Commission X-2
Cross-Division A-F
Solar System Ephemerides

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ADES adoption

- During this period, optical observers and data processing centers (MPC, NASA, ESA, NEODyS) consolidated the adoption of the ADES format, which was approved by Commission 20 at the 2015 IAU General Assembly.
- The transition process is on-going, but important applications are already in place such as the NEO Confirmation Page targets data processing for JPL-SSD/CNEOS and NEODyS-NEOScan computations.
- MPC started recently to share the MPC database through several replicas to major players, such as JPL, NEODyS and big surveys

Next generation surveys

- The next major challenge is preparing to process the increased flow of astrometric data due to the start of big surveys such as:
  - Vera Rubin Telescope
  - NEO Surveyor mission
  - Fly-Eye Telescope
- The data flow is expected to increase by up to two orders of magnitude relative to the current data flow, which primarily comes from the operational surveys.
- In view of this increased data volume, the Minor Planet Center (MPC) is making the necessary preparations and major software and data flow architecture reviews are undergoing.
- Similar adaptations are necessary for the other data processing centers.

DE440/DE441 delivered in 2020 by JPL.

- The planetary and lunar ephemerides called **DE440** and **DE441** have been generated by fitting numerically integrated orbits to ground-based and space-based observations (released in 2021). Seven years of new data have been added to compute DE440 and DE441, with improved dynamical models and data calibration.
- The orbit of Jupiter has improved substantially by fitting to the Juno radio range and Very Long Baseline Array (VLBA) data of the Juno spacecraft.
- The orbit of Saturn has been improved by radio range and VLBA data of the Cassini spacecraft, with improved estimation of the spacecraft orbit.
- The orbit of Pluto has been improved from use of stellar occultation data reduced against the Gaia star catalog.
- The ephemerides DE440 and DE441 are fit to the same data set, but DE441 assumes no damping between the lunar liquid core and the solid mantle, which avoids a divergence when integrated backward in time. Therefore, DE441 is less accurate than DE440 for the current century, but covers a much longer duration of years −13,200 to +17,191, compared to DE440 covering years 1550–2650.

IMCCE ephemerides

- Since 2016, three new versions of INPOP planetary and lunar ephemerides have been delivered by the IMCCE team:
  - **INPOP17a**, **INPOP19**, **INPOP21a**.
- They benefit from:
  - an improved modeling of the Moon rotation and orbit (INPOP17a),
  - the introduction of Bayesian methods for the asteroid mass determination,
  - the regular inputs of Juno, Mars Express and ExoMars data (INPOP19a, INPOP21a).
- Perturbations by TNOs have been included since 2020 after the introduction of recently analyzed Cassini observations.
- Constraint on the size of the Moon core has been obtained, INPOP21a gave a better description of the distribution of the mass for the outer solar system and new constraints on dilaton and graviton theories have been published using INPOP19a and INPOP20a.

IAA-RAS ephemerides

- In 2021 the IAA - Russian Academy of Sciences released a new version of planetary ephemerides, EPM2021, after 4 years since last release.
- EPM2021 ephemeris contains coordinates and velocities of the Sun, the Moon, eight major planets, Pluto, five asteroids (Ceres, Pallas, Vesta, Iris, Bamberga) and 4 TNO (Eris, Haumea, Makemake, Sedna), as well as TT-TDB and Euler angles for lunar physical libration.
- EPM2021 covers a time span of more than 400 years (1787–2214).
- EPM2021H ephemeris is the longer version of EPM2021, covering a time span of more than 30000 years (13199 BC — AD 17191). Within the EPM2021 time span, EPM2021 and EPM2021H are practically equal with the only exception of the Moon. EPM2021H uses the model of the precession of the Earth from (Vondrák et al. 2011). Also, the lunar model of EPM2021H does not have friction between crust and core.

New Impact Monitoring method at JPL

- In 2021 the JPL-CNEOS team announced the implementation of a new impact monitoring method (called Sentry-II) that replaces the Line-of-Variations method.
- This development is important because the new method is fully independent of the previous ones, thus improving the reliability of the results and of the cross-check validation with NEODyS and ESA.
- See (cneos.jpl.nasa.gov/sentry) for more detail.

Thanks!