The Minor Planet Center
Data Processing System

Matthew J. Holman
Harvard-Smithsonian Center for Astrophysics
Brief Minor Planet Center History

After WWII, the IAU established the Minor Planet Center at the Cincinnati Observatory in 1947.

Initial task:
Recovering all the lost minor planets

Of 1564 numbered objects (i.e. with good orbits), 30% were lost.

The MPC moved to the Smithsonian Astrophysical Observatory (SAO) in 1978.

The last two lost numbered asteroids (878) Mildred, discovered in 1916 and rediscovered in 1991; and (719) Albert, discovered in 1911 and rediscovered in 2000, were identified by Gareth Williams (MPC).
Ancient MPC Data Processing System
Mean discovery magnitude vs. Discovery Year

Congressional Mandates Regarding Potentially Hazardous Asteroids (PHAs)

1998: Find 90% of PHAs with $D > 1$km. (Achieved in 2010.)

2006: Find 90% of PHAs with $D > 140$m by the end of 2020.

Budget to support NEO surveys is growing

- $4$ M in 2010
- $20$ M in 2012
- $40$ M in 2014
- $50$ M in 2016

PHA Criteria:

- $q < 1.3$ au
- MOID $< 0.05$ au
- $H < 22$ ( $D > 140$m for $0.14$ albedo)
Chelyabinsk, 15 February 2013
By Alex Alishevskikh - Flickr: Meteor trace, CC BY-SA 2.0,
https://commons.wikimedia.org/w/index.php?curid=24726667
2014 AA

Discovered 1 Jan 2014 by Catalina Sky Survey

NASA/JPL-Caltech/CSS-Univ. of Arizona
Near-Earth Asteroid Discoveries by Survey

~140m and larger NEAs (as of 2018–Nov–11)

https://cneos.jpl.nasa.gov/stats/

Alan Chamberlin (JPL/Caltech)
Large Synoptic Survey Telescope

NEOCam

NEOCam - The NEOCam space telescope will survey the regions of space closest to the Earth’s orbit, where potentially hazardous asteroids are most likely to be found. NEOCam will use infrared light to characterize their physical properties such as their diameters. (Image credit: NASA/JPL-Caltech)
MPC Overview

• Hosted by the Smithsonian Astrophysical Observatory (SAO) at the Harvard-Smithsonian Center for Astrophysics (CfA).

• Granted authority by the International Astronomical Union (IAU).

• Functional sub-node of the Small Bodies Node of the NASA Planetary Data System.

• Funded 100% by NASA since 2008, via grants through 2017, now through a Cooperative Agreement via a sub-award from University of Maryland (PI Gerbs Bauer). SBN is responsible for oversight of the award.

• Growing to 10 FTEs + Equipment + Travel.
The MPC is hiring:
https://www.cfa.harvard.edu/hr/postings/18-62.html
MPC Roles and Responsibilities

• Process ~2 million new observations per month. The current MPC database holds ~175 million observations.

• Identify candidate NEOs in real time, from a stream of observations composed mostly of Main Belt Asteroids.

• Maintain the NEO Confirmation Page (NEOCP) to facilitate coordination of NEO follow-up observations.

• Warn of NEOs coming within 6 Earth-radii within next 6 months.

• Provide access to a database of ~800,000 objects with known orbits.

• Archive data with the Small Bodies Node of the NASA Planetary Data System.
MPC Operations:

How does the MPC do what it does?
The Minor Planet Center (MPC) is the single worldwide location for receipt and distribution of positional measurements of minor planets, comets and outer irregular natural satellites of the major planets. The MPC is responsible for the identification, designation and orbit computation for all of these objects. This involves maintaining the master files of observations and orbits, keeping track of the discoverer of each object, and announcing discoveries to the rest of the world via electronic circulars and an extensive website. The MPC operates at the Smithsonian Astrophysical Observatory, under the auspices of Division F of the International Astronomical Union (IAU).

All of the MPC's operating funds come from a NASA's Near-Earth Object Observations program grant. Much of the computer equipment that the MPC uses was provided by the Tamkin Foundation.
Typical Sequence of Events

1. Receive astrometry, carry out sanity checks, and archive the data.

2. If the observations correspond to a known object, natural or artificial, process later in background.

3. If object flagged as a possible NEO, or the location and motion suggest an NEO, post on NEO Confirmation Page.

4. Otherwise, into the Isolated Tracklet File (ITF).

5. NEO Confirmation Page entry is updated as new observations arrive, until enough data are available for a Minor Planet Electronic Circular (MPEC).
MPC Submission Information

For those wishing to submit astrometric observations for publication in the Minor Planet Circulars information is available on the format of astrometric observations. Observations, formatted as described therein, should be sent to obs@cfa.harvard.edu. Reports for new comets should also (following the redistribution of tasks at the 2015 IAU GA) be reported to the MPC. Note that visual reports of comet discoveries should be reported to mpc@cfa.harvard.edu.

Further technical information on Minor Planet Center submissions is available:

- Information on the pending introduction of the ADES format is available here.
- Observation format
- Indication of observational details
- Orbit format (export)
  - The HTML pages describing the new format for import of orbital elements will be available here at some future date.
- Orbit format (import) Orbits submitted for publication in the MPCs need to be in a special format.
  - The document describing the new format for import of orbital elements will be available here at some future date.
MPC1992 format

Data reported in ‘tracklets’ of 2+ astrometric observations

Each 80-character line represents an astrometric observation

Header includes observer details

Subject line can indicate possible NEOs

2014 AA

<table>
<thead>
<tr>
<th>Observations:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>K14A00A* C2014 01 01.26257 05 32 35.55 +13 59 45.0</td>
<td>19.1 VqEA002G96</td>
</tr>
<tr>
<td>K14A00A C2014 01 01.26896 05 32 28.89 +13 59 36.7</td>
<td>18.8 VqEA002G96</td>
</tr>
<tr>
<td>K14A00A C2014 01 01.28176 05 32 15.27 +13 59 16.4</td>
<td>18.9 VqEA002G96</td>
</tr>
<tr>
<td>K14A00A C2014 01 01.30701 05 31 47.92 +13 58 21.1</td>
<td>19.0 VqEA002G96</td>
</tr>
<tr>
<td>K14A00A C2014 01 01.30828 05 31 46.54 +13 58 17.9</td>
<td>19.0 VqEA002G96</td>
</tr>
<tr>
<td>K14A00A C2014 01 01.30955 05 31 45.15 +13 58 14.6</td>
<td>19.1 VqEA002G96</td>
</tr>
<tr>
<td>K14A00A C2014 01 01.31081 05 31 43.79 +13 58 11.1</td>
<td>18.9 VqEA002G96</td>
</tr>
</tbody>
</table>
Astrometry Data Exchange Standard (ADES) format

```xml
<?xml version='1.0' encoding='UTF-8'?>
<ades version="2017">
<obsBlock>
<obsContext>
<observatory>
<mpcCode>658</mpcCode>
<name>Dominion Astrophysical Observatory</name>
</observatory>
<submitter>
<name>D. D. Balam</name>
</submitter>
<telescope>
<aperture>1.82</aperture>
<design>Reflector</design>
<detector>CCD</detector>
</telescope>
<observers>
<name>D. D. Balam</name>
</observers>
<measurers>
<name>D. D. Balam</name>
</measurers>
<comment>
This is a comment
</comment>
</obsContext>
<obsData>
<optical>
<trkSub>2VA7520</trkSub>
<mode>CCD</mode>
<stn>658</stn>
<obsTime>2018-11-08T00:41:11Z</obsTime>
<ra>73°43'26"</ra>
<dec>37°23'57"</dec>
<rmsRA>0.15</rmsRA>
<rmsDec>0.15</rmsDec>
<astCat>2MASS</astCat>
</optical>
<optical>
<trkSub>2VA7520</trkSub>
<mode>CCD</mode>
<stn>658</stn>
<obsTime>2018-11-08T00:48:51Z</obsTime>
<ra>73°42'58"</ra>
<dec>37°24'10"</dec>
<rmsRA>0.15</rmsRA>
<rmsDec>0.15</rmsDec>
<astCat>2MASS</astCat>
</optical>
</obsData>
</obsBlock>
</ades>
```
Typical Sequence of Events

1. Receive astrometry, carry out sanity checks, and archive the data

2. **If the observations correspond to a known object, natural or artificial, process later in the background.**

3. If object flagged as a possible NEO, or the location and motion suggest an NEO, post on NEO Confirmation Page.

4. Otherwise, into the Isolated Tracklet File (ITF).

5. NEO Confirmation Page entry is updated as new observations arrive, until enough data are available for a Minor Planet Electronic Circular (MPEC).
Typical Sequence of Events

1. Receive astrometry, carry out sanity checks, and archive the data

2. **If the observations correspond to a known object, natural or artificial, process later in the background.** This is true of ~90% of the observations.

3. If object flagged as a possible NEO, or the location and motion suggest an NEO, post on NEO Confirmation Page.

4. Otherwise, into the Isolated Tracklet File (ITF).

5. NEO Confirmation Page entry is updated as new observations arrive, until enough data are available for a Minor Planet Electronic Circular (MPEC).
Typical Sequence of Events

1. Receive astrometry, carry out sanity checks, and archive the data

2. If the observations correspond to a known object, natural or artificial, process later in the background. This is true of ~90% of the observations.

3. If object flagged as a possible NEO, or the location and motion suggest an NEO, post on NEO Confirmation Page.

4. Otherwise, into the Isolated Tracklet File (ITF).

5. NEO Confirmation Page entry is updated as new observations arrive, until enough data are available for a Minor Planet Electronic Circular (MPEC).
Digest2 is a tracklet classifier that outputs a score that tracks the likelihood that the tracklet represents an NEO.

Tracklet classification is an essential capability for the NEOCP, on the critical path for the MPC's primary funded task.

The MPC applies Digest2 to all submitted candidates for the NEOCP and posts all objects scoring above a threshold.

The algorithm is a statistical ranging algorithm.

Source code is publicly available.
The NEO Confirmation Page

Please ensure you are familiar with the notes at the bottom of this page.

Problems? Comments?

Page last updated on Oct. 28.934 UTC.

Select object(s) from the current list of objects needing confirmation (NEO desirability score, discovery date, rough current position and magnitude given, as well as number of observations, arc, nominal H and number of days since it was last observed):

- All objects with $V = -30$ to 30, with DecL between -90° and +90°, with an NEO desirability score of 0% to 100%.

or just the objects selected below: Deselect All | Select All

<table>
<thead>
<tr>
<th>Temp Design</th>
<th>Score</th>
<th>Discovery</th>
<th>RA</th>
<th>DecL</th>
<th>V</th>
<th>Updated</th>
<th>Note</th>
<th>NEOID</th>
<th>Arc</th>
<th>H</th>
<th>Not Seen/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZUBD95A</td>
<td>51</td>
<td>2018 10 28.4</td>
<td>08 59.9</td>
<td>+38 30</td>
<td>21.4</td>
<td>Updated Oct. 28.52 UT</td>
<td>7 0.08</td>
<td>18.3</td>
<td>0.426</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBD835</td>
<td>78</td>
<td>2018 10 28.3</td>
<td>01 50.7</td>
<td>+45 42</td>
<td>20.9</td>
<td>Updated Oct. 28.47 UT</td>
<td>10 0.12</td>
<td>20.4</td>
<td>0.487</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBD70C</td>
<td>88</td>
<td>2018 10 28.3</td>
<td>02 08.1</td>
<td>+40 40</td>
<td>19.7</td>
<td>Updated Oct. 28.91 UT</td>
<td>15 0.59</td>
<td>24.8</td>
<td>0.052</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBD74B</td>
<td>100</td>
<td>2018 10 28.2</td>
<td>01 20.2</td>
<td>+39 10</td>
<td>20.8</td>
<td>Updated Oct. 28.89 UT</td>
<td>14 0.58</td>
<td>25.4</td>
<td>0.060</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBG666</td>
<td>100</td>
<td>2018 10 28.2</td>
<td>00 06.9</td>
<td>+32 33</td>
<td>19.8</td>
<td>Updated Oct. 28.84 UT</td>
<td>12 0.56</td>
<td>25.7</td>
<td>0.107</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBG669</td>
<td>93</td>
<td>2018 10 28.2</td>
<td>01 11.9</td>
<td>+37 56</td>
<td>19.8</td>
<td>Updated Oct. 28.85 UT</td>
<td>15 0.57</td>
<td>25.5</td>
<td>0.092</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBG662</td>
<td>46</td>
<td>2018 10 28.2</td>
<td>00 48.0</td>
<td>+43 29</td>
<td>21.3</td>
<td>Updated Oct. 28.55 UT</td>
<td>11 0.16</td>
<td>18.7</td>
<td>0.507</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBG661</td>
<td>69</td>
<td>2018 10 28.2</td>
<td>00 49.2</td>
<td>+43 08</td>
<td>21.0</td>
<td>Updated Oct. 28.44 UT</td>
<td>8 0.16</td>
<td>19.7</td>
<td>0.506</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBG660</td>
<td>63</td>
<td>2018 10 28.2</td>
<td>00 29.2</td>
<td>+43 10</td>
<td>21.1</td>
<td>Updated Oct. 28.53 UT</td>
<td>11 0.18</td>
<td>18.5</td>
<td>0.500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBG662</td>
<td>79</td>
<td>2018 10 28.2</td>
<td>00 28.2</td>
<td>+42 23</td>
<td>21.3</td>
<td>Updated Oct. 28.45 UT</td>
<td>11 0.18</td>
<td>21.4</td>
<td>0.500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBG666</td>
<td>55</td>
<td>2018 10 28.2</td>
<td>23 44.7</td>
<td>+39 21</td>
<td>20.7</td>
<td>Updated Oct. 28.37 UT</td>
<td>12 0.15</td>
<td>19.7</td>
<td>0.580</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBS62C</td>
<td>25</td>
<td>2018 10 27.4</td>
<td>09 00.0</td>
<td>+51 08</td>
<td>21.3</td>
<td>Updated Oct. 28.59 UT</td>
<td>16 1.05</td>
<td>17.9</td>
<td>0.452</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBS610</td>
<td>83</td>
<td>2018 10 27.3</td>
<td>07 41.7</td>
<td>+52 56</td>
<td>21.2</td>
<td>Updated Oct. 28.47 UT</td>
<td>20 1.09</td>
<td>19.3</td>
<td>0.475</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBS586</td>
<td>59</td>
<td>2018 10 27.1</td>
<td>19 15.4</td>
<td>+52 11</td>
<td>20.4</td>
<td>Updated Oct. 28.83 UT</td>
<td>24 1.63</td>
<td>10.2</td>
<td>0.120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P205Shk</td>
<td>40</td>
<td>2018 10 26.4</td>
<td>01 27.6</td>
<td>+42 47</td>
<td>20.5</td>
<td>Updated Oct. 28.55 UT</td>
<td>20 1.82</td>
<td>18.2</td>
<td>0.626</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A10yG7</td>
<td>90</td>
<td>2018 10 26.5</td>
<td>04 07.5</td>
<td>-11 10</td>
<td>17.7</td>
<td>Updated Oct. 28.46 UT</td>
<td>28 1.89</td>
<td>21.8</td>
<td>0.489</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A10R6G6</td>
<td>88</td>
<td>2018 10 26.5</td>
<td>04 22.5</td>
<td>-23 55</td>
<td>17.3</td>
<td>Updated Oct. 28.38 UT</td>
<td>22 1.79</td>
<td>20.1</td>
<td>0.571</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBCC6</td>
<td>38</td>
<td>2018 10 21.4</td>
<td>03 03.0</td>
<td>+44 19</td>
<td>20.9</td>
<td>Updated Oct. 28.36 UT</td>
<td>22 6.89</td>
<td>17.8</td>
<td>0.607</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBA2EB</td>
<td>10</td>
<td>2018 10 20.4</td>
<td>02 11.8</td>
<td>+17 10</td>
<td>19.8</td>
<td>Updated Oct. 28.20 UT</td>
<td>29 7.75</td>
<td>19.4</td>
<td>0.753</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ZUBC856</td>
<td>10</td>
<td>2018 10 20.3</td>
<td>01 41.8</td>
<td>+20 09</td>
<td>20.7</td>
<td>Updated Oct. 28.20 UT</td>
<td>26 7.79</td>
<td>19.6</td>
<td>0.752</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The information in the table (including any PCCP objects) is available in a text file. The layout of this file matches the table layout exactly, except that the R.A. is converted to decimal hours and the Decl. to decimal degrees.
Typical Sequence of Events

1. Receive astrometry, carry out sanity checks, and archive the data

2. If the observations correspond to a known object, natural or artificial, process later in the background. This is true of ~90% of the observations.

3. If object flagged as a possible NEO, or the location and motion suggest an NEO, post on NEO Confirmation Page.

4. **Otherwise, into the Isolated Tracklet File (ITF).**

5. NEO Confirmation Page entry is updated as new observations arrive, until enough data are available for a Minor Planet Electronic Circular (MPEC).
Isolated Tracklet File (ITF)

Monthly additions of tracklets to the ITF.

Courtesy of A. Mamoutkine/T. Spahr (SBN)
Typical Sequence of Events

1. Receive astrometry, carry out sanity checks, and archive the data

2. If the observations correspond to a known object, natural or artificial, process later in the background. This is true of ~90% of the observations.

3. If object flagged as a possible NEO, or the location and motion suggest an NEO, post on NEO Confirmation Page.

4. Otherwise, into the Isolated Tracklet File (ITF).

5. NEO Confirmation Page entry is updated as new observations arrive, until enough data are available for a Minor Planet Electronic Circular (MPEC).
Minor Planet Electronic Circular (MPEC)

M.P.E.C. 2018-U19
Issued 2018 Oct. 19, 14:42 UT

The Minor Planet Electronic Circulars contain information on unusual minor planets and routine data on comets. They are published on behalf of Division F of the International Astronomical Union by the Minor Planet Center, Smithsonian Astrophysical Observatory, Cambridge, MA 02138, U.S.A.

Prepared using the Tamkin Foundation Computer Network

MPC@FA.HARVARD.EDU
URL https://www.minorplanetcenter.net/ ISSN 1523-6714

2018 UA

Observations:

X18000A C2018 10 19.16634 23 45 19.04 +17 27 05.0 18.9 GVEU019703
X18000A C2018 10 19.17684 23 45 21.32 +17 26 30.2 VEU019703
X18000A C2018 10 19.18209 23 45 22.30 +17 26 10.4 18.6 GVEU019703
X18000A C2018 10 19.21348 23 45 28.52 +17 23 47.3 18.5 GVEU019703
X18000A C2018 10 19.21674 23 45 29.11 +17 23 29.3 VEU019703
X18000A C2018 10 19.22127 23 45 30.02 +17 23 03.4 18.2 GVEU019703
X18000A C2018 10 19.31492 23 46 20.27 +17 00 10.8 17.4 RoEUD19691
X18000A C2018 10 19.36026 23 46 30.81 +17 00 00.2 17.3 RoEUD19691
X18000A C2018 10 19.37111 23 46 31.90 +16 59 39.4 17.3 RoEUD19691
X18000A C2018 10 19.35216 23 46 37.26 +16 58 00.0 17.2 RoEUD19291
X18000A C2018 10 19.35336 23 46 38.59 +16 57 35.8 17.2 RoEUD19291
X18000A C2018 10 19.35459 23 46 39.96 +16 57 10.8 17.1 RoEUD19291
X18000A C2018 10 19.37528 23 47 07.44 +16 49 23.4 17.0 RoEUD19691
X18000A C2018 10 19.37628 23 47 09.00 +16 48 58.1 17.0 RoEUD19691
X18000A C2018 10 19.37728 23 47 10.58 +16 48 31.1 17.2 RoEUD19691
X18000A C2018 10 19.44188723 59 47.84 +18 31 50.9 16.3 GVEU01962
X18000A C2018 10 19.44303023 59 56.39 +18 32 11.9 16.3 GVEU01962
X18000A C2018 10 19.44303080 00 13.18 +18 32 53.3 16.3 GVEU01962

Observer details:

291 LPL/Spacewatch II. Observer R. S. McMillan. 1.8-m f/2.7 reflector + CCD.
691 Steward Observatory, Kitt Peak. Observer R. S. McMillan. 0.9-m f/3 reflector + CCD.
Q62 IfTelescope Observatory, Siding Spring. Observer M. Suzuki. 0.5-m reflector + CCD.

Orbital elements:

2018 UA

Earth MOID = 0.0002 AU

Ephemeris:

2018 UA

a, e, i = 1.39, 0.45, 3

Close approach of Earth
Further observations of this object are very much desired. Unless there are serious problems with much of the astrometry listed below, strongly hyperbolic orbits are the only viable solutions. Although it is probably not too serious to compute meaningful original and future barycentric orbits, given the very arc of observations, the orbit below has $e = 1.2$ for both values. If further observations confirm the unusual nature of this orbit, this object may be the first clear case of an interstellar comet.

Observations:

<table>
<thead>
<tr>
<th>Date</th>
<th>JD</th>
<th>Position</th>
<th>Proper Motion</th>
<th>Meas. Unc.</th>
<th>Obs. Unc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2017</td>
<td>018.47298</td>
<td>01 59 57.442±02 06 04.30</td>
<td>19.8 TLEU181F51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>018.49990</td>
<td>01 59 06.910±02 07 20.12</td>
<td>LKEU181F51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>018.39715</td>
<td>01 34 55.362±02 45 03.20</td>
<td>19.9 TLEU181F51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>018.40837</td>
<td>01 34 36.745±02 45 28.24</td>
<td>19.9 TLEU181F51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>018.41968</td>
<td>01 34 21.948±02 45 53.55</td>
<td>20.1 TLEU181F51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>018.43106</td>
<td>01 34 05.174±02 46 18.89</td>
<td>20.1 TLEU181F51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>018.86072</td>
<td>01 24 07.89±03 01 07.5</td>
<td>19.6 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>018.86492</td>
<td>01 24 02.21±03 01 16.3</td>
<td>19.8 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>018.86905</td>
<td>01 23 56.69±03 01 24.7</td>
<td>20.3 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>019.940934011</td>
<td>22 22.288±03 03 53.76</td>
<td>20.3 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>019.9473901011</td>
<td>22 18.372±03 03 59.57</td>
<td>20.3 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.17250</td>
<td>01 17 27.47±03 11 07.8</td>
<td>19.9 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.17348</td>
<td>01 17 26.22±03 11 09.6</td>
<td>20.2 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.17448</td>
<td>01 17 24.96±03 11 11.3</td>
<td>20.2 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.17546</td>
<td>01 17 23.73±03 11 13.0</td>
<td>20.6 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.222371</td>
<td>00 55 56.30±03 39 16.9</td>
<td>20.2 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.22623</td>
<td>00 55 57.37±03 39 20.5</td>
<td>19.5 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.22877</td>
<td>00 55 57.19±03 39 24.2</td>
<td>19.6 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.37476</td>
<td>00 55 56.71±03 42 45.0</td>
<td>20.4 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.37904</td>
<td>00 55 56.23±03 42 49.0</td>
<td>20.2 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.38132</td>
<td>00 55 52.35±03 42 53.7</td>
<td>20.4 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.229708</td>
<td>00 55 56.27±04 01 25.0</td>
<td>20.7 TVEU181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.30018</td>
<td>00 55 56.92±04 01 29.3</td>
<td>20.7 TVEU181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.30512</td>
<td>00 55 49.76±04 01 33.5</td>
<td>20.7 TVEU181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.46548</td>
<td>00 44.84±04 04 55.4</td>
<td>20.7 TVEU181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.47027</td>
<td>00 41.16±04 04 59.9</td>
<td>20.7 TVEU181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.47506</td>
<td>00 39.37±04 05 04.8</td>
<td>19.9 TVEU181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.18830</td>
<td>00 31 05.5±04 16 02.6</td>
<td>20.4 TVEU181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.18847</td>
<td>00 30 56.6±04 16 08.7</td>
<td>20.1 TVEU181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.20284</td>
<td>00 30 51.76±04 16 14.6</td>
<td>20.4 TVEU181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.233995</td>
<td>00 20 19.04±04 30 08.4</td>
<td>20.9 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.23917</td>
<td>00 19 16.75±04 30 12.3</td>
<td>20.9 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.24438</td>
<td>00 20 13.82±04 30 15.6</td>
<td>21.0 TVER181H06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2017</td>
<td>020.24957</td>
<td>00 20 10.85±04 30 19.7</td>
<td>20.7 TVEU181H06</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Observer details:

104 San Marcello Pistoiese. Observers P. Bacci, M. Maestripieni. Measurers
P. Bacci, L. Testi, G. Paglioli. 0.60-m f/4 reflector + CCD.
291 LPL/Spacewatch. Observer R. A. Mastaler. 1.8-m f/2.7 reflector + CCD.
334 Farpoint Observatory. Observer G. Hug. 0.69-m reflector + CCD.
926 Tenagra II Observatories. Observers M. Schwartz, P. A. Holczer. Measurers
M. Schwartz. 0.81-m f/7 Ritchey-Chretien + CCD.
F51 Pan-STARRS I. Haleakula. Observers J. Bulger, T. Lowe, A. Schultz,
M. Willsen. Observers K. Chambers, L. Demeure, R. Flewelling, M.
Huber, E. Lilly, E. Magnier, R. Wainscoat, C. Waters, R. Weryk. 1.8-m
Ritchey-Chretien + CCD.
G96 Mt. Lemmon Survey. Observer G. J. Leonard. Measurers E. J. Christensen,
D. C. Fuls, A. R. Gibbs, A. D. Grauer, J. A. Johnson, R. A. Kowalski,
1.5-m reflector + 10A CCD.
Current MPC Focus Areas

• Legacy System Migration
• New MPC Data Format
• New Algorithms and Services
Legacy System Migration

• We currently have a hybrid VMS-Linux system

• We are in the midst of a major legacy migration project, moving the remaining VMS processes to Linux machines.

Drivers, Features, and Goals of New System

• Full MPC staff capable of operating, maintaining, and developing the system
  • Modern code base: Linux, Python, Fortran/C(++,), Git, PostgreSQL
  • Performance and scaling to support a 10-100x data flow increase in the coming decade.
  • Support Astrometry Data Exchange Standard (ADES) format to handle better data (GAIA, etc.)
  • Provide full documentation.
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](https://minorplanetcenter.net/iau/info/ADES.html)
  - Test functionality available
- Assigning submissionsIDs & observationIDs
- Still accepting obs80 format

ADES Data Submission

Contents

- Astrometry Data Exchange Standard
- "Valid" ADES and submissions
- Submission procedures
  - HTTP
  - W3C schema validation
  - Enumerated field values
  - Other restrictions
  - Personally identifiable Information
- Additional resources at the GitHub repository
- Problems
New Algorithms: Linking

- Observed from Earth, asteroid trajectories are highly nonlinear
- This, with the high density of asteroids makes naïve linking difficult
- Unknown parameters (asteroid radial distance and velocity).
- Sparse observations can be separated by weeks, months, or years
- Brute force is impractical with 14m observations
New Algorithms: Linking

- Iterate over parameters (heliocentric distances and radial velocities)
- Apply a heliocentric transformation to a common reference time.
- Search for clusters.
- New solution is $O(n \log n)!$


New Algorithms: Faster MPChecker

**MPChecker** allows the user to query for nearby minor planets.

Given observatory code, date/time, RA/Dec, and search radius→ list of asteroids

This is used heavily by a variety of communities.

Current external version is brute force and takes a few seconds.

New approach is ~80x faster, and there is room for improvement.

- Precompute the geocentric RA/Decs of all MPs on daily intervals
- Organize the MPs by date/time and sky region (HEALPix)
- A query to MPChecker quickly figures out which sky regions are involved and which MPs might be in the neighborhood.
- Computes accurate positions of just those MPs from the designated observatory.
- Generates statistically robust uncertainty regions.
Summary

The Minor Planet Center is playing a key role in the search for NEOs.

It’s a challenging task, but we are keeping up.

We are in the midst of a major legacy migration project.

We are developing new algorithmic approaches.

We are planning for a massive increase in data volume.
Thank You

IF I HAD MORE TIME I WOULD WRITE A SHORTER LETTER.

BLAISE PASCAL

QuoteFinal.com
The MPC is hiring

- 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

See the SAO employment opportunities page:
https://www.cfa.harvard.edu/hr/postings/18-62.html
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
- Melissa Brucker
- Tyler Linder
- Larry Denneau (UH)
- Davide Farnocchia (JPL)
THE VIEW FROM THE SUN
THE VIEW FROM THE SUN
THE VIEW FROM THE SUN
THE VIEW FROM THE SUN
THE VIEW FROM THE SUN
THE VIEW FROM THE SUN
Faster n-body integrators

Symplectic n-body map:

A modified version of the Wisdom & Holman (1991) approach.

Uses canonical heliocentric coordinates.
Interleaves advances along Keplerian arcs with interactions terms.

Should be 10x faster for same accuracy.

The positions of the sun, large planets, and moon come from JPL’s
DE430 ephemeris but are stored in memory.

Integrates the orbits of the large asteroids in the field of themselves and
the sun and large planets.

Integrates the orbits of the small asteroids in the field of the sun, large
planets, and large asteroids.

Adding functionality for best handling close approaches.
Adding in gravitational harmonics where needed.
Adding in GR terms where needed.
MPC 1-opposition orbits versus year

- PS1 begins.
- Fainter limiting magnitude
- ~half of 1-opposition orbits have > 15 day arcs
Exposure Information

What

- Report "pointings" as exposures taken, or a planned sequence
- Community buy-in: PS, ATLAS, Catalina:
- All are welcome!!

Why

- Coordination of NEO follow-up activities
- Internal MPC data pre-processing
- Pre-covery.

How

- Automated submission of JSON file
- [https://www.minorplanetcenter.net/pointings/](https://www.minorplanetcenter.net/pointings/)

WIP

- Current: Testing live submissions
- Nov 1st, 2018: Announcement & Query API
- Mid-Nov 2018: Integrate into NEOCP

E.g.

- For square equatorially-aligned field

```json
{
  "action": "exposed",
  "surveyExpName": "AK101_Jxfp341-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"
}
```