IAWN MPC Update

19 October 2018

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Harvard-Smithsonian CfA

MPC OVERVIEW

MPC Overview

- Hosted by the Smithsonian Astrophysical Observatory (SAO) at the Harvard-Smithsonian Center for Astrophysics (CfA)
- Granted authority for operation by the International Astronomical Union (IAU)
- Functional sub-node of the Small Bodies Node (SBN) of the NASA Planetary Data System
- Funded 100% by NASA since 2008, via grants through 2017. Now funded through a Cooperative Agreement via a sub-award from University of Maryland. SBN is responsible for oversight of the award.
- Funded to grow to 10 FTEs + Equipment + Travel

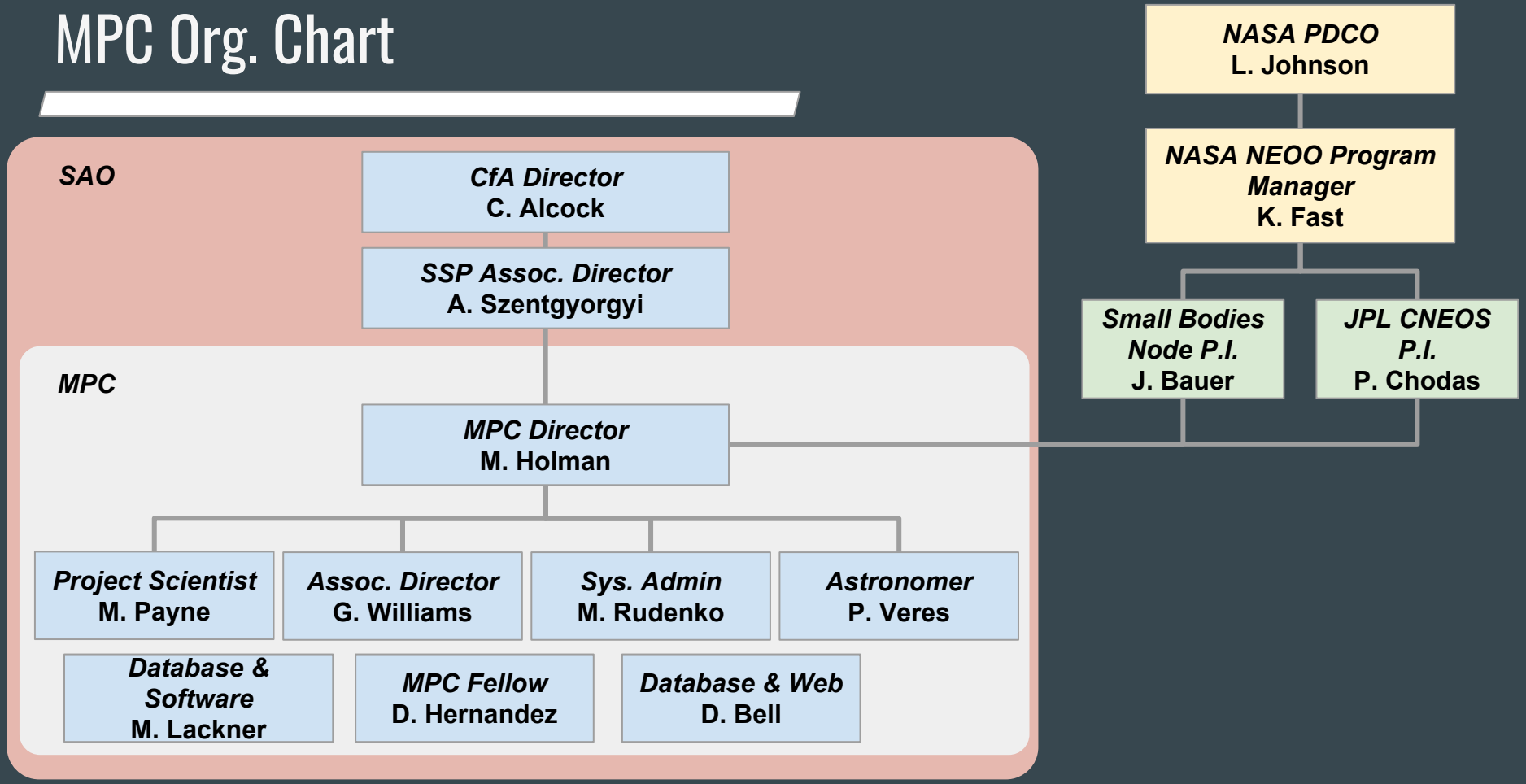
Roles and Responsibilities

- Process ~2 millions new observations per month. The current MPC database holds ~200 million observations.
- Process observations from all vetted sources. The bulk comes from large surveys.
- Identify NEOs within a stream of observations comprised mostly of Main Belt Asteroids.
- Keep up with NEO discoveries and orbits in real time.
- Maintain the NEO Confirmation Page to facilitate coordination of NEO follow-up observations. (20-100 unique objects posted each night.)
- Warn of NEOs coming within 6 Earth-radii within 6 months. For the MPC, the time horizon is typically a few days because of discovery circumstances.
- Designate new asteroid discoveries.
- Maintain and provide access to a database of ~800,000 objects with known orbits (~500,000 are numbered, i.e. have the highest quality orbits)

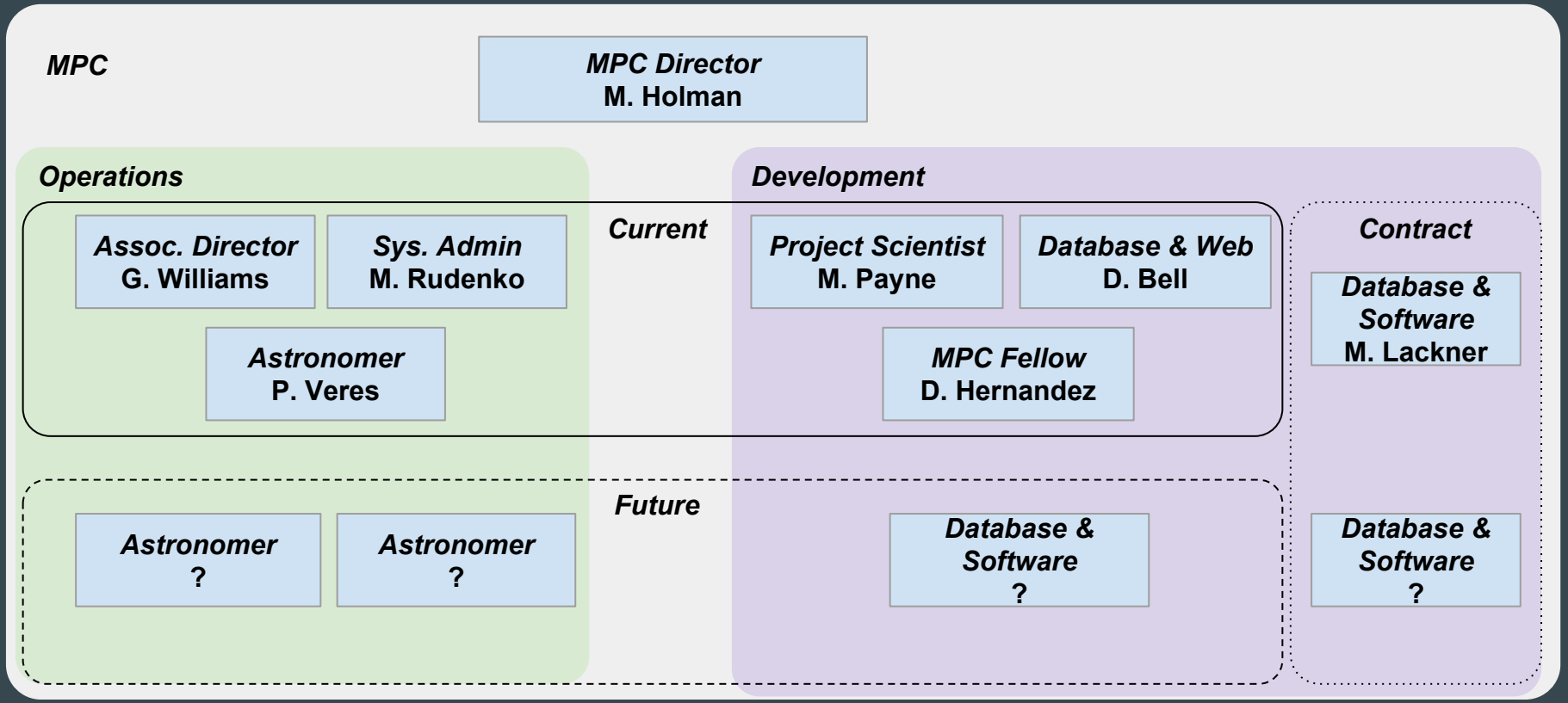
Roles and Responsibilities

- Archive data with the Small Bodies Node of the NASA Planetary Data System
- Maintain digest2 tracklet classification code
- Mirror databases to the survey community
- Prepare for increased data flow from future surveys
- Interact with MPC users to support their needs
- Interact with broader public through interviews and outreach

MPC Org. Chart



Staffing


MPC
MPC Director
M. Holman
Operations
Development
Current
Assoc. Director
G. Williams
Sys. Admin
M. Rudenko
Astronomer
P. Veres
Project Scientist
M. Payne
Database & Web
D. Bell
MPC Fellow
D. Hernandez
Contract
Database & Software
M. Lackner
Future
Astronomer
?
Astronomer
?
Database & Software
?
Database & Software
?

Staffing

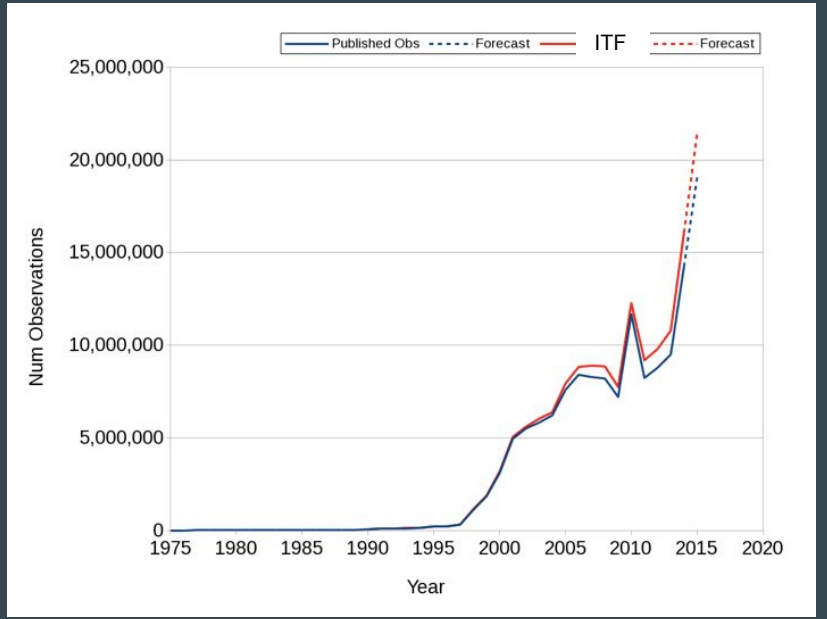
- Ramp up to ~10 FTE
  - Matt Holman: Director
  - Matt Payne: Project Scientist
  - Gareth Williams: Assoc. Director
  - Mike Rudenko: Sys Admin
  - Peter Veres: Astronomer-Operator
  - David Bell: DBA & Web Developer
  - David Hernandez: (MPC Fellow): Precision N-Body Development
  - Michael Lackner: Database & Software Development
- Future hires
  - Web Developer (Paresh Prema)
  - Astronomer-Operator
  - 2nd MPC Fellow, or another Astronomer-Operator

Computing Infrastructure

- Computing cluster deployed at SAO's Cambridge Discovery Park site.
- Similar hardware deployed at the Smithsonian's Herndon Data Center in Virginia.
- Exploring cloud computing, starting with serving static files via AWS.
- Working on moving the processes remaining on VMS machines to linux machines.
- Exploring using Harvard's Odyssey Research Computing Facility.

Drivers of Data Growth

- Generalized survey ramp-up
  - ~68,000 observations in 1990
  - ~10 million in 2007
  - ~14 million in 2010
  - ~ 25 million observations per year currently
- LSST
  - First light ~2019
  - Order of Mag more data
- NEOcam
  - Extended “Phase-A” funding



Drivers of Data Growth

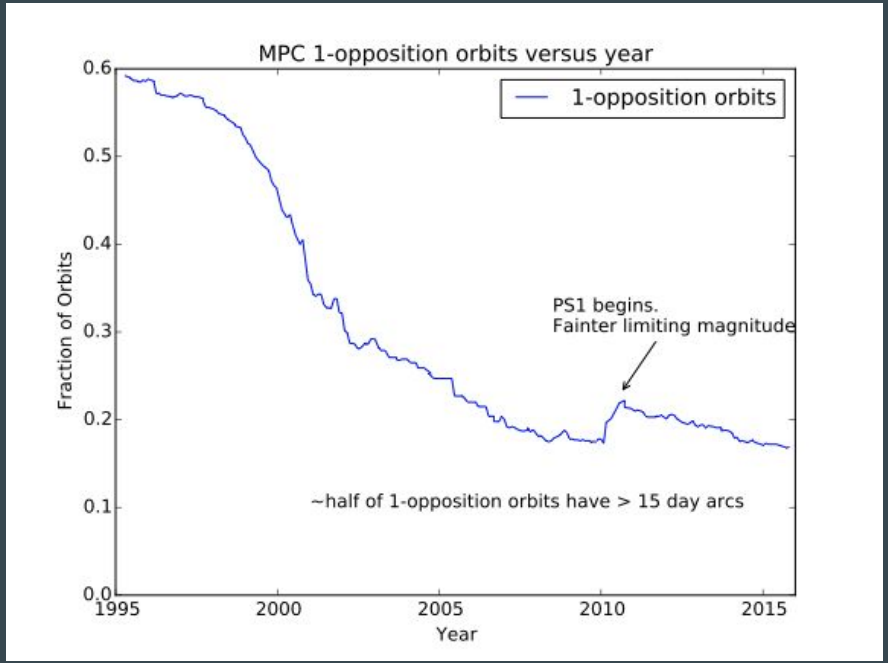
- ~2M Observations / Month Currently
- ~20 - 200M / Month in the future
- Each observation incurs associated computational costs
  - Database Storage & Retrieval
  - Orbit extrapolation & fitting
  - Tracklet Linking
- New Pipeline must be able to bear this increased load

Operation	Observations	Orbits	Exposures
	80-200 char	80-200 char	200-500 char
Inserts	2×10^6	3×10^4	2×10^4
Updates	5×10^6	1.5×10^5	2×10^4
Selects	1.5×10^5	1.5×10^5	2×10^4
Scans	10^2	10^2	10^2
Deletions	10^1	10^1	10^1

Table 1: The estimated number of monthly MPC data system operations of each operation category for each record type.

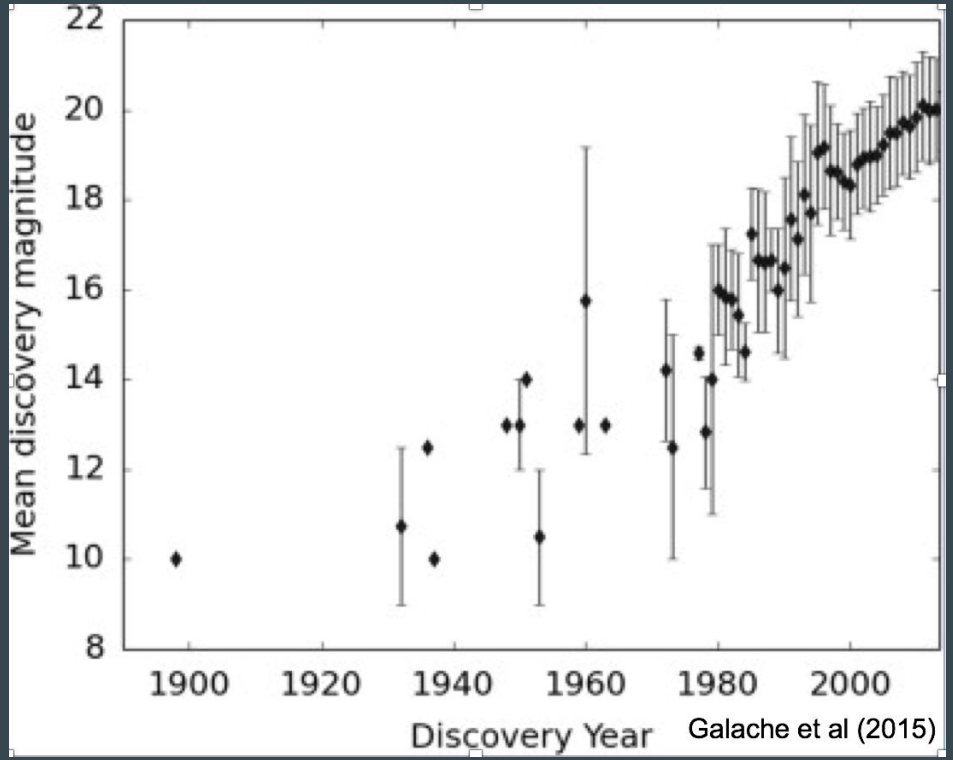
Drivers of Data Growth

- Pan-STARRS caused a step-change in 1-opposition orbits
- LSST will be bigger



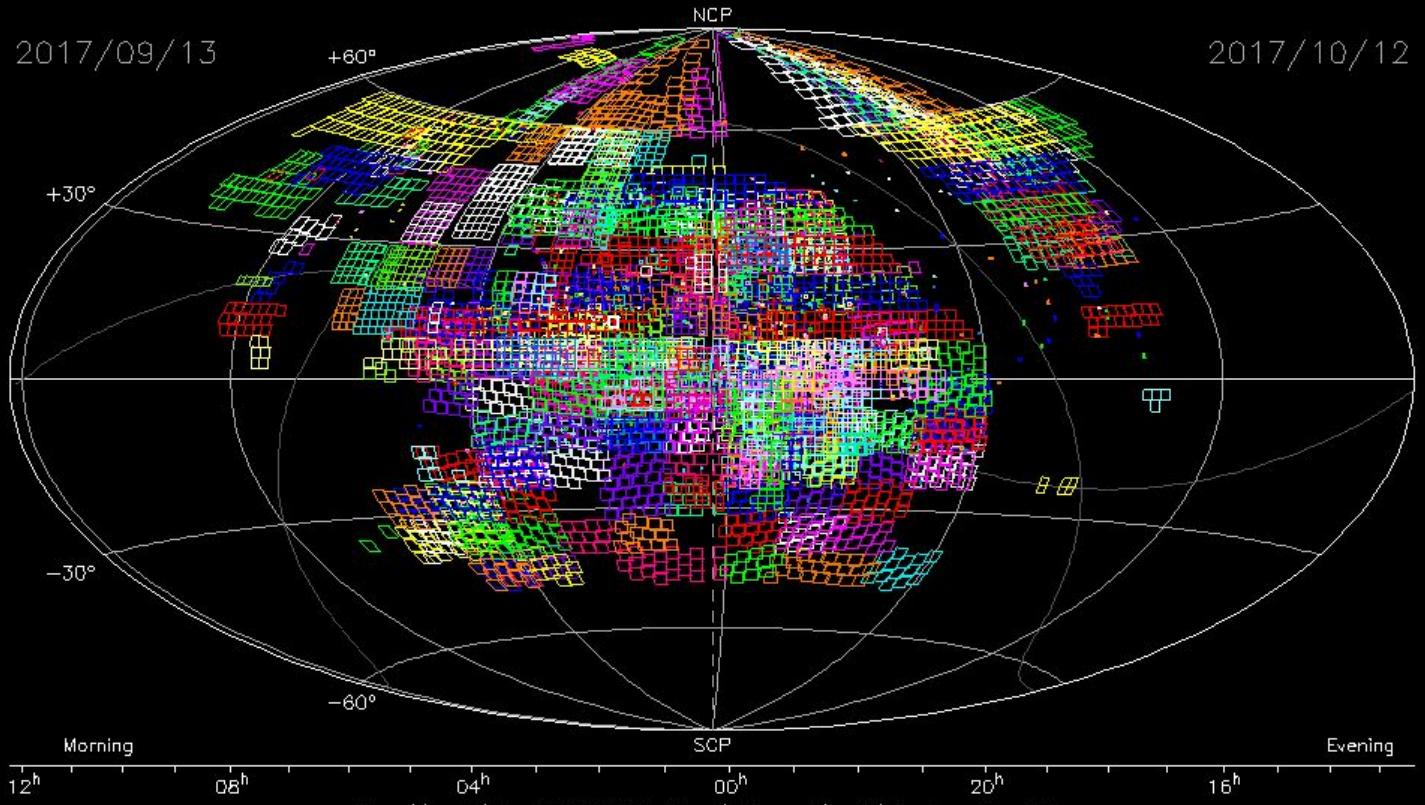
Drivers of Data Growth

- Evolution of Mean Discovery Magnitude



SKY COVERAGE

Plot prepared 2017/10/13.007 by the Minor Planet Center



Opposition Point = 00 15.9,+01 43. Fields reaching fainter than V = 20.0.

2017/10/12 (2017 285)	2017/10/11 (2017 284)	2017/10/10 (2017 283)	2017/10/09 (2017 282)	2017/10/08 (2017 281)
2017/10/07 (2017 280)	2017/10/06 (2017 279)	2017/10/05 (2017 278)	2017/10/04 (2017 277)	2017/10/03 (2017 276)
2017/10/02 (2017 275)	2017/10/01 (2017 274)	2017/09/30 (2017 273)	2017/09/29 (2017 272)	2017/09/28 (2017 271)
2017/09/27 (2017 270)	2017/09/26 (2017 269)	2017/09/25 (2017 268)	2017/09/24 (2017 267)	2017/09/23 (2017 266)
2017/09/22 (2017 265)	2017/09/21 (2017 264)	2017/09/20 (2017 263)	2017/09/19 (2017 262)	2017/09/18 (2017 261)
2017/09/17 (2017 260)	2017/09/16 (2017 259)	2017/09/15 (2017 258)	2017/09/14 (2017 257)	2017/09/13 (2017 256)

MPC Users Group

MPC Users Group

Role

- Guide improvements of the MPC and its processes and services for the current era,focusing primarily on the surveys and NEO follow-up operations.
- Help the MPC community get the most out of its collective resources, while meeting its main objectives.
- Best position the MPC and members of its community to cope with the increasing volume and velocity of data that will come from the expansion of current surveys.

Members

- Steve Chesley (JPL: Chair)
- Rob Seaman (Catalina)
- Marc Buie (SWRI)
- Richard Wainscoat (UH)
- Dave Tholen (UH)
- Carrie Nugent (Olin)

Alternates

- Tyler Linder
- Larry Denneau (UH)
- Davide Farnocchia (JPL)

MPC Users Group

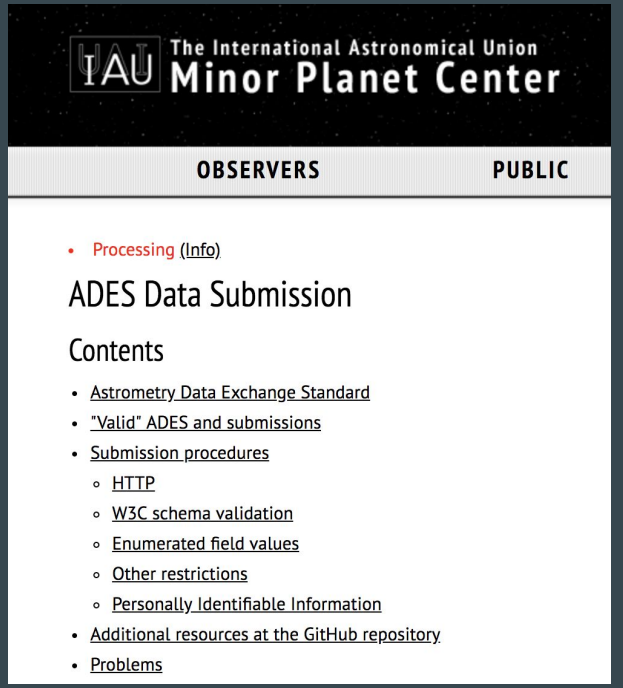
- Two meetings per year. One at the CfA (MPC). One at a user site.
- Recent Recommendations
  - Remove any dependence on VMS machines
  - Migrate to Database-Centric Operation
  - Mitigate any single-point staffing dependencies

- Work-in-Progress
  - Significant progress toward moving key processes off VMS machines to linux machines.
  - Training of staff to manage those process, as well as automation to reduce necessary personnel time.
  - Working on improving the externally accessible database.

ADES

ADES

- Developed from 2015 meeting at SAO, led by Steve Chesley
- Many more fields possible than current obs80 format
- XML & PSV versions
- MPC is accepting ADES-format submission
  - https://minorplanetcenter.net/iau/info/ADES.html
  - Test functionality available
- Assigning submissionIDs & observationIDs
- Still accepting obs80 format



EXPOSURE INFORMATION

Exposure Information

What

- Report exposure information (time, RA/Dec, orientation, filter, etc.) automatically throughout the night
- Or, Report a planned exposure sequence
- Community buy-in: PS, ATLAS, Catalina, ZTF
  - *All are welcome!!*

Why

- Community coordination of NEO follow-up activities
  - NEOCP-coordination to community to see what regions of sky being observed.
- Internal MPC data pre-processing
  - The MPC can trigger calculations in advance of the observations being reported.
- Community pre-covery.
  - Facilitate re-analysis of old exposures for unreported observations

Exposure Information

How

- Automated submission of JSON file
- https://www.minorplanetcenter.net/pointings/

WIP

- Ongoing testing of live submissions
- Expected ~Nov 1st, 2018:
  - Official announcement
  - Query API
- Expected ~ mid-Nov 2018:
  - Integration into NEOCP

E.g.

- For square equatorially-aligned field


```
{
   "action": "exposed",
   "surveyExpName": "AK101_Jxpf341-a",
   "mode": "survey",
   "mpcCode": "802",
   "time": "2018-01-01 11:22:33.456",
   "duration": 120,
   "center": [255.167,-29.008],
   "width": 2.5,
   "limit": 19.5,
   "filter": "r"
}
```

GENERALIZED MPCHECKER

Generalized MPChecker

Goal

- Statistically robust attribution of detections / tracklets to known orbits.

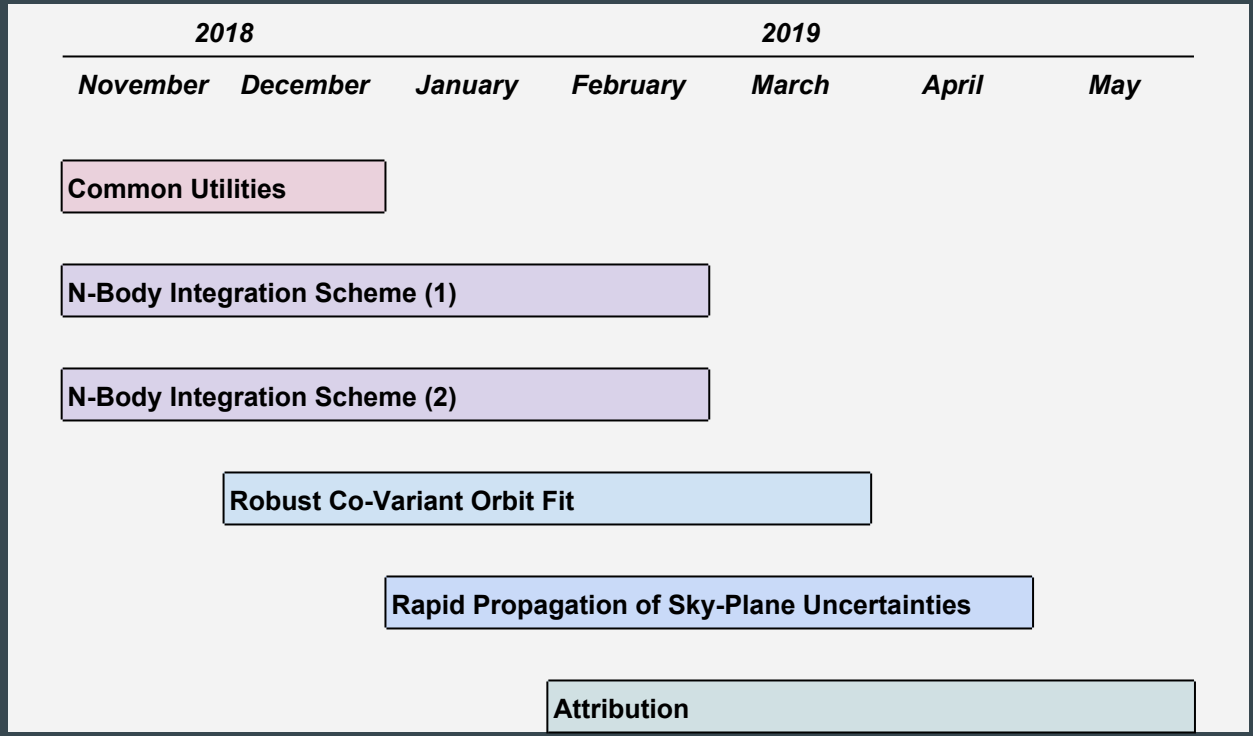
Requirements

- Accurate integration of orbits, incorporating multiple non-gravitational forces
- Robust generation of covariance statistics for orbital fits
- Rapid propagation of orbits (& uncertainties) to generate statistically robust uncertainty regions on the sky
- Rigorous criteria for the association of candidate detections / tracklets with propagated catalog orbits
- May 2019: Beta-versions .

Generalized MPChecker

Development Timeline

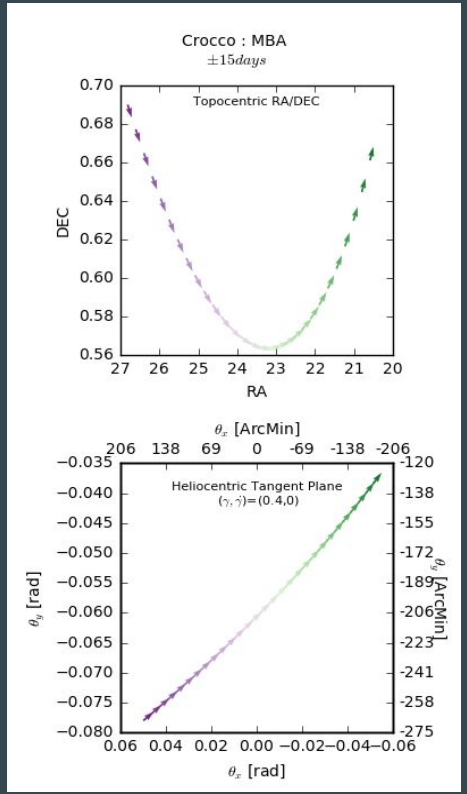
- Collaboration with LSST
- Completion by May 2019

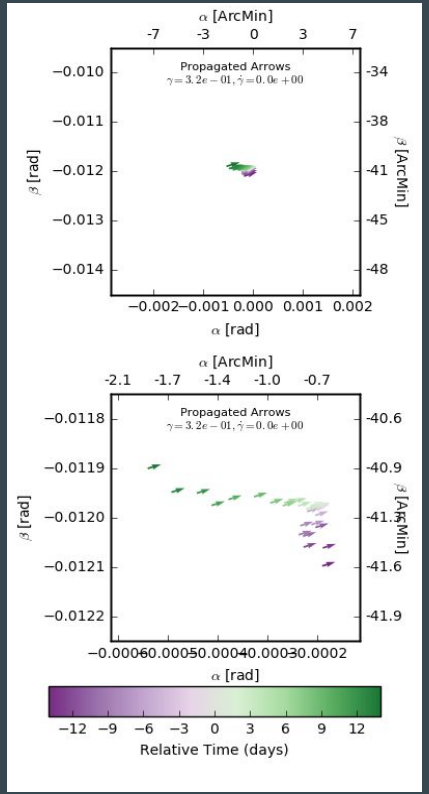


HELIOCENTRIC LINKING

HelioLinC:
Heliocentric Linking & Clustering

- Topocentric RA & Dec
- Heliocentric RA & Dec
- Transformed θ coordinates
- Propagated Arrows

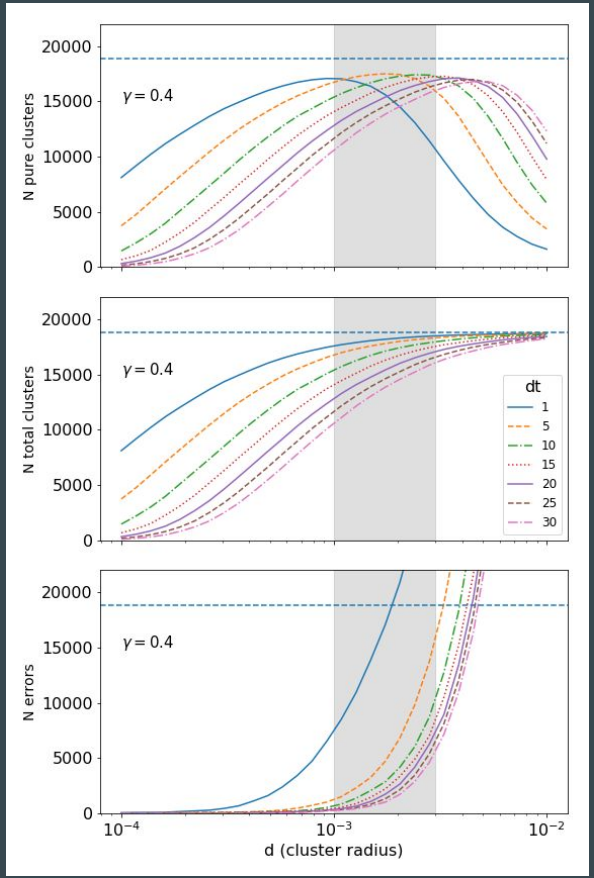




HelioLinC:
Heliocentric Linking & Clustering

Training Data:
The dependence of cluster identification and error rate on the tunable parameters

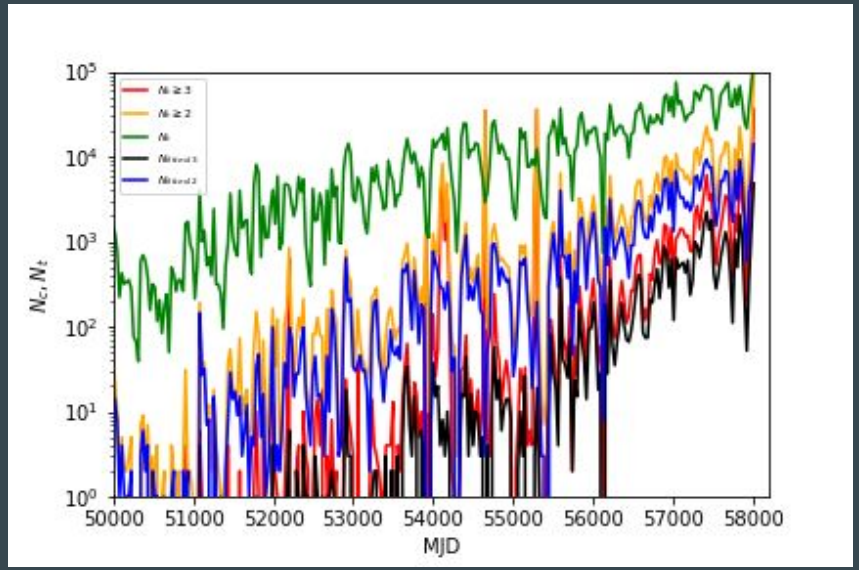
- Pure-Correct Clusters
- Pure+Mixed Clusters
- Erroneous Clusters



HelioLinC:
Heliocentric Linking & Clustering

- The total tracklets (green)
- Number of 3+ arrow clusters prior to vetting (red)
- Number of 3+ arrow clusters after vetting (black)
  - ~41,000
- Number of 2-arrow clusters prior to vetting (orange)
- Number of 2-arrow clusters after vetting (blue)
  - ~227,000
- Preliminary Independent Orbit Fitting
  - Gareth
  - ~99% success

- Paper submitted & reviewed
  - https://arxiv.org/pdf/1805.02638.pdf
  - Have Referee's report



UNCONFIRMED NEOS

Unconfirmed NEOs

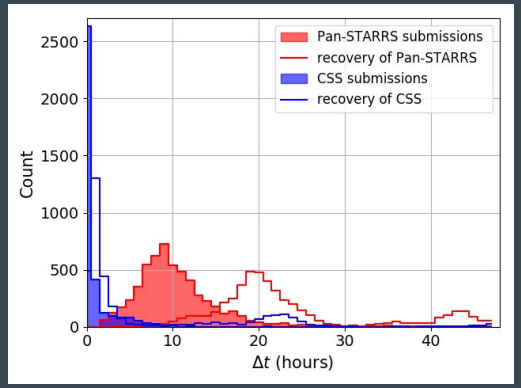
- Veres et al (2018) Accepted
- https://arxiv.org/pdf/1805.02804.pdf

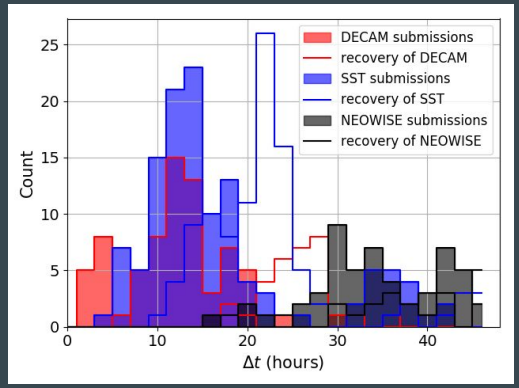
Classification	Number	(%)	Number with $D_2 = 100$
Initially Unconfirmed	1,909	11	915
NEA Discovery	5,117	31	3,768
NEA Attribution	708	4	492
Non-NEA (Discovery & Attribution)	8,546	50	184
Comet	231	1	67
Not a minor planet	109	1	92
Retracted	410	2	230
Summary	17,030	100	5,748

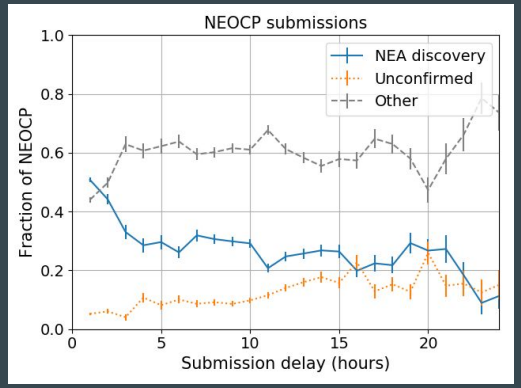
	All	$D_2 = 100$
Initially Unconfirmed	1,909	915
Initially-unconfirmed-but-subsequently-attributed	315	95
Currently Unconfirmed	**1,594**	**820**

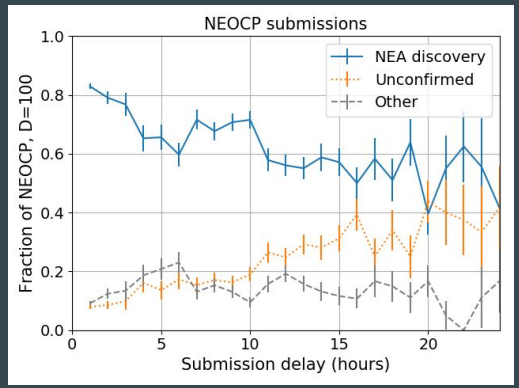
Unconfirmed NEOs

- Veres et al (2018) Accepted
- https://arxiv.org/pdf/1805.02804.pdf
- Submission and follow-up time delay of confirmed NEOCP candidates
- Large submission delay implies even larger recovery delay.
- NEO discovery rate drops and loss rate increases with increasing submission delay.









SUMMARY

Summary

- Build-up underway
  - New staff, additional hires underway
  - New Software and hardware
- Drivers of Data Growth (LSST, NEOCam)
  - Order of mag increase
  - Shapes efficiency requirements
- Community feedback from MUG
- Development:
  - ADES
  - Exposure / Pointings
  - MPChecker
  - Heliocentric Linking
- Unconfirmed NEOs

BACKUP

METRICS

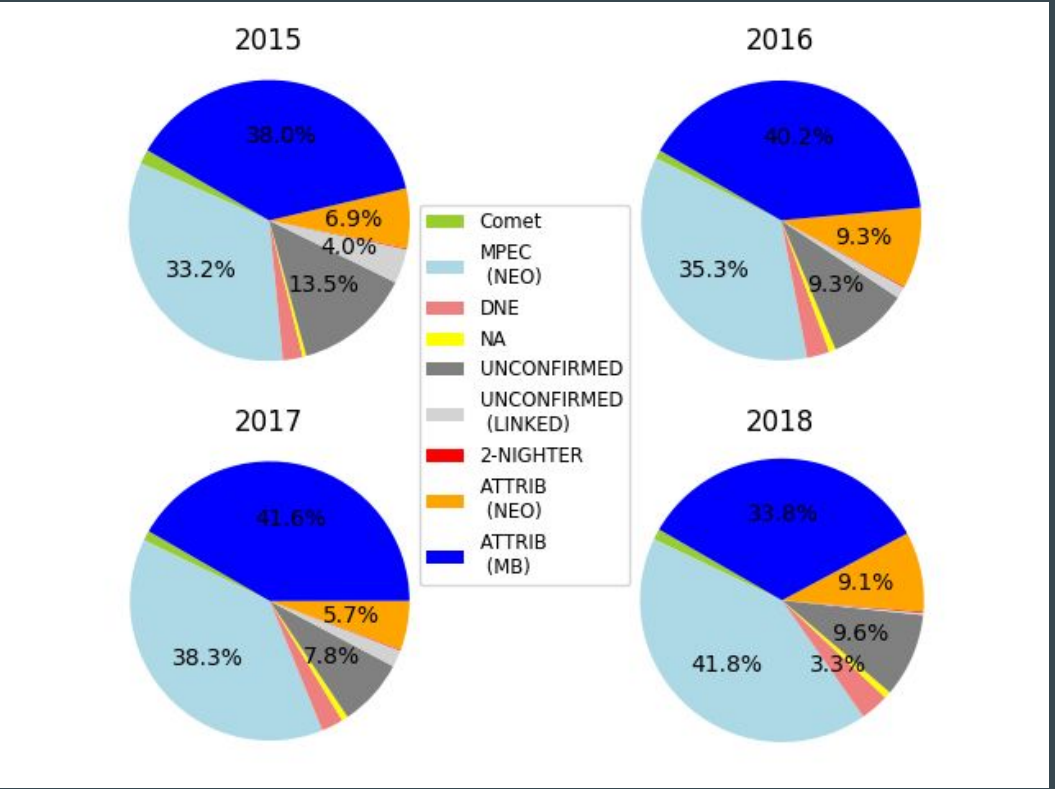
METRICS

- Survey & Follow-Up
  - Overall Data Volumes by Orbit Category ↞ *Easy*
- Tracking Improvement and Progress
  - Overall Inventory ↞ *Easy*
  - Key Time Intervals ↞ *Mixed*
- NEOCP-Specific
  - Key Time Intervals ↞ *Mixed*
- Routine, Non-Validated, Non-NEOCP Objects
  - ITF Linkages by destination category ↞ *Difficult*
  - Improvements / Additions ↞ *Difficult*

Anything “*Mixed*” or “*Difficult*” requires improvements to Db / Tracking

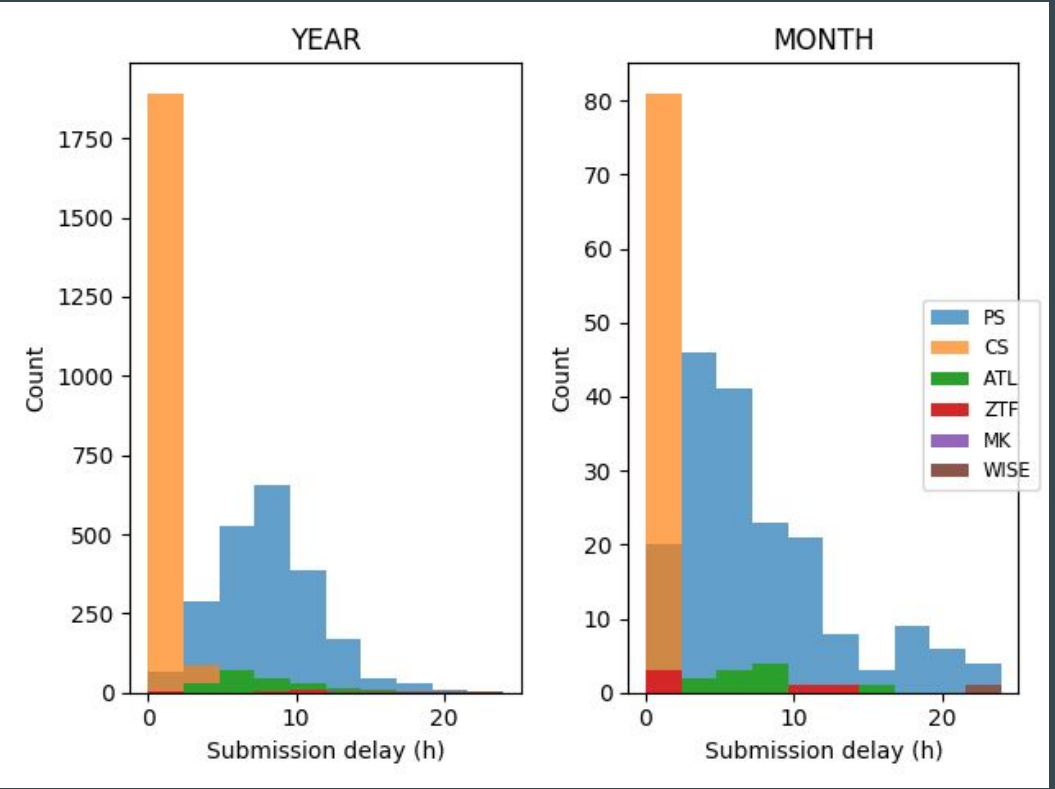
METRICS

- NEO Submissions
- Fate of tracklets
- WIP:
  - https://www.cfa.harvard.edu/~pveres/index1.html



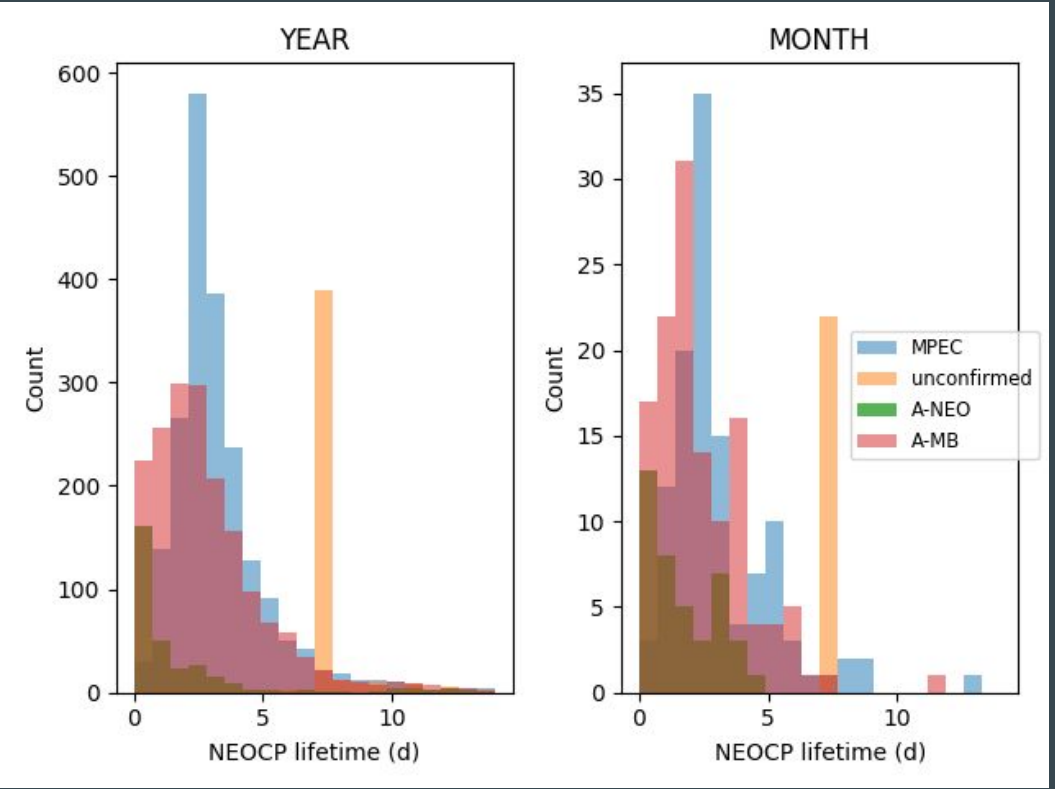
METRICS

- NEO Submissions
- Submission delay for tracklets
- WIP:
  - https://www.cfa.harvard.edu/~pveres/index1.html



METRICS

- NEO Submissions
- Time on NEOCP for tracklets
- WIP:
  - https://www.cfa.harvard.edu/~pveres/index1.html



Anticipating the future

- How will the MPC receive from future surveys like LSST?
- Will the MPC do the linking for LSST and NEOCam, or will those surveys report linked tracklets?
  - What science is lost if they only report links (sparse coverage, etc)?
- Can the MPC cope with a higher rate of false positives if the surveys report data of which they are less confident?
- What changes are needed to the MPC data operations to support detection and linking efficiency calculations for surveys, with the MPC being a shared component of other data pipelines?
- Will targeted follow-up be needed or feasible?
- Should the NEOCP follow-up model be replaced with something else?