IAA-PDC-15-04-17

From Sail to Soil – Getting Sailcraft Out of the Harbour on a Visit to One of Earth's Nearest Neighbours

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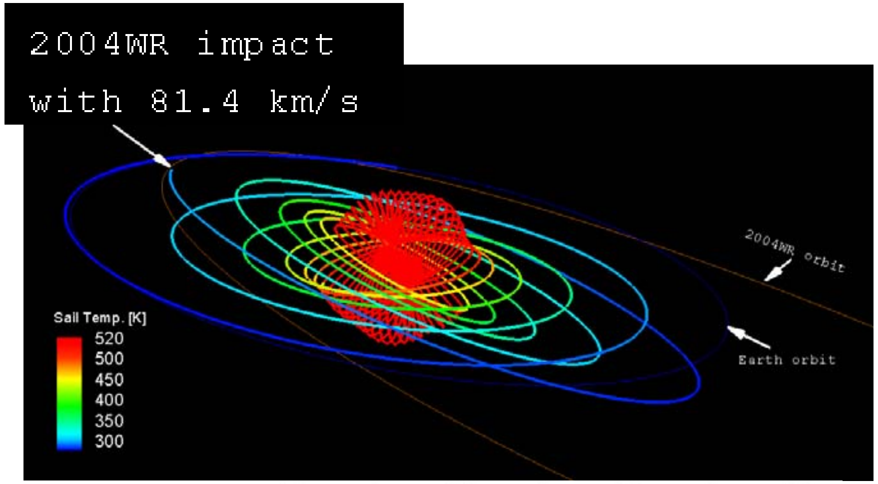
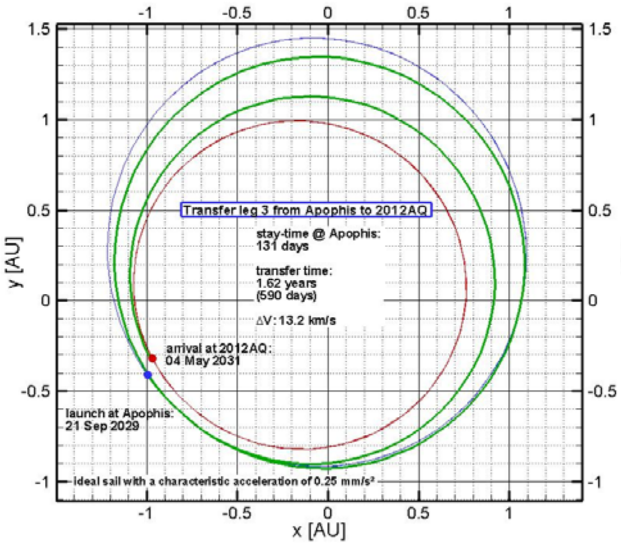
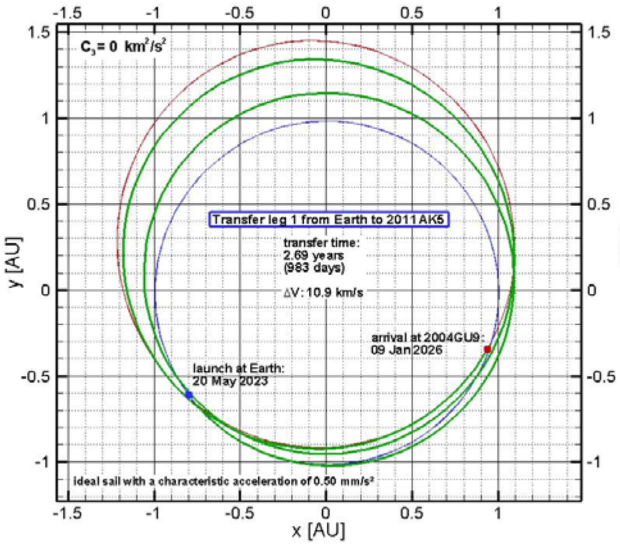
Why solar sailing? – well, you might as well ask…

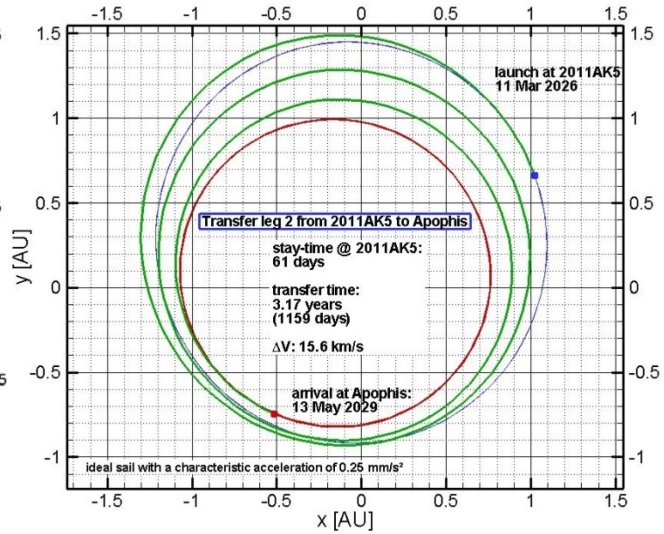
Why a 300 kg piggy-back launchable >75 km/s Kinetic Impactor?



Why rendezvous
3 NEAs in <10 years?
(sample-return option included)





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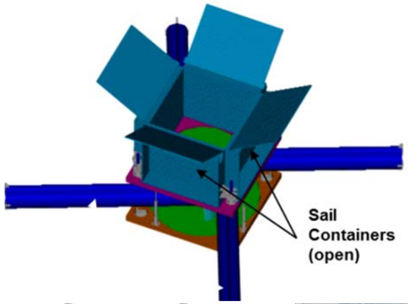
DLR & ESTEC
are proud to present
BREMEN
The
GOSSAMER
ROADMAP
Lorna '12

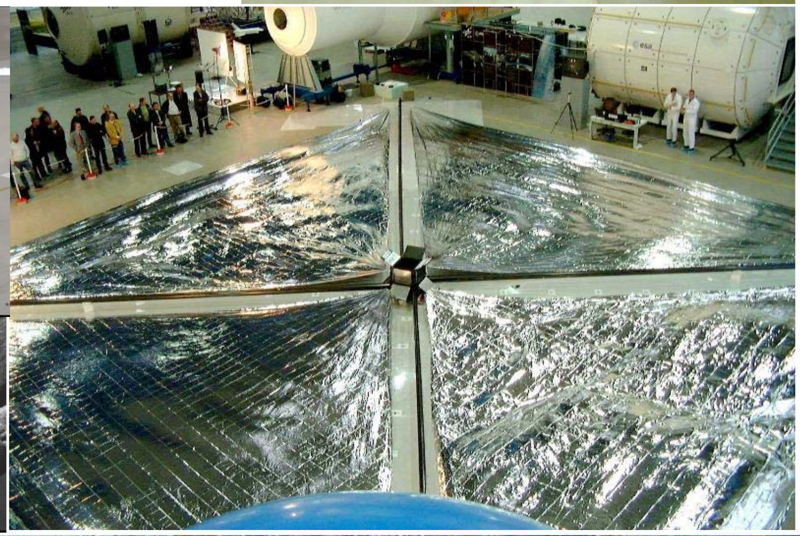
solar sailing at DLR
– no flight heritage, yet, but not magic either

The December 7th,1999 DLR/ESA Solar Sail Ground Demonstration

(20 m)² push-out boom, hoisted sail

- you need space – the European Astronaut Center hall next to the ISS model
    - Deployment Module: 24 kg
    - CFRP booms (4 x 14m, 101 g/m): 6 kg
    - Sails (20 m)², 4-12 µm foil: 5 kg
    - Dimensions: 60cm x 60 cm x 65cm

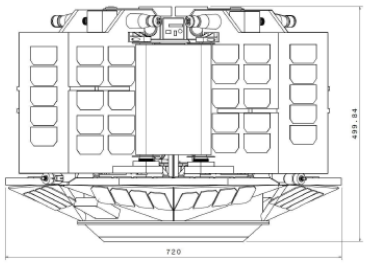


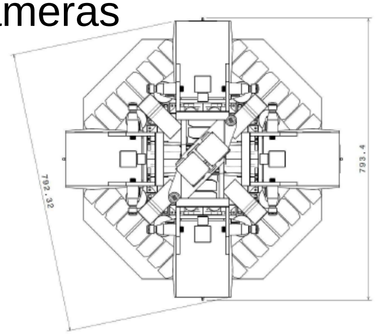


The GOSSAMER Roadmap
step 1 – deployment

GOSSAMER-1 – in-orbit deployment demonstrator

- (5 m)² sail area, all deployment-related mechanisms
- 1-boom, 2-quadrant EM in operation * →
- 1-boom EQM under construction now for extensive qualification testing to be finished by end of 2015
- proven MASCOT-style concurrent AIV approach **
- PFM detailled design progressed beyond PDR
- free-flyer independent spacecraft (really 5-in-1)
- “piggy-back” launch to LEO, <50 kg total ↓
- extensive instrumentation: 6 hi-res video cameras





* IAA-PDC-15-P-**20,** *P. Seefeldt et al,* Large Lightweight Deployable Structures …

** IAA-PDC-15-P-**66,** *C.D. Grimm et al,* On Time, On Target – …

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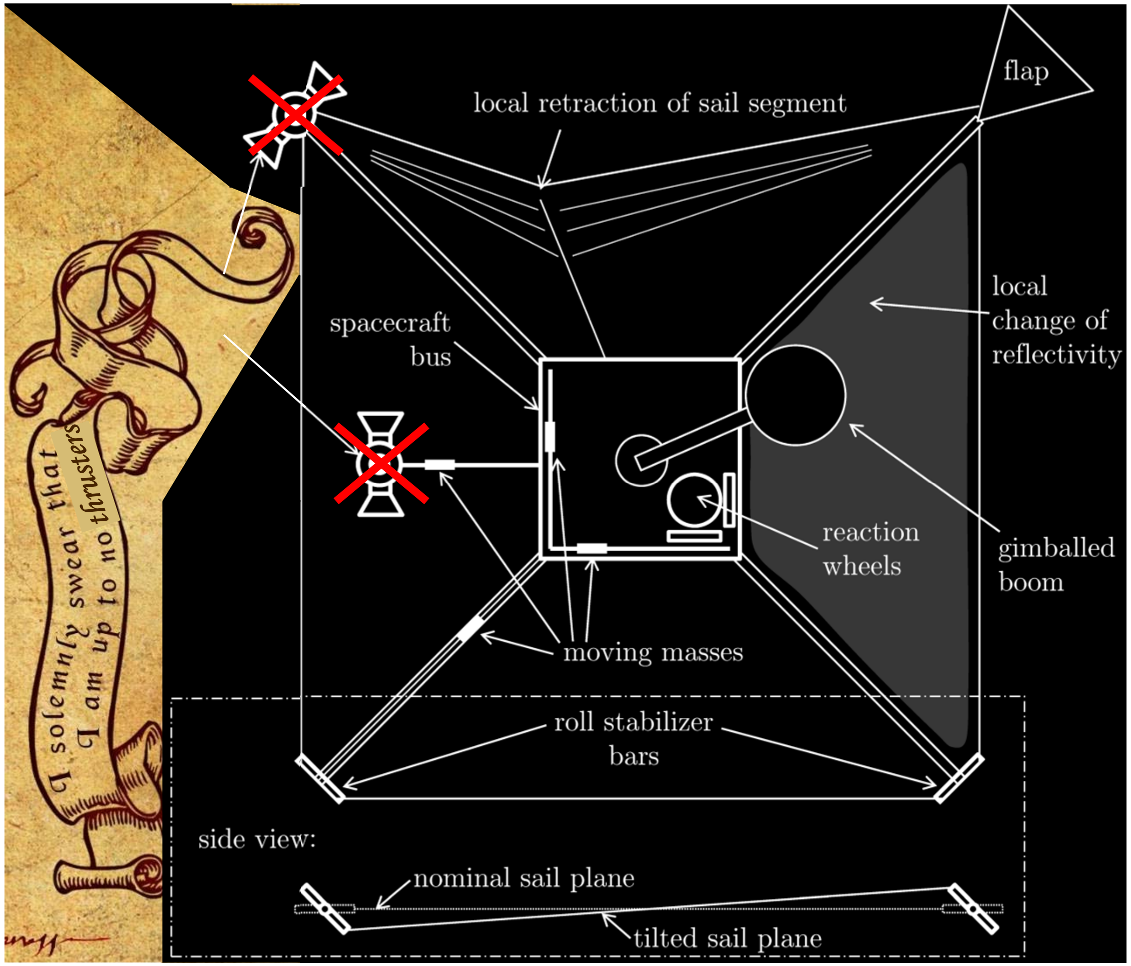
The GOSSAMER Roadmap
step 2 – control

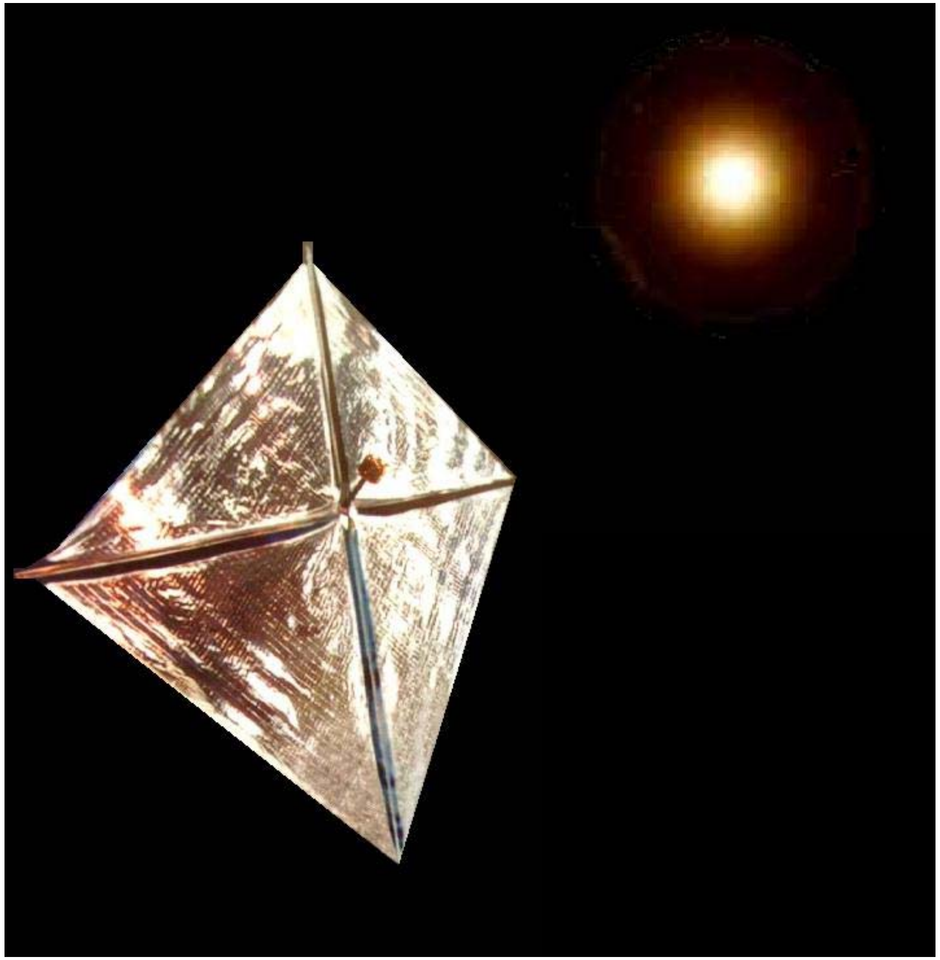


GOSSAMER-2 – in-orbit attitude & thrust vector control demo

- (20 m)² sail area
- orbit where solar radiation pressure is dominant – high LEO, MEO, GTO
- implementation of several (all?) control methods and all relevant mechanisms
- **find out what's the best – 1, 2,…, many combined?**
- ~2 years after GOSSAMER-1 flight: requires MASCOT-style concurrent AIV & project management *
- PFM free-flyer for "piggy-back" launch
- mass & undeployed size compatible with ASAP-micro & ESPA envelopes

* IAA-PDC-15-P-**66,** *C.D. Grimm et al,* On Time, On Target – How the Small Asteroid Lander MASCOT Caught a Ride …

The GOSSAMER Roadmap
step 3 – proving the principle



GOSSAMER-3 – all-up proof test science mission readiness demonstrator

- (50 m)² sail area
- initial orbit high enough to spiral out (sail up) – high LEO, MEO, GTO, LTO, $L_{1/2}$TO
- applies best control method(s)
- **prove that sails can operate science missions successfully**
  - ***tiny*** **science payload: imager & sail-environment interaction**
- ~2 years after GOSSAMER-2 flight: again, MASCOT-style concurrent AIV*
- PFM free-flyer for "piggy-back" launch
- mass & undeployed size compatible with ASAP-micro & ESPA envelopes
- **instrumentation to observe sail ageing in space, as long as it lasts**

* IAA-PDC-15-P-**66,** *C.D. Grimm et al,* On Time, On Target – …

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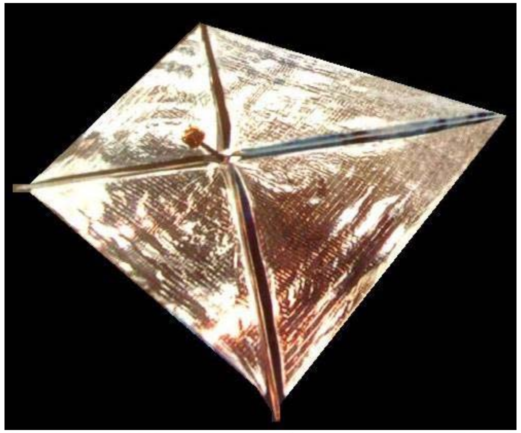
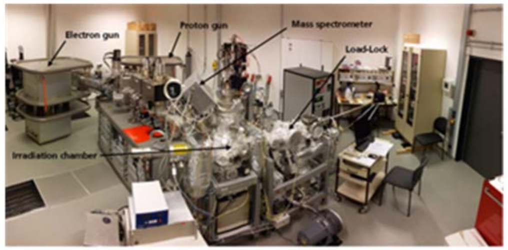
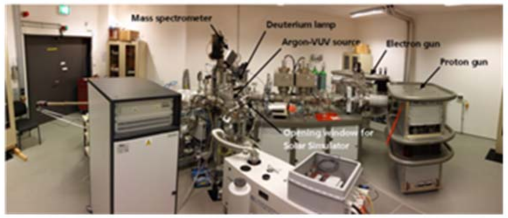
GOSSAMER-3 quality assurance – sail monitoring, pointing verification





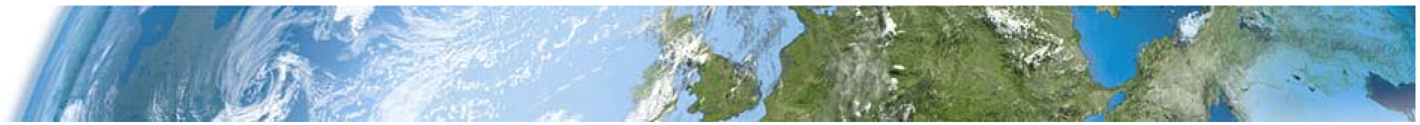


GOSSAMER-3 – instruments wish list

a *tiny* **science**(…-like) payload to **observe sail ageing** *

- wide-angle camera to observe **sail deployment and long-term foil behaviour** and provide **proof images for attitude control, pointing stability & accuracy**
- sensor to observe **interaction of a sail with solar wind's & geomagnetic field**
- sensor to observe **plasma, particle and energetic radiation sail environment**
- sensor to observe **large area foil reflectivity ageing**, e.g. **thermal equilibrium**
- sensor to observe **small-scale space weathering mechanisms of foil ageing**
- sensor to observe **core spacecraft (electronics)** electro**magnetic signature**
- sensor to observe **illumination changes and Sun glints off the sail surface**
- sensor to register **space debris and natural dust impacts on the sail foil**

* IAA-PDC-15-P-**20,** *P. Seefeldt et al,* Large Lightweight Deployable Structures for Planetary Defence: …



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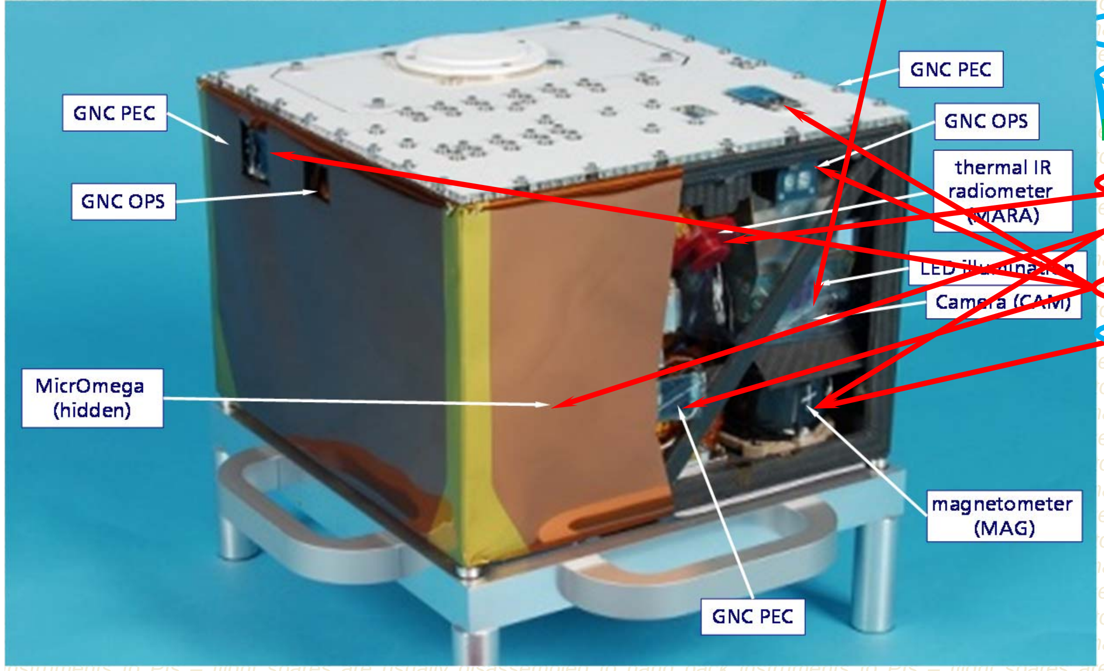
flight spares are usually disassembled to hand back instruments to PIs –

GOSSAMER-3 quality assurance – oh! ☺, a ready-made*** instruments package !?

*MASCOT Flight Spare instruments capabilities***

a *tiny*(…-like ;-) **science** payload**,*** to **observe sail ageing** *

- wide-angle camera to observe **sail deployment and long-term foil behaviour** and provide **proof images for attitude control, pointing stability & accuracy**



interaction of a sail with solar wind's & geomagnetic field
plasma, particle and energetic radiation sail environment
large area foil reflectivity ageing, e.g. **thermal equilibrium**
small-scale space weathering mechanisms of foil ageing
core spacecraft (electronics) electro**magnetic signature**
illumination changes and Sun glints off the sail surface
space debris and natural dust impacts on the sail foil

GOSSAMER-3 instruments left to be added

⊕ additional MAG instrument, 2 sensors spaced by ~1 m at 1 or 2 boom ends
⊕ e.g. Spherical EUV and Plasma Spectrometer (SEPS), 2 on opposite booms
⊕ e.g. acoustic pick-ups at rigging nodes, structural vibration accelerometers

* IAA-PDC-15-P-**20,** *P. Seefeldt et al,* Large Lightweight Deployable Structures for Planetary Defence: …
** IAA-PDC-15-P-**64,** *J.T. Grundmann et al & the MASCOT Team*, Mobile Asteroid Surface Scout (MASCOT) –…
*** IAA-PDC-15-P-**65,** *C. Lange et al,* Technology and Knowledge Reuse Concepts to Enable Responsive NEO Characterization …

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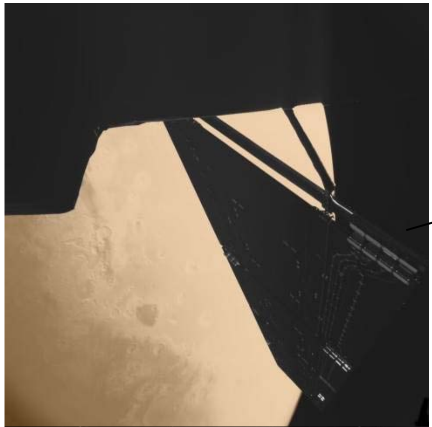
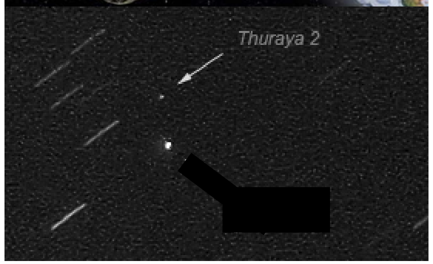
GOSSAMER-3 & MASCOT FS mission events wish list





__minimum mission__

- get launched cheap, deploy** & spiral up
- explore & improve sailing skills
- fly-by visit a target on time & look at it right

__nominal mission__

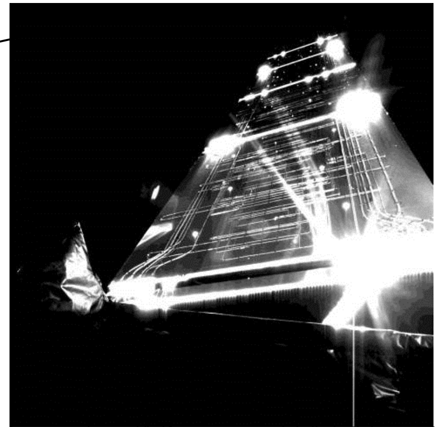
- explore practical flying in Earth-Moon system
- "all-up" navigation accuracy proof test
- low-altitude lunar gravity-assist fly-by

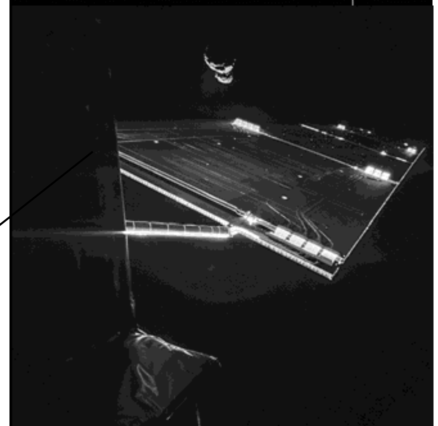
__extended mission__

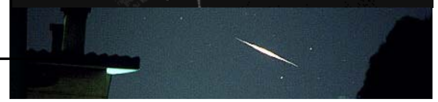
- transfers to Earth-Sun L_1, L_2 & pole-sitter
- demonstrate spaceweather Displaced- L_1

__extended extended mission__

- fly out to a convenient NEA – coorbital?
- rendezvous & drop MASCOT FS*,***,****
- …some grand finale…







* IAA-PDC-15-**04-08,** *S. Ulamec et al,* Relevance of PHILAE and MASCOT in-situ investigations for Planetary Defense

** IAA-PDC-15-P-**20,** *P. Seefeldt et al,* Large Lightweight Deployable Structures for Planetary Defence: …

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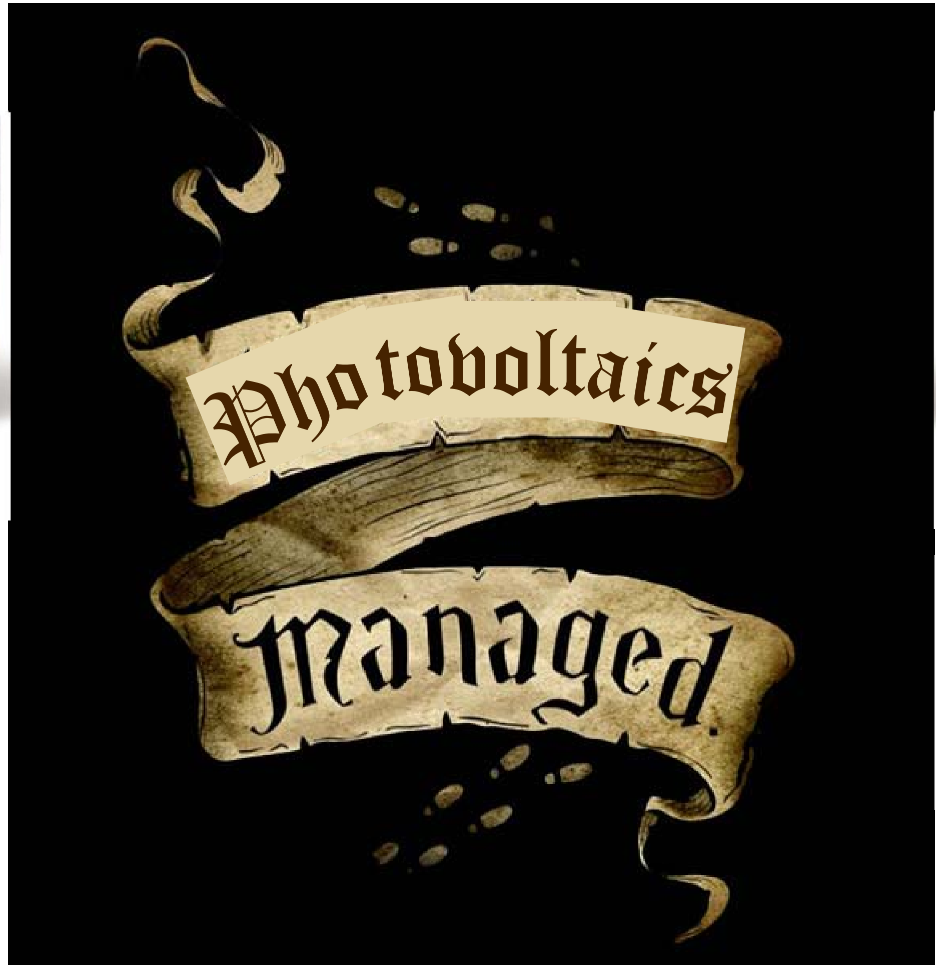
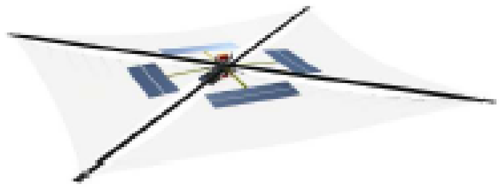
additional images: Boeing BSS via Gunter's SP, M. Langbroek

the GOSSAMER Roadmap for Solar Sailing – an Epilogue

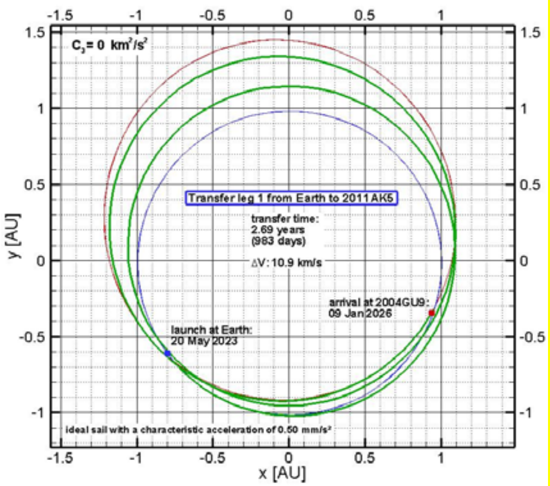


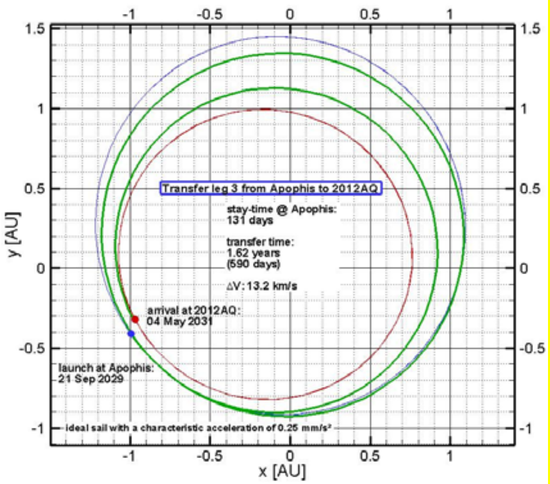


so bring on the lasers, bring on solar-electric propulsion! ☺

… and don't be shy about megawatts!! ;-)

EXERCISE – EXERCISE – EXERCISE – EXERCISE
PDC 2015



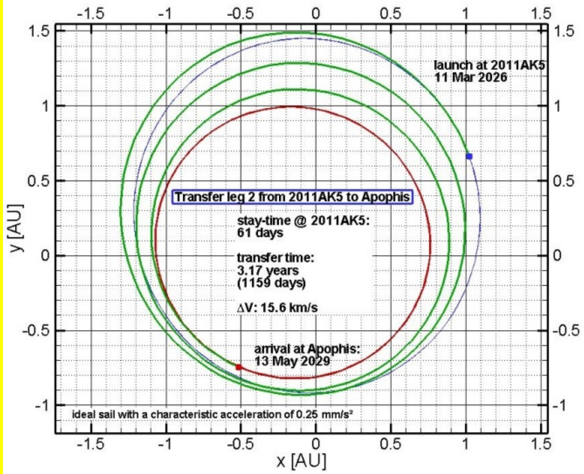


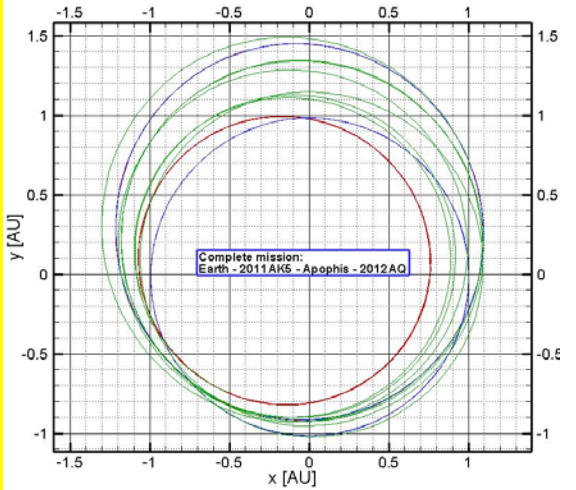
If GOSSAMER-3 had been launched according to the last Roadmap baseline in ~2020 we'd be on the way to 2015 PDC.

If it had been **2021 PDC**, we'd also be on the way.

why?

only Solar Sails can **change** interplanetary rendezvous **targets after launch** during cruise phase or other rendezvous in all cases





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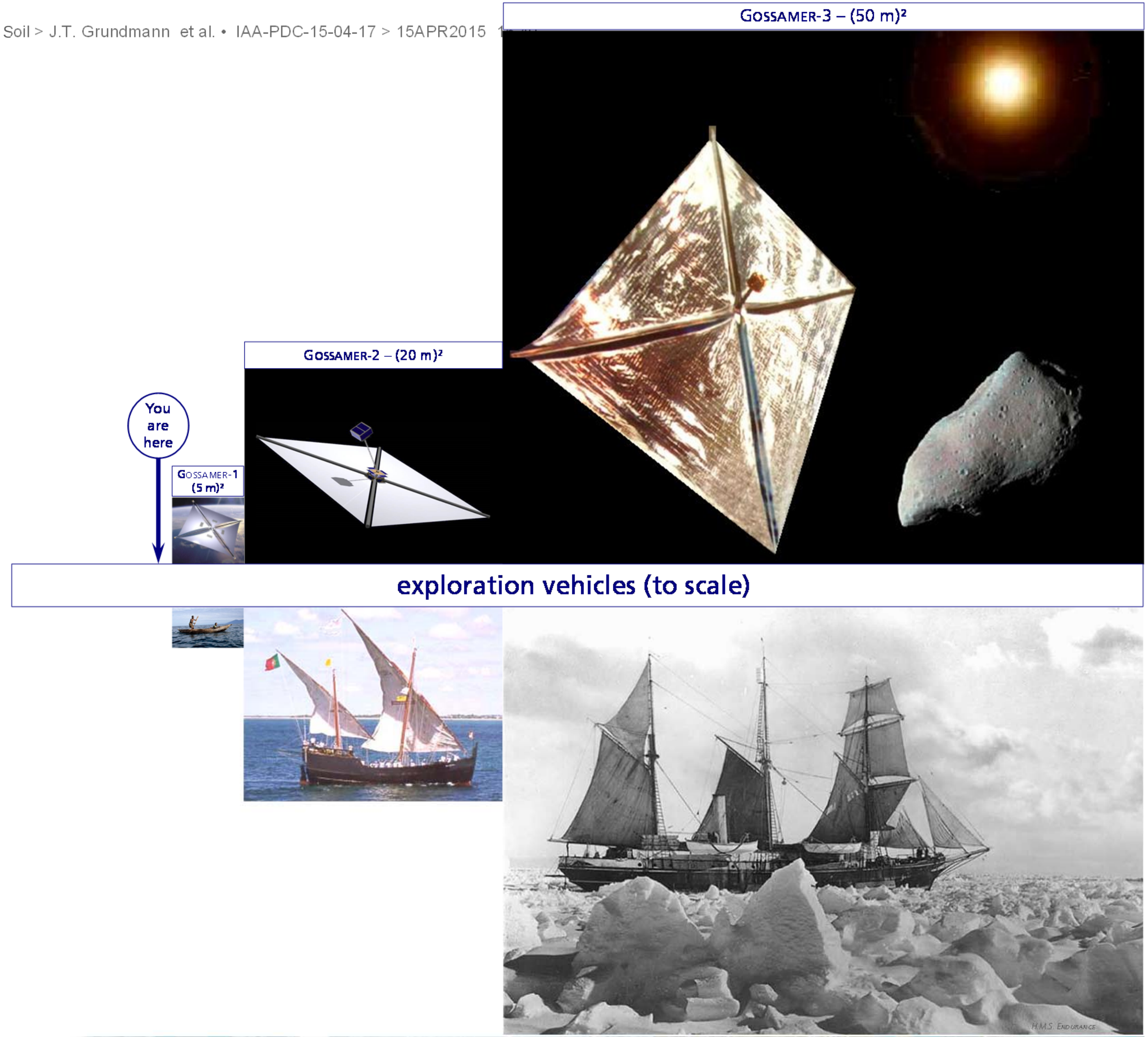
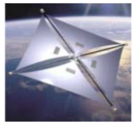
Questions?


GOSSAMER-3 – (50 m)^2
GOSSAMER-2 – (20 m)^2
You are here
GOSSAMER-1 (5 m)^2
exploration vehicles (to scale)
H.M.S. Endurance

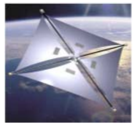
Thank you for your attention – take a look at these posters! ☺

our posters & talks – DLR @ PDC 2015

- IAA-PDC-15-**04-08** *S. Ulamec et al*
  Relevance of PHILAE and MASCOT in-situ Investigations for Planetary Defense
- IAA-PDC-15-**04-17** *J.T. Grundmann et al*
  From Sail to Soil – Getting Sailcraft Out of the Harbour on a Visit to One of Earth's Nearest Neighbours



- IAA-PDC-15-P-**20** *P. Seefeldt et al*
  Large Lightweight Deployable Structures for Planetary Defence: Solar Sail Propulsion, Solar Concentrator Payloads, Large-scale Photovoltaic Power



- IAA-PDC-15-P-**64** *J.T. Grundmann et al & <u>the MASCOT Team</u>*
  Mobile Asteroid Surface Scout (MASCOT) – Design, Development and Delivery of a Small Asteroid Lander aboard HAYABUSA2
- IAA-PDC-15-P-**65** *C. Lange et al*
  Technology and Knowledge Reuse Concepts to Enable Responsive NEO Characterization Missions based on the MASCOT Lander
- IAA-PDC-15-P-**66** *C.D. Grimm et al*
  On Time, On Target – How the Small Asteroid Lander MASCOT Caught a Ride Aboard HAYABUSA2 in 3 Years, 1 Week and 48 Hours

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