Cheng | APL, Chair |
| Paul Abell | JSC |
| Brent Barbee | GSFC |
| Olivier Barnouin | APL |
| Lance Benner | JPL |
| Steve Chesley | JPL |
| Carolyn Ernst | APL |
| Andy Rivkin | AP |
| Dan Scheeres | Univ. Colorado |
| Angela Stickle | APL |
| Megan Bruck-Syal | LLNL |
| Eugene Fahnestock | JPL |
| Derek Richardson | Univ. Maryland |
| Eileen Ryan | Magdalena Ridge Obs. |
| Paul Miller | LNLL |

# Participación en AIM – AIDA de la comunidad de Ciencias Planetarias

- **Universidad de Alicante:**
  - Estudio dinámica del regolito (levitación por rotación rápida primario) en col. IAA Granada
  - Modelización de la estructura interna
  - Co-coordinación del WG on Physical and Dynamical Properties

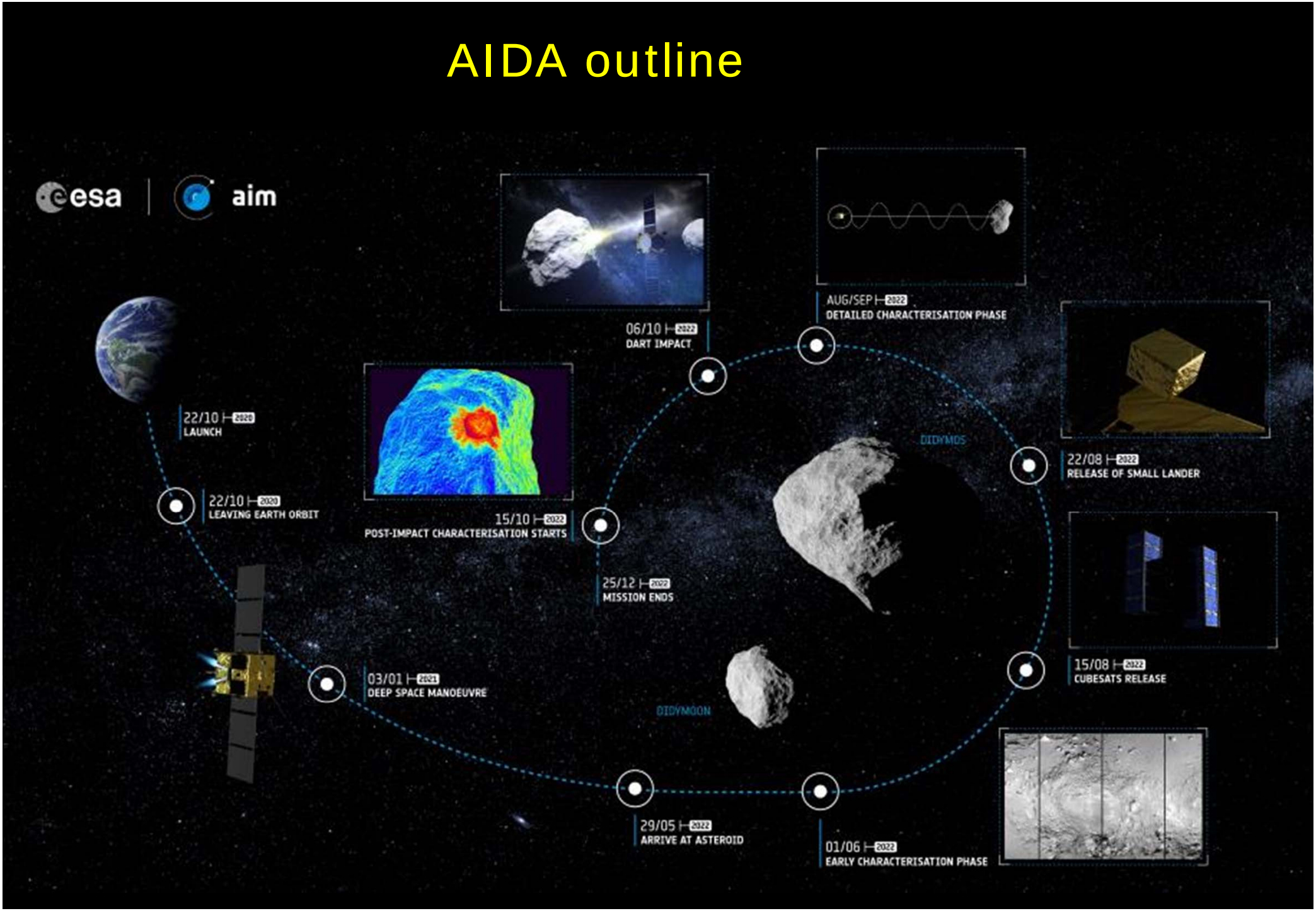
- **Institut de Ciències del Espai. ICE-IEEC (Barcelona):**
  - Instrumentación en CUBESATS (col. Swedish Institute of Space Physics y Royal Institue of Technology, Suecia):
    NAC (Narrow Angle Camera) +
    VES (Video Emission Spectrometer)

- **Instituto de Astrofísica de Canarias (Tenerife)**
  - Estudio de cámara térmica (col. Neil Bowles , Oxford U., UK y Marco Delbo, OCA-Niza, Francia)
  - Participació en el grupo de observaciones remotas.

- **Universidad de Vigo**
  - Instrumentación en CUBESATS (nephelometer: partículas de polvo).

- **Industria aeroespacial.**
  - GMV: CUBESATS (radiociencia, imagen, gravimetría)
  - PLDSPace: Experimentos en micro-gravedad

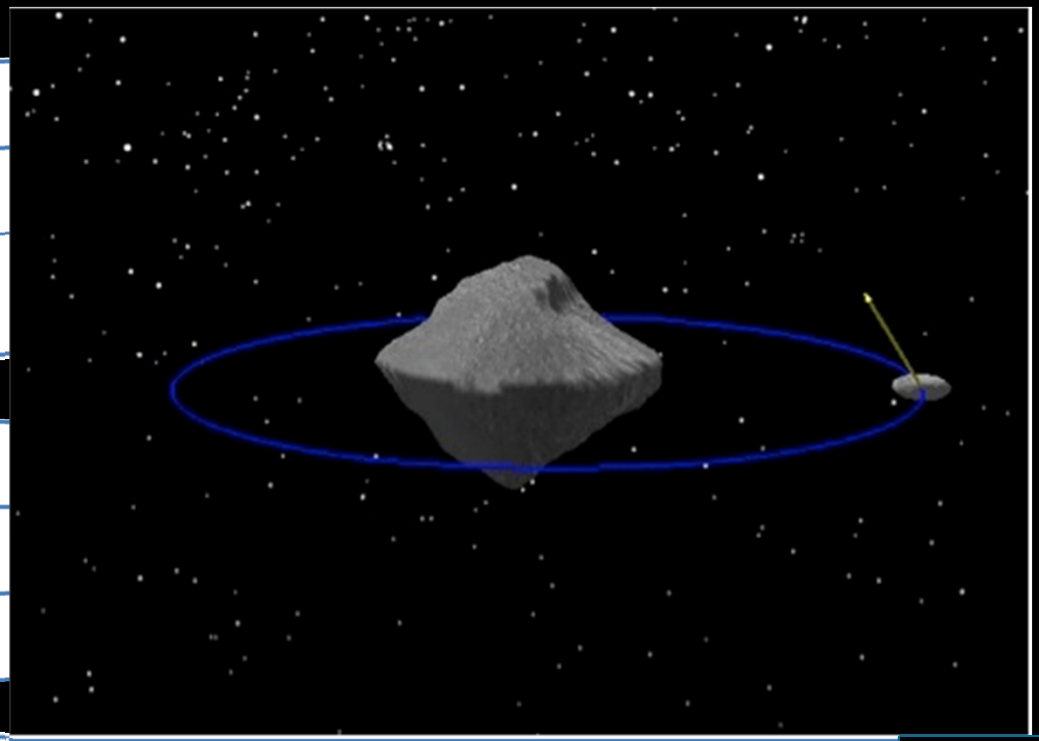
# AIDA outline



# 65803 Didymos: AIDA target

| | |
|---|---|
| Heliocentric eccentricity $e$ | e = 0.383752501 +/- 7.7e-9 |
| Heliocentric semimajor axis $a$ | 1.6444327821 +/- 9.8e-9 AU |
| Heliocentric inclination to the ecliptic $i$[5] | 3.4076499° +/- 2.4e-6° |

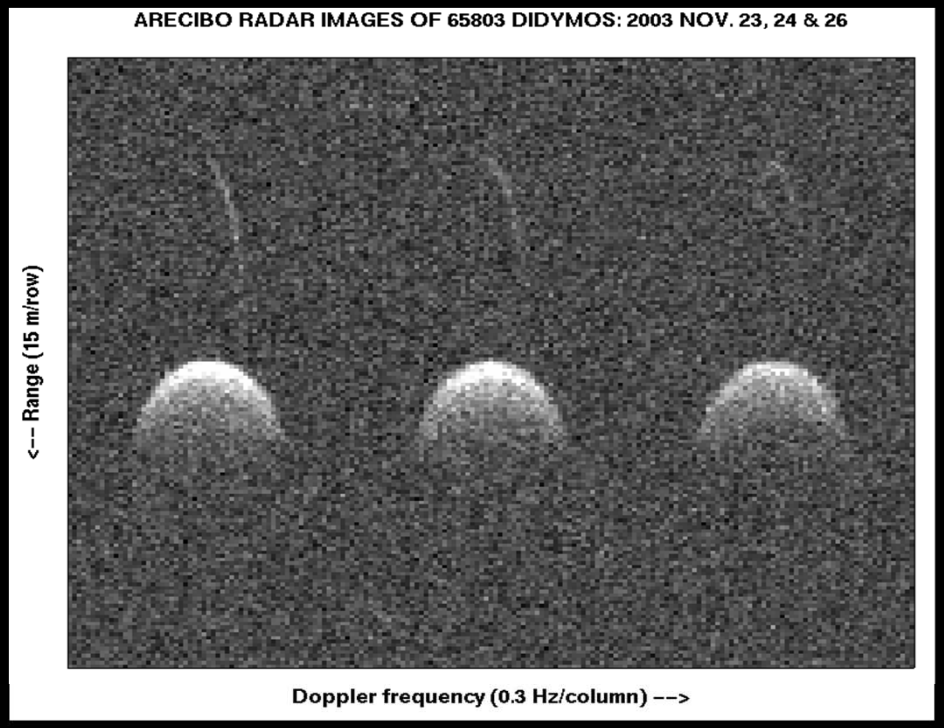
| | |
|---|---|
| Diameter of Primary[1] $D_P$ | 0.780 km +/- 10% |
| Diameter of Secondary $D_S$ | 0.163 km +/- 0.018 km |
| Bulk density of the primary[2] $\rho_P$ | 2100 kg/m$^3$ +/- 30% |



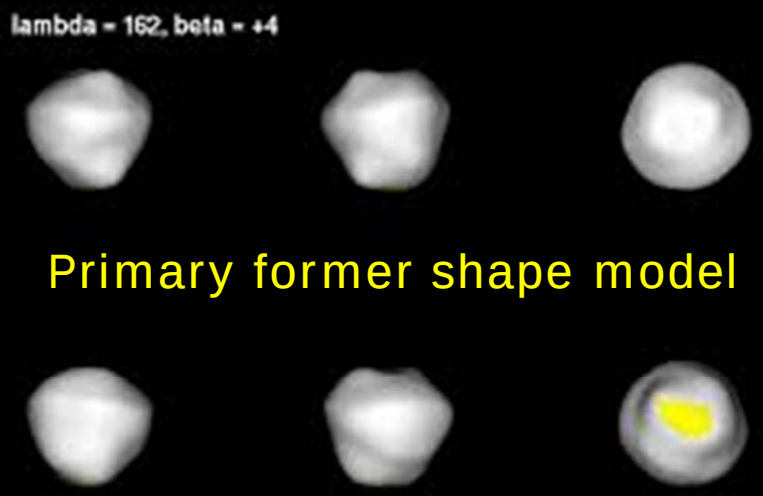
| | |
|---|---|
| Secondary (shape)[3] elongation $a_s/b_s$ and $b_s/c_s$ | 1.3 +/- 0.2<br>>1 (assumed: 1.2) |
| Distance between the centre of primary and secondary $a_{orb}$ | 1.18 km +0.04/-0.02 km |
| Total mass of system | 5.278e11 kg +/-0.54e11 kg[4] |
| Geometric Albedo | 0.15 +/- 0.04 |
| Rotation period of the primary | 2.2600 h +/- 0.0001 h |

| | |
|---|---|
| Obliquity to the heliocentric orbit | 171° +/-9° |
| Diameter ratio $D_S/D_P$ | 0.21 +/- 0.01 |
| Secondary orbital period $P_{orb}$ | 11.920h +0.004/-0.006 |

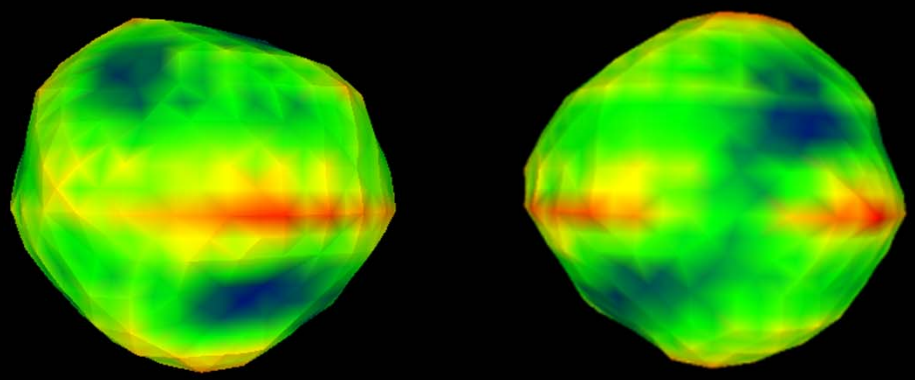
**S type (maybe LL?)**




Radar observations




Primary former shape model



Primary current shape model

# ESA Council at Ministerial Level 2016

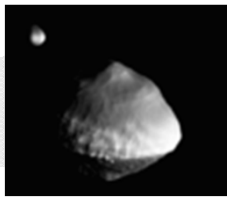
AIM in its baseline definition did not reach full budget approval (250M€). However, several countries calling for:


- a very important mission to **demonstrate planetary defense** in the frame of the **AIDA international cooperation**

- recognition of AIDA's **high technical** and **scientific interest**

- recognition of the great **public support and inspirational component of AIDA**

# AIDA = AIM-D$^2$ + DART



**Target:**
**binary NEA Didymos in 2024**

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AIM-D$^2$: Asteroid Impact Mission - Deflection Demonstration
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- ESA AIM rendezvous spacecraft
  - Orbiter payload to characterize Didymos dynamical system and study impact results (Framing camera + 1 cubesat)
  - Asteroid proximity operations.
  - ~~Lander release on secondary asteroid: deep interior analysis~~
  - ~~Deep-space optical communication demonstration~~
  - Deploy and operate Cubesat in interplanetary space and spectral characterization of secondary
- NASA DART interceptor and Earth-based observing
  - Perform kinetic impact on Didymos' satellite
  - Measure asteroid deflection to within 10%
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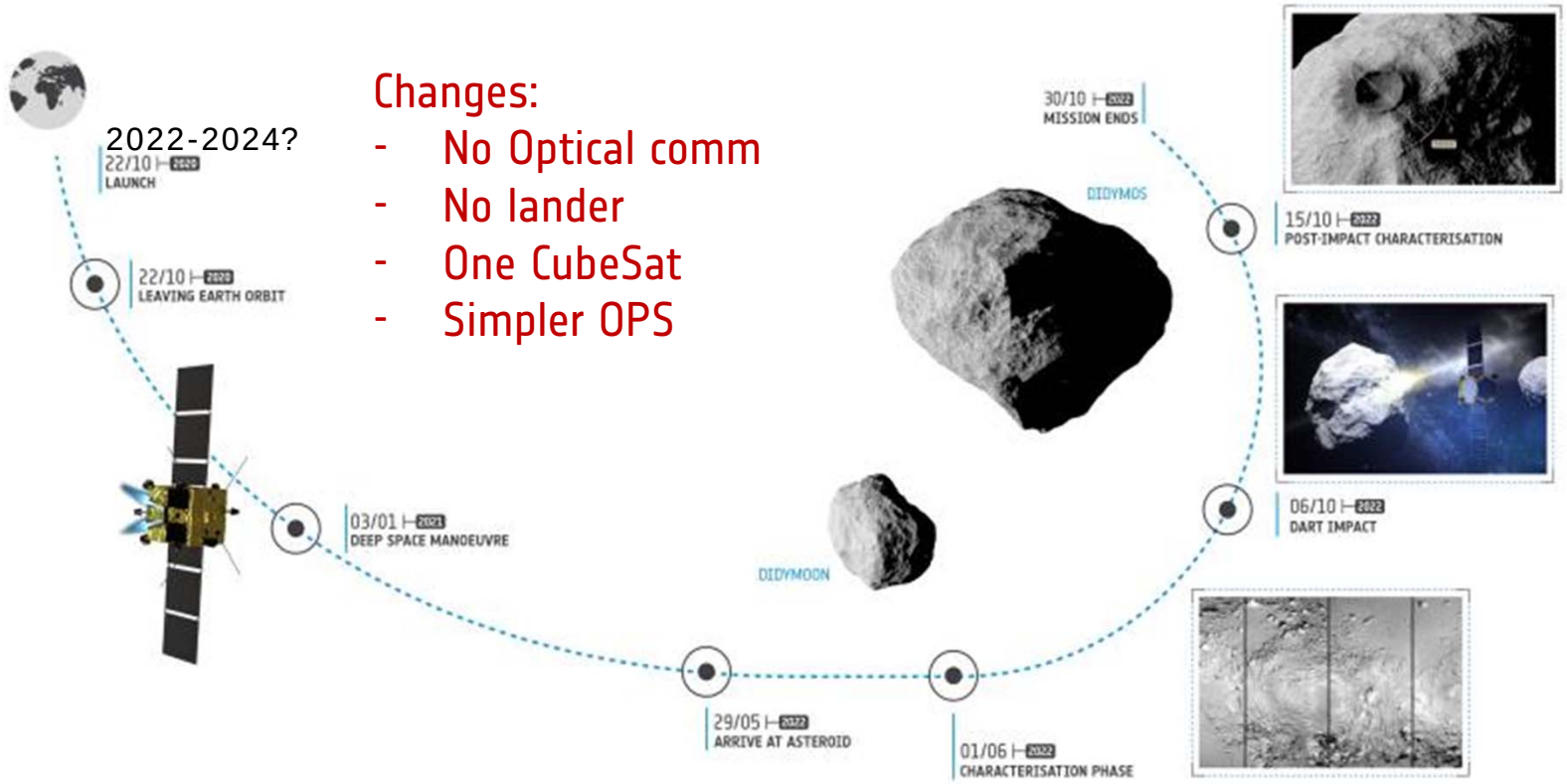
  - Autonomous guidance with proportional navigation to hit center of 150 meter target body

# AIM-D²

Simplification of the mission scenario meeting main mission objectives:

**Full characterisation of DART impact** and **measurement of Didymos deflection**

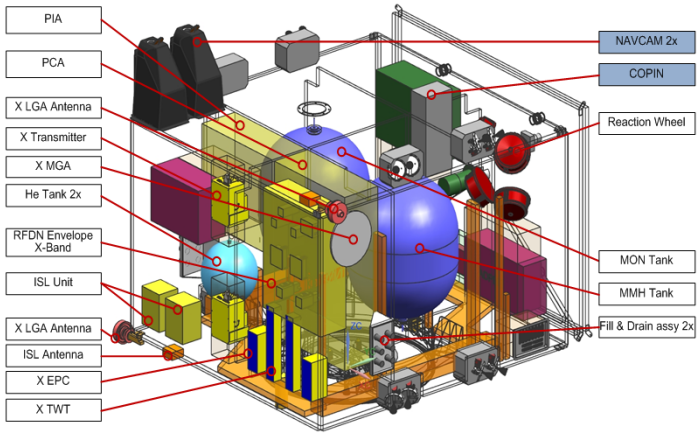


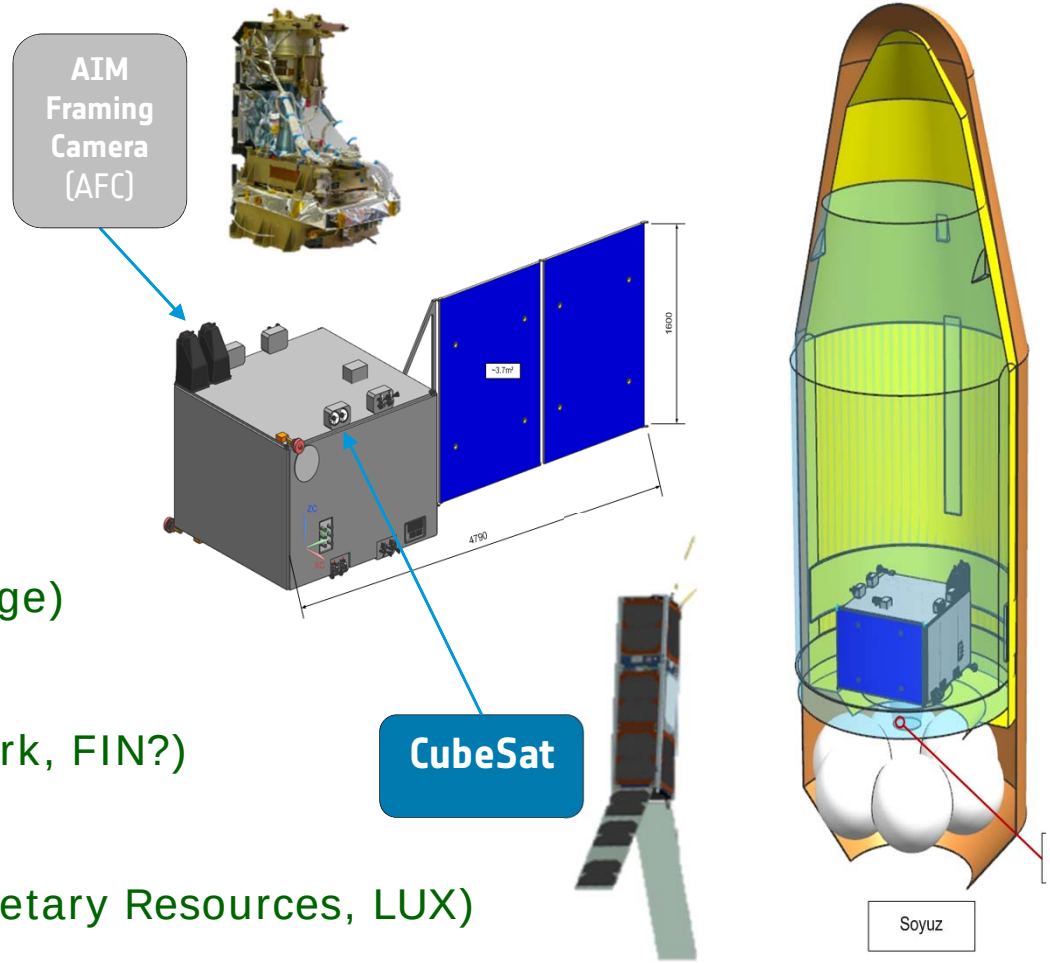

Changes:

- No Optical comm
- No lander
- One CubeSat
- Simpler OPS

Same transfer trajectory / Direct escape (Soyuz)
1.5 years cruise / 4 months close operations

# AIM-D² payload




- Supported payload (baseline):
  - AFC (Aim Framing Camera) (in storage)
  - ASPECT (ASteroid SPECtral Imaging)
    (under consolidation work, FIN?)
- Optional payload:
  - HYP (Imaging spectrometer) (Planetary Resources, LUX)
  - LIDAR (laser planetary altimeter, PT+PL)

**Dry mass growth potential of 40 kg for additional payload**

# AIDA/AIM-D$^2$ relevance

**AIDA/AIM relevance to mitigation** by addressing 2/3 needs in asteroid impact risk:

- ➔ Improve knowledge of geophysical properties at NEA size range
- ➔ Test our ability to deflect a small asteroid (DART momentum transfer/observation of damage on secondary)
- **(X** Complete the inventory of NEA population)

**AIDA/AIM relevance to asteroid mining**:

- ➔ Improve knowledge of asteroid mechanical and geophysical properties
- ➔ Understand response of asteroid material to external action in low-gravity environment
- ➔ Gain experience in close-proximity operations

# AIDA/AIM-D$^2$ science

**Science return**

➔ First images of a binary asteroid
➔ Constraints for asteroid formation models

➔ First images and in-situ analysis of the smallest asteroid ever visited

➔ Internal structure through bulk density and system dynamics

➔ First documented impact experiment at asteroid scale
➔ First impact observation due to known projectile
- Understanding physical/compositional properties/ geophysical processes
- Validation of numerical simulations and models of hyper-velocity impacts/collisional evolution

➔ Seismic transmission/attenuation comparing images before/after impact (diplacement of boulders/mass movement/change in landforms)

# SUMMARY

- Simplified AIM s/c achieves full asteroid mitigation objectives.
- Deep-space CubeSats technology demonstration compatible with reduced cost and schedule scenarios ➔ mission risk reduction during impact observations and additional information relevant to resources characterization.
- Close-proximity operations reduced in duration and complexity with a direct reduction of cost by >20M€
- Delay to 2022 launch opportunity

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