Precautionary Planetary Defence

Aaron Boley and Michael Byers

Outer Space Institute

University of British Columbia

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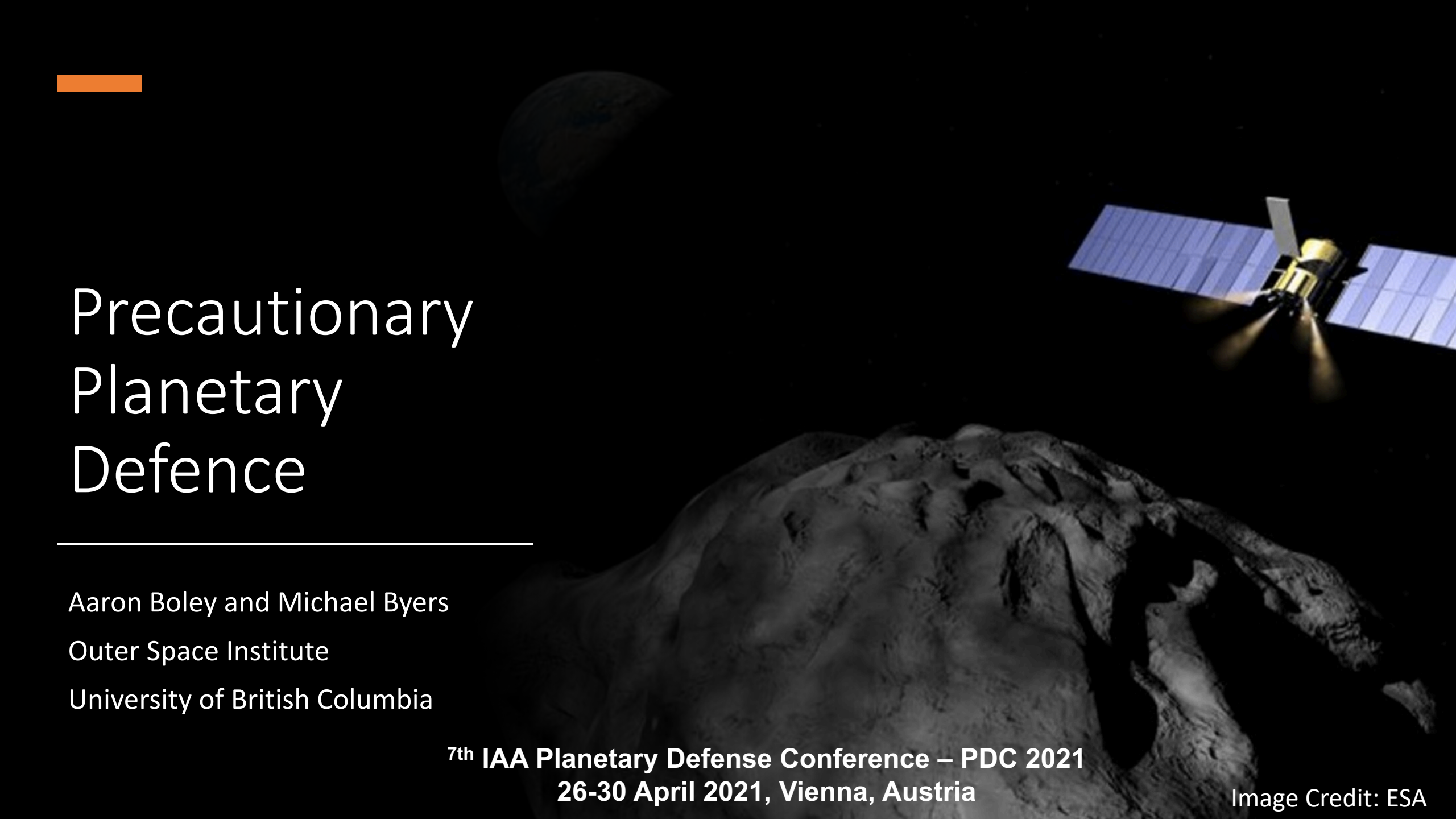
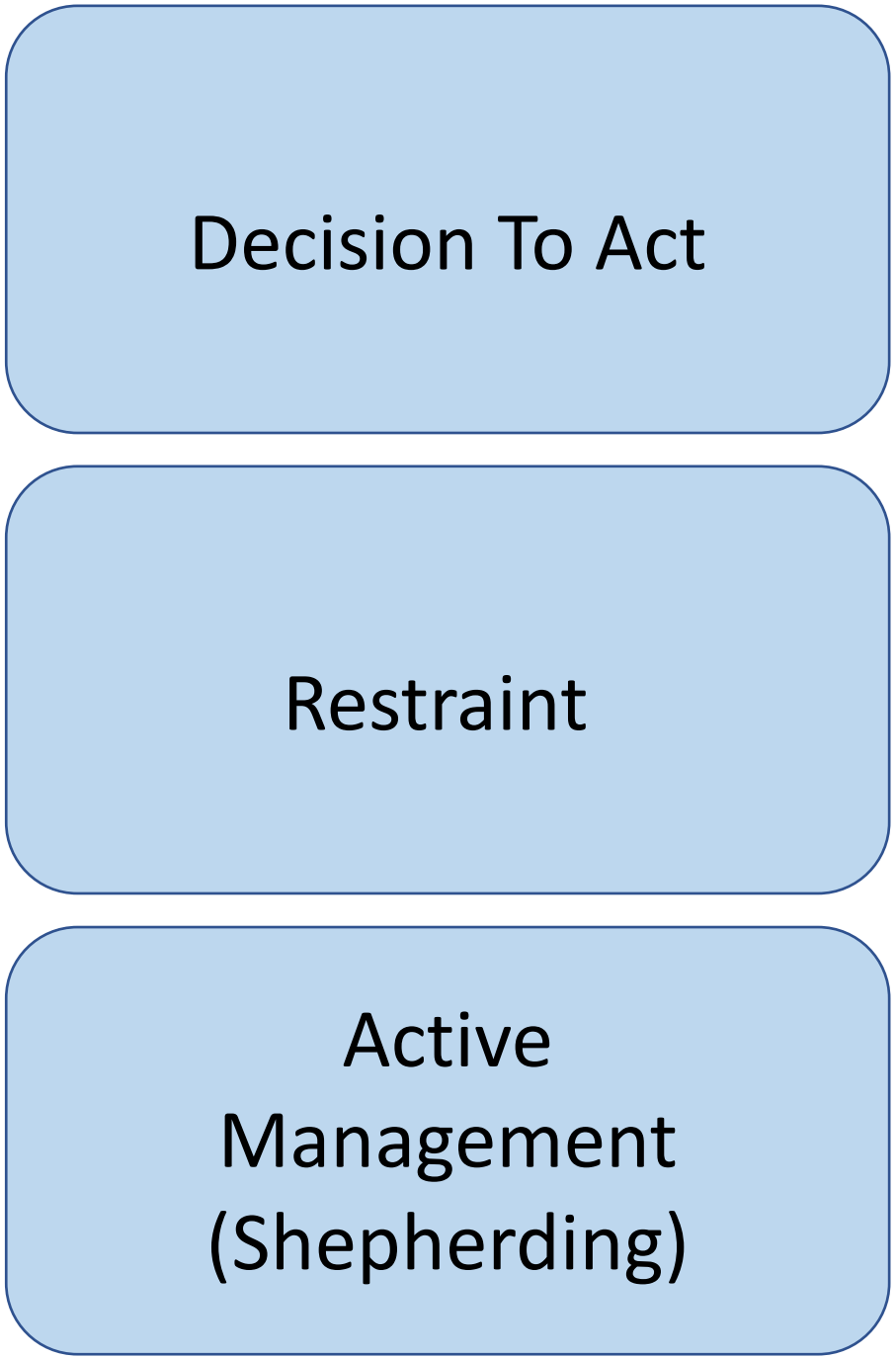


Image Credit: ESA



Decision-making scenarios often involve determining whether, when, and how to respond to a high-probability impactor

There are further considerations.

- When should we choose to limit visits to an asteroid?
- When should we be proactive (moving asteroids to safer harbours)?

Showing Restraint

- Let’s use Apophis as an instructive example
  - Dangerous in size
  - Multiple keyhole complexes
  - Up until March 2021 [1], accessibility of keyholes was of concern due to uncertainty
  - Huge interest in the asteroid from scientists and the public

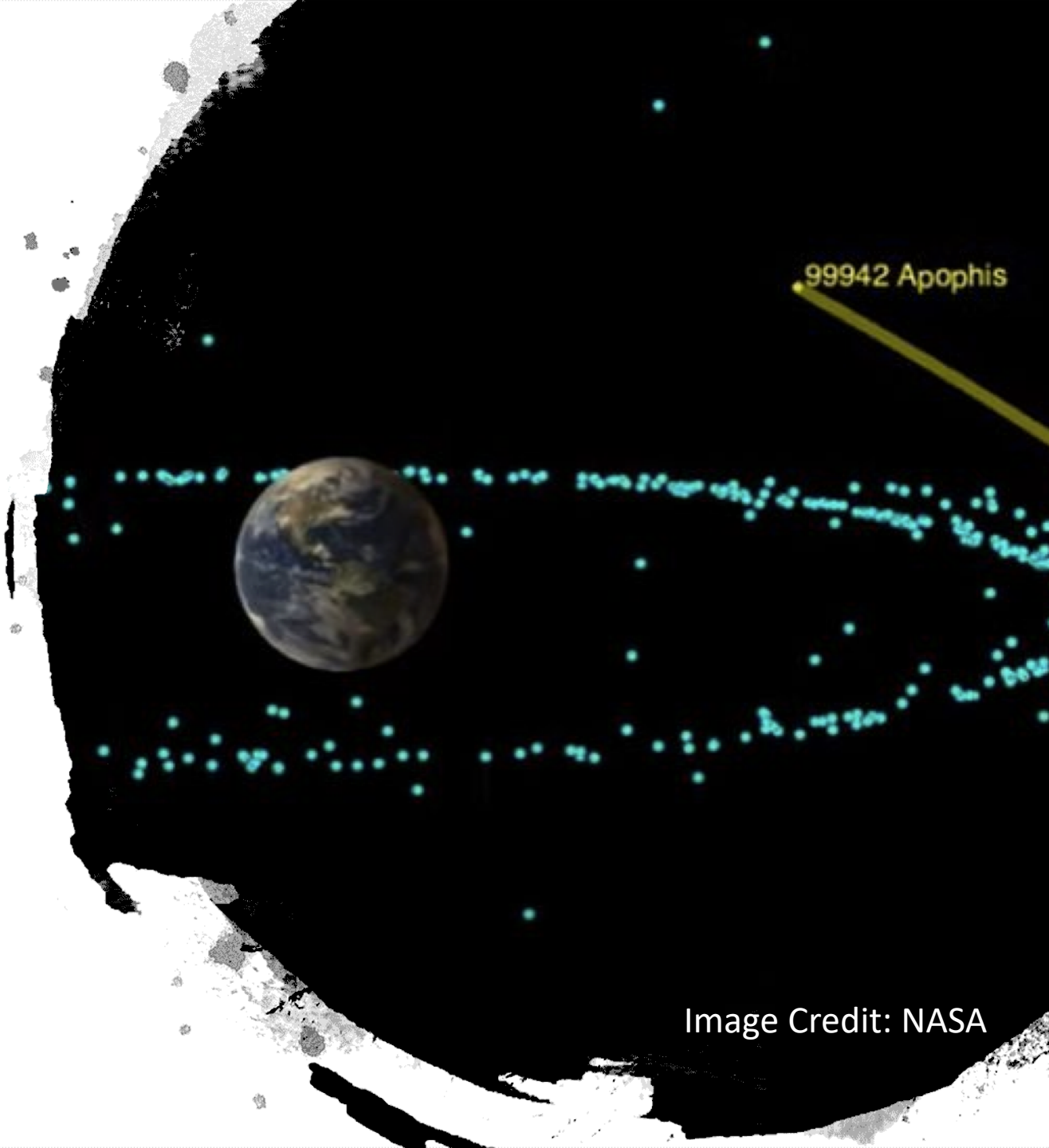
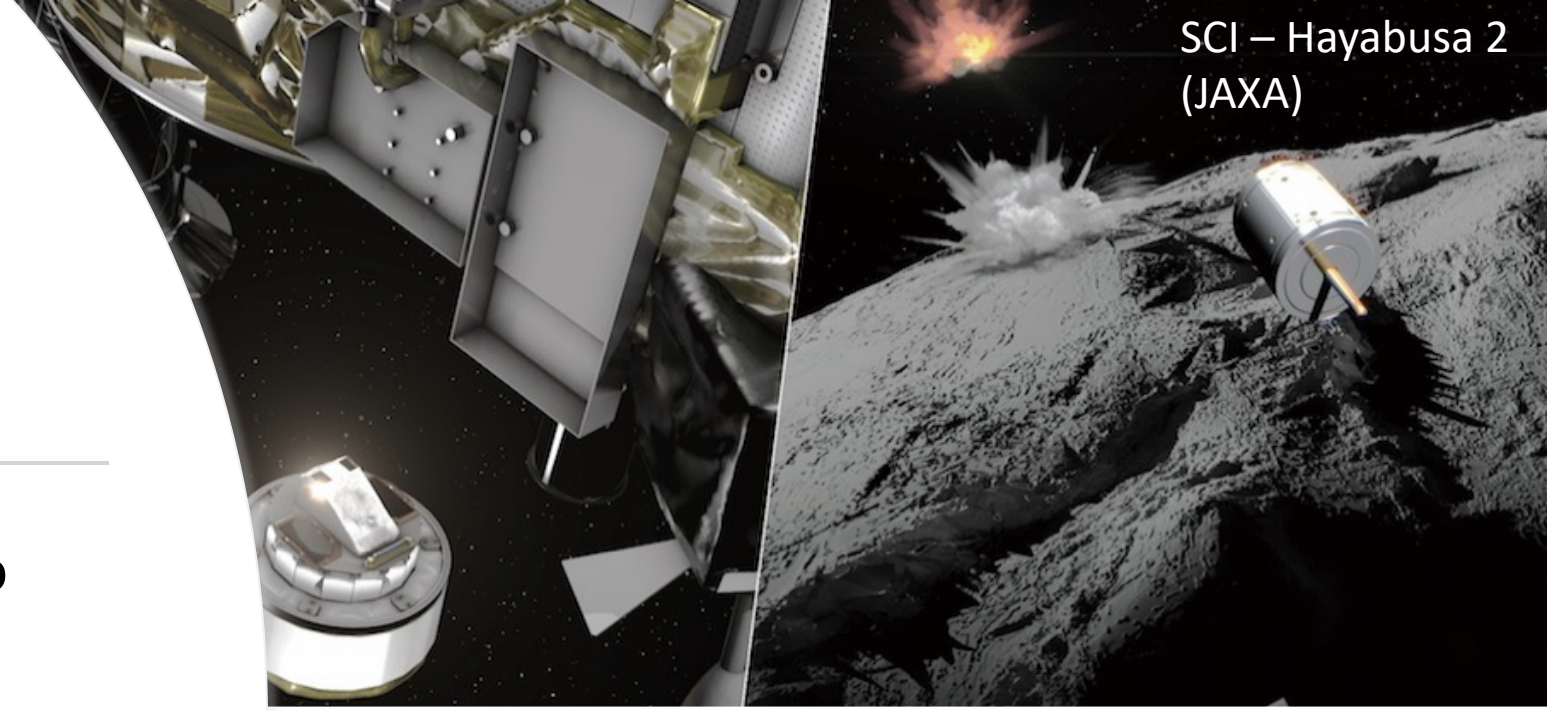


Image Credit: NASA

[1] CNEOS press release

What to do when everyone wants to go?

- Multiple state actors may wish to visit a high-value asteroid (e.g., Apophis)
- Non-state actors might get involved with their own plans
- Deep space traffic management
- Outcomes include low-probability, high-consequence mission failures



See also discussion in Chesley and Farnocchia 2021

Why might non-state actors become involved?

- Test or demonstrate technology
- Generate Publicity
- Play Hero
- *Something that we've not thought of*
- Eventually, asteroid mining will be a consideration

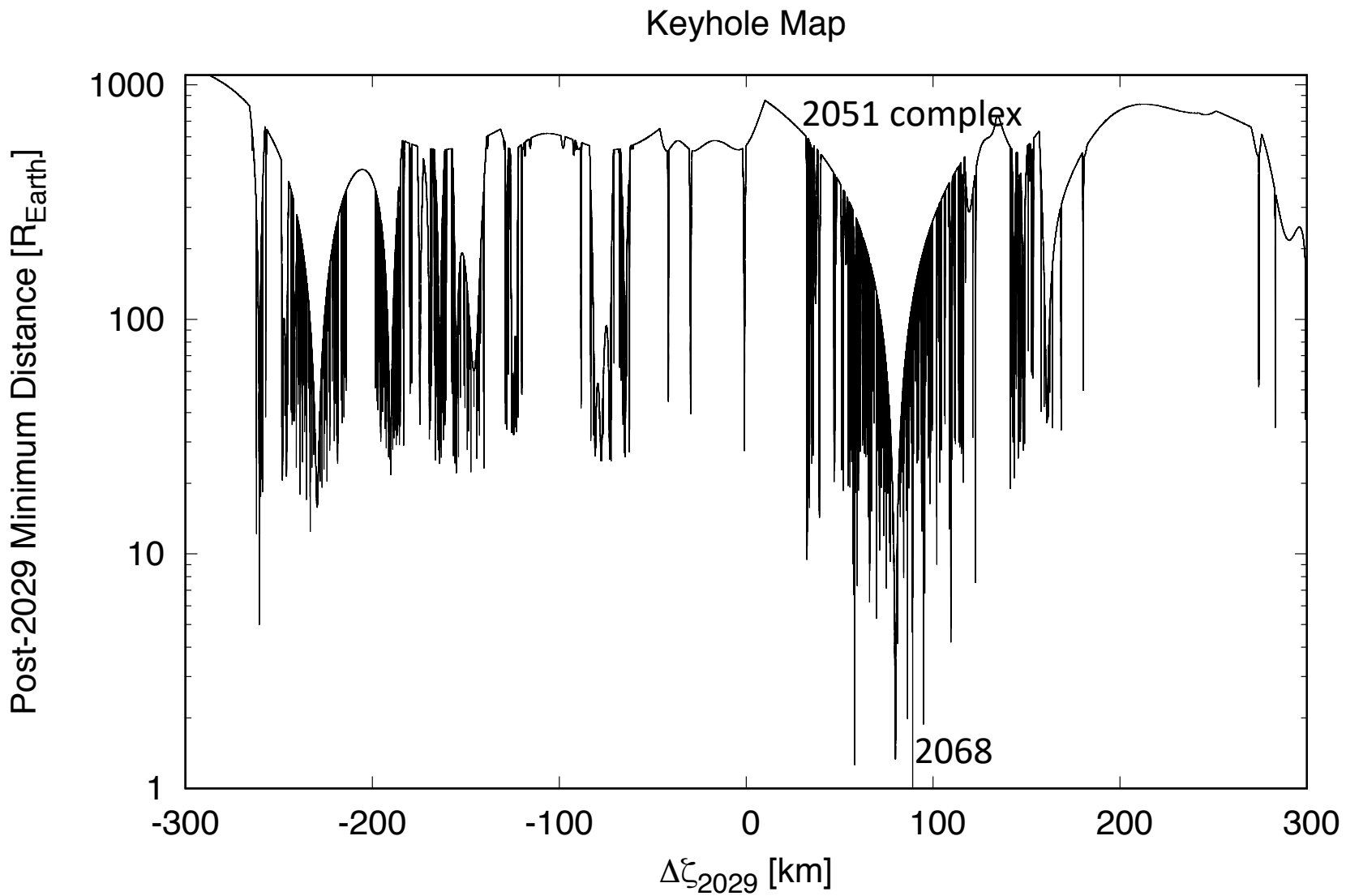
Image credit: SpaceX

Showing Restraint

To what degree should activities be limited?

Do we apply the precautionary principle, and if so, how?

Hypothetically, imagine a situation in which Apophis's uncertainty still overlapped the 2051 complex.



If restraint is warranted, who decides?

- What about SMPAG?
  - Advisory only. Seeks to develop cooperative activities
- The launching state has authority for granting launch licenses
- Provided past levels of cooperation are maintained, SMPAG provides framework for planetary defence decision making, but:
    - Growing worries about breakdown in cooperation [1] and militarization of cis-lunar space [2]

[1] Boley & Byers (2020), Science. [2] Hitchens (2021), Breaking Defense

Image credit: DARPA

But don’t forget we have highly capable non-state actors

- SpaceX and Starship, SpaceIL (Beresheet), NASA mining contracts for the Moon [1]
- Varying national regulation, not directly involved with SMPAG

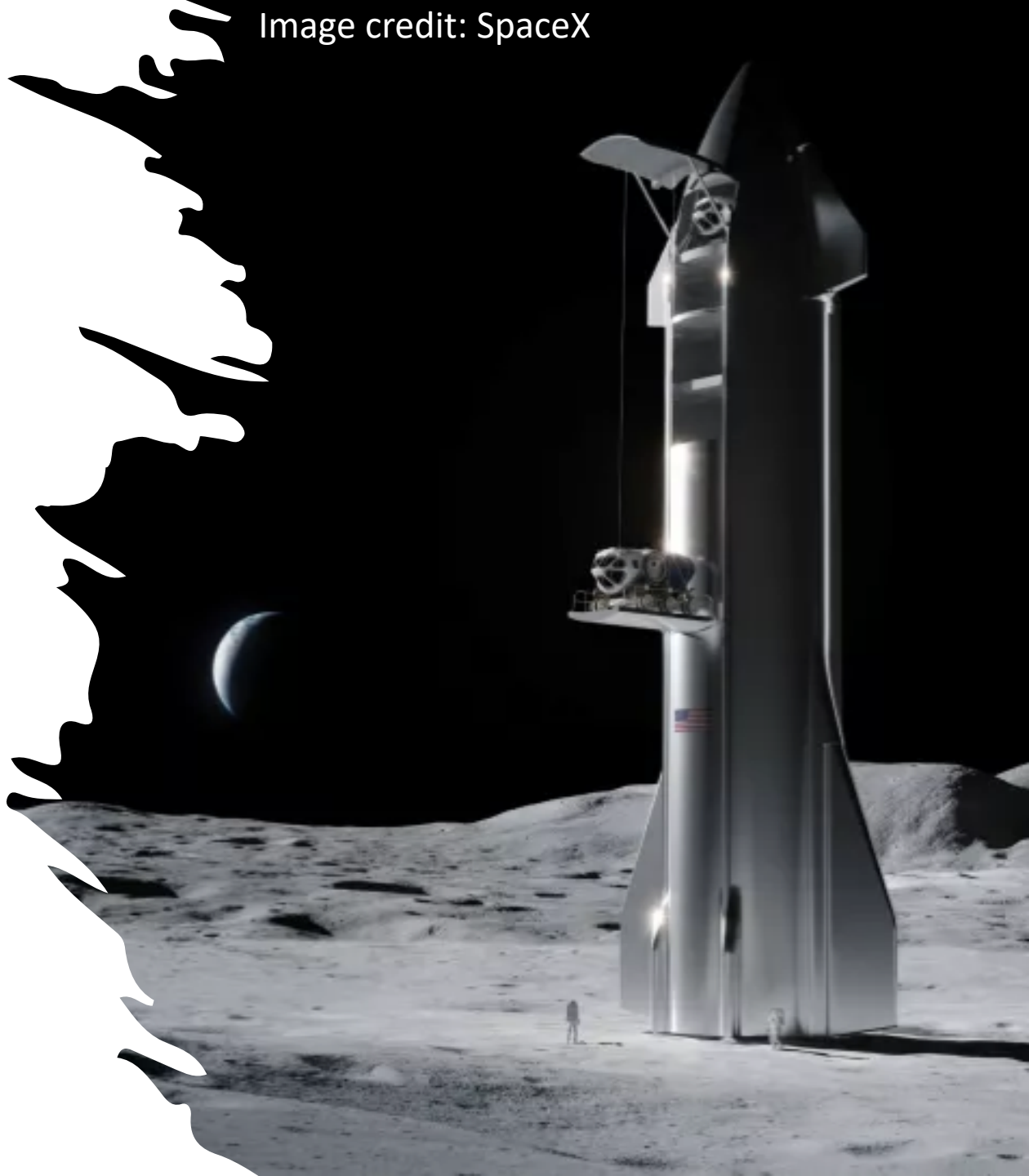


Image credit: SpaceX

[1] NASA, Press Release, 3 December 2020

UN Security Council Role

- Security council resolution possible, but heavy-handed approach to a solvable problem
- Resolutions must be supported by nine of the 15 members
  - No vetoes by any of the five permanent members (China, Russia, US, UK, France)
- But preparatory resolution could be very useful
  - E.g., requiring any state planning or licensing a mission to an asteroid to consult with SMPAG

Image credit: Shannon Stapleton/Reuters

Active Management

- Maybe a given asteroid has an uncomfortably large collision probability well into the future
- Maybe an asteroid is in an OK spot, but it could be better
- Safe harbour [1] or Safest Accessible Harbour

Object Designation	Year Range	Potential Impacts	Impact Probability (cumulative)
29075 (1950 DA)	2880-2880	1	1.2e-4
101955 Bennu (1999 RQ36)	2175-2199	78	3.7e-4
(2000 SG344)	2069-2113	101	2.6e-3
(2009 JF1)	2022-2022	1	2.6e-4
(2007 FT3)	2024-2116	164	1.4e-6
(2008 JL3)	2027-2119	27	1.6e-4
(2021 EU)	2024-2056	3	4.6e-5
(2010 RF12)	2095-2119	59	4.7e-2
(2005 QK76)	2030-2107	9	6.8e-5
(2005 ED224)	2023-2064	5	2.6e-6
(1994 GK)	2051-2067	5	6.9e-5
(2008 UB7)	2048-2100	31	3.5e-5

Screen capture of CNEOS Sentry

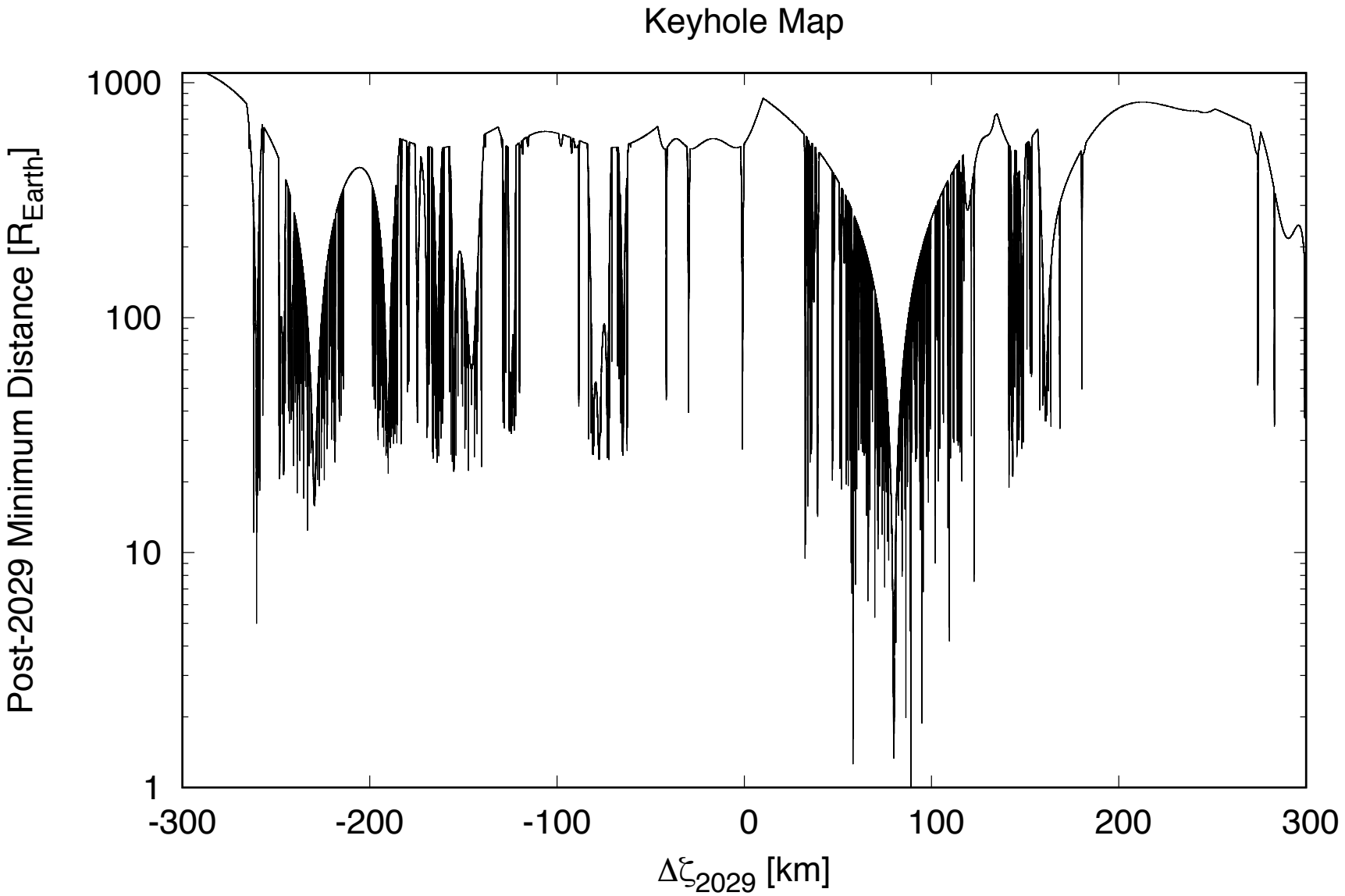
[1] Yeomans et al. 2009, PDC2009

Active Management

As a thought experiment, if we had the means, would we try to make Apophis safer?

Is any non-impact trajectory good enough?

Can we compare the relative safety of harbours? (E.g., is the cusp better than the nominal position in this plot?)



Conflict between restraint and active management

A strict approach to the precautionary principle might suggest that no active management should be done

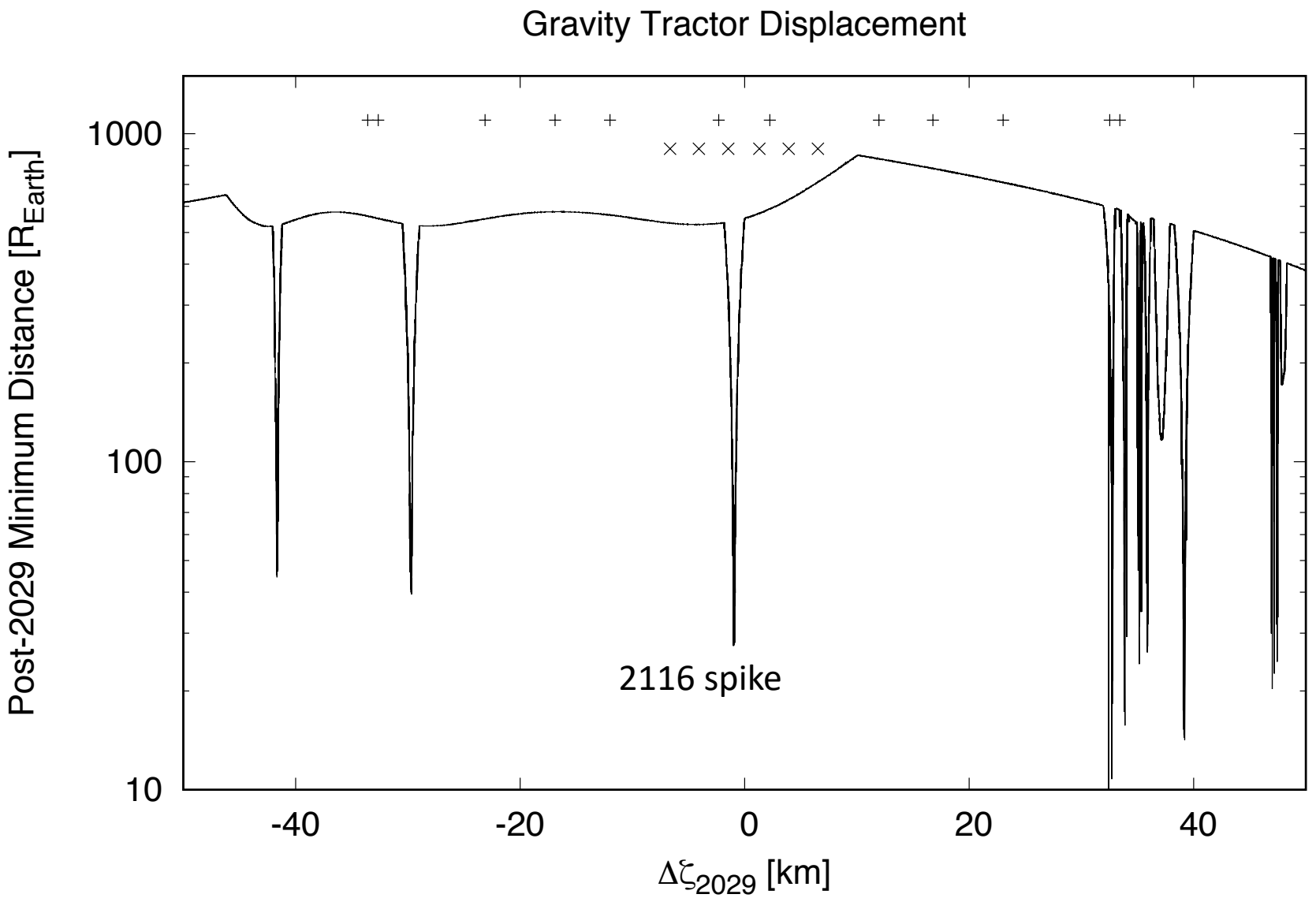
Arguably, at a minimum, we need tractoring practice so that we have options (or can respond to an emergency)

A fully reusable gravity tractor might not be far away

How hard would it be to tractor Apophis to a different harbour (as a thought experiment)?

Crosses (x) are 10^{-12} m s^{-2} for 2026-2027, 2027-2028, and 2028-2029

Plusses (+) are 10^{-11} m s^{-2} for 6 months starting in either April or October (2026, 2027, 2028)



See also Yeomans et al. 2009, PDC2009, Figure 5