

Overview

1. What is a TLE?
2. What problems do they have?
3. What is the new proposed format, OMM?
4. Some details to consider
5. OMM support in the open source ecosystem
6. Conclusions and Q&A

1. What is a TLE?

Well...



pleiszenburg.de

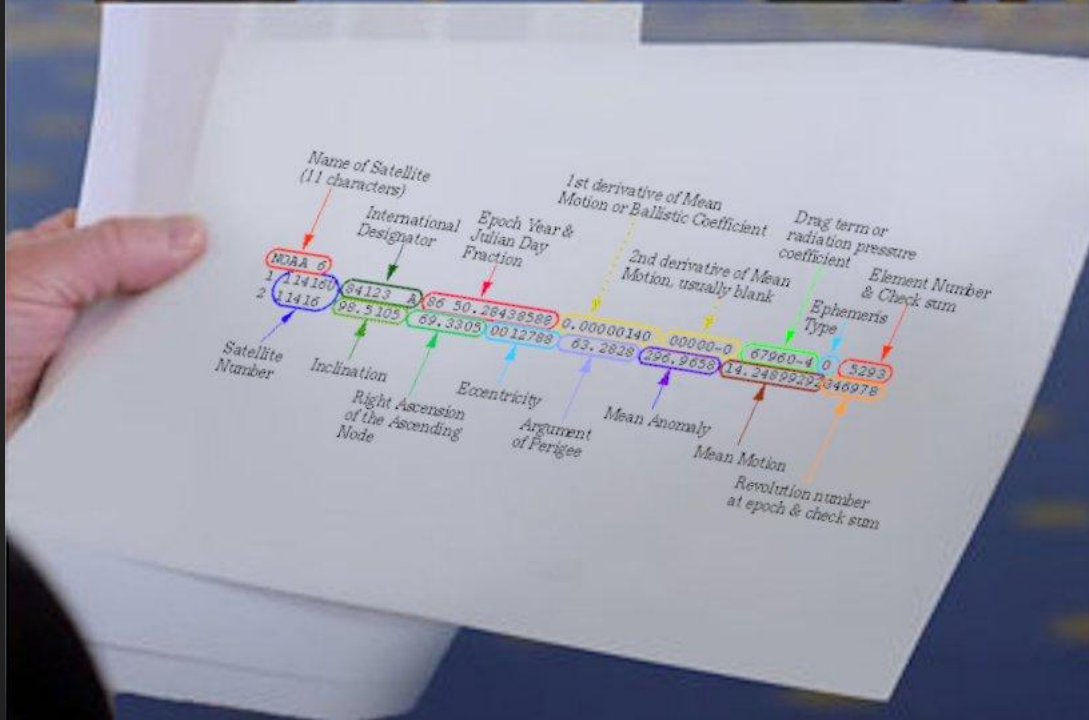
@pleiszenburg

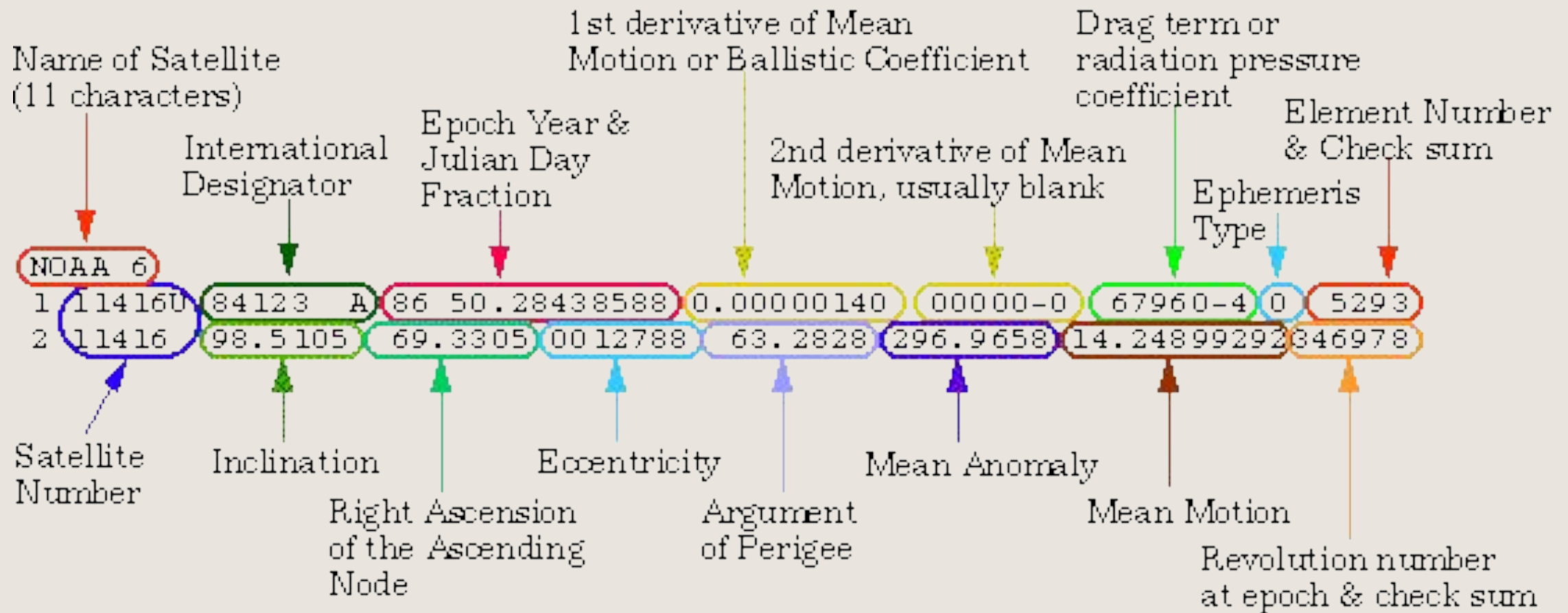
How about "a zombie data encoding system dating back to the punched card days with an amazing Y2056 problem (among other issues)"?

10:26 AM · Sep 24, 2020

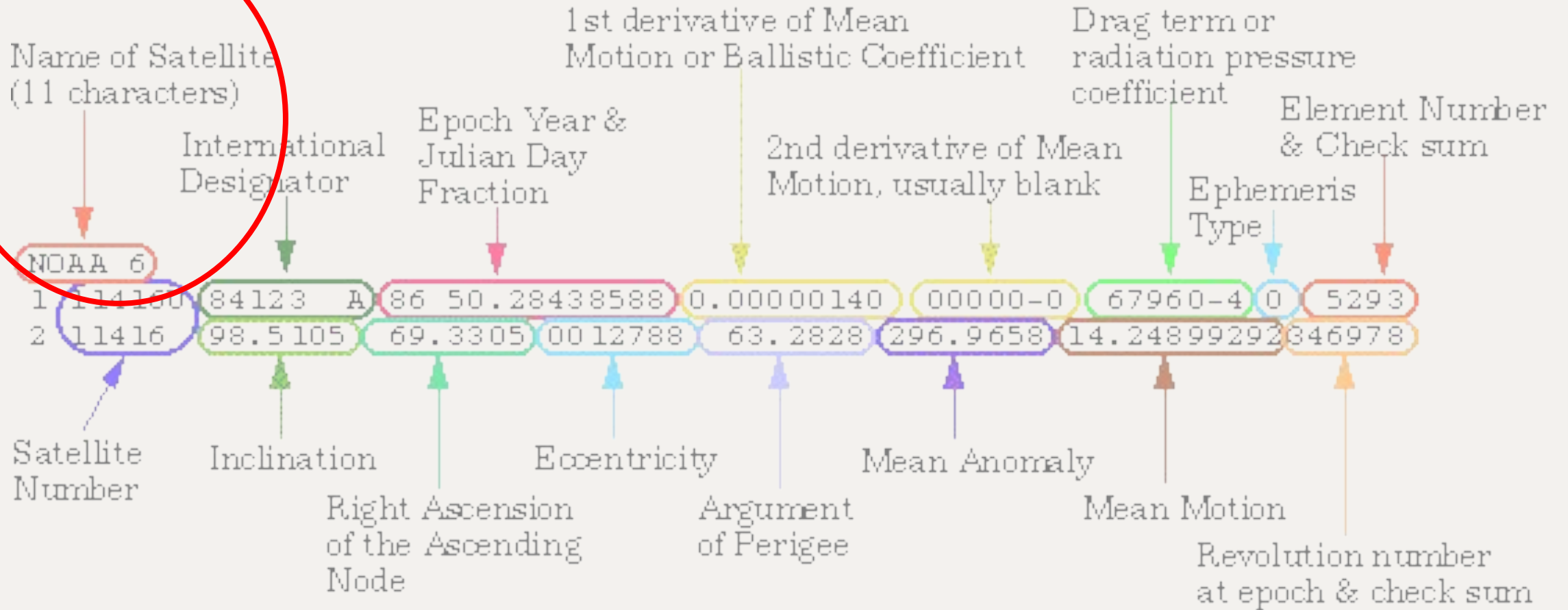
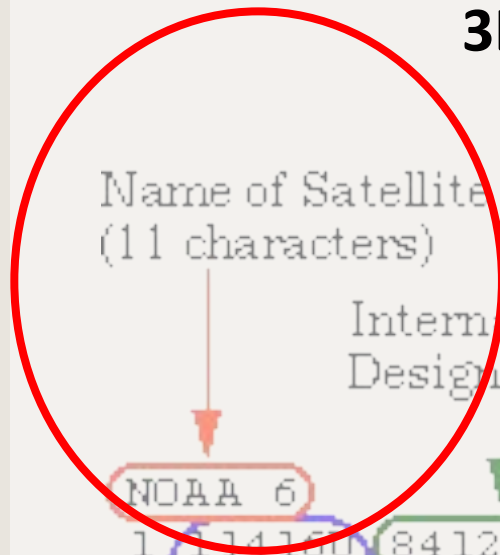


See pleiszenburg.de's other Tweets



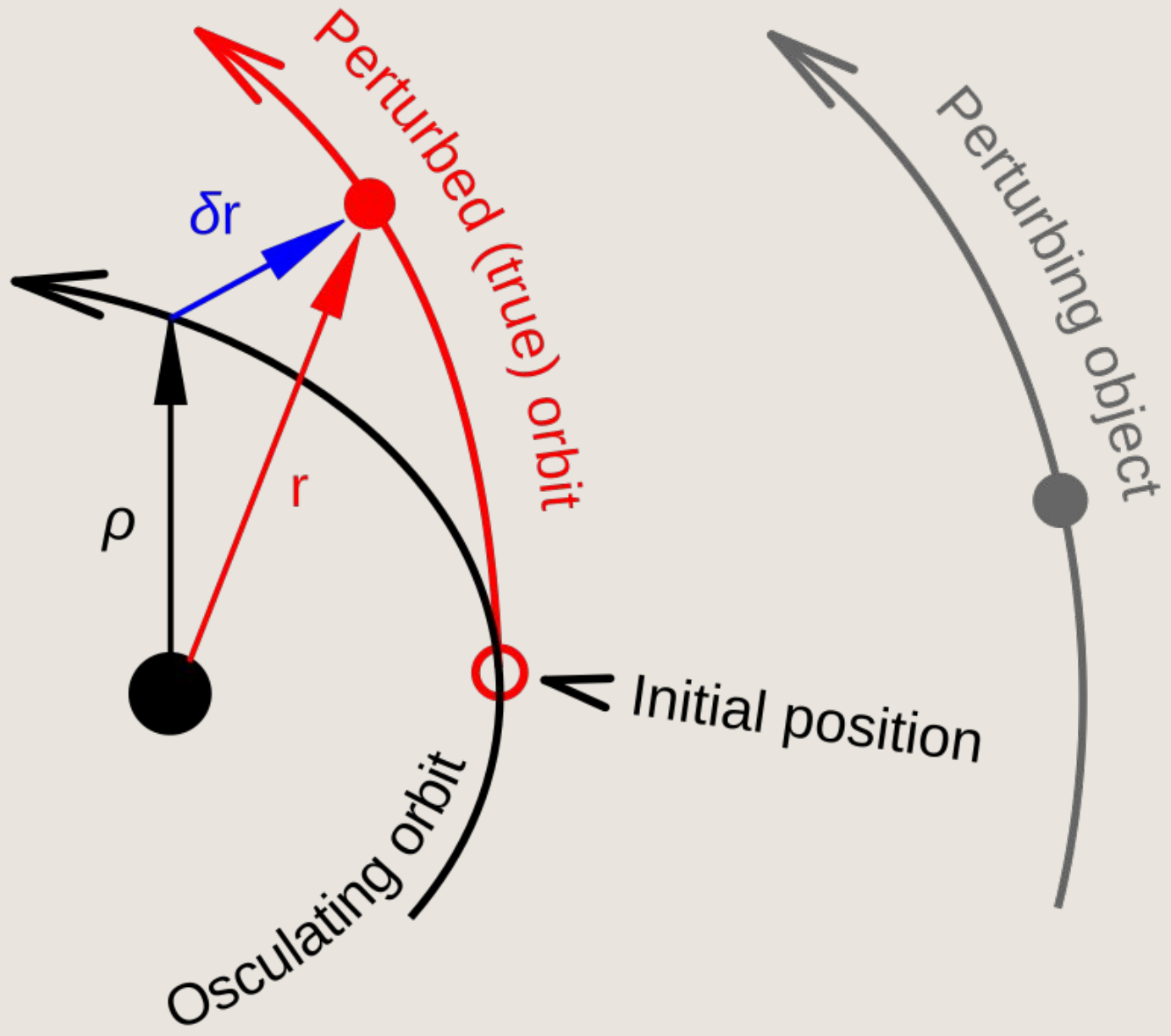


TLE = Two-Line Element
3LE = Three-Line Element



“The US government has provided GP or **general perturbations orbital data** to the rest of the world since the 1970s. These data are produced by fitting observations from the US Space Surveillance Network (SSN) to produce Brouwer mean elements using the SGP4 or Simplified General Perturbations 4 orbit propagator.

Many of you are familiar with this **data in the form of TLEs or Two-Line Element Sets.**”



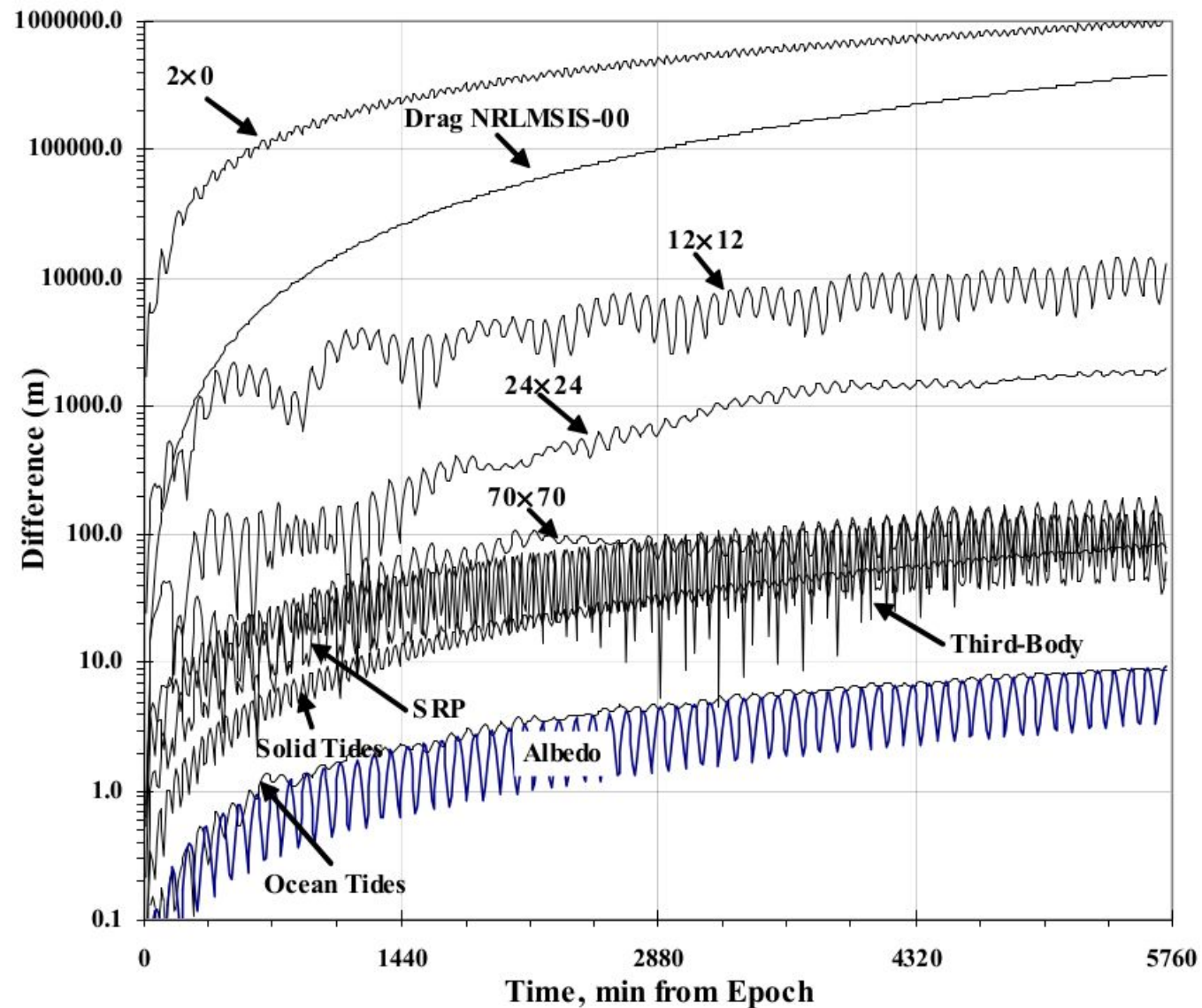


Figure 9-17. Force Model Comparisons — LEO 500×500 km, 97.6° . This figure shows RSS position differences for several forces. This is the JERS satellite, NORAD# 21867 which is also Sun-synchronous.

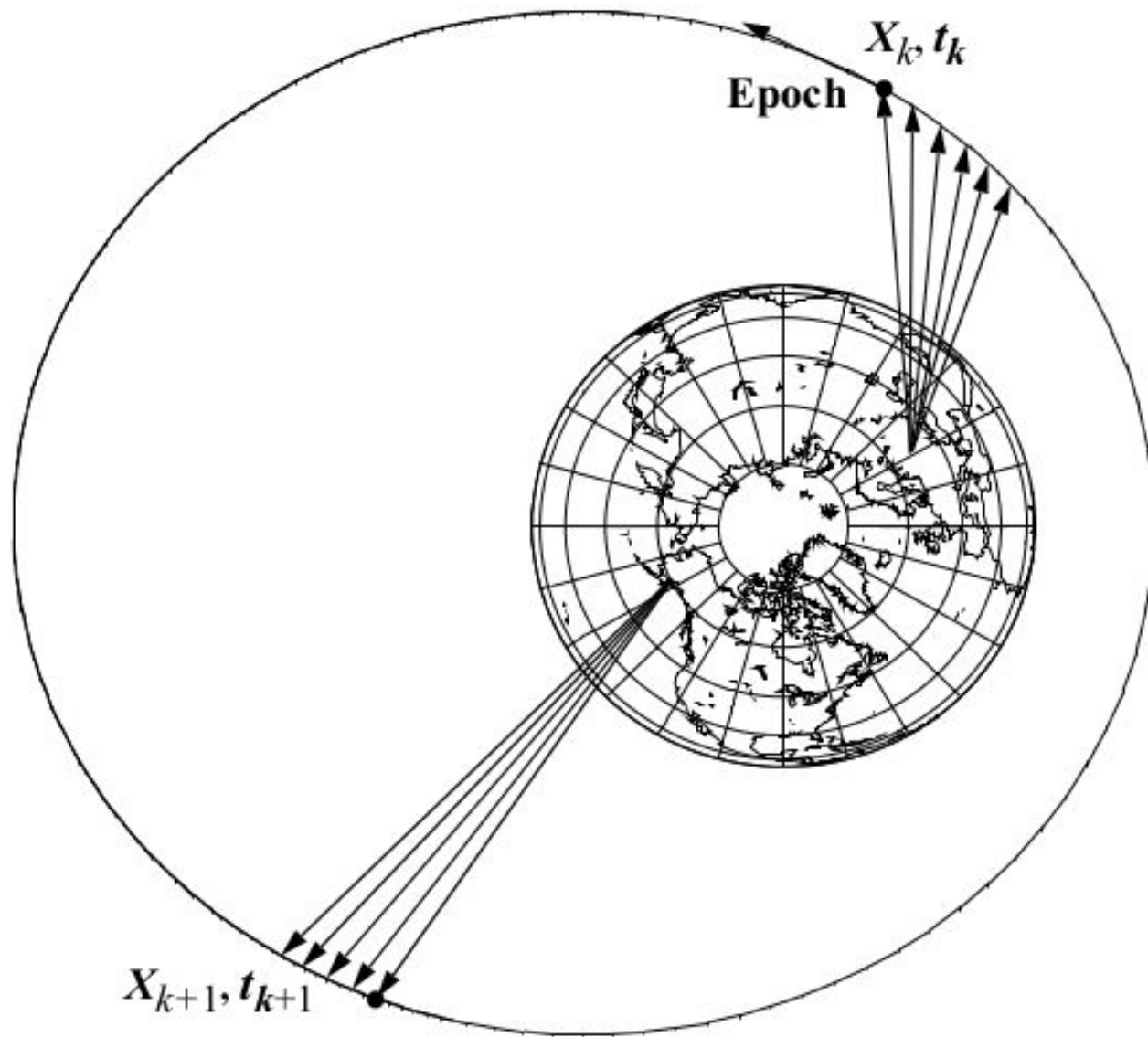


Figure 10-7. Observations from Multiple Passes. Differential correction minimizes the sum of the squares of the residuals by referring all corrections to a single state at a *fixed epoch*, t_k . The Kalman filter finds a state update at each observation time, t_{k+1} .

NORAD Two-Line Element Sets Current Data

Today from
The Center for Space Standards & Innovation

Current as of 2020 Sep 25 14:06:01 UTC (Day 269)

System Notices


Future Availability of TLE Data
Last Updated 2007 May 16



Supplemental TLE Data

[Space Track TLE Retriever 3](#)

[Space Track Data Access](#)

Special-Interest Satellites

[Last 30 Days' Launches](#)  

[Space Stations](#)  

[100 \(or so\) Brightest](#)  



[Active Satellites](#)  

[Analyst Satellites](#)  


[Indian ASAT Test Debris](#)  

[FENGYUN 1C Debris](#)  


[IRIDIUM 33 Debris](#)  

[COSMOS 2251 Debris](#)  

Weather & Earth Resources Satellites

[Weather](#)  

[NOAA](#)  

[GOES](#)  

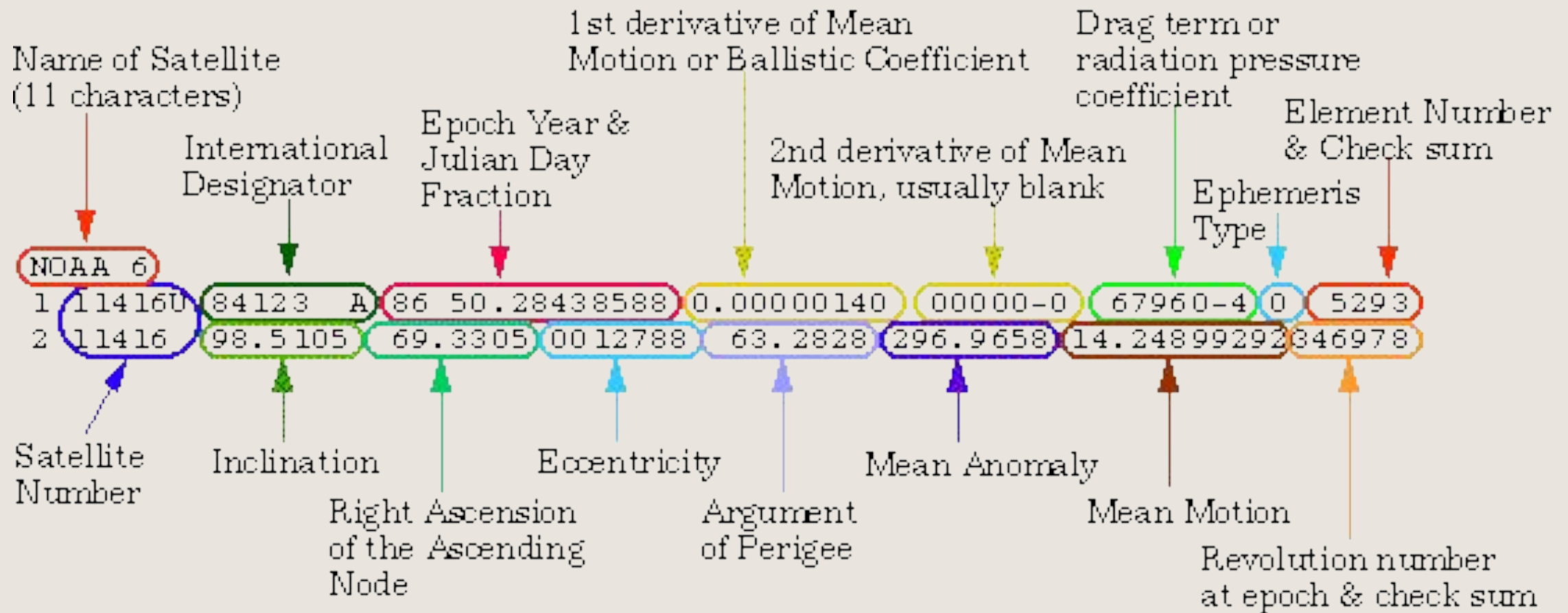
[Earth Resources](#)  

2. What problems do TLEs have?

Quite a few, to be honest

All highly accurate propagation techniques transmit elements using as many digits as possible to minimize unnecessary errors—we want to transmit with the same precision we use to determine the element set. Unfortunately, formats like the TLE set introduce uncertainty by arbitrarily limiting the number of decimal digits for each parameter. Because the element set has finite digits for each variable, we can determine the maximum accuracy available at the epoch through the transmission format. Recognize that, with only eight decimal places given in the epoch time value, it is accurate only to about 0.0004 seconds. We determine this accuracy by assuming the original value is unknown to $\pm 5 \times 10^{-9}$ days, or about $\pm 4.3 \times 10^{-4}$ seconds.

Now consider a roughly circular orbit with an altitude of 390 km and a velocity of about 7.6 km/s. The satellite travels about 4 m in 0.00043^s . The eccentricity is given to seven decimal places. This introduces an error at epoch which for a GEO satellite is about 2 m ($r \approx a\Delta e$). The angles provide only four decimal places, which introduce an uncertainty at epoch of about 6 m for LEO satellites and about 35 m for GEO satellites. Remember that these estimates are based solely on the given data and have nothing to do with their mathematical formation and subsequent use. For precise orbit determination, even these errors probably aren't acceptable.





brianweeden ✓ @brianweeden · Dec 3, 2020



Replying to @brianweeden

5/ Hence why the new S-Band Space Fence is a big deal. For the first time, we can track objects down to a few cm (lower limit has not been publicly revealed) well enough to get orbits
lockheedmartin.com/en-us/products...



brianweeden ✓

@brianweeden

6/ However, the volume of data output by the Space Fence is more than the existing computer systems were designed to handle, and the increase in objects will far exceed the 69,999 object limit in the legacy catalog, as noted by the GAO (gao.gov/assets/660/653...)



Space-Track @SpaceTrackOrg · Nov 25, 2020



The [#satellite](#) catalog is growing faster than ever. When [@18SPCS](#) begins to publish Space Fence elsets for [#SpaceDebris](#) object numbers above 270,000, we will be ready. Users will be able to access them through our GP and GP_History API classes: space-track.org/documentation#...



Space-Track
@SpaceTrackOrg

For systems that can't transition directly to the flexible CCSDS OMM format for the full range of 9-digit object numbers, [@SpaceForceDoD](#) developed [#Alpha5](#) numbering schema as a stopgap that allows their sensors to use up to 339,999 objects in the legacy fixed-width TLE/3LE format

11:50 PM · Nov 25, 2020



***3. What is the
new proposed format, OMM?***

You're gonna love it!





CelesTrak

[TLE Data](#) ▾

[Satellite Catalog](#) ▾

[SOCRATES](#)

[Space Data](#) ▾

[Library](#) ▾

A New Way to Obtain GP Data (aka TLEs)

by Dr. T.S. Kelso

2020 May 27

Background

The US government has provided GP or *general perturbations* orbital data to the rest of the world since the 1970s. These data are produced by fitting observations from the US Space Surveillance Network (SSN) to produce Brouwer mean elements using the SGP4 or *Simplified General Perturbations 4* orbit propagator.

Recommendation for Space Data System Standards

ORBIT DATA MESSAGES

RECOMMENDED STANDARD

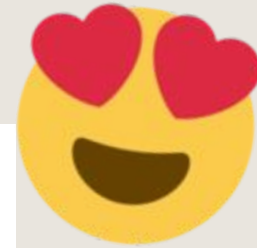
CCSDS 502.0-B-2

Note:
This current
issue includes
all updates through
Technical Corrigendum 1,
dated May 2012.

BLUE BOOK
November 2009



```
OBJECT_NAME: "STARLINK-1329"  
OBJECT_ID: "2020-025A"  
EPOCH: "2020-09-24T22:00:01.999584"  
MEAN_MOTION: 15.05572894  
ECCENTRICITY: 0.0001294  
INCLINATION: 53.0005  
RA_OF_ASC_NODE: 48.0334  
ARG_OF_PERICENTER: 99.318  
MEAN_ANOMALY: 18.6926  
EPHEMERIS_TYPE: 0  
CLASSIFICATION_TYPE: "U"  
NORAD_CAT_ID: 45531  
ELEMENT_SET_NO: 999  
REV_AT_EPOCH: 177  
BSTAR: 0.00097839  
MEAN_MOTION_DOT: 0.00014001  
MEAN_MOTION_DDOT: 0
```



Navigation Data
Messages (NDM)

**Orbit Data Messages
(ODM)**

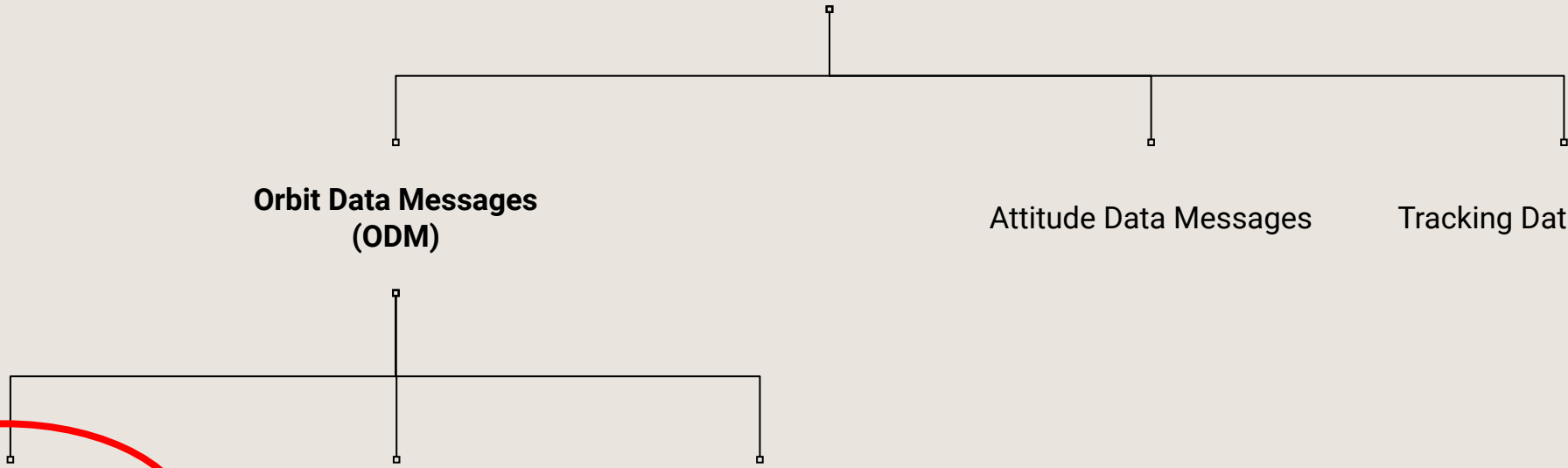
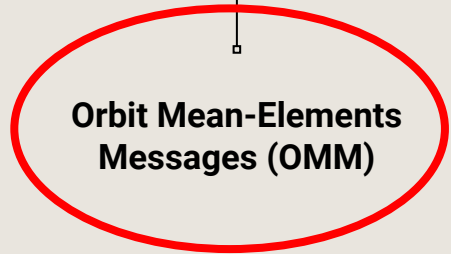
Attitude Data Messages

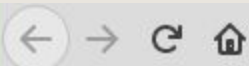
Tracking Data Messages

**Orbit Mean-Elements
Messages (OMM)**

Orbit Parameter
Messages (OPM)

Orbit Ephemeris
Message (OEM)





view-source:https://celestrak.com/NORAD/elements/gp.php?NAME=NUSAT-8&FORMAT=JSON-PRETTY

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[{
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  "OBJECT_ID": "2020-003C",
  "EPOCH": "2020-12-13T01:18:50.258304",
  "MEAN_MOTION": 15.27921509,
  "ECCENTRICITY": 0.0012107,
  "INCLINATION": 97.2988,
  "RA_OF_ASC_NODE": 50.6425,
  "ARG_OF_PERICENTER": 162.6718,
  "MEAN_ANOMALY": 281.7748,
  "EPHEMERIS_TYPE": 0,
  "CLASSIFICATION_TYPE": "U",
  "NORAD_CAT_ID": 45018,
  "ELEMENT_SET_NO": 999,
  "REV_AT_EPOCH": 5081,
  "BSTAR": 9.2874e-5,
  "MEAN_MOTION_DOT": 2.462e-5,
  "MEAN_MOTION_DDOT": 0
}]
```



https://celestrak.com/NORAD/elements/gp.php?NAME=NUSAT-8&FORMAT=XML

This XML file does not appear to have any style information associated with it. The document tree is shown below.

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-<ndm xsi:noNamespaceSchemaLocation="https://sanaregistry.org/r/ndmxml/ndmxml-1.0-master.xsd">
  -<omm id="CCSDS_OMM_VERS" version="2.0">
    -<header>
      <CREATION_DATE/>
      <ORIGINATOR/>
    </header>
    -<body>
      -<segment>
        -<metadata>
          <OBJECT_NAME>NUSAT-8 (MARIE)</OBJECT_NAME>
          <OBJECT_ID>2020-003C</OBJECT_ID>
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          <TIME_SYSTEM>UTC</TIME_SYSTEM>
          <MEAN_ELEMENT_THEORY>SGP4</MEAN_ELEMENT_THEORY>
        </metadata>
        -<data>
          -<meanElements>
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            <MEAN_MOTION>15.27921509</MEAN_MOTION>
            <ECCENTRICITY>.0012107</ECCENTRICITY>
            <INCLINATION>97.2988</INCLINATION>
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            <ARG_OF_PERICENTER>162.6718</ARG_OF_PERICENTER>
            <MEAN_ANOMALY>281.7748</MEAN_ANOMALY>
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```

4. Some details to consider

“Not everything that shines is made out of gold”...

***5. OMM support
in the open source ecosystem***

Could be better, but could also be worse

Name	OMM read	OMM write	Notes
python-sgp4	XML, CSV	In progress	Only elements, no covariances or metadata. JSON write in progress.
Orekit	KVN	Missing	
beyond	KVN, XML	KVN, XML	
python-satellitle	In progress	In progress	JSON and CSV read in progress. XML and JSON write in progress.
<u>oacmpy</u>	KVN, XML	Missing	Only export to CZML.
ccsds-ndm	XML	XML	

Conclusions

- It is already time to switch away from TLE/3LE!
- There is at least one open source library fully supporting OMMs
- Two-way conversion between the old and new format seems to be missing
- XML is hard, also for pros

Thanks a lot!

<hello@juanlu.space>