SPICE for Hera

Status and Future Work

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Hera SOWG
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Hera Operational SPICE Kernel Dataset

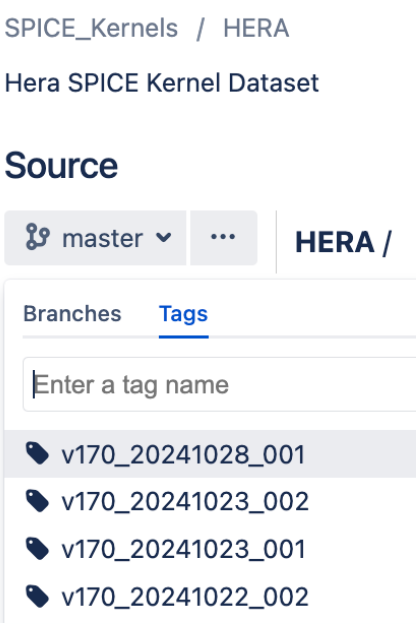
- After a successful launch on 7th October, we have kick-off automatic updates of the SPICE Kernel Dataset which has been moved to ‘operational’ status.

- As such, the Hera SPICE Kernel Dataset is now automatically updated when our operational pipeline processes:
  - Time Correlation Packets (TCPs) to produce Spacecraft Clock Kernels (SCLK)
  - Measured quaternions from Housekeeping Telemetry to produce attitude kernels (CK)
  - Trajectory updates from FDy (OEM) to produce trajectory kernels (SPK)

- Each automatic update results in a new version of the SPICE Kernel Dataset. **Every version is unique and time tagged.** In addition, every version has associated meta-kernels including the version in the filename:
  - hera_ops_v170_20241023_002.tm

Configuration for ESA missions

- The SPICE Kernels and Cosmographia configuration for each mission can be downloaded from:
  - BitBucket: https://s2e2.cosmos.esa.int/bitbucket/projects/SPICE_KERNELS ← **Best Option!**
    - git clone --depth 1 https://s2e2.cosmos.esa.int/bitbucket/scm/spice_kernels/hera.git
    - SKD releases are tagged in BitBucket with the full SKD version
  - FTP/HTTPS: http://spiftp.esac.esa.int/data/SPICE/
    - ZIP file: http://spiftp.esac.esa.int/data/SPICE/hera/misc/skd/hera.zip



Reminder

- After cloning/downloading the SPICE Kernel Dataset (SKD), there are just two steps to configure the mission:
- Create local copy of the meta-kernel:
- **cp kernels/mk/hera_ops.tm kernels/mk/hera_ops_local.tm**
- Update the PATH_VALUES in the local meta-kernel with the absolute path to your kernels directory
  - **PATH_VALUES = ('/Users/aescalante/spice/missions/hera/kernels')**

Operational Meta-kernels

- The following meta-kernels are now included in the operational SKD (decribed at https://www.cosmos.esa.int/web/spice/spice-for-hera):
  - **hera_ops.tm** ← for reconstructed data and science analysis
    - ck/hera_sc_meas_241008_241020_s241021_v01.bc ← HKT quaternions
    - spk/hera_fcp_000024_241007_261118_v01.bsp ← FDy OEM
    - sclk/hera_step_241021_v01.tsc ← TCPs for OBT-UTC conversions
  - **hera_plan.tm** ← for predicted data and planning
    - ck/hera_sc_crema_2_1_LPO_241007_270303_f181203_v01.bc ← Default attitude
    - spk/hera_fcp_000024_241007_261118_v01.bsp ← FDy OEM
    - sclk/hera_fict_181203_v01.tsc ← Fictional clock
  - hera_crema_2_1.tm ← CReMA 2.1 scenario including asteroid phase
  - hera_study_PO_EMA_2024.tm ← Mission Analysis study scenario including asteroid phase

SPICE Kernel Dataset Updates - Trajectory

- Flight Dynamics trajectory delivered to ESS via GFTS
  - ORBS__000024.HERA

- When an OEM is received, it is automatically processed to generate an SPK and ingested in the SKD:

Dear Hera colleagues,

here is the list of the new operational kernel(s) available:

Source files (OEM, AEM, TCP and/or Telemetry):

ORBS__000024.HERA

Produced kernels (SPK, CK and/or SCLK and MK):
---
hera_fcp_000024_241007_261118_v01.bsp
hera_ops_v170_20241022_002.tm
hera_plan_v170_20241022_002.tm

Both OPS and PLAN meta-kernels are updated

SPICE Kernel Dataset Updates – HK Telemetry

- ESS access EDDS to request Time Correlation Packets (TCP) and measured quaternions periodically.
- When a new time correlation is identified, the TCP is processed by the pipeline to generate an updated Spacecraft Clock kernel (SCLK).
- Then measured quaternions are retrieved and time stamped with the OBT to UTC conversion defined by the generated SCLK and used to produce a measured attitude CK.

Dear Hera colleagues,

here is the list of the new operational kernel(s) available:

Source files (OEM, AEM, TCP and/or Telemetry):
---
hera_tm_tcp_20241007000000_20241023065219.dat

Produced kernels (SPK, CK and/or SCLK and MK):
---
hera_step_241021_v01.tsc
hera_ops_v170_20241023_001.tm
hera_plan_v170_20241023_001.tm

Dear Hera colleagues,

here is the list of the new operational kernel(s) available:

Source files (OEM, AEM, TCP and/or Telemetry):
---
hera_hk_aocs_measured_attitude_20241023000000.tab

Produced kernels (SPK, CK and/or SCLK and MK):
---
hera_sc_meas_241009_241020_s241021_v01.bc
hera_ops_v170_20241023_001.tm

OBT-UTC time conversions with SPICE

- The Spacecraft Clock Kernel (SCLK) contains a list of time correlation pairs (piecewise linear function coefficients) defining the relation between spacecraft onboard time (OBT) and UTC (or ephemeris time, etc)

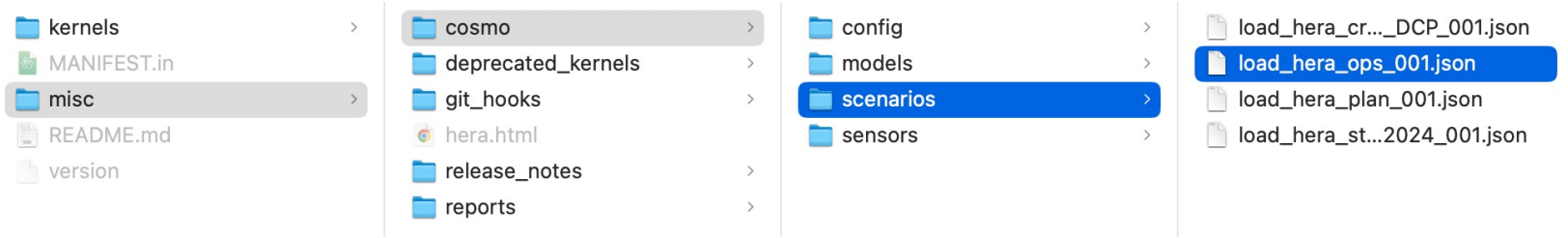
- The SCLK can therefor be used with SPICE to **convert between OBT and UTC times** (and viceversa). Here is an example snippet with SpiceyPy:

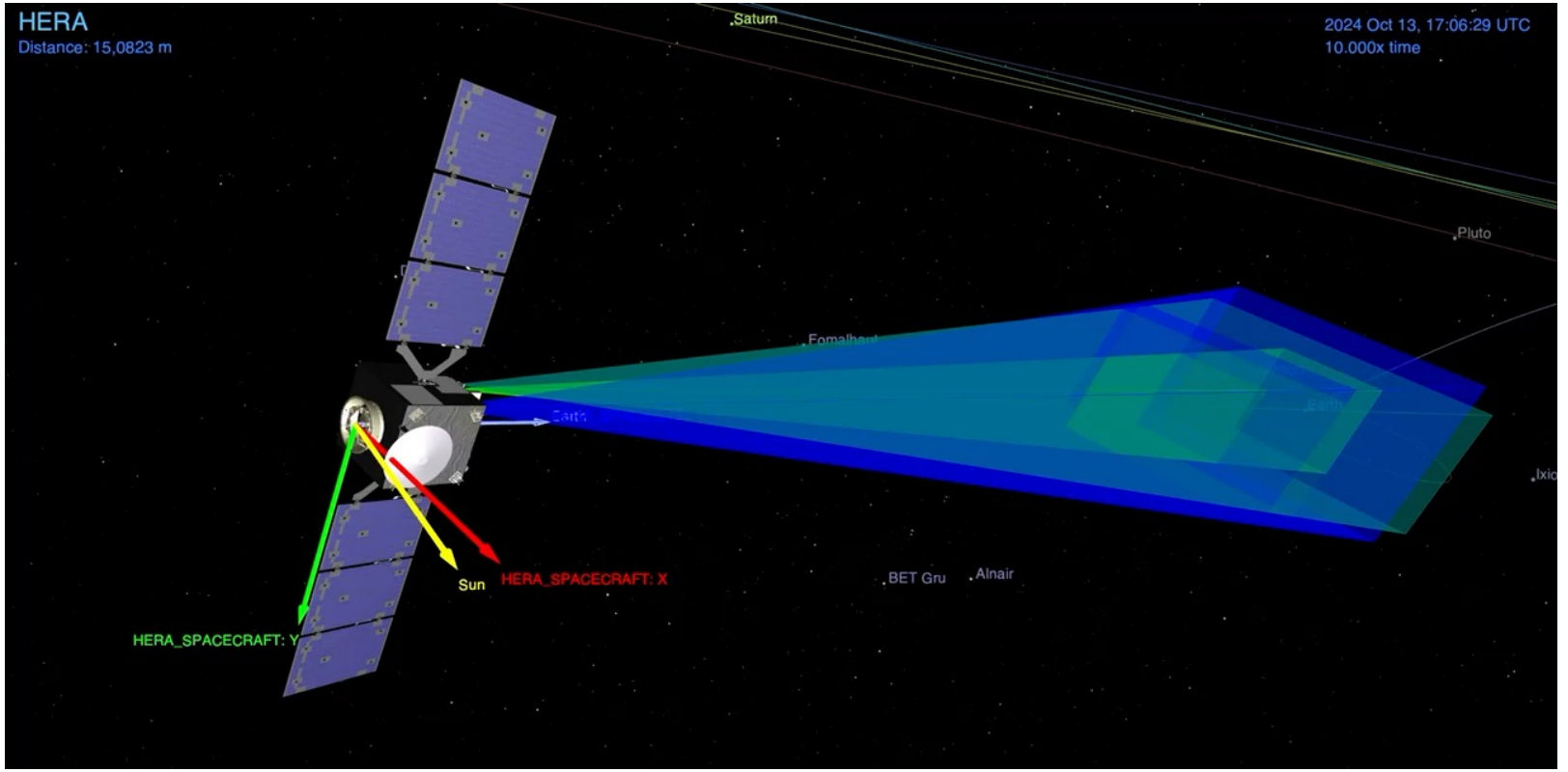
```python
import spiceypy
# load OPS meta-kernel including step SCLK
spiceypy.furnsh('../hera/kernels/mk/hera_ops_local.tm')
# convert UTC to ET and then to SC clock Ticks
et1 = spiceypy.utc2et('2024-10-20')
clock = spiceypy.sce2t(-91, et1)
# convert SC clock ticks to ET and then to UTC
et2 = spiceypy.sct2e(-91, clock)
utc2 = spiceypy.et2utc(et2, 'ISOC', 3)
```

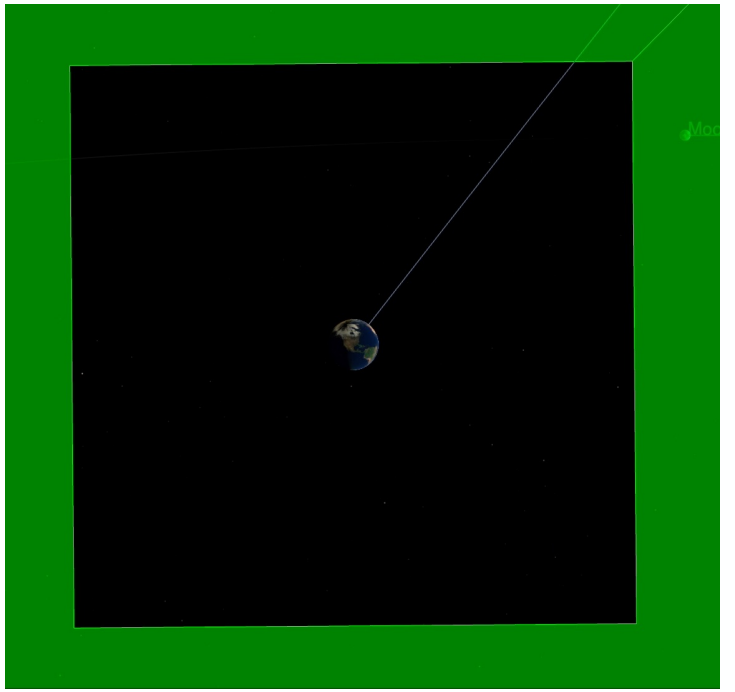
```
SCLK_PARTITION_START_91  = ( 0.0000000000000E+00 )

SCLK_PARTITION_END_91    = ( 1.0000000000000E+14 )

SCLK01_COEFFICIENTS_91   = (

   0.0000000000000E+00     7.8155681846584E+08     1.0000000000000E+00
   7.4772197200000E+08     7.8156822779769E+08     9.8828885217355E-01
   7.5170072800000E+08     7.8156828779769E+08     1.0000365691165E+00
   2.2141757480000E+09     7.8159060551340E+08     9.9176114006768E-01
   2.2181405740000E+09     7.8159066551340E+08     1.0000404888262E+00
   4.5341581240000E+09     7.8162600562783E+08     1.0146591451065E+00
   4.5380334740000E+09     7.8162606562783E+08     1.0000372621802E+00
   6.3429885790000E+09     7.8165360808329E+08     9.9989388938377E-01
   6.3469211560000E+09     7.8165366808329E+08     1.0000368605244E+00
   1.2240621701000E+10     7.8174360213155E+08     9.9987283434231E-01
   1.2244554361000E+10     7.8174366213155E+08     1.0000367377304E+00
   1.8087932356000E+10     7.8183282827958E+08     1.0086679555702E+00
   1.8091830725000E+10     7.8183288827958E+08     1.0000370575718E+00
   5.1366247608000E+10     7.8234063440318E+08     1.0029367367974E+00
   5.1370168255000E+10     7.8234069440318E+08     1.0000376789515E+00
   8.2542835887000E+10     7.8281636948548E+08     1.0007673578689E+00
   8.2546765032000E+10     7.8281642948548E+08     1.0000374787605E+00

                           )
```

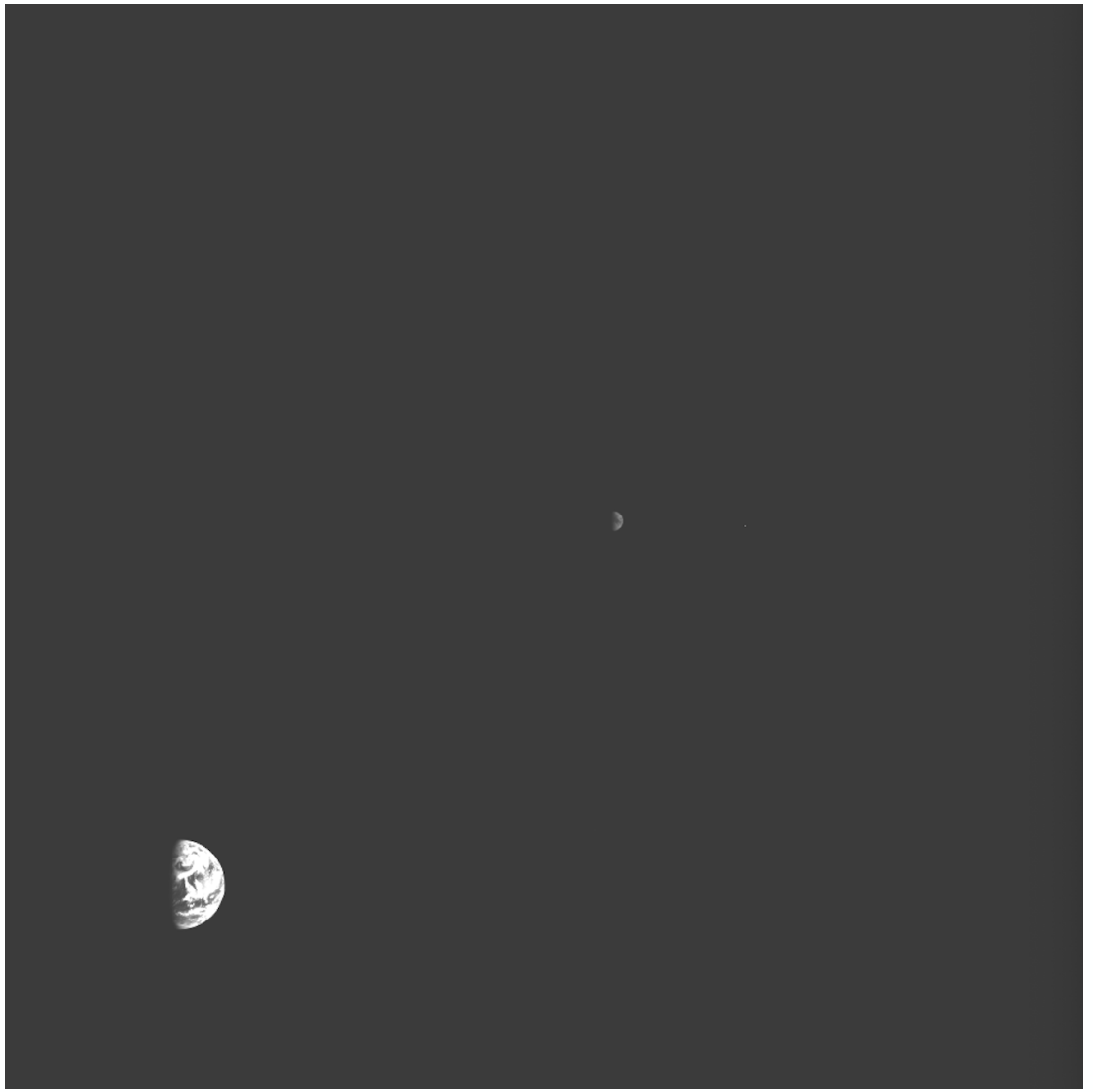
Visualization in Cosmographia

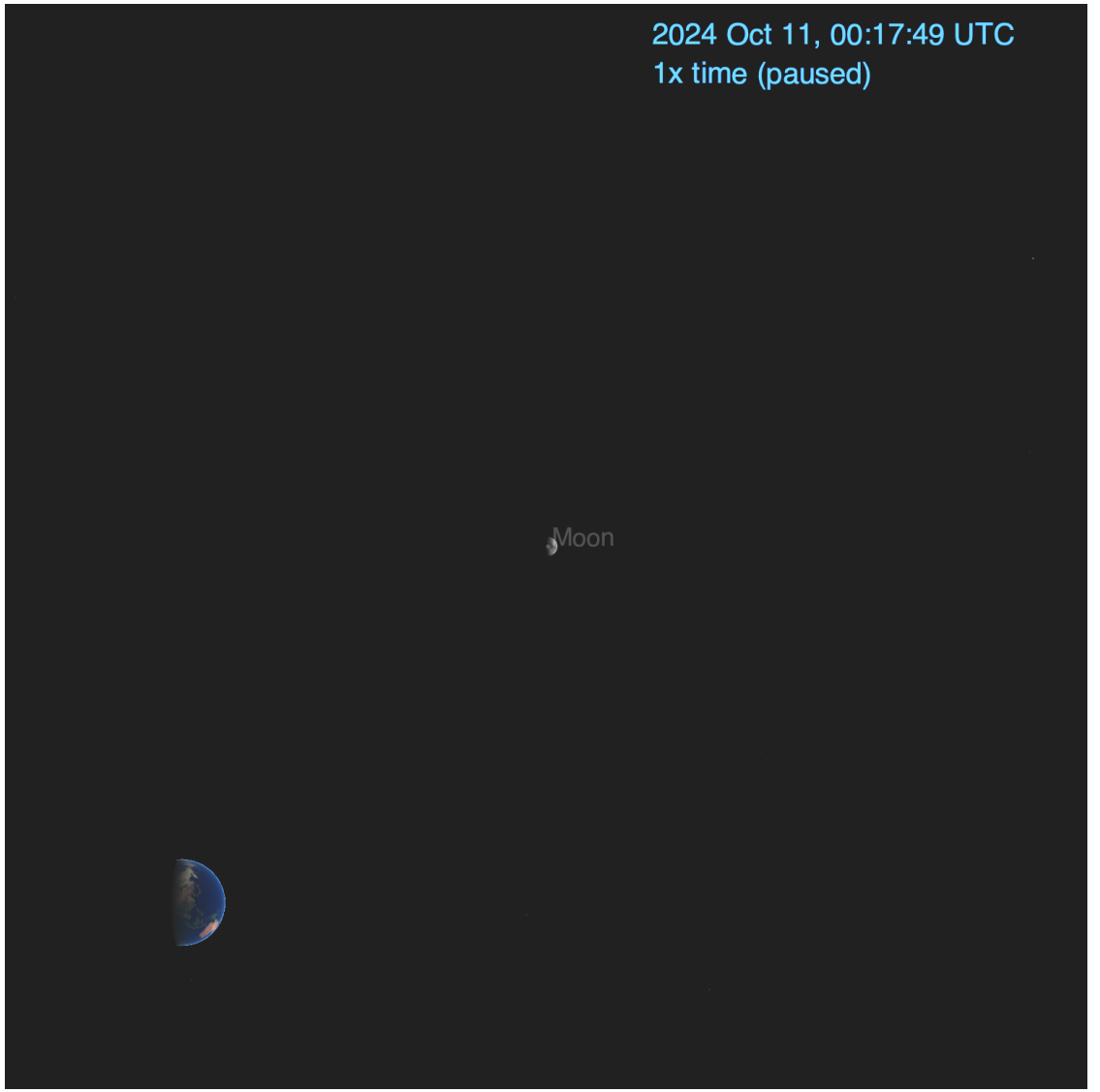
- With the OPS meta-kernel data including measured quaternions and OEM we can visualise the LEOP and NECP operations:










2024 Oct 11, 00:17:49 UTC
1x time (paused)
Moon

Future Updates

- Automatic generation of default attitude CK for FDy OEM trajectory updates
  - A CK will be produce by the operational pipeline and included in the planning meta-kernel hera_plan.tm

- Retrieval of Solar Array rotation angles from housekeeping telemetry and CK generation
  - hera_sa_meas_yymmdd_YYMMDD_sYYMMDD_vVV.bc

- If anything is missing, instruments parameters, alignment calibrations,… let us know!

Keeping in touch

COMMUNICATE

- Everything is accessible from: **http://spice.esac.esa.int**
- Contact the service via e-mail **spice@cosmos.esa.int**

- We will set up a mailing list **spice_hera@cosmos.esa.int** for notifying automatic updates of the SPICE Kernel Dataset.
    - **If you want to join the mailing list please contact us!**

COLLABORATE

- If you are a SPICE Kernel producer or a bi-product of your investigations are Ancillary Data (Reconstructed Trajectory, S/C Orientation, Natural Body Ephemeris) please contact us and share your data with the community.