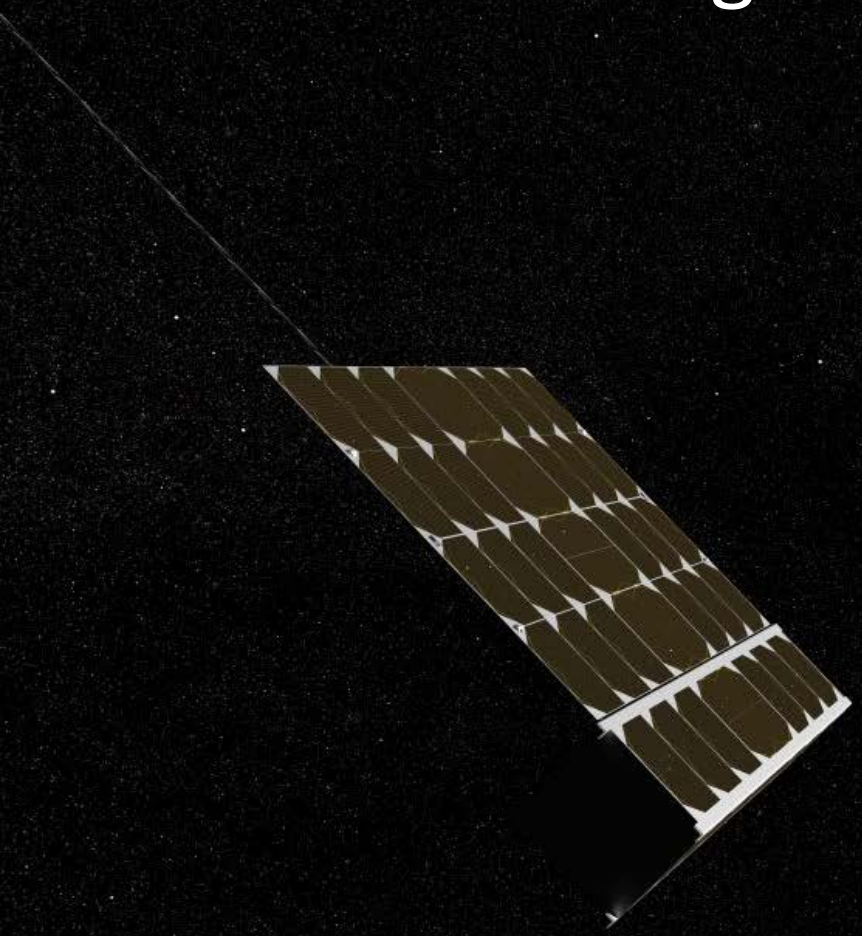
Asteroid Touring Nanosatellite Fleet



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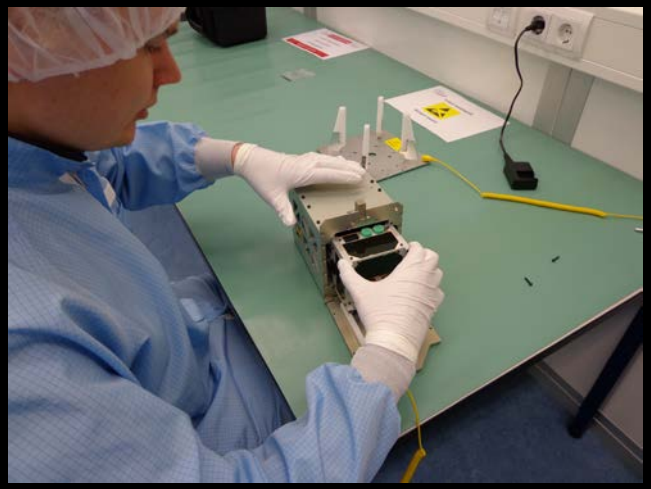
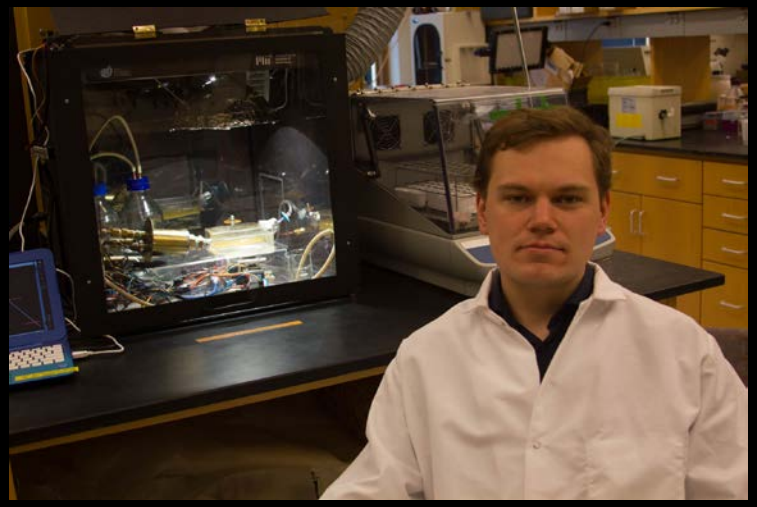
+ Pekka Janhunen, Andris Slavinskis, and the MAT collaboration

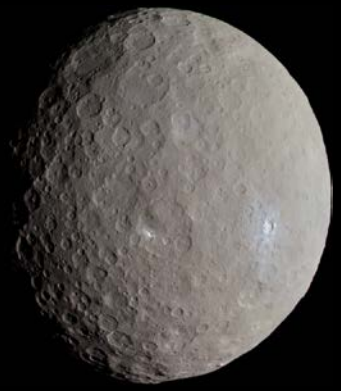
Bio

- 2010 MSc in Physics, University of Tartu, Estonia
- 2010-2015 ESTCube-1 team, leader of Electrical Power Subsystem
- 2014 PhD in Physics University of Tartu, Estonia
- 2015 - 2019 Postdoc at MIT, Seager Group (astrobiology and instrumentation development for the MAT mission)





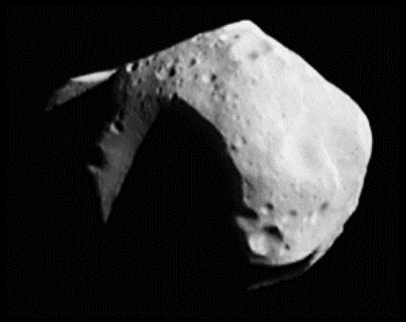
Only 12 asteroids have been visited this far



1 Ceres

Image Credit: NASA / JPL-Caltech / UCLA / MPS / DLR / IDA / Justin Cowart

4 Vesta



253 Mathilde
NEAR /NASA

433 Eros
NEAR Shoemaker
NASA/JPL/JHUAPL

21 Lutetia
ESA 2010 MPS for OSIRIS Team
MPS/UPD/LAM/IAA/RSS D/INTA/UPM/DASP/IDA

243 Ida and Dactyl
Galileo/NASA

951 Gaspra
Galileo/NASA / JPL/USGS

2867 Šteins
Rosetta ESA MPS for OSIRIS Team
MPS/UPD/LAM/IAA

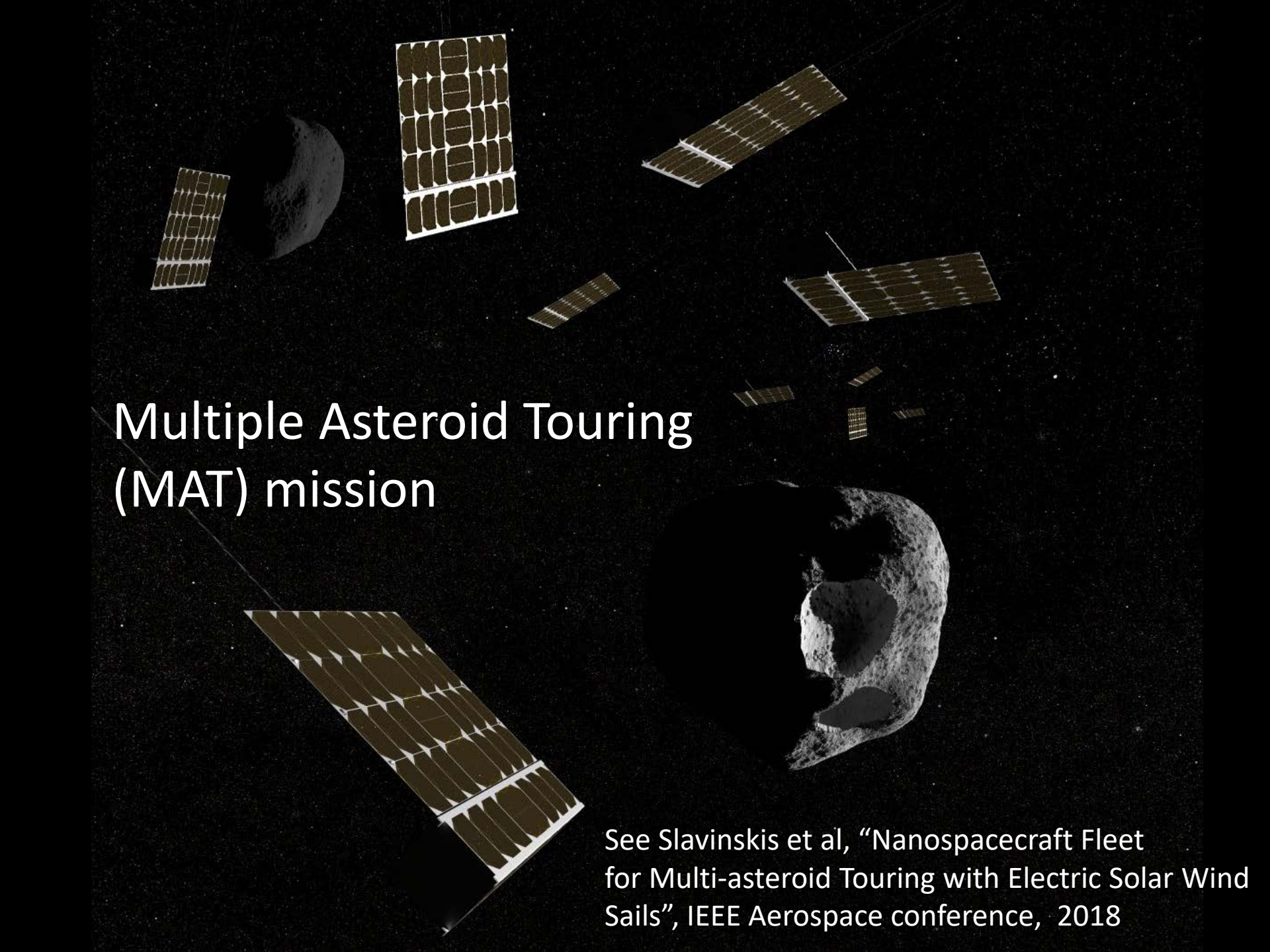
9969 Braille
Deep Space 1/NASA/JPL/USGS

25143 Itokawa
Hayabusa/JAXA

4179 Toutatis
Chang'e/CNSA

5535 Annefrank
Stardust/JPL/NASA

Multiple Asteroid Touring (MAT) mission

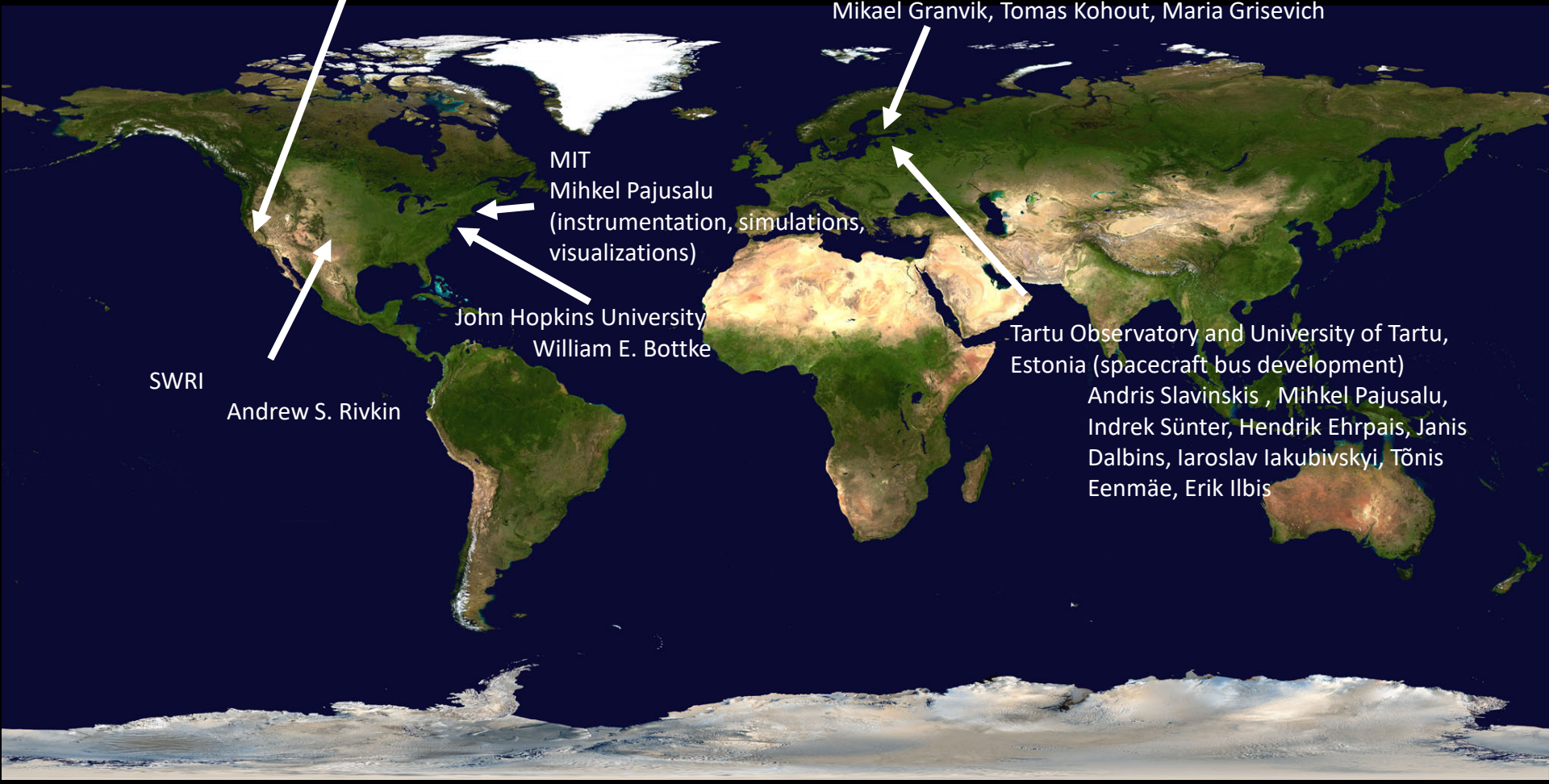


See Slavinskis et al, “Nanospacecraft Fleet for Multi-asteroid Touring with Electric Solar Wind Sails”, IEEE Aerospace conference, 2018

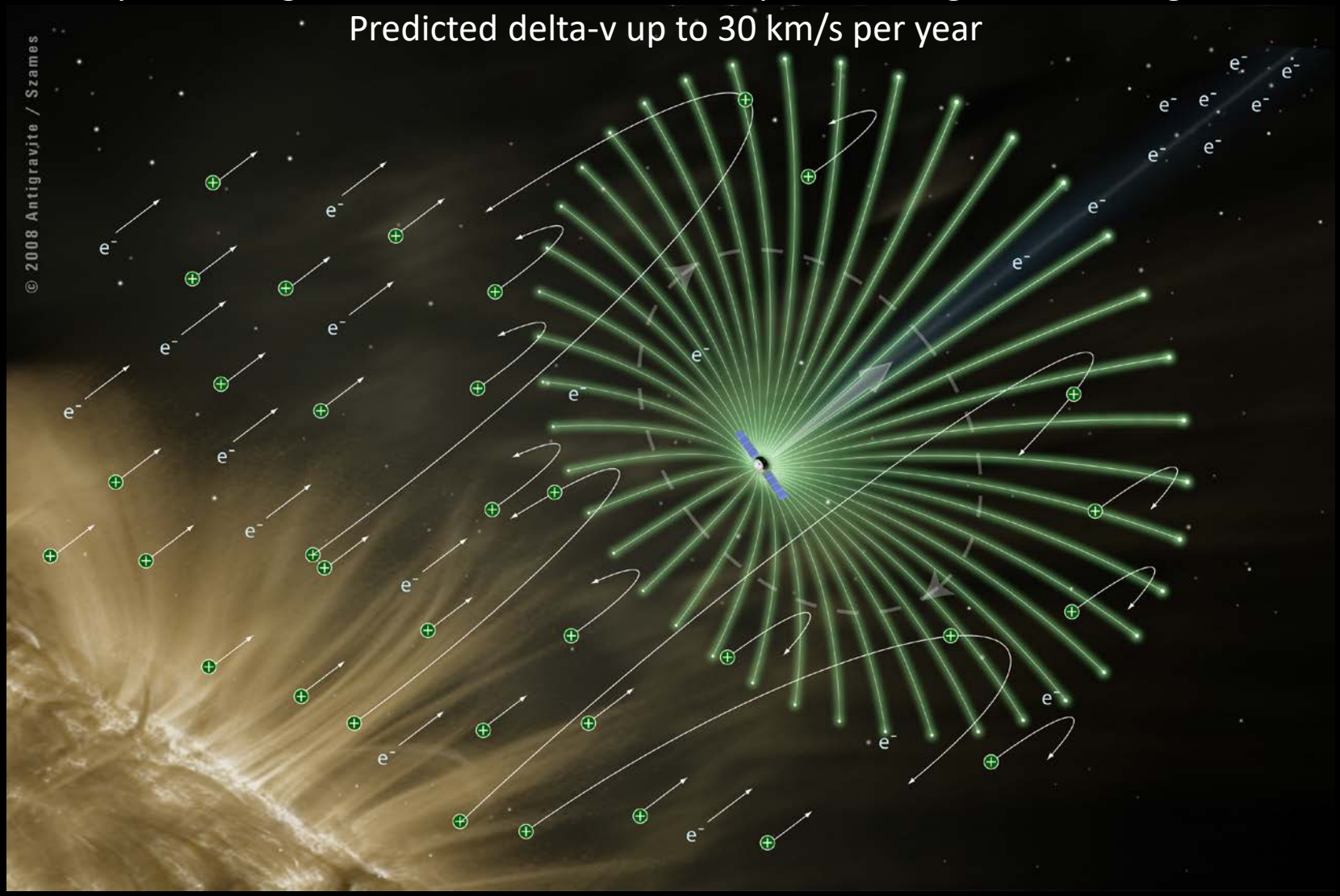
Mission details

- The reference mission contains 50 identical CubeSats
  - Estimated total cost <100 million USD
- Each to visit 6 targets on average
  - 100 km – 1000 km flybys
- Total of 300 visits during 3.2 years
- Even if 50% are successful, number of visited asteroids would increase by a factor of 10
- First published concept from Finnish Meteorological Institute (Pekka Janhunen et al, “Asteroid touring nanosat fleet with single-tether E-sails”, 2017)

Collaboration



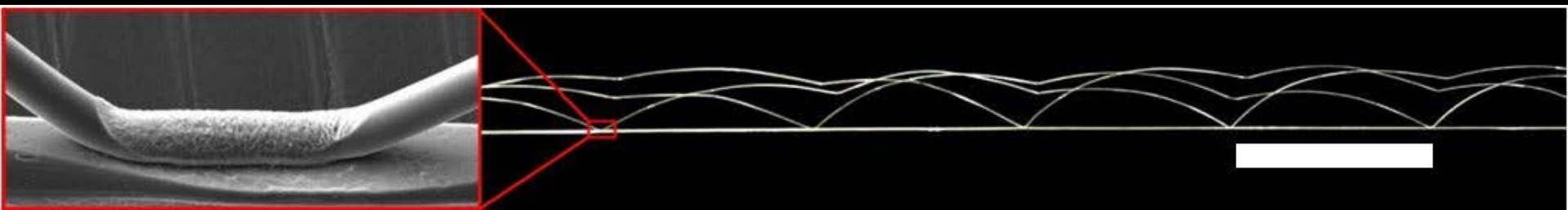
Electric solar wind sail could make multiple asteroid touring feasible
Works by extracting momentum from solar wind plasma using a set of charged tethers
Predicted delta-v up to 30 km/s per year



Inventor: Pekka Janhunen, Finnish Meteorological Institute
www.electric-sailing.fi

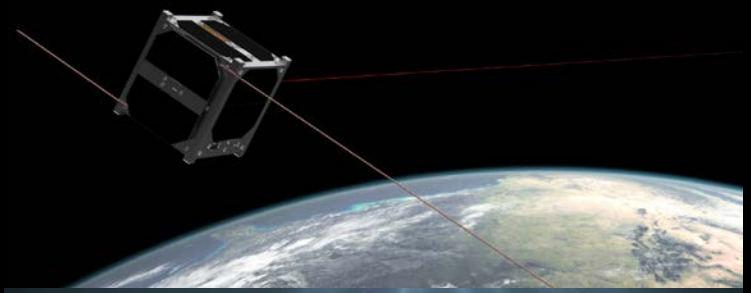
E-sail tethers

- Design called Heytether (by P. Janhunen)
  - Somewhat similar to Hoytether by Dr. Robert P. Hoyt
- An end unit (a separate nanosatellite) is used to provide torque on the wire
- Charged up by electron guns
  - Cold cathode electron guns tested on orbit on ESTCube-1
  - Other types of electron guns might be used on the final mission



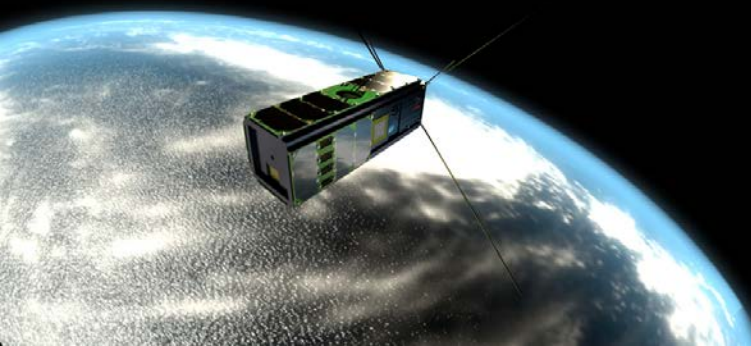
E-sail related missions

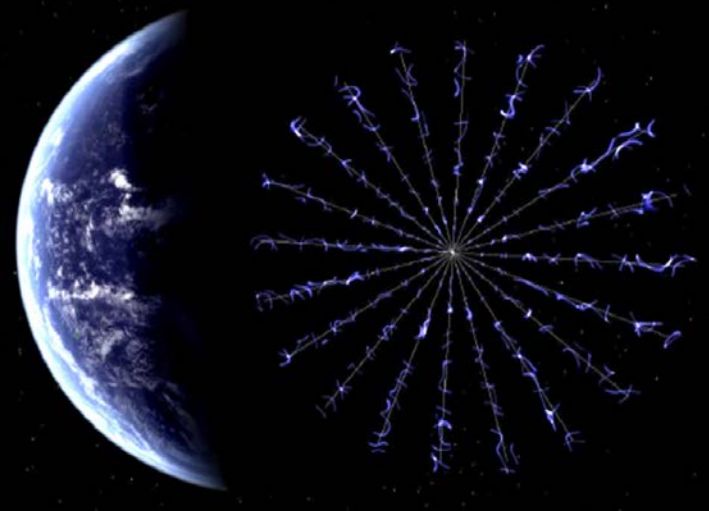
ESTCube-1



ESTCube-2

Aalto-1



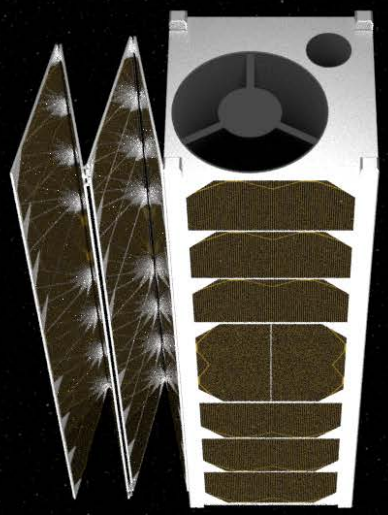


NASA: Heliopause Electrostatic Rapid Transit System (HERTS)

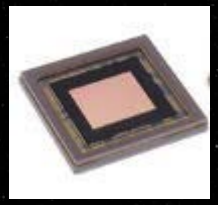
A single MAT nanospacecraft

Solar cell array
~40 W peak at 1 AU

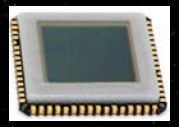
Mass: 5-6 kg



Multispectral telescope
~230 mm focal length
Coaxial Startracker/framing camera
Visual FPA + MIR FPA



0.3-1 µm
IMX264
as reference



1-5 µm
TACHYON 6400
Uncooled PbS

Contains E-sail module
and remote unit
Reaction wheels

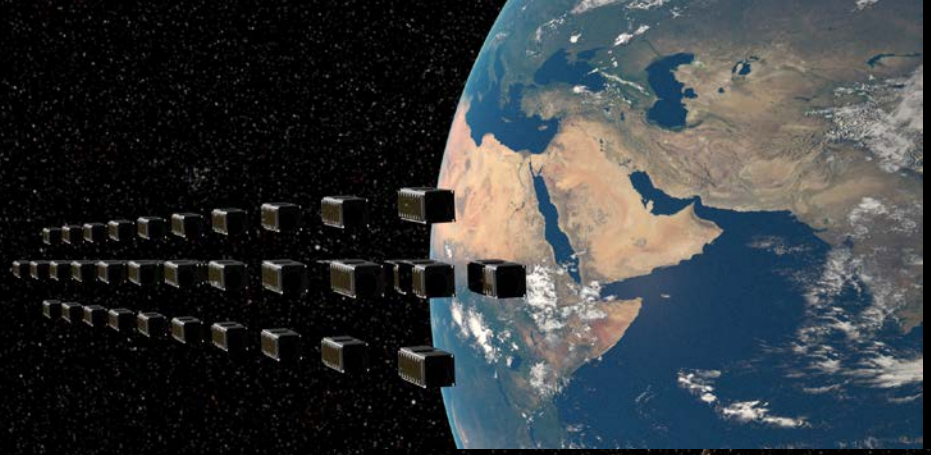
Deployed spacecraft

Remote unit ~1 kg
Independent propulsion

Centrifugally deployed aluminum tether, 20 km long (0.2 kg), charged to 20 kV

Main spacecraft ~4 kg
Electrospray propulsion (Accion Systems TILE as reference) for spin-up and course correction
Electron guns for charging

1



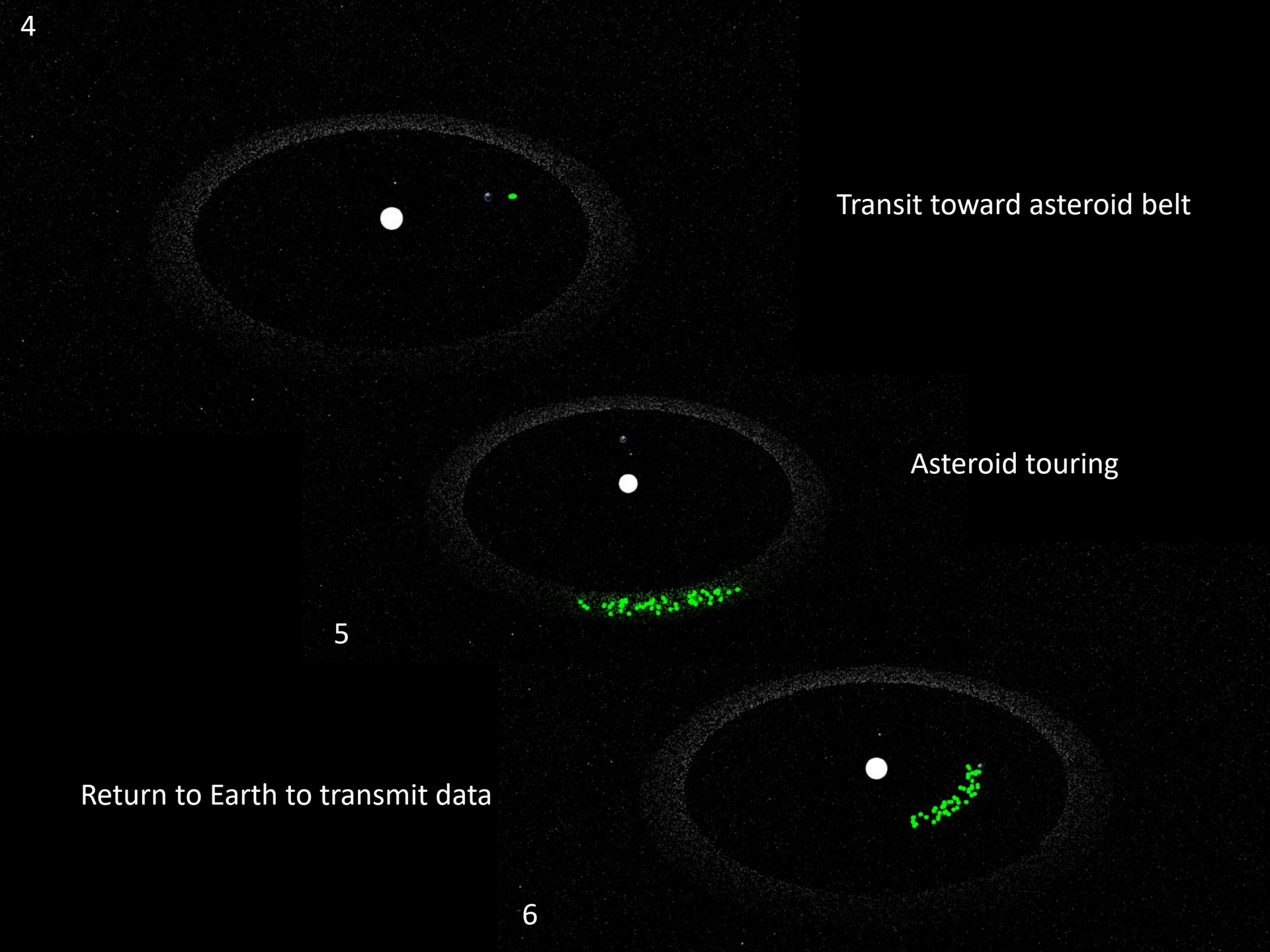
50 probes launched at once

Spin-up and
E-sail deployment

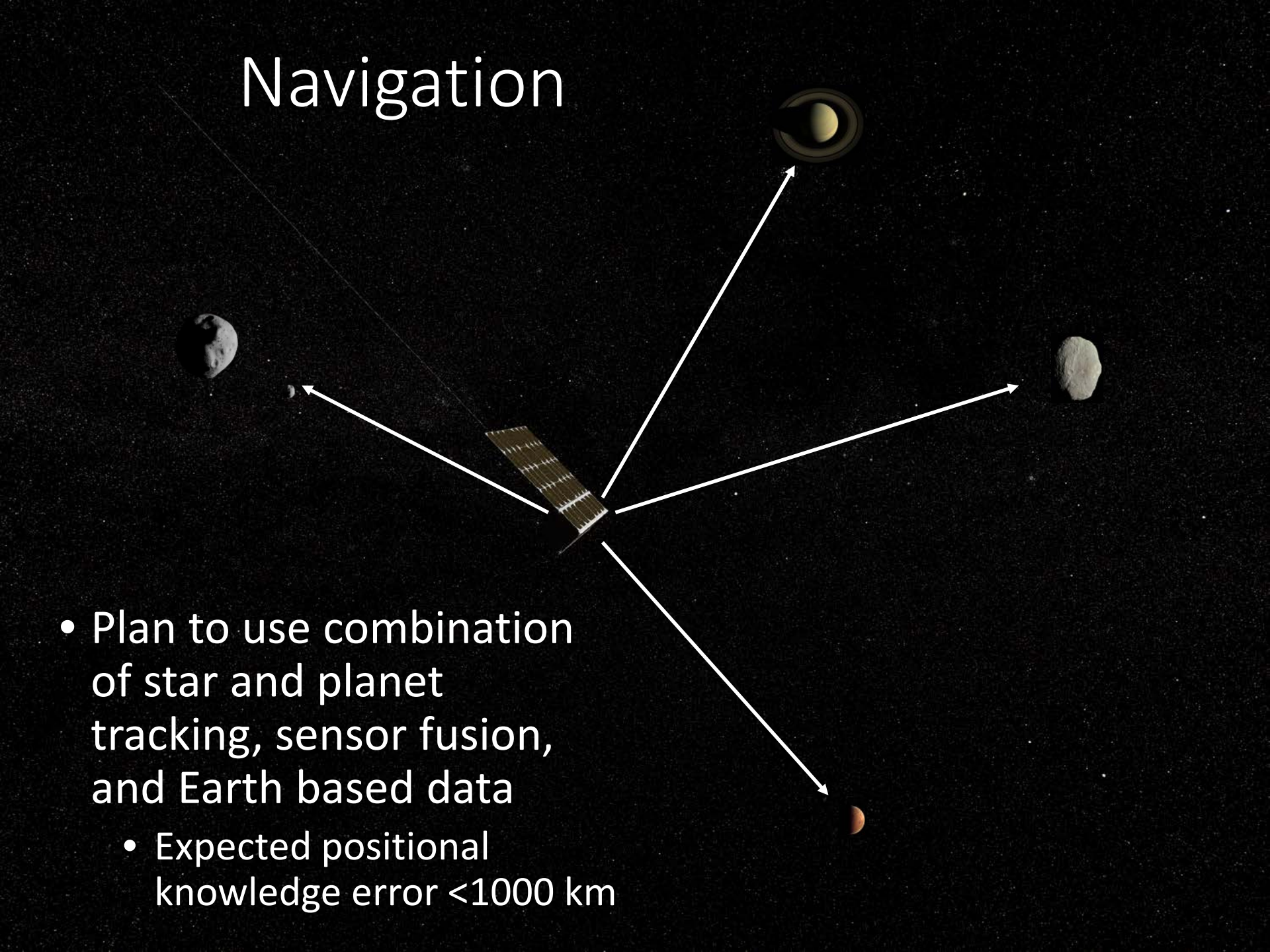
2

Departure from Earth-Moon system

3


4
Transit toward asteroid belt
Asteroid touring
5
Return to Earth to transmit data
6

Navigation



- Plan to use combination of star and planet tracking, sensor fusion, and Earth based data
  - Expected positional knowledge error <1000 km

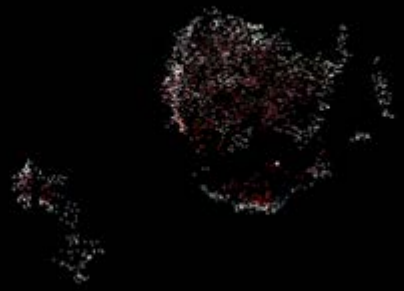
Expected image quality: approx 2 m resolution at 100 km in visual range.
Simulated image, 65803 Didymos as a reference target (0.8 km diameter, 10 km/s relative speed)

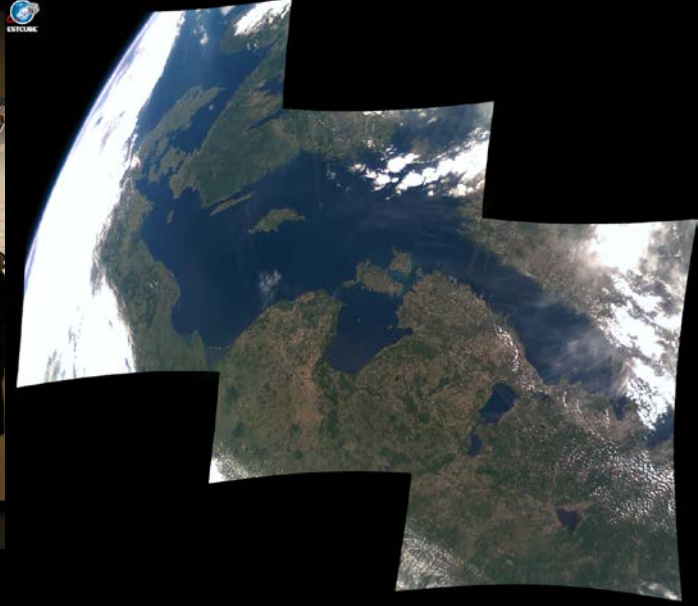
Reconstruction

Asteroid surface is good for structure-from motion

Should allow asteroid shape model reconstruction and precise flyby trajectory estimation

SFM
(This example by VisualSFM)





- ESTCube-1
- Started 2008
- Launch May 2013, mission end May 2015
- First test of E-sail on orbit (failed due to broken motor)

ESTCube-2

- Satellite expected to be ready in 2018
- Launch tentatively in 2019 (ride not secured)

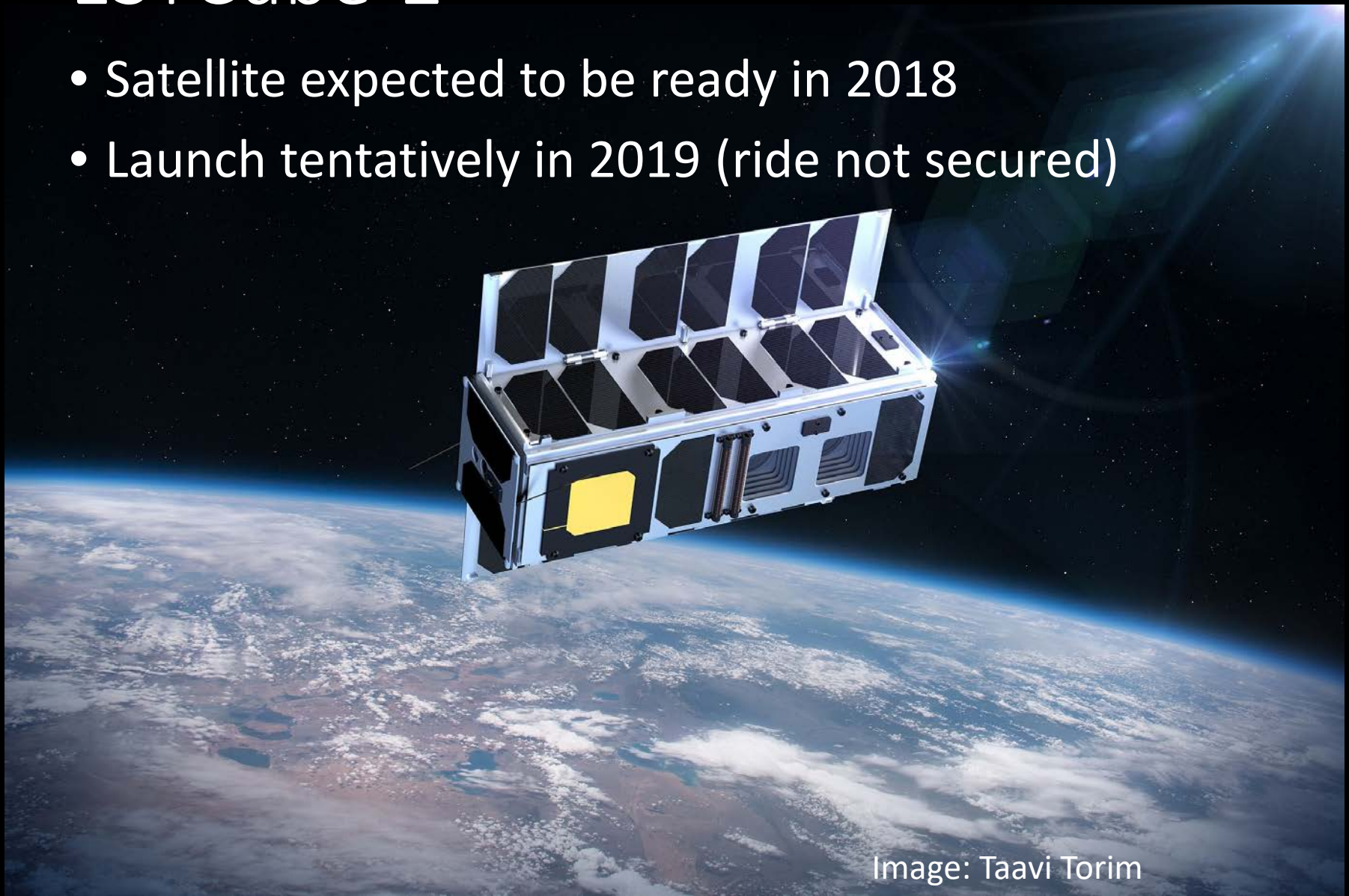
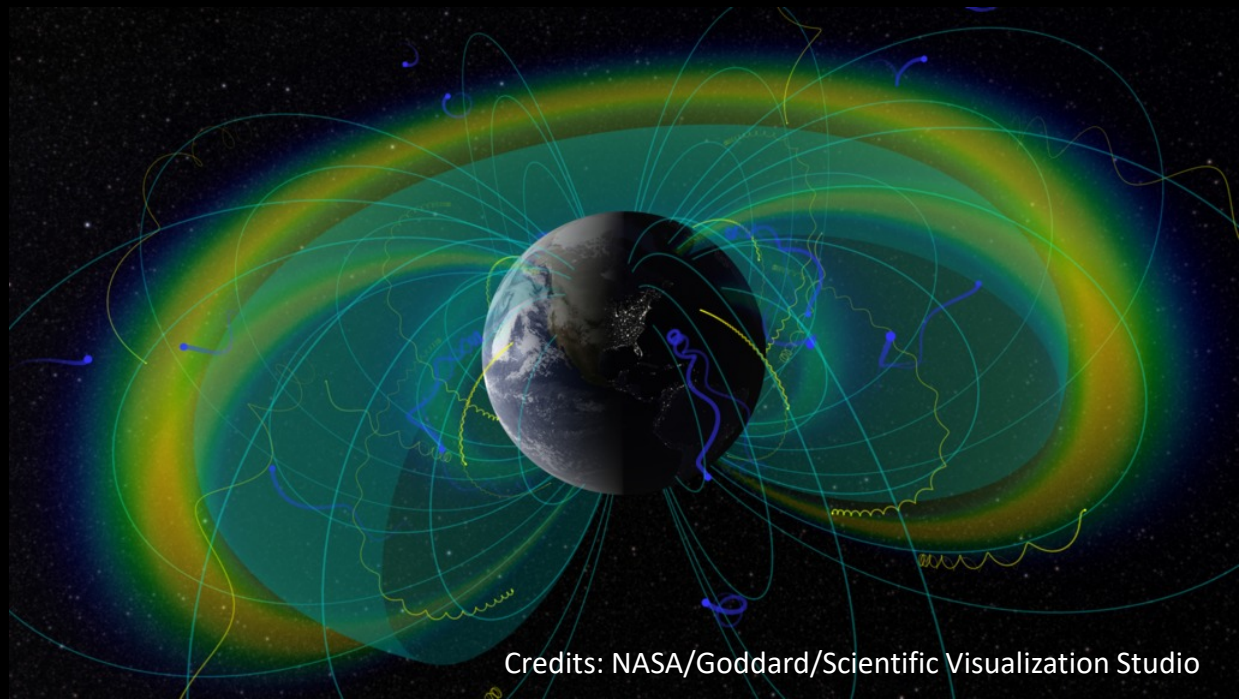


Image: Taavi Torim

ESTCube-3

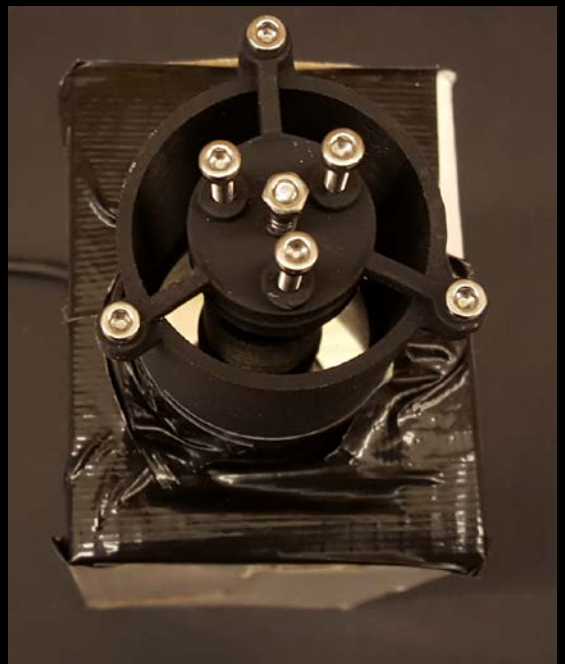
- Planned followup to ESTCube-2
- Test E-sail outside of van Allen belts
- Launch to GTO or translunar injection
  - Should be possible to enter heliocentric orbit



Credits: NASA/Goddard/Scientific Visualization Studio

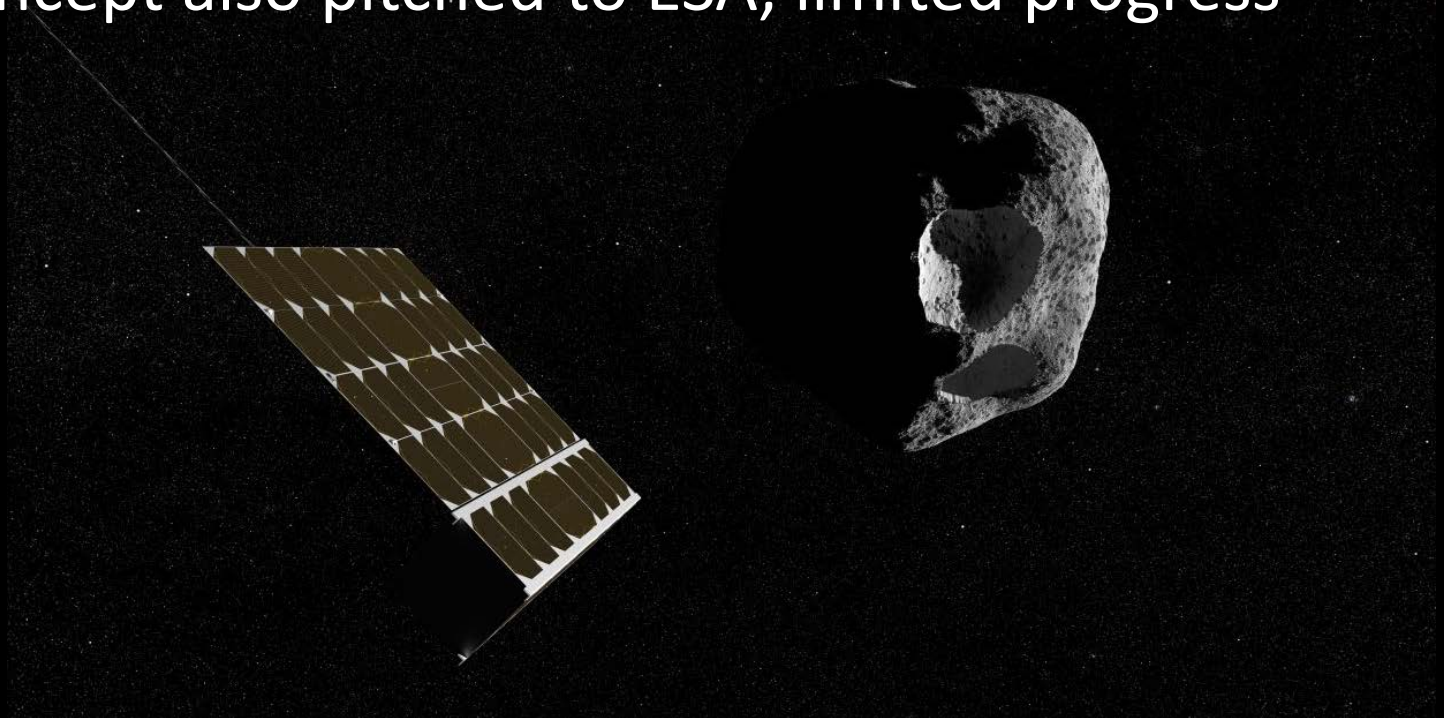
MAT progress

- Proof of concept instrumentation under development
  - <1 kg, <1U spectral imaging system
  - Image simulations ongoing to determine expected mapping quality
- General concept design



Conclusion

- Mission concept being developed
- Main instrument is being designed
- E-sail will be tested on ESTCube-2, tentatively 2019
- Concept also pitched to ESA, limited progress



For more information:

Nanospacecraft Fleet for Multi-asteroid Touring with Electric Solar Wind Sails

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***Abstract*—We propose a distributed close-range survey of hundreds of asteroids representing many asteroid families, spectral types and sizes. This can be implemented by a fleet of nanospacecraft (e.g., 4–5-unit CubeSats) equipped with miniature imaging and spectral instruments (from near ultraviolet to near infrared). To enable the necessary large delta-v, each spacecraft carries a single electric sail tether which taps the momentum from the solar wind. Data are stored in a flash memory during the mission and downlinked at an Earth flyby. This keeps deep-space network telemetry costs down, despite the large number of individual spacecraft. To navigate without the use of the deep-space network, optical navigation is required to track stars, planets and asteroids. The proposed mission**