A Proposal for an

Astrometry Data Exchange Standard

to be presented for adoption by

Commission 20: Position & Motion of Minor Planets, Comets & Satellites

of the

International Astronomical Union

Version 2015-June-1

1 Introduction

This document proposes a standard for exchanging astrometric data of small solar system objects, e.g., asteroids, comets, and natural satellites. Astrometry Data Exchange Standard is intended to be proposed for adoption by IAU Commission 20 (Position and Motion of Minor Planets, Comets and Satellites) at the IAU General Assembly to be held in August 2015. For the purpose of this document we will refer to this standard as IAU2015.

In this document we propose a definition of data types/records that will facilitate transmission and storage of astrometric data, as generated by the observers, stored by the MPC, and processed by the orbit computers. In subsequent extensions to the standard we may propose also data types/record structures to handle other data products generated in the process, e.g., orbits and ephemerides.

The standard defines certain data types, which are detailed lists of information that either can or must be included in data submission, storage and exchange. These lists can be thought of either as records, such as the ones in a database, or as object classes, user defined data types, and so on. However, what is defined as part of the standard is the information content, not how these structures are implemented in computer codes handling the data.

The proposed standard is based on an initiative undertaken starting in mid-2014 by S. R. Chesley (JPL), D. Farnocchia (JPL), A. Milani (Univ. Pisa), and F. Spoto (SpaceDyS). The standard was discussed with invited representatives of the interested community during a workshop hosted by the MPC on May 7 and 8, 2015. The present document represents a consensus among the attendees as the best path forward. The MPC workshop attendees were

- A. B. Chamberlin (JPL)
- S. R. Chesley (JPL, IAU Comm. 20 President)
- E. Christensen (Univ. Arizona, Catalina Sky Survey)
- P. W. Chodas (JPL, NASA NEO Program Office Manager)
- L. Denneau (IfA, Univ. Hawaii, ATLAS & Pan-STARRS)
- D. Farnocchia (JPL)
- J. L. Galache (CfA, MPC)
- T. Grav (PSI, NEO-WISE)
- M. J. Holman (CfA, MPC Interim Director)
- R. S. McMillan (Univ. Arizona, Spacewatch)
- M. Micheli (ESA ESRIN, SpaceDys)
- A. Milani (Univ. Pisa, NEODyS, IAU Comm. X.2, incoming President)
- M. Rudenko (CfA, MPC)
- G. B. Valsecchi (INAF, IAU Div. F President)
- G. Williams (CfA, MPC Assoc. Director)

Moreover, the present draft reflects inputs received from J. D. Giorgini (JPL) and D. J. Tholen (IfA, Univ. Hawaii).

2 Motivation

The MPC already has a standard format, referred to as MPC1992, and a message protocol for receiving astrometry, and it uses the same format to redistribute the data to users. This format is limited to 80 columns and comes with limitations such as:

- No characterization of astrometric and photometric errors;
- Insufficient precision in time and angle fields;
- Lack of flexibility and extensibility.

The purpose of this standard is to ensure that all of the useful and available observational information is submitted, permanently stored, and disseminated as needed. Availability of more complete information will allow one to process the data more correctly, leading to better accuracy and reliability. In this way it will be possible to fully exploit the ever improving accuracy and increasing number of both optical and radar observations. For instance, the number of optical observations has increased by two orders of magnitudes in recent decades and the accuracy is soon likely to improve by two orders of magnitude.

3 Requirements

The new standard must have the following key features:

- The number of fields present in the file must be flexible;
- Some fields may be mandatory, others optional or encouraged;
- The format must be compatible with new fields, perhaps devised for local use and not envisioned by the standard;
- Implementation and data processing issues are to be decided and managed locally and should not be prescribed by the data standard beyond what is necessary to efficiently communicate the desired information;
- A format that can be easily converted to plain text for human consultation/editing and email exchange is desirable.
- The standard should discriminate between the data produced by the observers and those that are the output of orbit computers.

To achieve the desired flexibility and extensibility, the defined data types include fields that may be either mandatory or optional. The reason is that some data may not be available: this case will be predominate for historical data that have been stored before the adoption of this standard, but also in the near future not all the observers may be ready to supply them, even if such data necessarily exist in their processing procedure. Optional fields may be left blank, possibly to be supplied later if it becomes feasible. Mandatory fields are required, the data record being considered invalid without them.

The MPC is responsible for permanently storing and for disseminating the data submitted by the observers. To preserve the exact reported values, the content of the fields should be treated as ASCII character strings. Leading and trailing blanks are ignored.

4 Observational data

This section lists the data types that are submitted to the MPC or are otherwise made available by observers. They must be stored and preserved at the MPC, and disseminated to any interested customers. Among the optional fields, some are strongly encouraged and failure to provide them might result in de-weighting of the corresponding observations when fitting an orbit to the observations.

The number of digits in the provided measurements should be consistent with the stated or assumed uncertainty, e.g., no more than 1.5 significant figures beyond the measurement accuracy. The MPC may reject observations reported with a gratuitous number of digits.

4.1 Optical observations

An optical observation contains information about the astrometry and photometry of an image source. It should correspond to a Solar System moving object. Optical observations are usually assembled in tracklets. A tracklet is a group of observations that are confirmed as belonging to the same object by the observer through direct inspection of the frames (e.g., in a blinking sequence), or by a software package (e.g., via great circle fit). A tracklet is typically a set of 3 to 5 ground-based observations of a moving object over a time span of up to a few hours, or anyway from the same night. For objects in the outer solar system a tracklet could be assembled from a few nights of data.

The following table describes the field names for optical observations, including visible and infrared wavelengths. Though not optical, radio interferometry measurements should also be reported in this category. The reported string lengths are to be considered as maxima.

Field	Type	Description
OBJ_ID	19 char	Solar System object identifier in new MPC packed form, containing (if available) number (first 9 characters, e.g., 000000433 for 433) followed by provisional designation (next 10 characters, e.g., K14A00012A for 2014 AA12). Typically filled by follow-up observer for targeted observations. Ultimately validated or filled by the MPC. The MPC will document the new packed form. Mandatory for distribution from the MPC, encouraged for the observer for targeted observations.
TRK_MPC	8 char	Globally unique tracklet identifier assigned by the MPC. Mandatory for the MPC.

TRK_OBS	8 char	Observer assigned tracklet identifier, unique within submission batch. The same as temporary designation for typical survey operations. Mandatory.
OBS_ID	18 char	Unique observation alphanumeric identifier assigned by the MPC. Observers can only fill this field to communicate a correction to an observation previously reported. Mandatory for the MPC.
FRAG	2 char	Fragment designation. Optional.
DISC	1 char	Discovery flag, = '*' if a discovery observation, = '+' if earliest reported observation for an object without a discovery position on the discovery night (only for historical discoveries). Filled by the MPC. Optional.
TECH	1 char	Mode of observation, e.g., C for CCD and P for photographic. Full list provided by the MPC. Mandatory.
REF	12 char	Standard reference field filled by the MPC. Mandatory for the MPC.
SUB_FMT	3 char	Format in which the observation was submitted, e.g., M92 for 80 column format or I15 for this standard. Filled by the MPC. Mandatory for the MPC.
TIME	21 char	UTC time of the observation, YYYYMMDD.ddd (up to 12 decimal digits). Mandatory.
FLAG	6 char	Flag(s) to communicate observing circumstances. List of flags provided by the MPC. Optional.
RA, DEC	Numeric	Astrometric J2000.0 equatorial right ascension and declination in decimal degrees. (See NOTE at bottom of table.) For offset/occultation measurements with respect to a planet/star, the J2000.0 values are ΔRA*COS(DEC) and ΔDEC. Mandatory.
FRM	5 char	Reference frame for reported angular measurements, e.g., 'J2000' for J2000.0 equatorial. Mandatory.
AST_CAT	5 char	Star catalog used for the astrometric reduction or for the occulted star in the case of occultation observations. List of possible catalog codes provided by the MPC. Mandatory for future submissions.

STN	4 char	Observatory code assigned by the MPC. The four character codes will be backward compatible, with a 4th character being added to identify different telescopes on the same site, e.g., 568a, 568b, etc. List of observatory codes provided by the MPC. Mandatory.
PRG	2 char	Program code assigned by the MPC. PRG is used to identify different observing programs/observers at the same telescope. For surveys and other large producers, the MPC will increment PRG for a given observatory code to document a significant operational change reported by the observing team. Optional.
LOG_SNR	Numeric	The log10 of the signal-to-noise ratio of the source in the image integrated on the entire aperture used for the astrometric centroid. Mandatory for future submissions.
RMS_RA, RMS_DEC	Numeric	Random component of the RA*COS(DEC) and DEC uncertainty (1σ) in arcseconds as estimated by the observer as part of the image processing and astrometric reduction. RMS_RA^2 and RMS_DEC^2 are the diagonal elements of the RA-DEC covariance matrix obtained from the astrometric fit. Optional but encouraged.
RMS_CORR	Numeric	Correlation between RA and DEC that may result from the astrometric reduction. It can be especially relevant for trailed images or cases with a poor distribution of reference stars. This is derived from the RA-DEC covariance matrix obtained from the astrometric fit, i.e., the off-diagonal term is RMS_CORR*RMS_RA*RMS_DEC. Optional.
UNC_TIME	Numeric	Estimated time uncertainty in seconds. Unlike the preceding RMS fields, which indicate random errors, this field indicates the presumed level of systematic clock error. This field is generally only used to communicate problems with clock calibration. Optional.
MAG	Numeric	Apparent magnitude in specified band. Optional.
BAND	2 char	Image measurement band. Mandatory if MAG present.
PHOT_CAT	5 char	Star catalog used for the photometric reduction. Mandatory for future submissions if MAG is present.

RA_S, DEC_S	Numeric	J2000.0 right ascension and declination of the star used in the occultation in decimal degrees. Mandatory for occultations.
PHOT_AP	Numeric	Photometric aperture radius in arcseconds. Optional, but encouraged for comets.
NUC_MAG	Logical	Nuclear magnitude flag for comets. 0 for total magnitude (most comet and all asteroid observations), 1 for nuclear magnitude. Primarily used for archival data, PHOT_AP should be used for future. Optional.
RMS_MAG	Numeric	Apparent magnitude uncertainty (1σ) in magnitudes. Optional.
EXP	Numeric	Exposure time in seconds. Optional.
SHW	Numeric	Seeing Full Width Half Max (FWHM) in arcseconds. Optional.
CS_RMS	Numeric	Comparison star RMS in arcseconds. Optional.
NOTE	200 char	Comment provided by the observer. This field can be used to report additional information that is not reportable in the FLAG field, but that may be of relevance for interpretation of the observations. Optional, should be used sparingly by major producers.

NOTE: At the workshop there was considerable discussion on decimal vs. sexagesimal reporting. However, the clear consensus was to opt for decimal degrees since both orbit computers and astrometric reduction tools use decimal degrees internally, and sexagesimal only is an intermediate I/O format. While some operational situations may require sexagesimal values, e.g., for telescope control, we note that conversion scripts are straightforward and that ephemeris generation will continue to provide sexagesimal outputs.

Additional information needs to be supplied for satellite and roving observations, for which the position of the observer is required. Satellite and roving observations can be recognized by the presence and the value of the field SYS.

Field	Type	Description

SYS	7 char	Coordinate system for station coordinates. Roving: • 'WGS84' (geodetic reference ellipsoid, GPS coordinates are normally obtained in this frame) • 'ITRF' (cylindrical) • 'IAU' (IAU planetary cartographic model for bodies other than Earth) Space-based: • 'ICRF_AU' • 'ICRF_KM' (Cartesian). Mandatory for satellite and roving observations.
CTR	Numeric	Origin of the reference system. Use public Horizons codes, e.g., 399 is geocenter, 10 is Sun center (http://naif.jpl.nasa.gov/pub/naif/toolkit_docs/C/req/naif_ids.html). Mandatory for non-terrestrial observations.
POS1, POS2, POS3	Numeric	Station coordinates. • For WGS84: E longitude (deg), latitude (deg), and altitude (m). • For ITRF: E long (deg), R_{xy} (km), R_z (km). • For IAU: longitude (deg), latitude (deg), and altitude (m) as defined by the corresponding IAU cartography standard (http://astrogeology.usgs.gov/groups/IAU-WGCCRE) • For ICRF: J2000.0 equatorial rectangular coordinates (au or km). The number of digits provided should be consistent with the uncertainty of the coordinates. Mandatory for roving and satellite observations.
POS_COV11, POS_COV12, POS_COV13, POS_COV22, POS_COV23, POS_COV33	Numeric	Upper triangular part of POS covariance matrix in same units of POS coordinates (e.g., km^2 if SYS = 'ICRF_KM'). Missing fields are presumed zero. Optional.

4.2 Radar observations

Radar astrometry is reported as either the time delay or Doppler frequency shift between transmitter and receiver. It is fundamentally different from optical astrometry not only because of the different observable, but also because the individual data points are 1-dimensional and of high fractional precision, potentially at the few meter level in accuracy.

Some fields are the same as those used for optical observations:

- OBJ_ID, mandatory for radar observations
- OBS_ID, which can only be supplied by the measurer to report a correction to previously reported astrometry
- TECH to indicate delay or Doppler
- REF
- SUB_FMT
- NOTE
- TIME: since radar astrometry is a normal point representing data taken over an extended period, the observation time is chosen by the measurer to an integral second (usually but not always to an integral minute) and has no error. The time in fractional day must be reported with 12 decimal digits, so that rounding errors are insignificant at the current level of accuracy, e.g., ranging would be affected at the mm level. The exact measurement time can always be obtained by rounding to the nearest UTC second.

The radar specific fields are below.

Field	Type	Description
RAD	Numeric	Value of the observed quantity in s for delay, Hz for Doppler. Mandatory.
RMS_RAD	Numeric	Measurement uncertainty (1σ) in μs for delay, Hz for Doppler. Mandatory.
COM	Logical	Flag to indicate that the observation is reduced to the center of mass. False implies a measurement to the peak power position, which is usually interpreted as the leading edge of the target, with the reflection point being modeled one object radius prior to the center of mass. Mandatory.
FRQ	Numeric	Carrier reference frequency in MHz. Mandatory.
TRX	4 char	Station code of transmitting antenna. List of station codes provided by the MPC. Mandatory.
RCV	4 char	Station code of receiving antenna. List of station codes provided by the MPC. Mandatory.

4.3 Observation submission header

The submission of observational data to the MPC is accompanied by an information header, e.g., to list observers and measurers. Below are the fields to be included in the submission header.

Field	Type	Description
COD	4 char	Observatory code. List of possible observatory codes provided by the MPC. It must be the same as the one in the observation records. (MPC Question: How about radar? Is it RCV or TRX?) Mandatory.
CON	String	Contact name (initials then surname), optional comma then contact address. Mandatory.
ACK	String	Acknowledgement text. Optional. (*)
AC2	String	Valid email address(es) to which the acknowledgement text is sent. Mandatory. (*)
OBS	String	List of observers (initials then surname), comma separated. Mandatory.
MEA	String	List of measurers (initials then surname), comma separated. Mandatory.
TEL	String	Telescope description. Mandatory.
NET	String	Astrometric catalog(s) used for astrometric and photometric reductions. To be reported only if the observations are reduced with respect to a catalog that is not in the list provided by the MPC. Otherwise the information is obtained from the individual observation records.
COM	String	Comment(s). Optional.
TYP	String	Description of type of objects included in batch. It will be used to indicate new NEO candidates or observations of NEOCP objects. Optional.
NUM	Numeric	Number of observations in batch. Optional.
PXS	Numeric	Pixel size in arcseconds. Optional.
DTS	String	Detector array size X x Y. Optional.
DTD	String	Detector description. Optional.
FLT	String	Filter description. Optional.
SWE	String	Description of software for astrometry and photometry. Optional.

SWS	String	Description of software for astrometric solution. Optional.
SWD	String	Description of software for object detection. Optional.
SWM	String	Description of software for measurement. Optional.
COI	String	Name(s) of Co-I(s) (initials then surname), comma separated. Optional.
COL	String	Name(s) of collaborator(s) (initials then surname), comma separated. Optional.
FND	String	Description of funding source. Optional.

(*) – Note that the ACK and AC2 fields are private and will not be publicly distributed by the MPC but only used for the submission process.

5 Observation residuals

Once an orbit is computed by fitting the observational data, some users may wish to exchange the information on the residuals as well as the information on the statistical treatment applied to the observations. These fields are usually filled by orbit computing centers and can be consulted by observers to assess their astrometric performance. None of these fields is required for submitting astrometry to the MPC, nor is the MPC required to store these data in case the observer provides them.

The inclusion of the residuals as part of the standard was discussed at length at the workshop. The reasons for including residuals in the astrometry exchange standard are the following:

- Residuals are generally reflective of the observational errors and, especially for well constrained orbits, are not very sensitive to the dynamical model;
- Observers are interested in knowing the quality of their observations;
- Residuals afford an assessment of the internal consistency of a tracklet, which is not visible in the astrometry itself;
- Availability of residuals facilitates research on the statistical treatment of astrometry and photometry.

5.1 Observation residual header

Residuals not only depend on the astrometric and photometric measurements but also on a specific trajectory, i.e., osculating orbit, dynamical model, and photometric model. This information must be reported in an observation residual header.

Field	Type	Description
ORB_ID	String	Local reference for orbit, e.g., 'JPL solution 7'. Mandatory if residuals are reported.
ORB_PRD	String	Orbit producer. Can be institution, individual, or even email address, e.g., 'MPC'. Mandatory if residuals are reported.
PHOT_MOD	String	Description of the photometric model. Mandatory if photometric residuals are reported and the model is different from the standard H & G model with G=0.15. A value of 'G=0.35' indicates an alternate value of G in the H-G system. Other standard values for this field will be established by the MPC in consultation with the research community.
PHOT_PRD	String	Producer of photometric residuals. Can be institution, individual, or even email address, e.g., 'MPC'. Mandatory if photometric residuals are reported.

5.2 Optical astrometry residuals

Field	Type	Description
RES_RA, RES_DEC	Numeric	Residuals in RA*COS(DEC) and DEC in arcseconds. Optional.
SEL_AST	1 char	Inclusion/rejection flag for astrometry. A/D for automatic accept/delete, a/d for manual accept/delete. Mandatory if RES_RA and RES_DEC present.
SIG_RA, SIG_DEC	Numeric	Adopted RA*COS(DEC) and DEC uncertainties (1σ) in arcseconds. May be different from the observer provided uncertainties. Mandatory if RES_RA and RES_DEC present and different from 1 arcsecond.
SIG_CORR	Numeric	Adopted correlation between RA*COS(DEC) and DEC. May be different from the observer provided correlation. Mandatory if RES_RA and RES_DEC present and different from 0.
SIG_TIME	Numeric	Adopted time uncertainty (1σ) in seconds. May be different from the observer provided uncertainty. Mandatory if RES_RA and RES_DEC present and different from 0.
B_RA, B_DEC	Numeric	Adopted RA*COS(DEC) and DEC biases in arcseconds. Mandatory if RES_RA and RES_DEC present and different from 0.
B_TIME	Numeric	Adopted time bias in seconds. Mandatory if RES_RA and RES_DEC present and different from 0.

5.3 Optical photometry residuals

Field	Type	Description
RES_MAG	Numeric	Photometric residual in magnitudes. Optional.
SEL_PHOT	1 char	Inclusion/rejection flag for photometry. A/D for automatic accept/delete, a/d for manual accept/delete. Mandatory if RES_MAG present.
SIG_MAG	Numeric	Adopted magnitude uncertainty (1σ) in magnitudes. Could be different from the observer provided uncertainty. Mandatory if RES_MAG present and different from the observer provided uncertainty.
B_MAG	Numeric	Adopted photometric bias in magnitudes. Mandatory if RES_MAG present and different from 0.

5.4 Radar residuals

Field	Type	Description
RES_RAD	Numeric	Residual of the radar measurement in μs for delay, Hz for Doppler. Optional
SEL_RAD	1 char	Inclusion/rejection flag for radar astrometry. A/D for automatic accept/delete, a/d for manual accept/delete. Mandatory if RES_RAD present.
SIG_RAD	Numeric	Adopted uncertainty for the radar measurement in μs for delay, Hz for Doppler. Mandatory if RES_RAD present and different from the observer provided uncertainty.

6 Format and Packaging

After extensive discussion at the MPC workshop, a consensus was reached that the new standard should support two file formats. XML was selected as the primary vehicle for exchanging data, in large part because of its advantages for computer input/output applications. Among other modern data exchange standards, XML was judged to have the desired maturity and stability (in terms of published standards, schema, user base and available libraries) in comparison to some more recent developments that are still evolving, e.g., JSON. XML files are more verbose than those of less flexible formats, but they typically afford excellent compression ratios (e.g., 10:1 and better), substantially mitigating file transmission issues.

However, XML is not suited for on-screen viewing and editing, and thus a PSV format (i.e., pipe separated value, similar to CSV) that carries the same information as the XML format will be supported by the standard, although exchange in this format is not encouraged. Rather, we consider it preferable for users to convert PSV files to XML after viewing and editing and before transmission.

Because of its inherent flexibility, there are no significant packaging challenges with XML. A data file may have only observations, only residuals, or both. Also an XML file may have multiple data types (e.g., radar, ground-based optical, space-based optical, occultation or offset observations) within a file without difficulty. And header information is readily absorbed into the XML file structure, including for multiple batches in a single file. Such flexibility can be preserved in the PSV file format, but not with the same elegance afforded by XML.

The standard is case insensitive for the field names (keywords) contained in the files. However, the usage of upper case keywords is recommended for better readability.

The proposed standard will include I/O libraries in a number of programming languages, and conversion scripts to and from XML and PSV. This software will allow for robust error checking, file merging/splitting, and other utility functions.

6.1 Primary exchange format – XML

The exact formulation of the XML format is still under development, but it should be similar to the example given below where a single `BATCH` submission block includes a `HEADER` and a `DATA` block. Multiple `BATCH` blocks may be included in one submission file when, for example, the header information changes within a given submission.

```
<BATCH>
 <HEADER>
  <COD>F51</COD>
  <CON>P. Villa</CON>
  <ACK>New Camera Test</ACK>
  <AC2>pancho.villa@gmail.com</AC2>
  <OBS>P. Villa, F. Madero</OBS>
  <MEA>P. Villa, F. Madero</MEA>
  <TEL>2.24-m University of Hawaii reflector</TEL>
 </HEADER>
 <DATA>
  <OBSDATA>
   <OBS_ID>a1b2c3d4</OBS_ID>
   <OBJ_ID>K15H00076D</OBJ_ID>
   <TRK_OBS>a</TRK_OBS>
   <TRK_MPC>e6f7g8h9</TRK_MPC>
   <TECH>C</TECH>
   <FLAG></FLAG>
   <STN>F51</STN>
   <PRG>3</PRG>
   <TIME>20150425.47</TIME>
   <RA>215.65605</RA>
   <DEC>-13.547872</DEC>
   <AST_CAT>2MA</AST_CAT>
   <RMS_RA>0.15</RMS_RA>
   <RMS_DEC>0.13</RMS_DEC>
   <RMS_COR>0.21</RMS_COR>
   <MAG>21.9</MAG>
```

```
    <PHOT_CAT>2MA</PHOT_CAT>
    <BAND>w</BAND>
    <RMS_MAG>0.25</RMS_MAG>
    <LOG_SNR>0.7</LOG_SNR>
    <NOTE>High winds affected tracking</NOTE>
   </OBS>
   <OBSDATA>
   ...
   </OBSDATA>
   <OBSDATA>
   ...
   </OBSDATA>
   <OBSDATA>
   ...
   </OBSDATA>
  </DATA>
</BATCH>
```

In the XML format users are encouraged to add neither leading nor trailing blanks.

6.2 Secondary format – PSV

Despite its advantages, XML makes it hard to visually inspect observation files and manually edit records, which is sometimes required. Therefore, another accepted exchange format is a simple text Pipe Separated Values (PSV) file. (An example is depicted at right.) Blanks will normally be used as padding to obtain column alignment of the data fields, but this is not strictly necessary. Since the pipe character '|' serves as delimiter it is not an allowed character in the fields defined by this standard. Null fields are empty (i.e., consecutive delimiters: '||') or filled with blanks in the blank-padded format.

```
COD F51
CON Pancho Villa
ACK Thanks
AC2 pancho.villa@gmail.com
OBS P. Villa, F. Madero
MEA P. Villa, F. Madero
TEL 2.24-m University of Hawaii reflector

OBS_ID  |OBJ_ID    |TRK_OBS|TRK_MPC |TECH|FLAG |STN |PRG|TIME           |RA        |DEC       |AST_CAT|RMS_RA|RMS_DEC|RMS_COR|MAG |PHOT_CAT|BAND|RMS_MAG|LOG_SNR|NOTE
a1b2c3d4|K15H00076D|a      |e6f7g8h9|C   |     |F51 |03 |20150425.469150|215.656050|-13.547872|2MA    |0.15  |0.13   |0.21   |21.9|2MA     |w   |0.25   |0.70   |High winds affected tracking
a1b2c3d5|K15H00076D|a      |e6f7g8h9|C   |     |F51 |03 |20150425.493760|215.650858|-13.545606|2MA    |0.16  |0.15   |0.17   |21.5|2MA     |w   |0.23   |1.10   |Cold and sleepy
```

In the PSV format a *data block* includes, in the following order: 1) a header section, 2) a keyword record and 3) data records. Multiple data blocks can be concatenated in one PSV file. The header information is generally optional, but mandatory for MPC submissions. The keyword record is always mandatory. New data blocks (e.g., submission batches) are distinguished by either a new set of header records (i.e., records without the | character) or by a new keyword record. Each data block can have a different keyword list, as defined by the corresponding keyword record. In this way, for instance, different data types (e.g., optical and radar) can be in the same file without necessarily including all possible fields on each data record.

Within a given data block, the header information is given as:

```
HEADER_KEY1 HEADER_VALUE1
HEADER_KEY2 HEADER_VALUE2
…
```

For MPC submissions the first header record must give the COD for the submitting observer. These lines can be recognized when parsing the file since they do not contain a ‘|’ character.

The first non-blank record following the header must be the *keyword record*, a PSV record specifying the keywords and the order that they take in the current batch.
`KEY1 | KEY2 | KEY3 | …`
To readily recognize the keyword record when parsing the file we require that the first keyword be either `OBS_ID` or `OBJ_ID`, even when it has a null value. Thus, the keyword record must have one of these two keywords as the first six non-blank characters.

After the keyword record, the observation data records are reported as
`VALUE1 | VALUE2 | VALUE3 | …`
For easier visual inspection and editing, the PSV file can optionally be blank-padded for column alignment. The blank padding can be extended to the keyword record, which will keep the keywords above their data columns, or the blank padding can include only the data records, which will generally lead to a more compact format.

The standard will also define a default PSV template compliant with the standard, so that observers will have a human readable format that can be widely used for basic astrometric submission purposes. The PSV example shown here, with 163 columns plus the NOTE field, is representative of the form that this default PSV file will take. Conversion utilities will include the option to produce files with the default template. However, use of the default template is not required: the only requirement for submission is the compliance with the general standards detailed in this document.

6.3 Packaging

After adoption by the IAU and the MPC, IAU2015 will become the MPC’s primary means of submission and dissemination and observers are strongly encouraged to adopt the new format as soon as practicable. (The MPC1992 80-column format will be deprecated but continue to be accepted for an indefinite but limited time period.) The submission of IAU2015 observations to the MPC will be possible in three ways:

- Web upload
- cURL
- email (XML only)

The only acceptable format for email submission is anticipated to be XML, either compressed or uncompressed. For the observers who prefer the PSV format, a web interface to enter submission header and observational records will be provided. The backend engine of the web interface will convert the supplied data to XML as a part of the ingestion pipeline at the MPC. The MPC will also disseminate the data as defined by this standard, eventually with the option of downloading the observation residual data and submission headers.

The observational data defined in Sec. 4 must be packaged within a single file. In particular, when satellite or roving observations are exchanged the information on the observer location must be contained in the file. On the other hand, the residuals and the other related fields may be included in the observation file or stored in a separate file. In the case of a single file, the observation residual fields have to be horizontally concatenated to the observational data and the residual header has to be vertically concatenated to the submission header. In the case of two different files, OBS_ID should be reported on each record in the residual file to allow cross-referencing with the observation records.

6.4 Input/Output Software

To support the transition to the new format, software tools will be made publicly available. An ad hoc volunteer software committee was formed at the MPC workshop. Co-chairs are A. Chamberlin and L. Denneau. Additional membership includes P. Chodas, T. Grav, S. Keys and A. Milani. The objective of this committee is to facilitate the development of software and libraries in a number of widely used languages, e.g., Perl, Python, FORTRAN, C++. The software packages will include I/O libraries for extending custom software and scripts for file utilities such as error checking, conversion (between PSV and XML), merging and splitting.