Catalina Sky Survey:
NEO Discovery, Follow-Up and Beyond

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On behalf of CSS

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Overview

- Survey activities
- NEOfixer targeting broker
- Tracklet benefit estimates
- Follow-up activities
- New + upcoming

CSS Survey

- Stable operations of 1.5-m (G96) and 0.7-m (703) survey telescopes
  - Last 3 years:
    - Over 4,000 NEO discoveries (44% of total)
    - Over 400 new large H<22 discoveries (30% of total)
    - Nearly 100 PHA discoveries
    - One impactor (2022 WJ1), one mini-moon (2020 CD3)
- Jointly operate part-time 2.25-m (V00), "Bok NEO Survey"
  - Partnered with Spacewatch and U. of Minnesota
  - Scheduled 6-7 nights/lunation
  - Productivity has approximately doubled every year since 2019
 - 2022: ~6% of all NEO discoveries, 5% of H<22

NEO targeting broker

- Publicly available since March 2022
- Goal: optimally improve the quality of the NEO catalog, prioritizing Planetary Defense
- Creates customized targeting recommendations, combining object Importance with observation Benefit, Cost, and Urgency
- Facilitates coordination between observers
- Orbits, ephemerides and uncertainties are independently calculated using Find_Orb
- 130 users and 100+ MPC codes created. More are welcome!

Follow-up Benefit

- NEOfixer estimates the benefit of all historical NEO tracklets. How?
  - Iteratively solve the orbit, add one tracklet at a time, ordered by *submission time*
  - Benefit = Ratio of pre-tracklet uncertainty to post-tracklet uncertainty
  - E.g. If 10" uncertainty before observation, and 0.1" after, then Benefit = 100

NEOfixer Benefit: 2020 AN3 / K20A03N
Importance 114 (H=20.5, MOID=0.003)
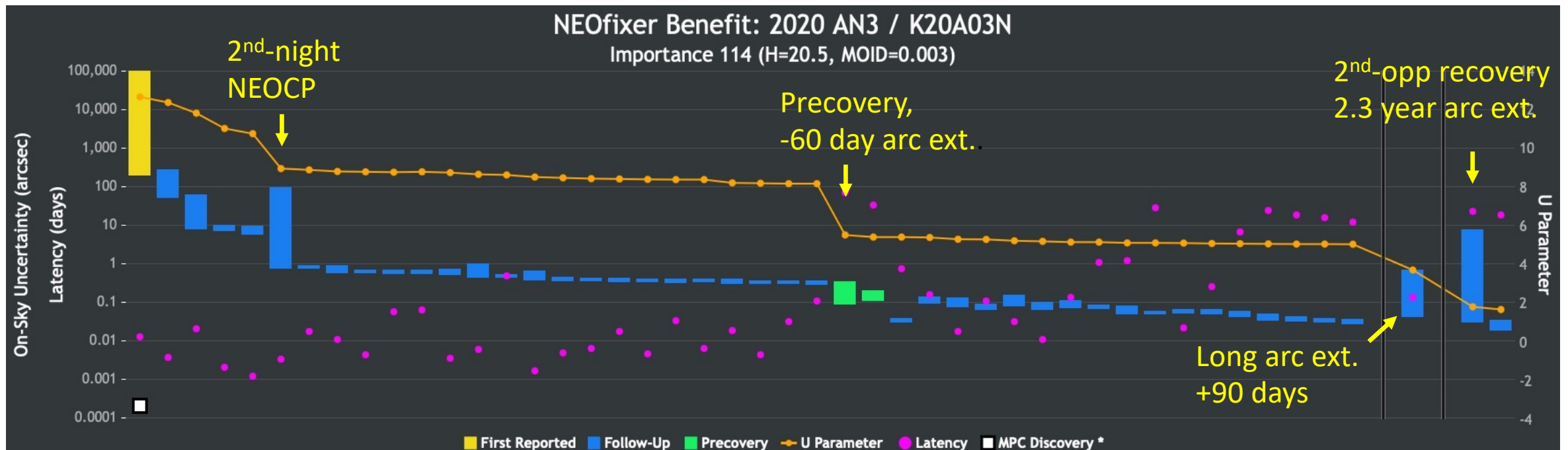
Follow-up Benefit

- Benefit information can help measure performance of MPC codes or groups of codes

NEO Tracklets, 2020-2022
Top 50 MPC Codes

NEO Follow-up Tracklets, 2020-2022
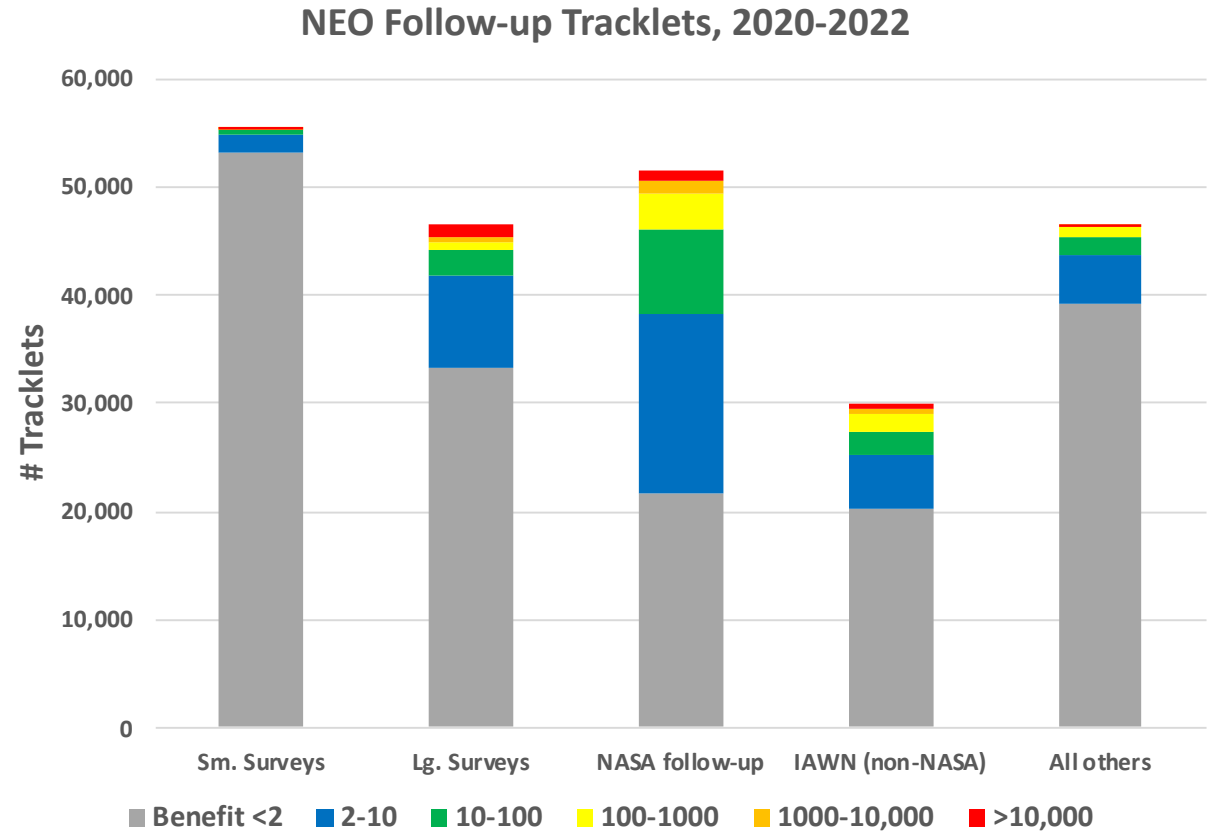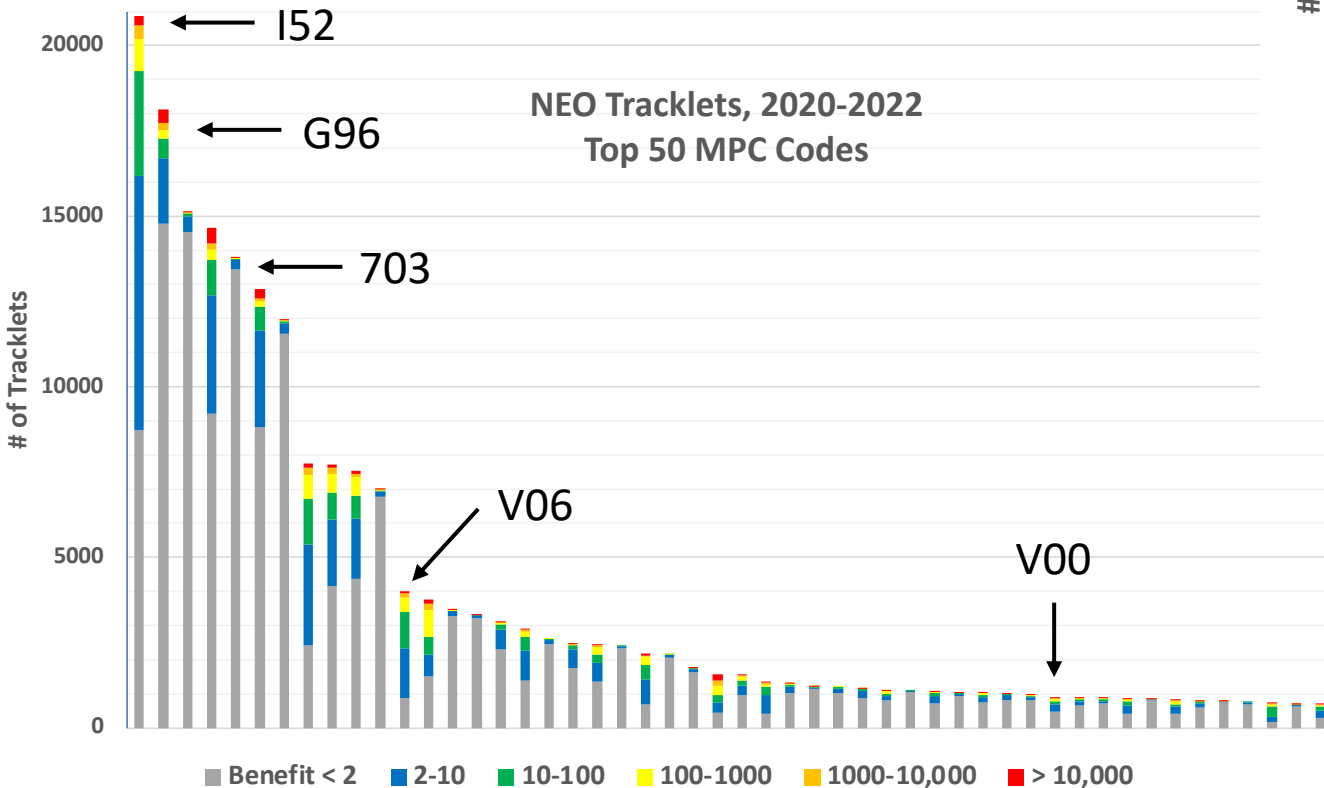
- Benefit <2 is considered "low-benefit"
- Follow-up programs should avoid creating low-benefit tracklets!
- NEOfixer can help….

Follow-up Benefit

- Targeted follow-up provides 75% of the beneficial tracklets.

- Larger surveys also provide some beneficial incidental follow-up

- Survey "re-discoveries" are extremely high-benefit (>10,000x orbit improvement)
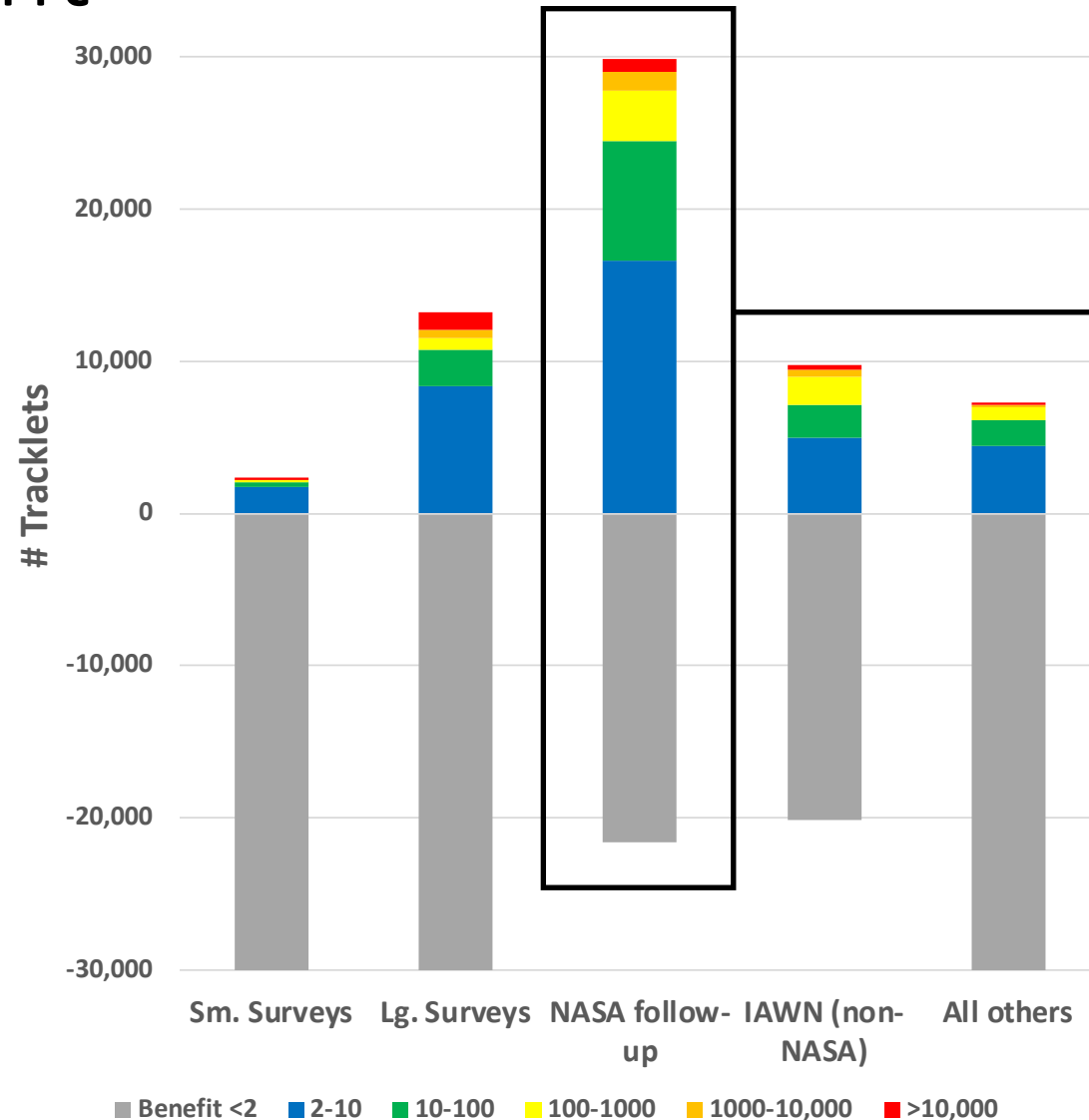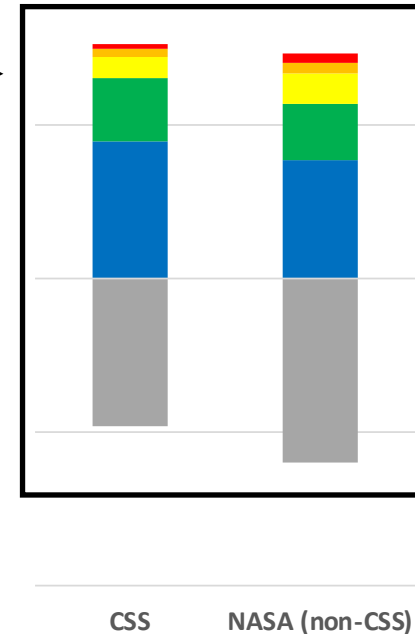

NEO Follow-up Tracklets, 2020-2022
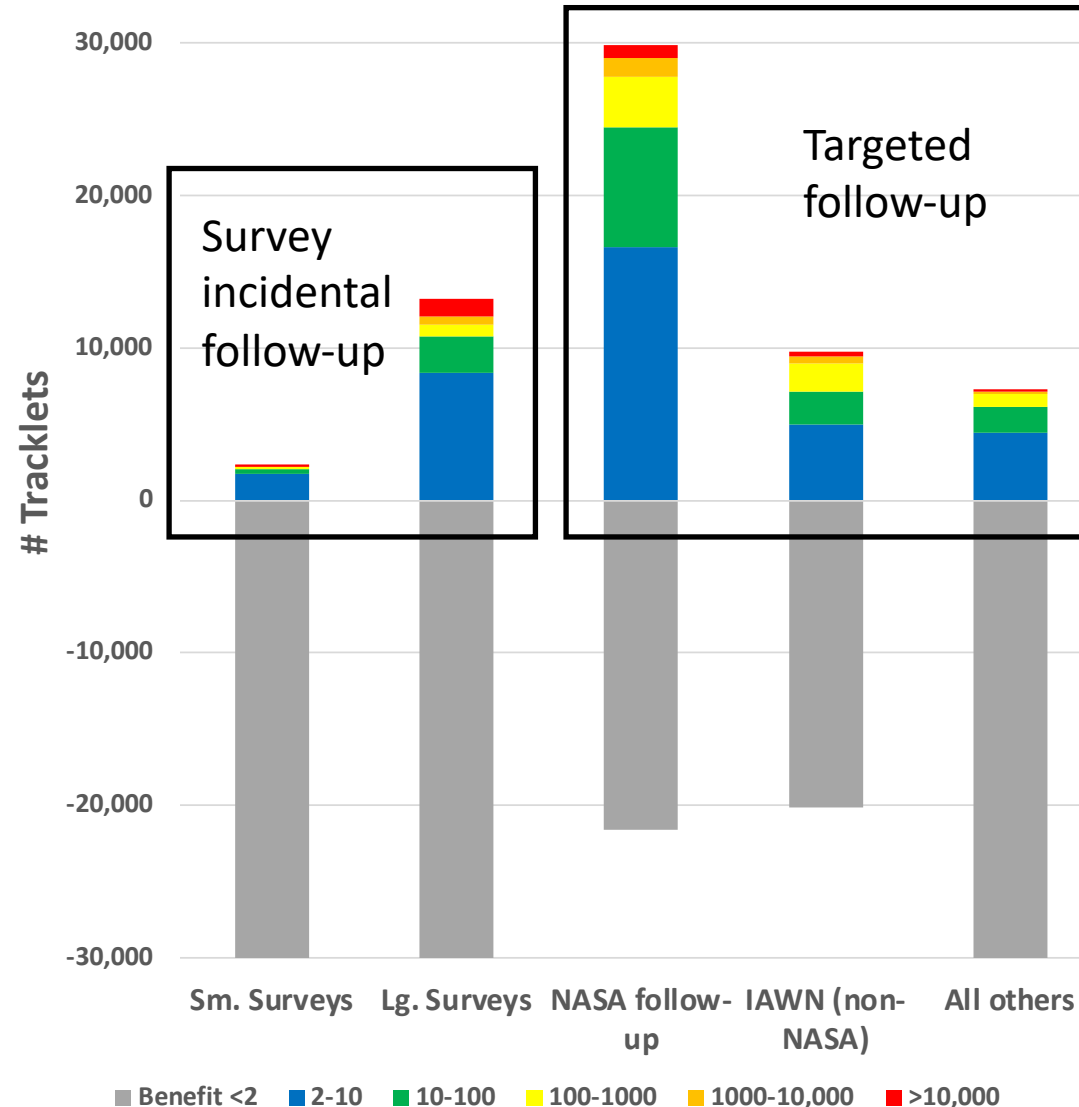
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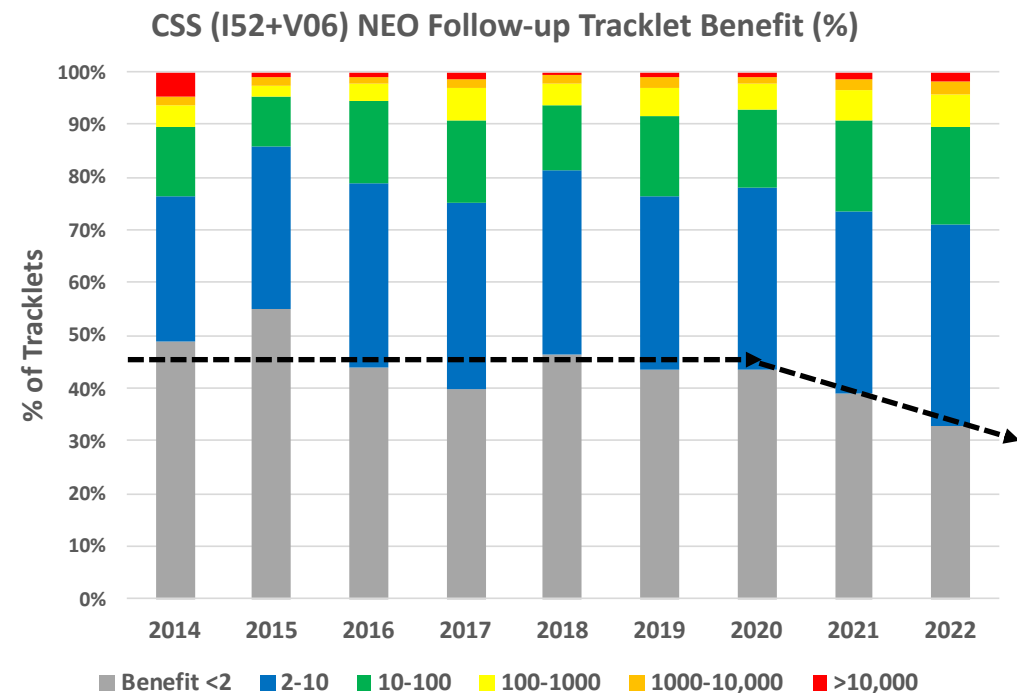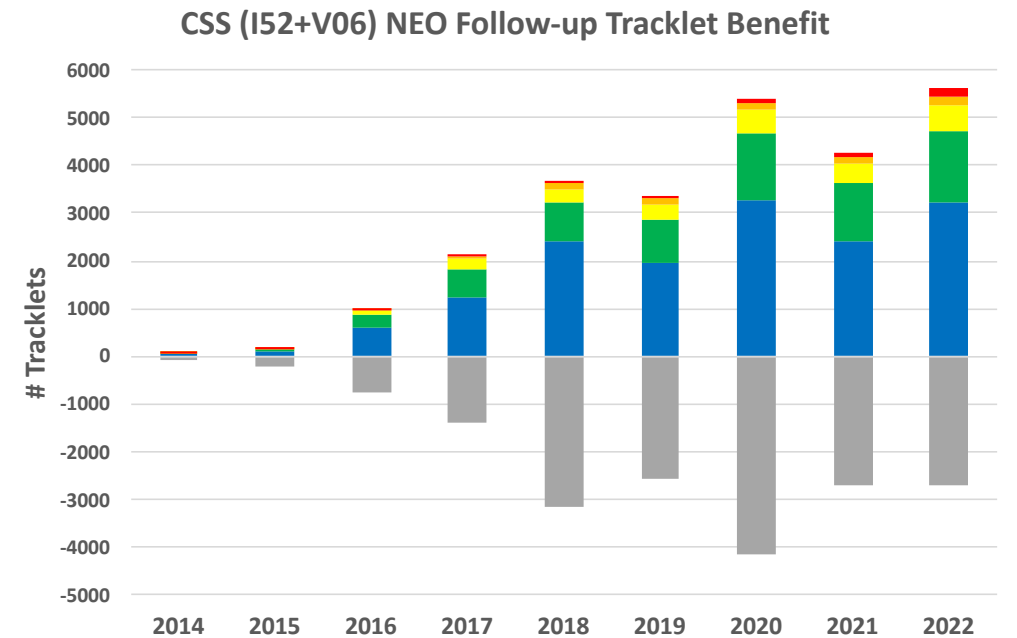

NEO Follow-up Tracklets, 2020-2022

CSS accounts for about half of NASA's follow-up:

CSS Follow-Up

- CSS is the most prolific NEO follow-up program
  - Full-time use of I52 (1.0-m)
  - Part-time (~25%) use of V06 (1.5-m)
- Focus on orbit improvement of NEOCP objects and cataloged NEOs, 2nd apparition recovery
- CSS accounts for nearly 33% of global "beneficial" targeted follow-up
- Working to improve aggregate benefit. Note low-benefit fraction trending downward →
- NEOfixer integration began in 2021

CSS (I52+V06) NEO Follow-up Tracklet Benefit

CSS (I52+V06) NEO Follow-up Tracklet Benefit (%)

Benefit <2 ■ 2-10 ■ 10-100 ■ 100-1000 ■ 1000-10,000 ■ >10,000

New + upcoming

- Faint (V>24) follow-up using data from 6.5 – 8-m telescopes
  - Recovered 3 PHAs using Gemini N+S. Imaged 2 PHAs with LBT.
  - Proposals submitted for additional 20+ PHA recoveries for 2023B.
- CSS image data, 2020-present available through PDS/SBN:
  - *https://sbn.psi.edu/pds/resource/css.html*
  - Nightly data submitted next-day, posted quickly
  - Pre-2020 data being reprocessed
- Zooniverse citizen science project launching 2023 Q2
  - Volunteers will review moving object candidates, from recent and reprocessed data

Conclusion

- CSS continues to be a stable and effective NEO discovery survey

- CSS follow-up activities are prolific and beneficial

- NEOfixer is operational, can steer observers toward beneficial follow-up, and can evaluate community follow-up performance

- Contact me at *eric@arizona.edu*

- NEOfixer: *https://neofixer.arizona.edu*

- CSS archive (PDS/SBN): *https://sbn.psi.edu/pds/resource/css.html*