The importance & challenges of rapid response

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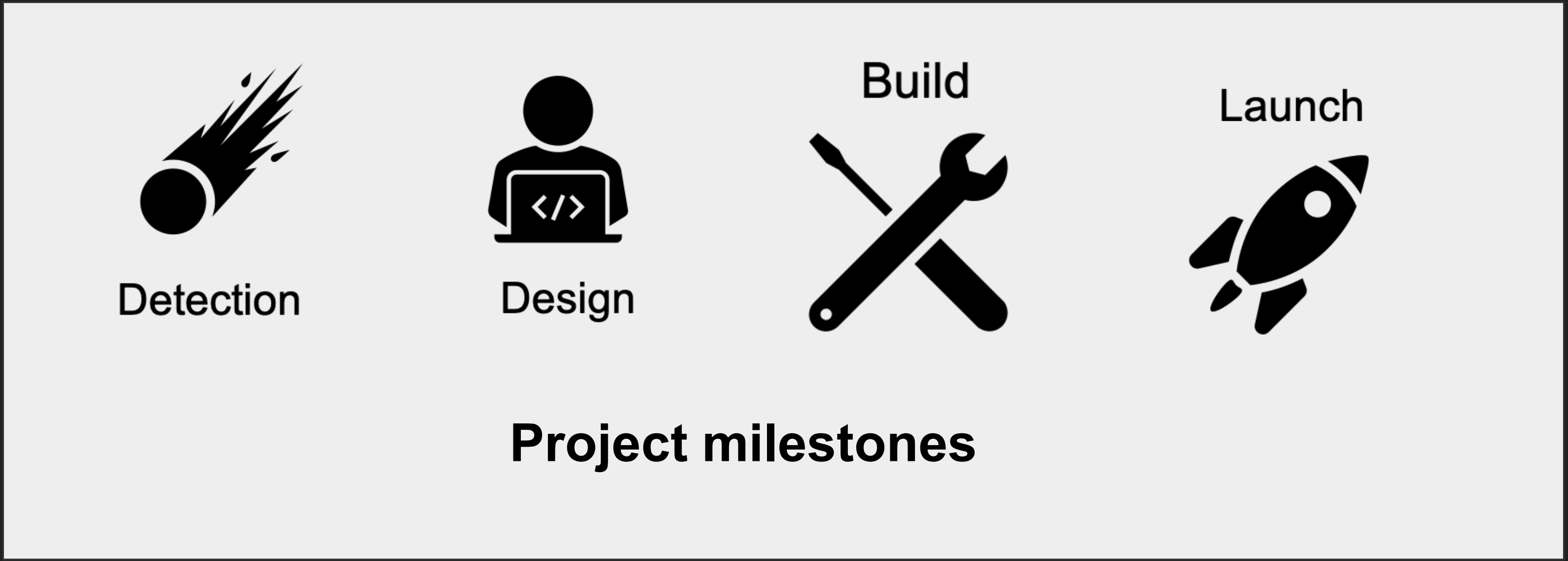
(Pre-decisional information -- for planning & discussion purposes only)

Gemini Observatory / AURA/NSF/Joy Pollard

Missions to NEOs, ISOs, & LPCs

- Proposal timelines
- Target detection
- Rapid response concepts
- Challenges & Outlook

Traditional mission planning sequence



Donitz et al. (2020). *Blue Sky Study Report, JPL Internal, Available upon request.*

Example: NASA Juno Mission (Jupiter)

Prehistoric times

1980's +
Selected 2004

2004 onwards

2011

Donitz et al. (2020). *Blue Sky Study Report, JPL Internal, Available upon request.*

Proposal timelines - NASA

- Discovery or New Frontiers (up to $1 Billion USD):
  - New mission selected every 2 to 5 years
  - Launch dates 5-10 years post-selection

  → Overall: **10 -15yrs +**

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- SmallSat missions: ~$55-100 M USD
  - Ride-alongs for Discovery, New Frontiers
  - No dedicated launch vehicle!
  - → Risk: launch delay for Psyche → smallsat EscaPADE delayed by yrs

Proposal timelines

ESA – Rosetta (9 yrs approval → launch)

- 1970’s – first Rosetta mission concepts
- 1986 – Comet Haley global campaign
- 1993 – Mission approved
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JAXA – Hayabusa2 (7 yrs)

- 2007 – study began for follow-up to Hayabusa
- 2009 – Hayabusa2 mission concept
- 2010 – JAXA approves mission
- 2014 – Launch

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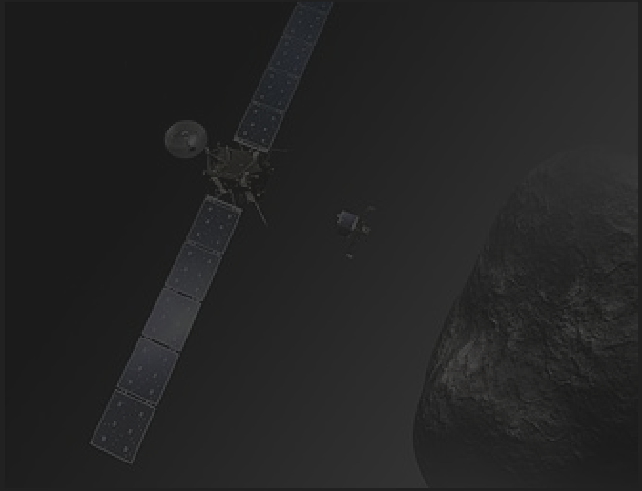

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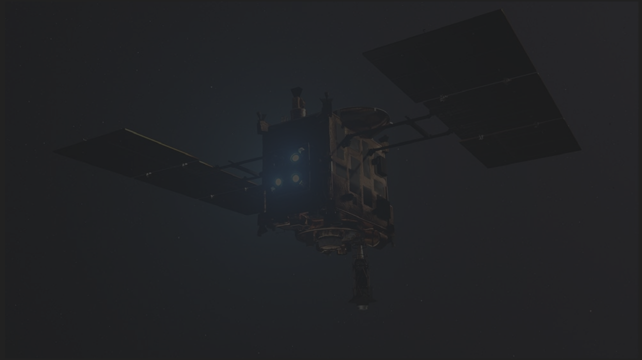

+ Frequent collaborations between ESA, JAXA, & NASA. (instruments, data, etc)

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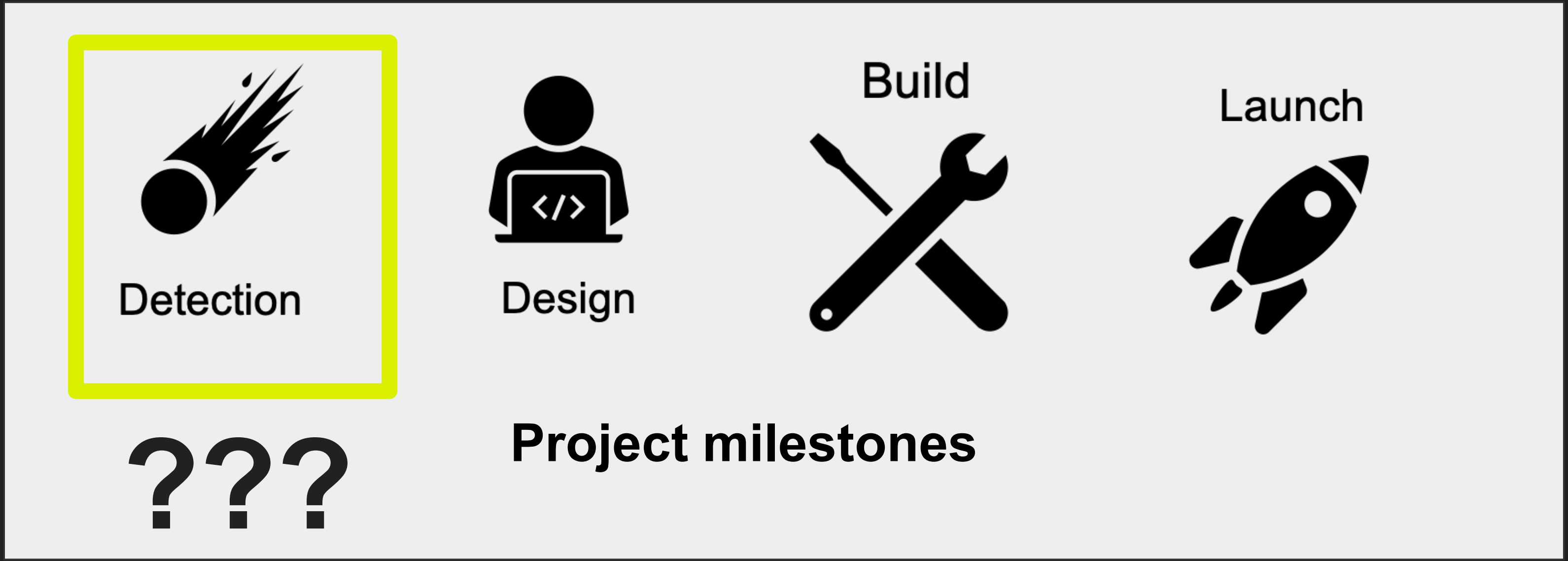

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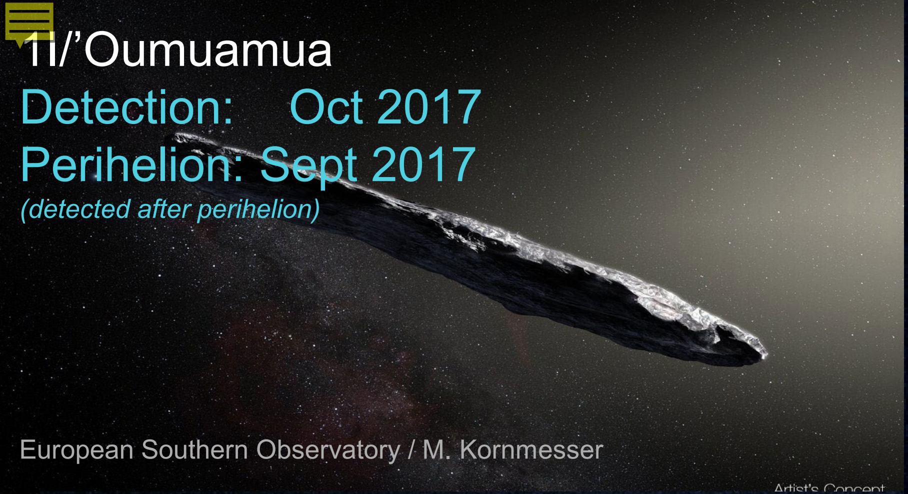
Missed Opportunities?



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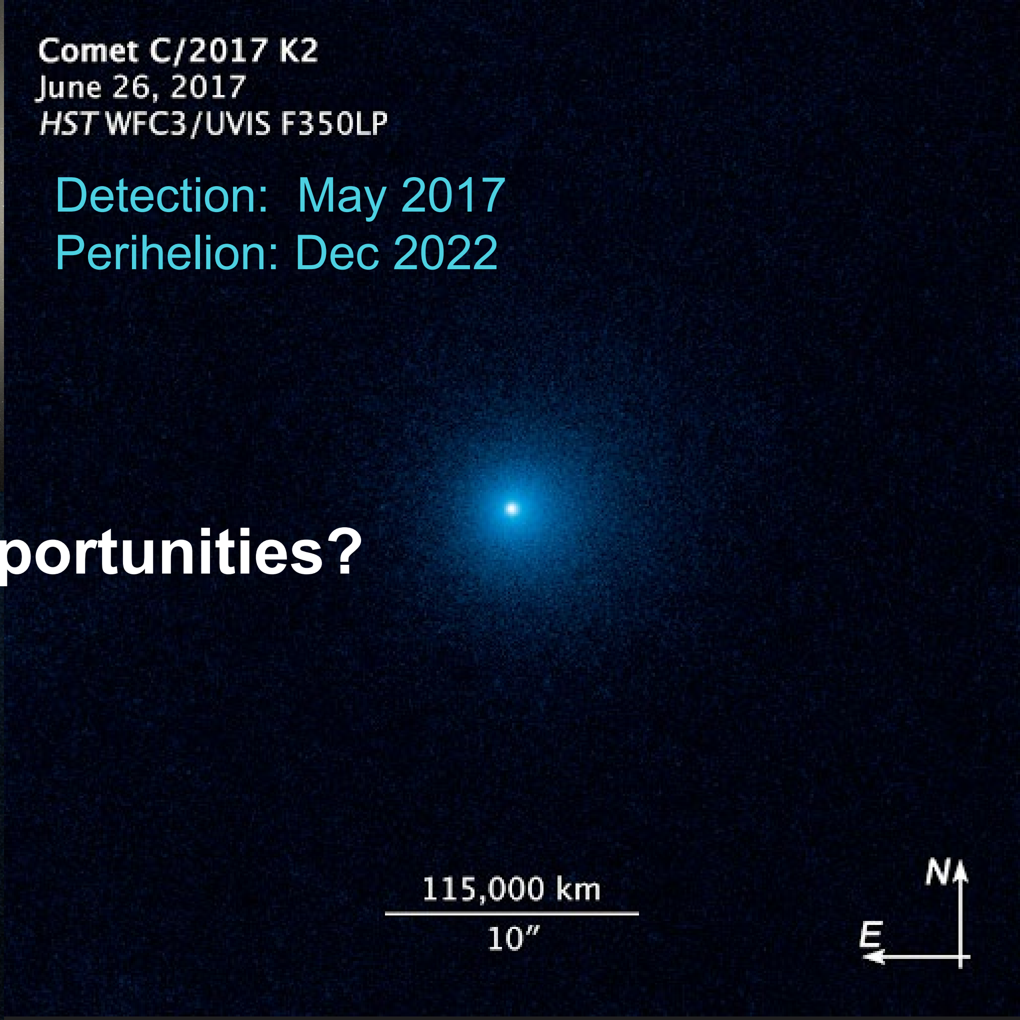
Detection: Oct 2017

Perihelion: Sept 2017

(detected after perihelion)



Detection: May 2017

Perihelion: Dec 2022

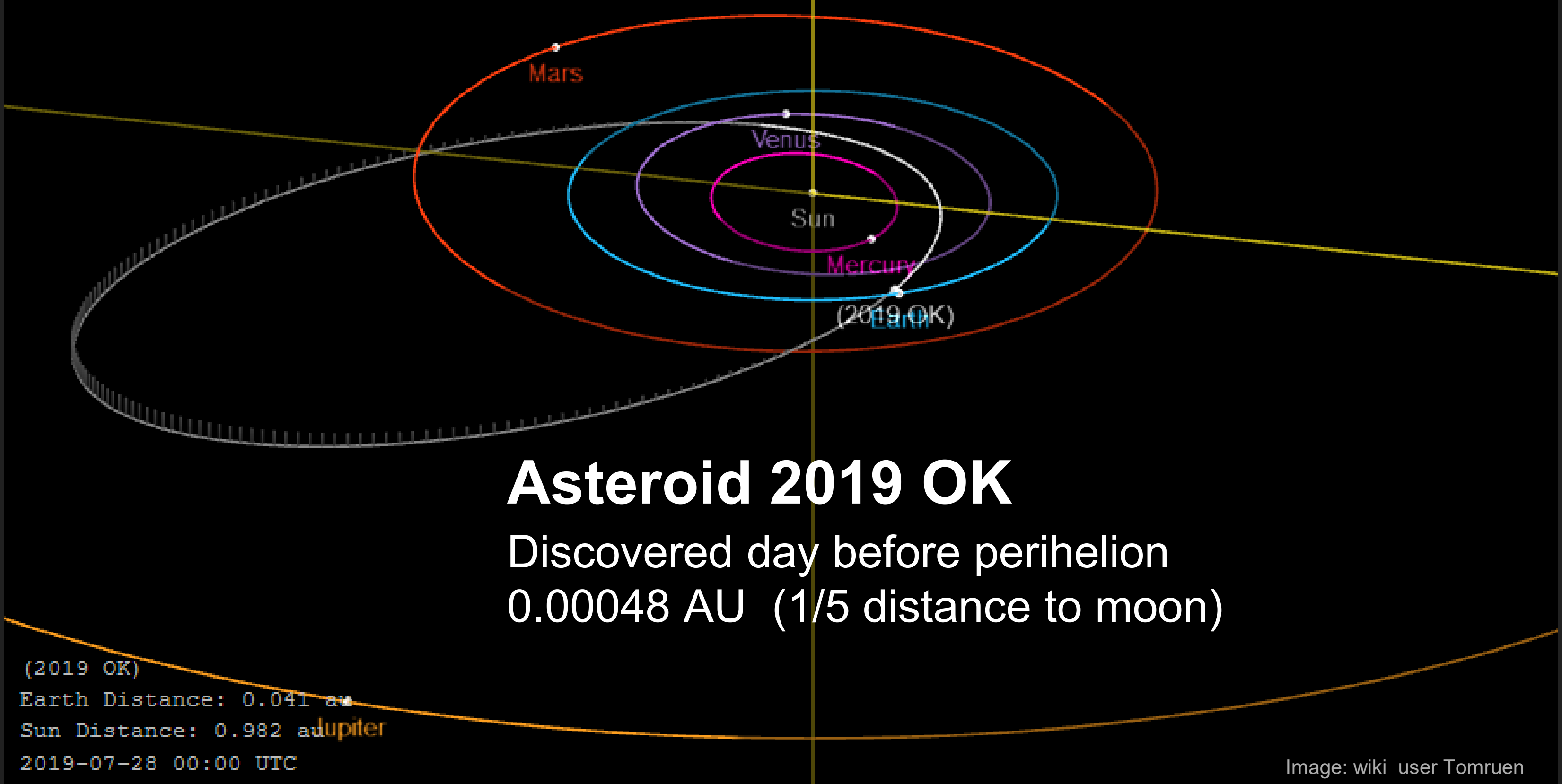
2I/Borisov

Detection: Aug 2019

Perihelion: Dec 2019

Meech et al. (2017); *"MPEC 2019-S72 : 2I/Borisov = C/2019 Q4 (Borisov)"*
"MPEC 2017-N26 : COMET C/2017 K2 (PANSTARRS)"

NEOs / potentially hazardous asteroids
Near miss?



Asteroid 2019 OK

Discovered day before perihelion
0.00048 AU (1/5 distance to moon)

Image: wiki user Tomruen

How far in advance can we detect NEOs, ISOs, & LPCs?

Some sky survey telescopes

PanSTARRS 1 & 2

- Hawaii, 2008-present
- Discovers >50% of new NEOs, comets (IfA)
- Apparent magnitude 24

Vera C. Rubin Observatory

- Chile, estimated 2023
- Will catalog 61% of all NEOs that are > 140m
- Apparent magnitude ~24 (single), 27 (stacked)

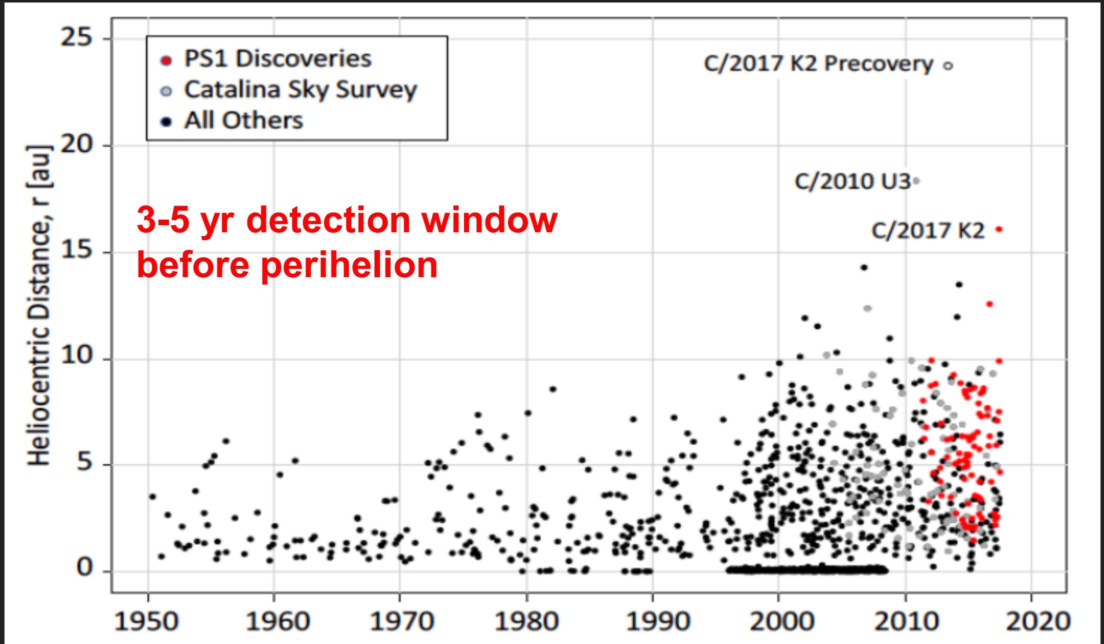
Brightness impacts detectability

Active comets – brighter, long tail

More asteroidal – dimmer, lower albedo

Detecting NEOs, ISOs, and LPCs

- LPC's (Wilman Jr, 1995; Castillo-Rogez+, 2018)



Willman Jr (1995).
Castillo-Rogez et al. (2019) AAS.

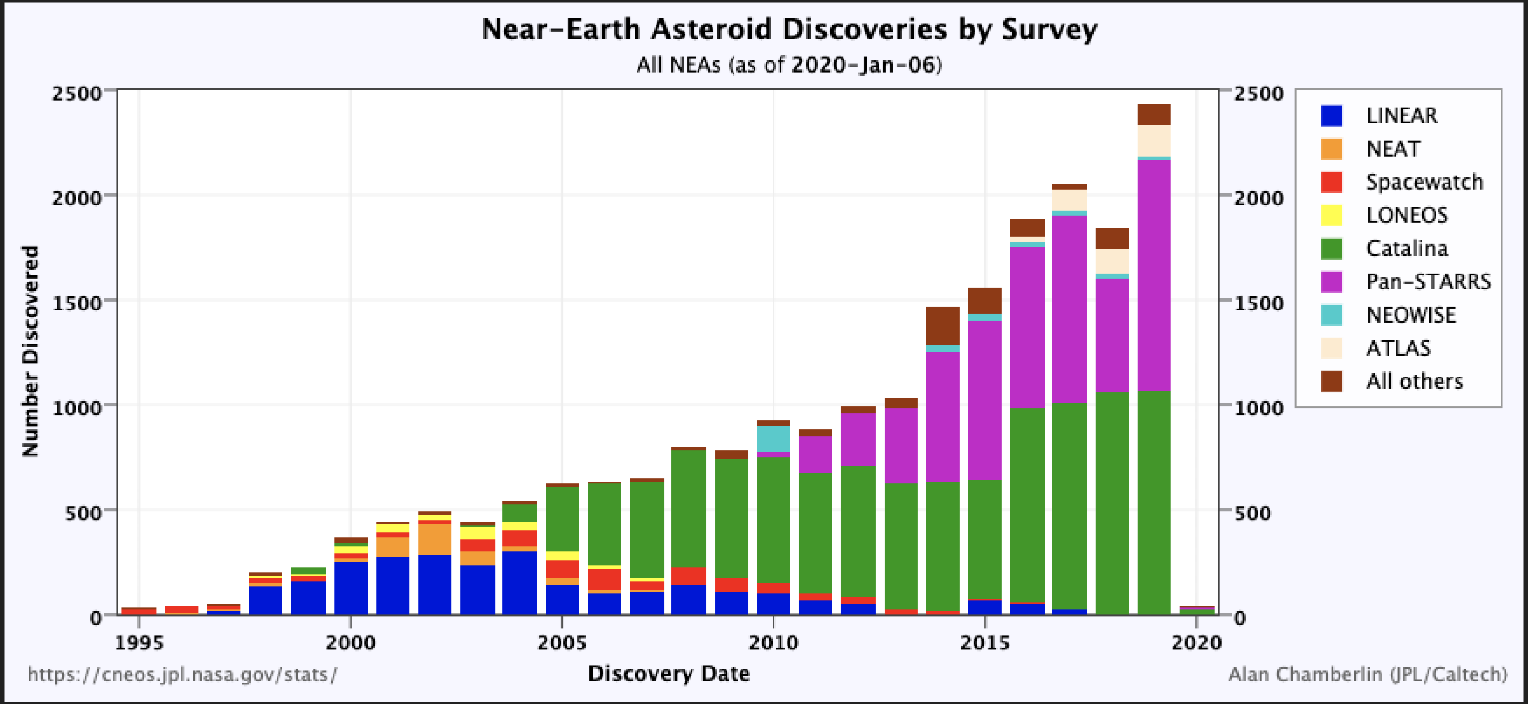
Detecting NEOs, ISOs, and LPCs

- LPCs: several per year, 3-5yrs before perihelion

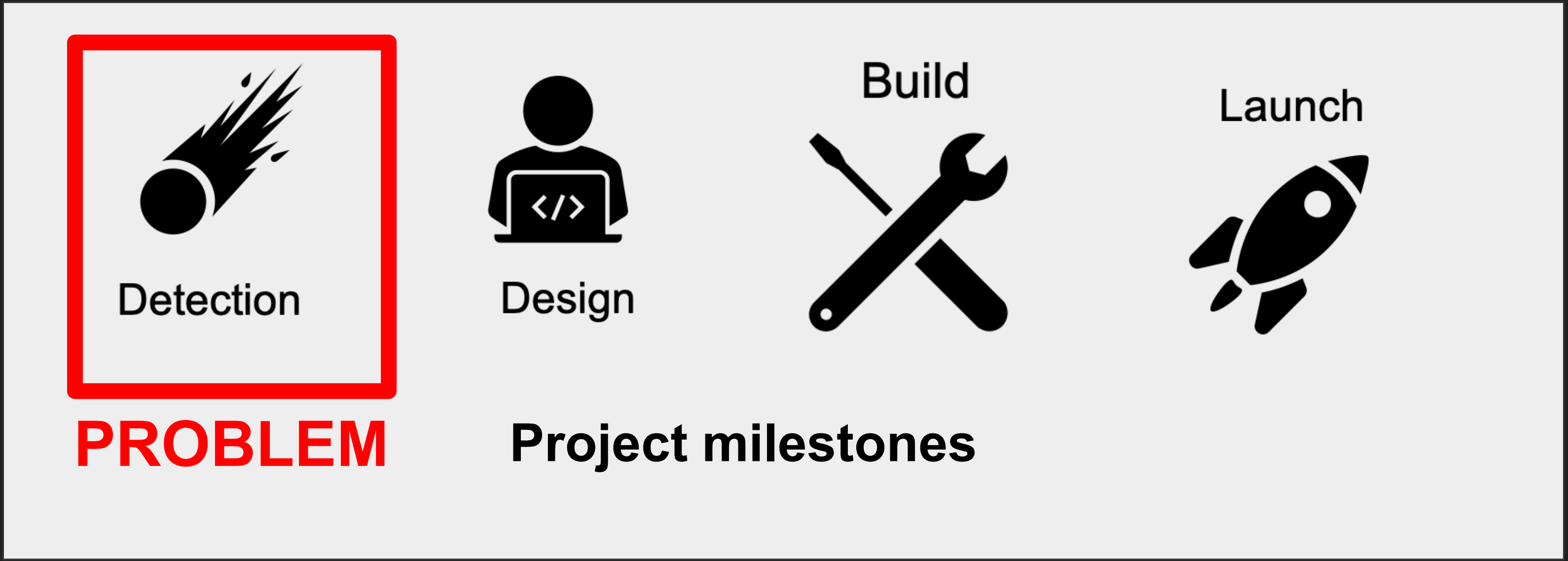
- ISO's: 1-2 per year with the Vera C. Rubin Observatory (Trilling + 2017; Hoover + 2022)

Detecting NEOs, ISOs, and LPCs

- LPCs: several per year, 3-5yrs before perihelion
- ISO's: 1-2 per year with the Vera C. Rubin Observatory (Trilling + 2017; Hoover + 2022)
- NEO's:



Traditional mission planning sequence



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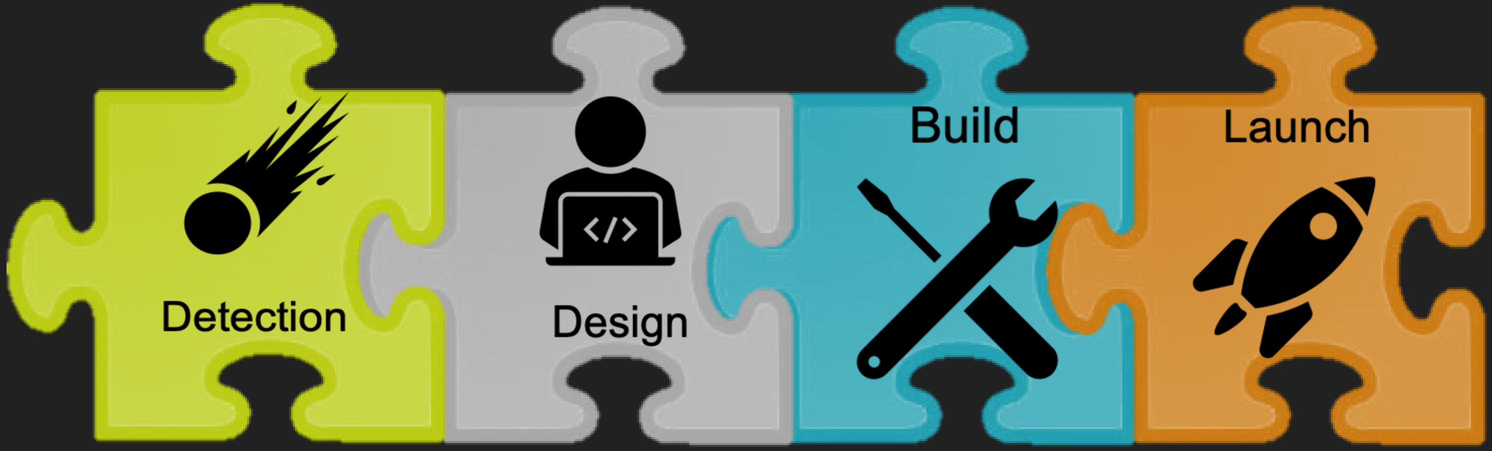
Solution:

Rapid response missions

Changing the paradigm



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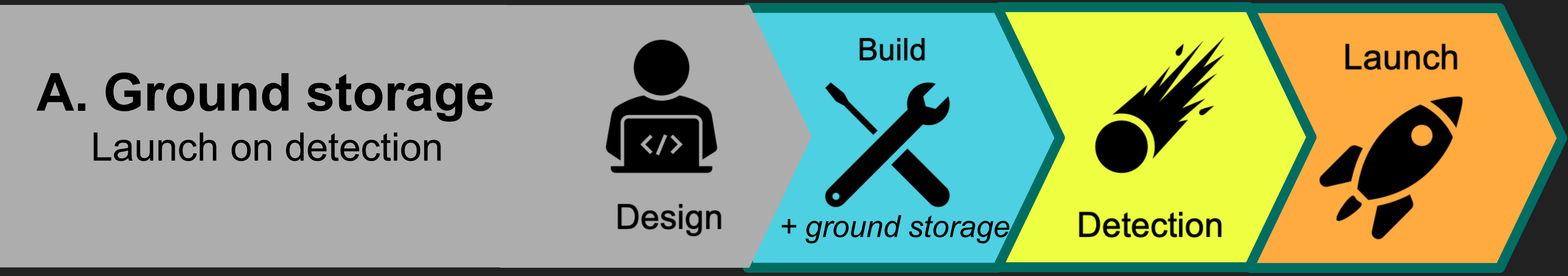
Rapid response architectures and Concept Studies



“Bridge” concept (2019 Planetary Science Summer Seminar)

1st flyby of a yet-to-be discovered ISO

Approach: Main spacecraft + autonomous impactor
Wait in ground storage until target detection

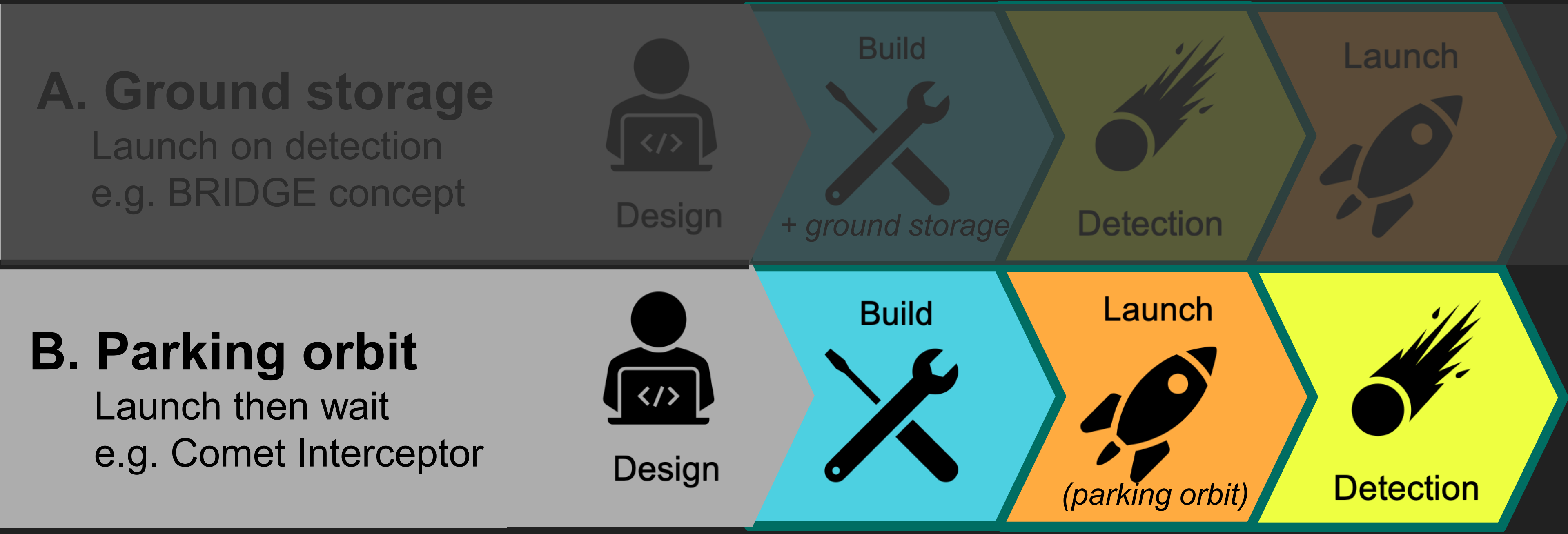
Science: Chemical & isotopic composition incl. organics, & geologic morphology

Payload: Camera, impactor, near-IR, mid-IR, UV point spectrometers

Preliminary cost estimate by JPL Team-X between Discovery- and NF-class

Moore et al. (2021). Planetary & Space Science

Rapid response architectures and Concept Studies



Comet Interceptor (ESA/JAXA)

1st encounter with a dynamically new LPC or ISO

Approach: Main spacecraft + 2 smaller probes
Parking orbit (Sun-Earth L2).
Short period comet as backup after 3yr

Science: 3D profile of surface & coma composition, shape, & structure

Payload: multiple cameras, spectrometers, dust, and plasma instruments

Developed under ESA's Fast-Class program — cost ~roughly equivalent to Discovery

Jones, G. et al. Comet Interceptor: A Mission to a Dynamically New Solar System Object. *Phase B Proposal. See also https://www.cometinterceptor.space/*

Rapid response architectures and Concept Studies

A. Ground storage
Launch on detection
e.g. BRIDGE concept

Design → Build *+ ground storage* → Detection → Launch

B. Parking orbit
Launch then wait
e.g. Comet Interceptor

Design → Build → Launch *(parking orbit)* → Detection

C. Build on detection
e.g. Xenia concept

Design → Detection → Build → Launch

SmallSats: *Xenia* concept to Comet K2 (FY19 JPL study)

1st in situ exploration of an Oort Cloud Comet

Twin SmallSats, shown w/ Hale-Bopp (Artist Conception)

Approach: Twin smallsats (block redundancy)
Build, test, & launch in < 2yrs!

Science: Protoplanetary disk temperature
Nucleus jet activity

Payload: UV spectrometer (isotopes) +
High-res camera

Consistent w/ increased SIMPLEx cap, but required dedicated, large launch vehicle

Donitz et al. (2020). *IEEE Aerospace Conference Proceedings*

Rapid response missions to ISOs, LPCs, and NEOs are feasible.

How can we enable them over the coming decade?

Programmatic

Challenges:

- LPCs, ISOs, & NEOs are only discoverable shortly before perihelion
- Current opportunities are too restrictive (cadence, LV, regulations)

Approach: Rapid response architectures

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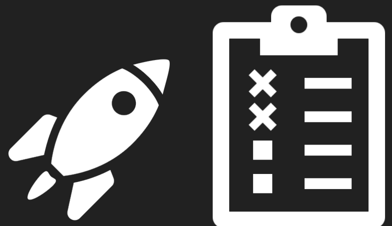
Approach: Rapid response architectures

Recommendations:

- Evaluate implications of proposals with unspecified targets & dedicated LVs
- Assess procurement for dedicated vehicles & long lead items – “pool of parts”

Engineering



Challenges:

- Rapid spacecraft development, certification, and launch
  - NASA: Long Phase A/B - each mission mostly re-designed from scratch

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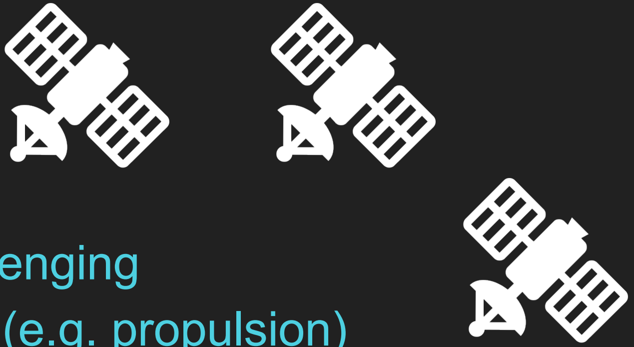
Recommendations:

- Spacecraft standardization - e.g. modular bus, interfaces & software blocks
- Multi-functional components (low TRL)
- Fast but reliable testing approach

Technology



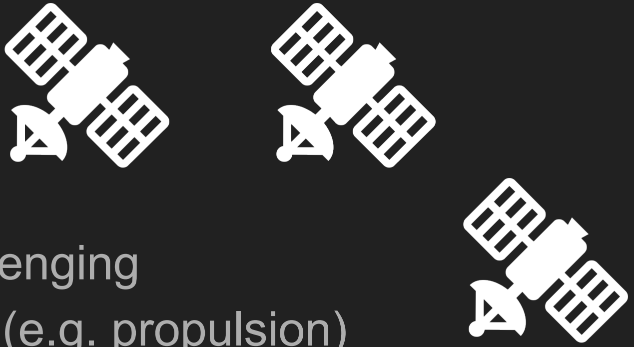
Challenges:

- Navigation at NEOs, LPCs, and ISOs is *very* challenging
- Smallsats can assist, but have intrinsic limitations (e.g. propulsion)

Approach:

- Multi-spacecraft architectures → increase science return
- Autonomy → improve navigation & decrease risk

Technology



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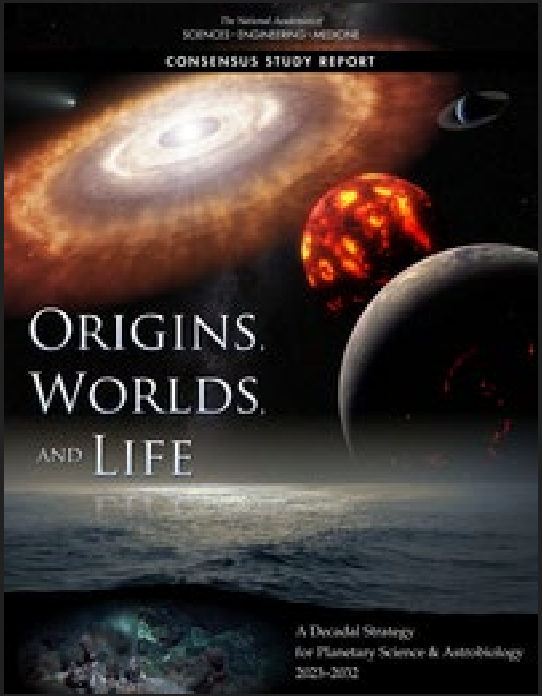
Recommendations:

- Concept studies to de-risk multi-spacecraft architectures
- Technology maturation (autonomy, navigation, manufacturing)

Outlook

2023-2032 Planetary Science & Astrobiology Decadal Survey

Coordinated white paper campaign (Donitz et al., Meech et al., Moore et al., +)



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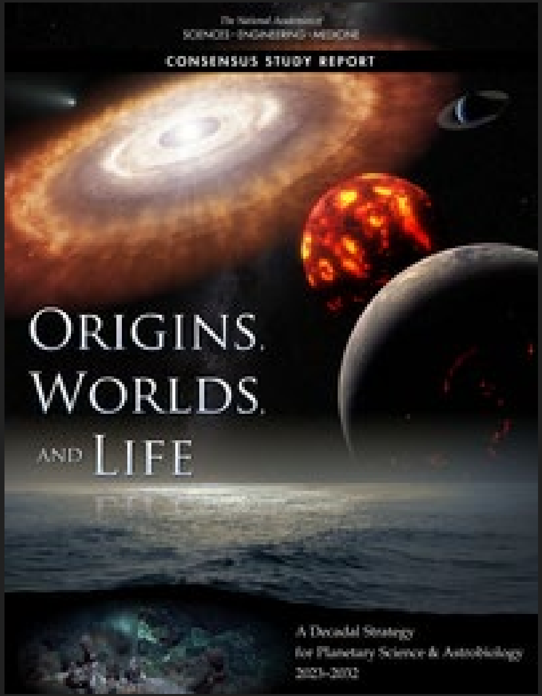

Achieved policy success!

"**Recommendation:** In the coming decade, NASA should develop an approach for a rapid response, flyby characterization of emerging, short-warning-time (< 3 years) threats and science opportunities"

Recommended: 50% increase in cost cap for small sats
Increased investment in autonomy tech

Outlook

NEOs, ISOs, and LPCs are high-value targets

- Require a rapid response architecture
- Mission concept studies demonstrate feasibility at a range of cost caps

BUT current programmatic constraints create challenges

Coordinated effort by the scientific community can make these missions a reality.

Questions?