Solar Sails for CubeSats

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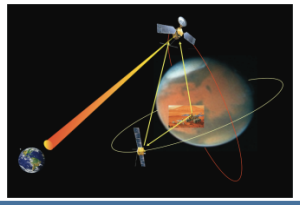
Preliminary progress report:
The NASA Innovative Advanced Concepts (NIAC) task on which this reports is still in progress. No mission described herein has been approved or funded.

Getting to Interplanetary CubeSats

Six Technology Challenges

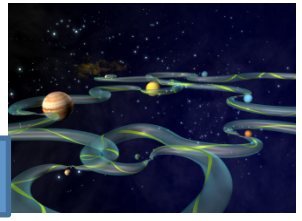
1. Interplanetary environment



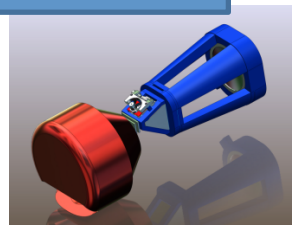
2. Telecommunications

3. Propulsion (where needed)

4. Navigation



5.Instruments



6. Maximizing downlink info content

Taxonomy

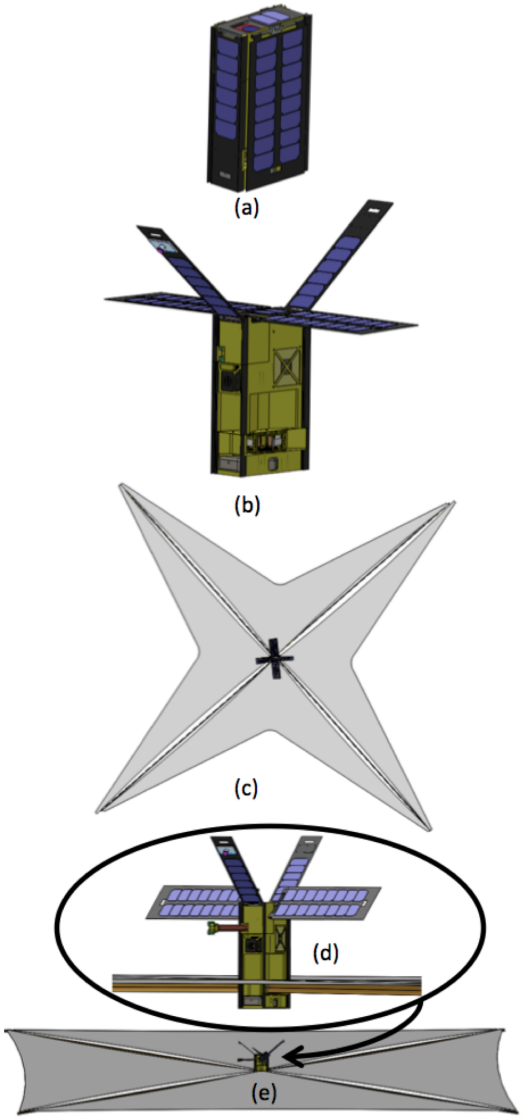
- Launch off C_3>0 ~ballistic traj
  - Cruiser
- Depart from "Mothership", 10s to 100s m/sec
  - Companion
  - Orbiter
  - Lander
  - Impactor
- Self-propelled

  1 – 10 km/sec/yr
  - *Electric*
  - *Solar Sail*

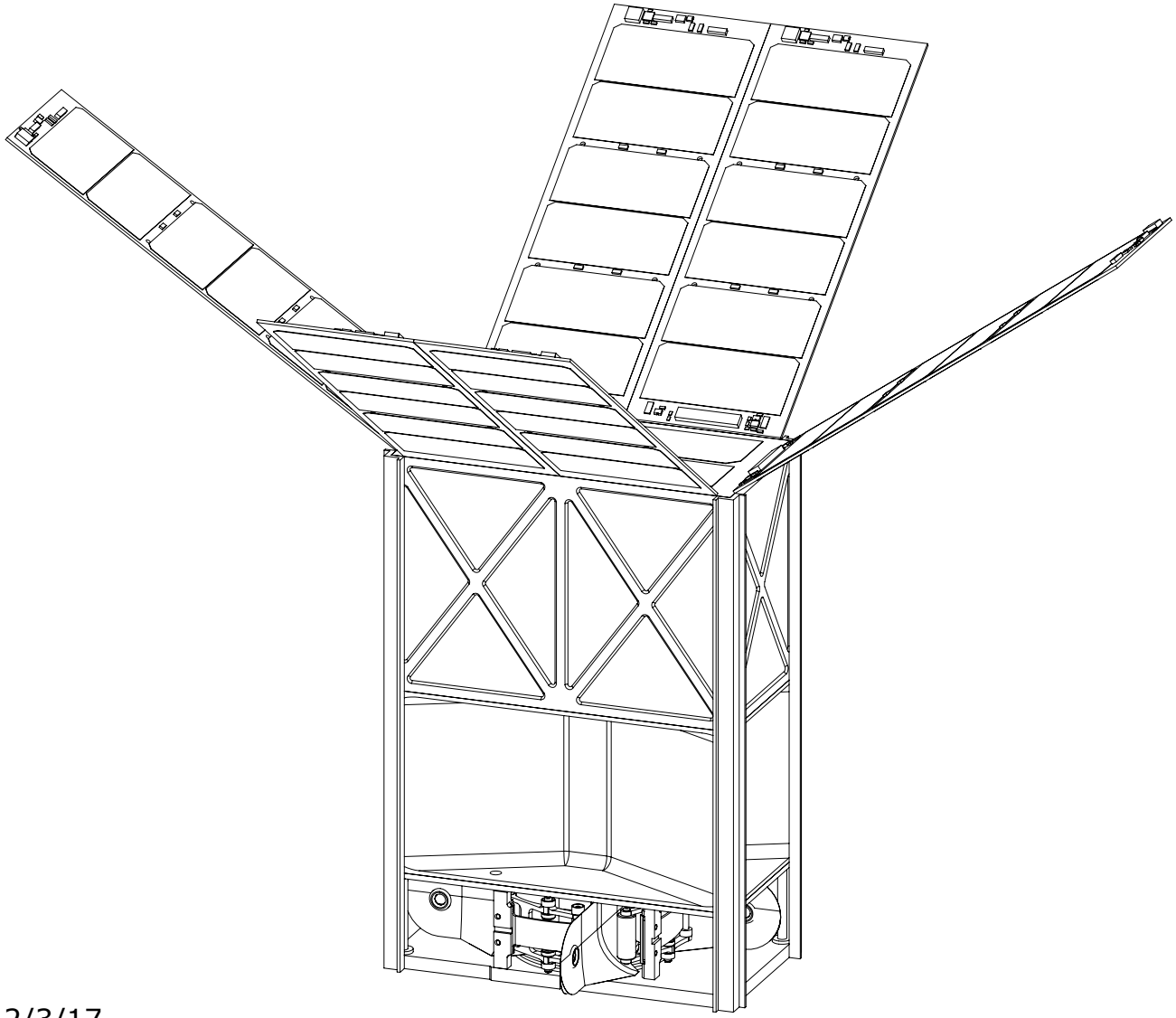
A Workable Interplanetary CubeSat System Architecture emerges from the maturation of six key technologies

LightSail 1[tm]: Planetary Society, Stellar Exploration, CalPoly-SLO

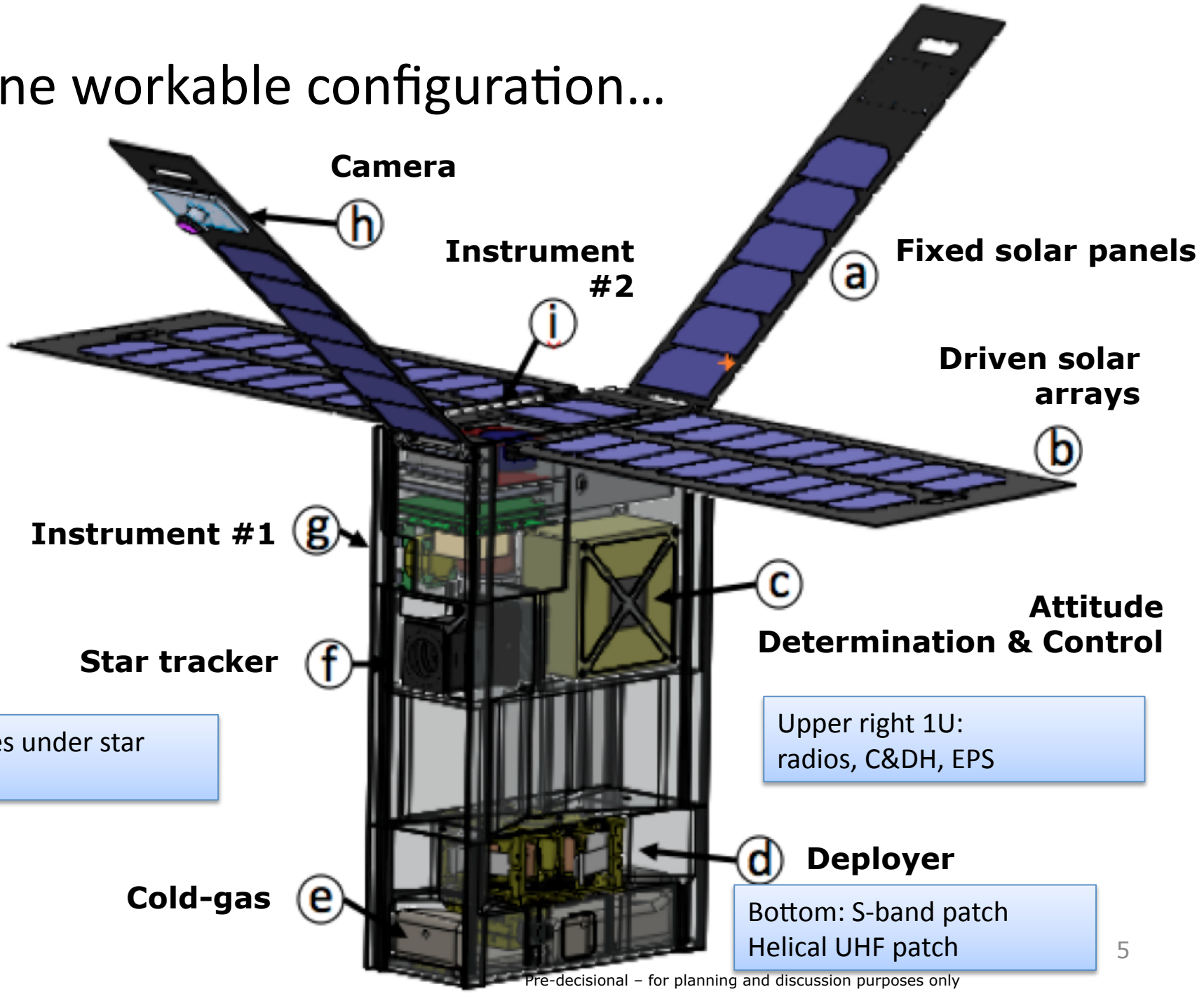
RAX-2: University of Michigan

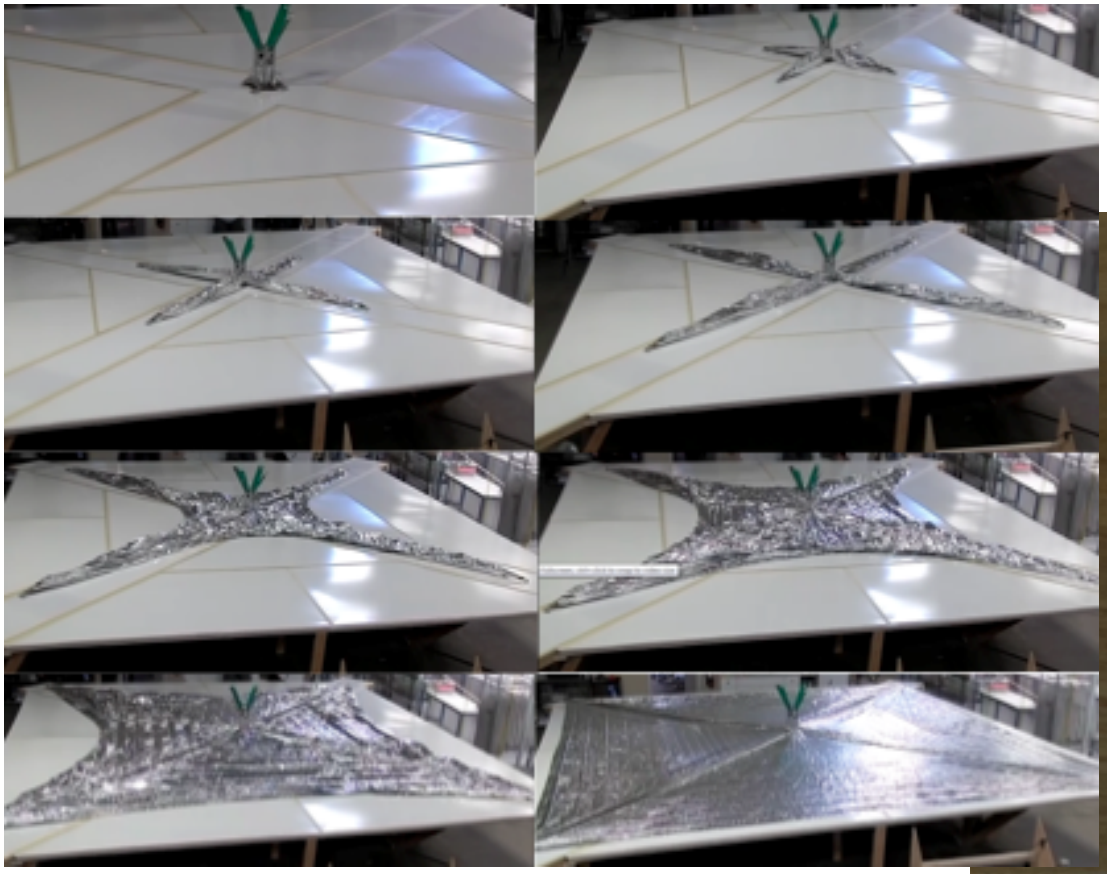


One Preliminary Configuration



One workable configuration…





3. Propulsion

Solar Sail Possibilities

1 µg @1 AU ➔ theoretical ~300 m/sec/yr

- Current technology
  - *Ikaros* (2010: 1 µg), *LightSail*[tm] *1* (2013?: 6 µg),
  - Electrochromic surfaces for 2-axis control
  - Switch to Kapton[tm] from Mylar[tm] would yield multi-year life

- Next 5-10 year projection (2021: 20 µg)
  - Tip vanes configured to provide 3-axis electrochromic control without moving parts.
  - Material thickness decrease 2-3X to enable larger sail packed into limited CubeSat volume.
  - Advanced (more expensive) material booms to enable longer boom to handle larger sail for same boom mass & volume.

- Next 10-20 years (2026: <100 µg?)
  - Even thinner materials, sublimating substrate, more advanced booms.
  - High temp materials to allow close solar approach, high ΔV in short time.
    - (a 91 µg (at 1 AU) sail starting from 0.3 AU reaches 100 AU in 17 yrs; 0.2 AU ➔ 13 yrs)
  - Most spacecraft functions printed on inner part of sail.*

* As discussed at Kendra Short/JPL 2012/3/19 NIAC Printable Spacecraft Workshop

In principle, you can build a sail…

- For propulsion, or as an antenna, or both.
- That is maneuverable in position and attitude.
- Up to ~10 m on a side square, or most any axisymmetric shape, to fit into ~2 U of a CubeSat, or larger on a bigger satellite.
- With low to moderate geometric accuracy (centimeters to millimeters)
- Having conducting and non-conducting portions at scales from <1 mm to meters, with whatever connectivity you can draw on two sides of an insulating sheet.
- With conducting (easy) or non-conducting (harder) structural spars.
- 3-axis stabilized or spinning.

If you don’t want a sail, you can…

- Build a tether/antenna to kilometers in length.
- Use crossed tethers and spin.
- Add structure for 3rd dimension (e.g., inflatables, deployable booms)

- Use more of you imagination...