Cosmographia Workshop

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ESA SPICE Service

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Agenda

9:00 – 9:30	Class Introduction
9:30 – 10:30	Cosmographia settings, controls and display options
10:30 – 11:10	Setting ESA missions scenario
11:10 – 11:30	Coffee break
11:30 – 12:30	Loading catalog files (sensors, observations, shape models)
12:30 – 13:00	Summary
13:00 – 14:00	Lunch
14:00 – 15:00	Scripting
15:00 – 15:30	Cosmographia JUICE plugin
15:30 – 16:00	Open topics

SPICE-ENHANCED Cosmographia

Class Introduction

- NAIF offers for public use a **SPICE-enhanced** version of the visualization tool Cosmographia.
    - Available for Windows, Mac and Linux.

- This is an interactive tool used to produce **3D visualizations** of:
    - Planets; moons; asteroids; comets; ephemerides, sizes and shape models
    - Spacecraft trajectories and orientations
    - Instrument field-of-views and footprints

- Cosmographia has many user controls, allowing one to manage what and how is displayed, the point of view position and aperture, how fast the animation progresses and more.

- The **ESA SPICE Service provides the setup and instructions** to load the SPICE supported ESA Missions in Cosmographia.

→ THE EUROPEAN SPACE AGENCY

Class Introduction

- The purpose of this class is to show how to first **setup Cosmographia and use it for the ESA missions**.
- We want you to get hands-on Cosmographia!

- The key points we will cover:
  1. Install Cosmographia (if you have not done it before)
  2. Getting familiar with the Cosmographia Interface, controls and visualization options
  3. Downloading SPICE Kernel Dataset and configuring the Cosmographia scenario
  4. Loading catalog files: sensors, observations, shape models
  5. Modifying catalog files
  6. Cosmo-scripting
  7. Cosmographia JUICE plugin
  8. Open Discussions

Installing Cosmographia

- Cosmographia can be downloaded from the NAIF or ESA SPICE Service sites.
  - NAIF: https://naif.jpl.nasa.gov/naif/cosmographia_components.html
  - ESS: https://www.cosmos.esa.int/web/spice/cosmographia

Installing Cosmographia

PDS Planetary Data System | Find a Node

Jet Propulsion Laboratory
California Institute of Technology

+ View the NASA Portal

NAIF The Navigation and Ancillary Information Facility

- Home
- Announcements
- About SPICE
- About NAIF
- For New Projects
- For the Public
- Data
- Toolkit
- Utilities
- WebGeocalc
- Cosmographia
- Documentation
- Tutorials
- Lessons
- Training
- Bugs
- Useful Links
- Rules
- Giving Credit
- Feedback
- Support
- Getting Help
- Site Map

SPICE-enhanced Cosmographia Components

NAIF has tried to provide installer packages that will work in the indicated computing environments. But there may be compatibility issues in getting the tool to work on any given machine. You or your system administrator may need to install missing or different versions of system components on your machine in order to get Cosmographia to execute. **Caution: these packages are rather large, as indicated.**

These installers include options to allow downloading of the Cosmographia-SPICE User's Guide and associated catalog templates, and several real mission examples, consisting of catalog files and allied kernels.

- SPICE-enhanced Cosmographia 4.2 for Mac OSX (64-bit) (528 MB)
  Compatibility: OS X 10.15 or later
- SPICE-enhanced Cosmographia 4.2 for Windows (64-bit) (560 MB)
  Compatibility: Windows 10 or later
- SPICE-enhanced Cosmographia 4.2 for Linux (64-bit) (636 MB)
  Compatibility: Built on a machine running Ubuntu 16, but should run under most modern versions of the Linux operating system such as CentOS, RHEL and SUSE.

The installers noted above include a set of generic SPICE kernels and corresponding catalog files that will be loaded into Cosmographia at start-up. These provide solar system body ephemerides and orientation spanning the period of 1950 to 2050.

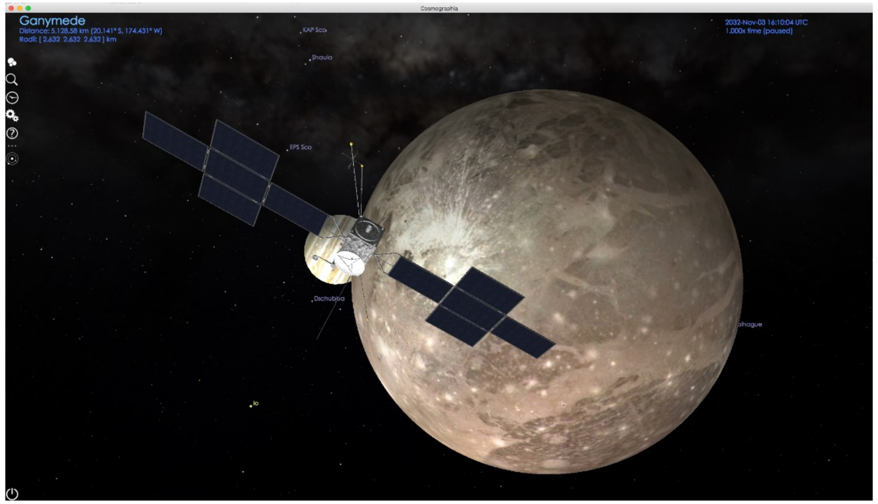
The on-line Cosmographia User's Guide is available here.

SPICE » Cosmographia

- Home
- Data
- Missions
- WebGeocalc
- Cosmographia
- Training
- Planetary Science Archive

SPICE-ENHANCED COSMOGRAPHIA VISUALIZATION TOOL

NAIF offers for public use a SPICE-enhanced version of the visualization tool Cosmographia. This is an interactive tool used to produce 3D visualizations of planet ephemerides, sizes and shapes; spacecraft trajectories and orientations; and instrument field-of-views and footprints. Cosmographia has many user controls, allowing one to manage what is displayed, what vantage point is used, and how fast the animation progresses. The ESA SPICE Service provides the setup and instructions to load the SPICE supporteed ESA Missions in Cosmographia.



Cosmographia originated as primarily a general interest solar system simulator, and it still works wonderfully in that role. However, with permission from the tool's author, NAIF is extending the open source Cosmographia tool to make use of SPICE kernels to accurately model the observation geometry of planetary missions for which substantial or complete sets of SPICE data are available. With these extensions SPICE-enhanced Cosmographia should also be of interest to professional scientists and engineers.

DOWNLOADS

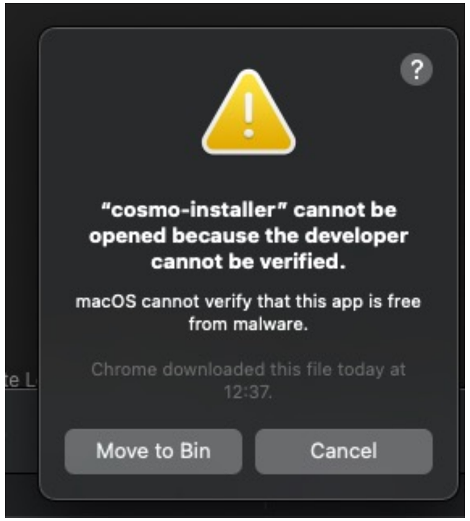
Cosmographia is a stand-alone application for which executable binaries have been prepared on relatively recent versions of OSX, Windows and Linux. They likely work on more modern versions of the named operating systems and perhaps on some older versions as well. The latest version (4.2) of SPICE-enhanced Cosmographia for the different flavour of OS is available in the following links:

- SPICE-enhanced Cosmographia for Mac OSX (64-bit) (528 MB) Compatibility: OS X 10.15 or later
- SPICE-enhanced Cosmographia for Windows (64-bit) (560 MB) Compatibility: Windows 10 or later
- SPICE-enhanced Cosmographia for Linux (64-bit) (636 MB) Compatibility: Built on a machine running Ubuntu 16, but should run under most modern versions of the Linux operating system such as CentOS, RHEL and SUSE.

You can also obtain older versions of Cosmographia here.

Installing Cosmographia

- Cosmographia is NOT available in the esa365 catalogue but should not require admin permissions to be installed.
- Download the installer for your platform from any of the previous links and place it in a directory different from the default Apps/Programs directory



- In Mac you may get the warning of "unknown developer"
  - Hold ***control*** key and ***left-click*** the installer
  - Then hit **Open**
  - You may get the warning again, just hit cancel and do it again
  - After a couple of times you should get the wizzard running

- Follow the installation steps and again select an appropriate directory for installing Cosmographia
  - It can be **wherever you want in your computer**, does not have to be with the kernels
  - Just DO NOT choose the default Apps directory as esa365 may block the app from running

Installing Cosmographia

- In Windows we have encountered an issue for some users with Cosmographia 4.2.
- The setup completes without errors but it is not possible to launch the app after the installation.

- NAIF is investigating the issue but have not found a workaround yet.
  - Suspect is incompatibility between some visual libraries.

- For those users, we recommend either:
  - Installing Cosmographia on a Linux virtual machine.
  - Installing Cosmographia 4.1 (cosmoscripting for Windows is not available for < 4.2)

- If you encounter any issues during installation please let us know!

Cosmographia Interface

Hands-on explore the Cosmographia interface:

- Solar System Objects
- Find Object (cmd + f)
    - Point at, Go to
- Time Control
    - Select date and Time rate
    - Select Time and Date (cmd + t)
    - Pause/Resume time (cmd + p); Fast-forward x10 (cmd + l), Slow down /10 (cmd + k), Reverse (cmd + j)
- Settings
    - Graphics: Atmospheres/Clouds (Earth, Venus, Titan), Shadows, Star Birghtness, Extra Light
    - Guides: Orbits, Labels, Stars and Constellations, Text and Vectors sizes
    - Interface: Spice Driven Bodies, Units, Record Video Resolution
    - Add-ons: All asteroids, Enceladus' Geysers
- Help: User's Guide, Navigation Basics, Keyboard shortcuts

Cosmographia Interface

- File
    - Open Catalog, Screenshot/Record, Run script
- Time menu
- Camera
    - Find, Go to object
    - Inertial Frame, Body Fixed Frame
- Guides
- Window

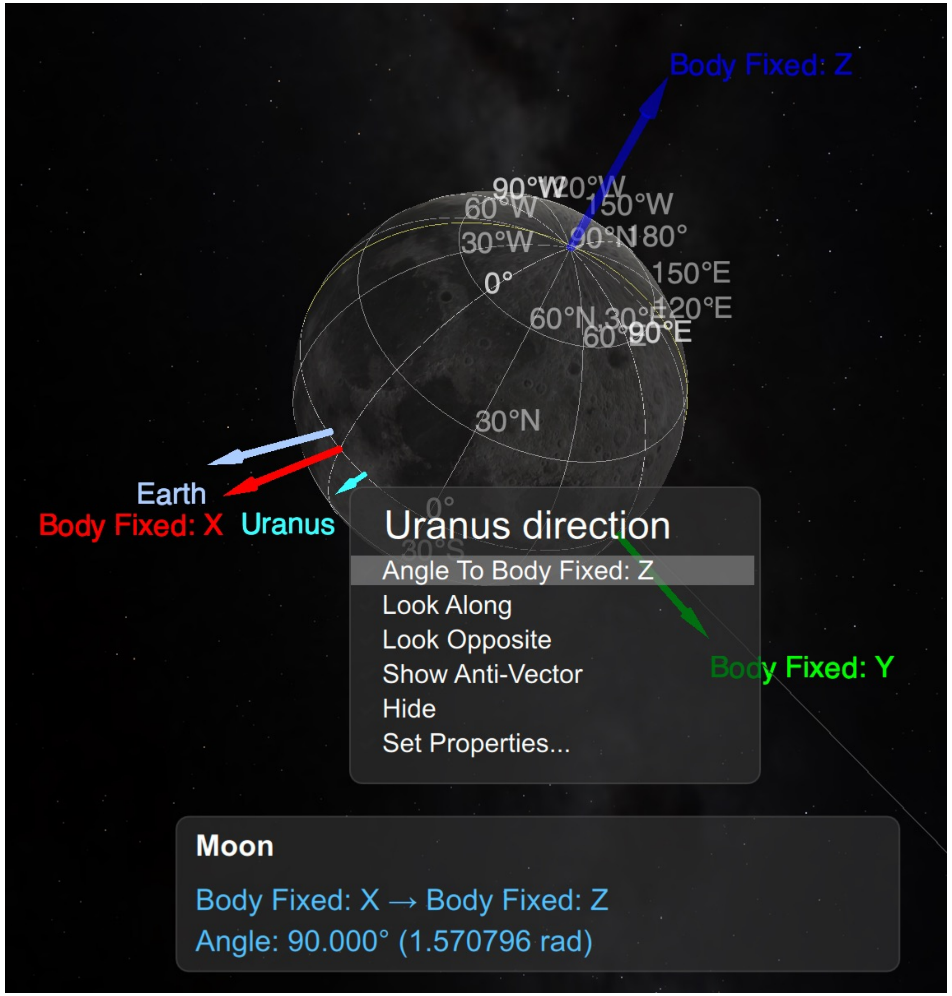
Navigation Basics

- Camera Motion
  - Double click to an object to go close to it and select it
  - Scroll down/up for zoom in/out
  - Left drag the mouse to move the camera aroung the central object
  - Right drag the mouse to pan the view without chaning camera position
  - Shift + right drag (or pinch the trackpad) to change the field-of-view of the camera (default 50 degrees)

- Displaying things with right click on objects
  - Point at, Go to, Set as center, Set as Fixed center, Track
  - Reference frames: Inertial, Body Fixed, SPICE Frames
  - Directions: Velocity, Sun, Earth, Secondary-to-Object (click on secondary and right click on object)
  - Distance from secondary to object
  - Trajectory, Lon/Lat grid, Terminator

Navigation Basics

- Single Vector options: Select (left click) object with vector and right click on vector
    - Look Along (specially useful for Direction vectors or Instrument Boresights)
    - Look Opposite
    - Show anti-vector
    - Hide and Show Properties
- Two Vectors options:
    - Select (left click) object with primary vector, left click on primary vector and right click on secondary vector.
    - Angle from Primary Vector to Secondary Vector



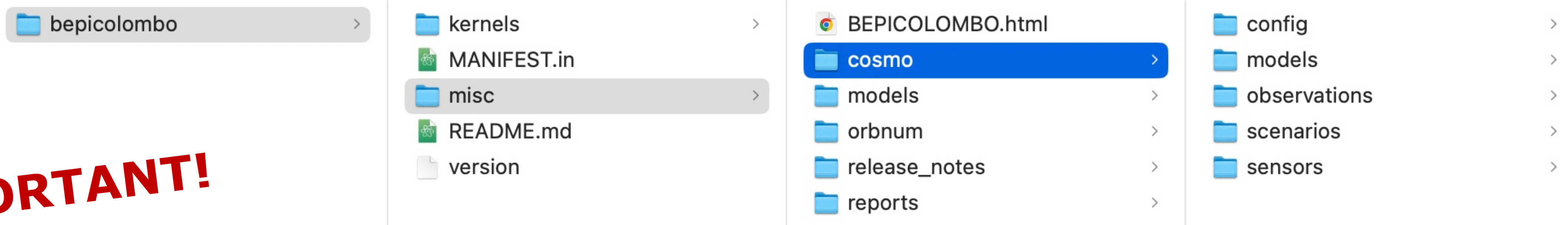
Configuration for ESA missions

- The ESA SPICE Service provides SPICE Kernel Datasets for a large set of missions:

BEPICOLOMBO PUBLIC	HUYGENS PUBLIC
COMET-INTERCEPTOR PUBLIC	INTEGRAL PUBLIC
EnVision PUBLIC	JUICE PUBLIC
esa_generic PUBLIC	JWST PUBLIC
EUCLID PUBLIC	LUNAR-GATEWAY PUBLIC
ExoMars2016 PUBLIC	MARS-EXPRESS PUBLIC
ExoMarsRSP PUBLIC	ROSETTA PUBLIC
Gaia PUBLIC	SMART-1 PUBLIC
GIOTTO PUBLIC	SOLAR-ORBITER PUBLIC
GNSS PUBLIC	VENUS-EXPRESS PUBLIC
hera PUBLIC	XMM PUBLIC

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/bepicolombo.git
  - FTP/HTTPS: http://spiftp.esac.esa.int/data/SPICE/
    - ZIP file: http://spiftp.esac.esa.int/data/SPICE/BEPICOLOMBO/misc/skd/BEPICOLOMBO.zip



IMPORTANT!

- After cloning/downloading the SPICE Kernel Dataset (SKD), there are just two steps to configure the mission:
  - Create local copy of the meta-kernel: **mv kernels/mk/bc_plan.tm kernels/mk/bc_plan_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/bc/bepicolombo/kernels')**

Brand new Git Hooks!

- The previous steps are mandatory to prepare a meta-kernel with an absolute path to the kernels that Cosmographia can load to access the data:

master ··· BEPICOLOMBO / misc / cosmo / config / **spice_ops_BEPIC.json**

Source view | Diff to previous | History | 136 B

```
{
   "version": "1.0",
   "name": "Cosmographia BEPIC Example",
   "spiceKernels": [
      "../../../kernels/mk/bc_ops_local.tm"
   ]
}
```

- We have prepared a git hook distributed with the SKD in BitBucket to automatically do this!
  - http://spiftp.esac.esa.int/temp/ess/git_hooks.zip
  - Either run the script update_local_mks.sh from the SKD root folder to configure the local met—kernels
    - Linux and Mac: cd [SKD_PATH] && ./misc/git_hooks/skd_post_merge/update_local_mks.sh
    - Windows: cd [SKD_PATH] , misc/git_hooks/skd_post_merge/update_local_mks.bat
  - Or install the git hooks so every time you pull updates or checkout branches the meta-kernels are automatically updated.

Brand new Git Hooks!

- To install the git hooks:
  - For OS X or Linux:
    - cd [SKD_PATH]
    - chmod +x misc/git_hooks/skd_post_merge/install_hook_linux_or_mac.sh
    - ./misc/git_hooks/skd_post_merge/install_hook_linux_or_mac.sh
  - For Windows:
    - cd [SKD_PATH]
    - misc\git_hooks\skd_post_merge\install_hook_windows.bat

Brand new Git Hooks!

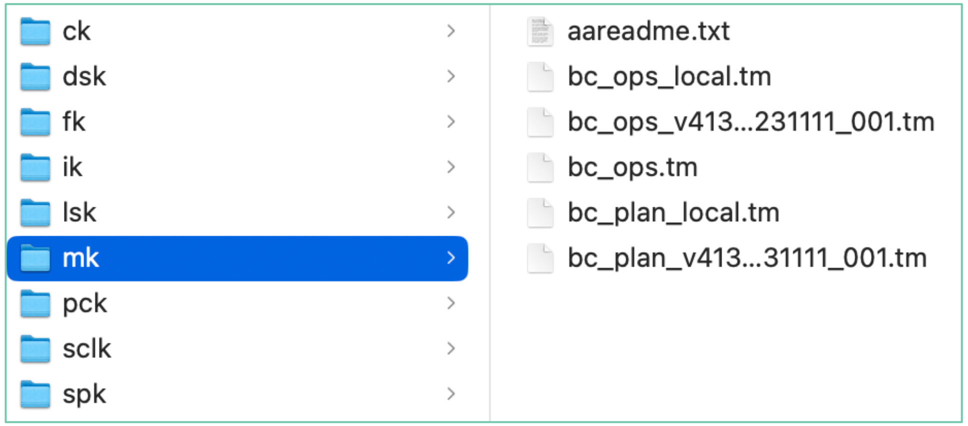
```
(base) ESAC01111205:temp aescalante$ cd bepicolombo/
(base) ESAC01111205:bepicolombo aescalante$ chmod +x misc/git_hooks/skd_post_merge/install_hook_linux_or_mac.sh
(base) ESAC01111205:bepicolombo aescalante$ ./misc/git_hooks/skd_post_merge/install_hook_linux_or_mac.sh
INSTALLING POST-MERGE AND POST-CHECKOUT HOOKS TO:
Installed at /Users/aescalante/spice/missions/temp/bepicolombo/.git
(base) ESAC01111205:bepicolombo aescalante$ ls -l kernels/mk/
total 128
-rw-r--r--  1 aescalante  1276952531   6162 Apr 28  2021 aareadme.txt
-rw-r--r--@ 1 aescalante  1276952531  16032 Nov 11 11:21 bc_ops.tm
-rw-r--r--@ 1 aescalante  1276952531  16032 Nov 11 11:21 bc_ops_v413_20231111_001.tm
-rw-r--r--@ 1 aescalante  1276952531   8804 Nov 11 11:21 bc_plan.tm
-rw-r--r--@ 1 aescalante  1276952531   8804 Nov 11 11:21 bc_plan_v413_20231111_001.tm
(base) ESAC01111205:bepicolombo aescalante$ git checkout develop
Switched to branch 'develop'
Your branch is up to date with 'origin/develop'.
Platform: OSX
Removing old local Meta-Kernels...
Creating updated local Meta-Kernels...
Creating bc_plan_local.tm
Creating bc_plan_v413_20231111_001_local.tm
Creating bc_ops_local.tm
Creating bc_ops_v413_20231111_001_local.tm
Local Meta-Kernels updated successfully...
(base) ESAC01111205:bepicolombo aescalante$ ls -l kernels/mk/
total 240
-rw-r--r--  1 aescalante  1276952531   6162 Apr 28  2021 aareadme.txt
-rw-r--r--@ 1 aescalante  1276952531  16032 Nov 11 11:21 bc_ops.tm
-rw-r--r--@ 1 aescalante  1276952531  16072 Nov 25 12:08 bc_ops_local.tm
-rw-r--r--@ 1 aescalante  1276952531  16032 Nov 11 11:21 bc_ops_v413_20231111_001.tm
-rw-r--r--@ 1 aescalante  1276952531  16072 Nov 25 12:08 bc_ops_v413_20231111_001_local.tm
-rw-r--r--@ 1 aescalante  1276952531   8804 Nov 11 11:21 bc_plan.tm
-rw-r--r--@ 1 aescalante  1276952531   8844 Nov 25 12:08 bc_plan_local.tm
-rw-r--r--@ 1 aescalante  1276952531   8804 Nov 11 11:21 bc_plan_v413_20231111_001.tm
-rw-r--r--@ 1 aescalante  1276952531   8844 Nov 25 12:08 bc_plan_v413_20231111_001_local.tm
```

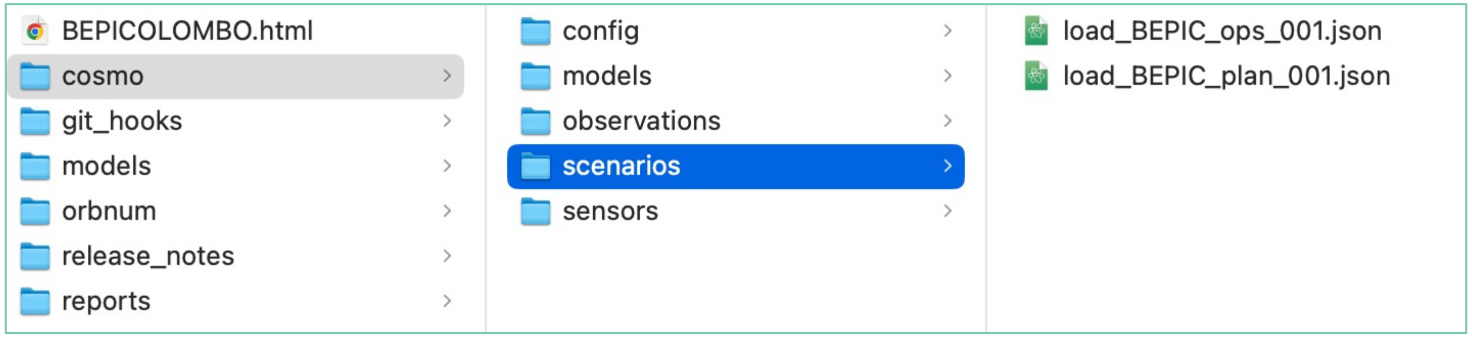
```
(base) ESAC01111205:bepicolombo aescalante$ cat kernels/mk/bc_ops_local.tm
KPL/MK

Meta-kernel for BepiColombo Dataset v413 -- Operational 20231111_001
===========================================================================
```

```
\begindata

   PATH_VALUES       = ( '/Users/aescalante/spice/missions/temp/bepicolombo/kernels' )

   PATH_SYMBOLS      = ( 'KERNELS' )
```

Loading the mission scenario

- Once the local meta-kernels are ready, we can go back to Cosmographia and load the mission scenario.
- Scenarios are the main file to be loaded to get the pre-configured mission into Cosmographia.
- In principle, there is a different scenario file for each meta-kernel in the SKD:





load_BEPIC_ops_001.json

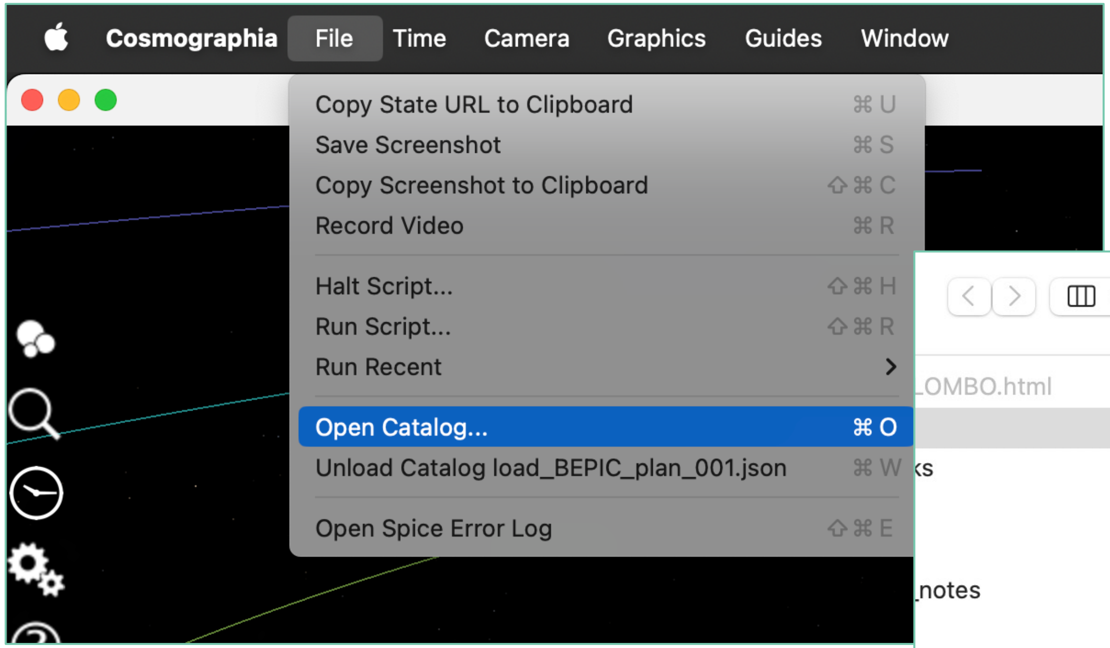
```
{
   "version": "1.0",
   "name": "Cosmographia BEPIC Example",
   "require": [
        "../config/spice_ops_BEPIC.json",
        "../config/spacecraft_BEPIC_arcs.json",
        "../config/sensors_BEPIC_arcs.json"
    ]
}
```

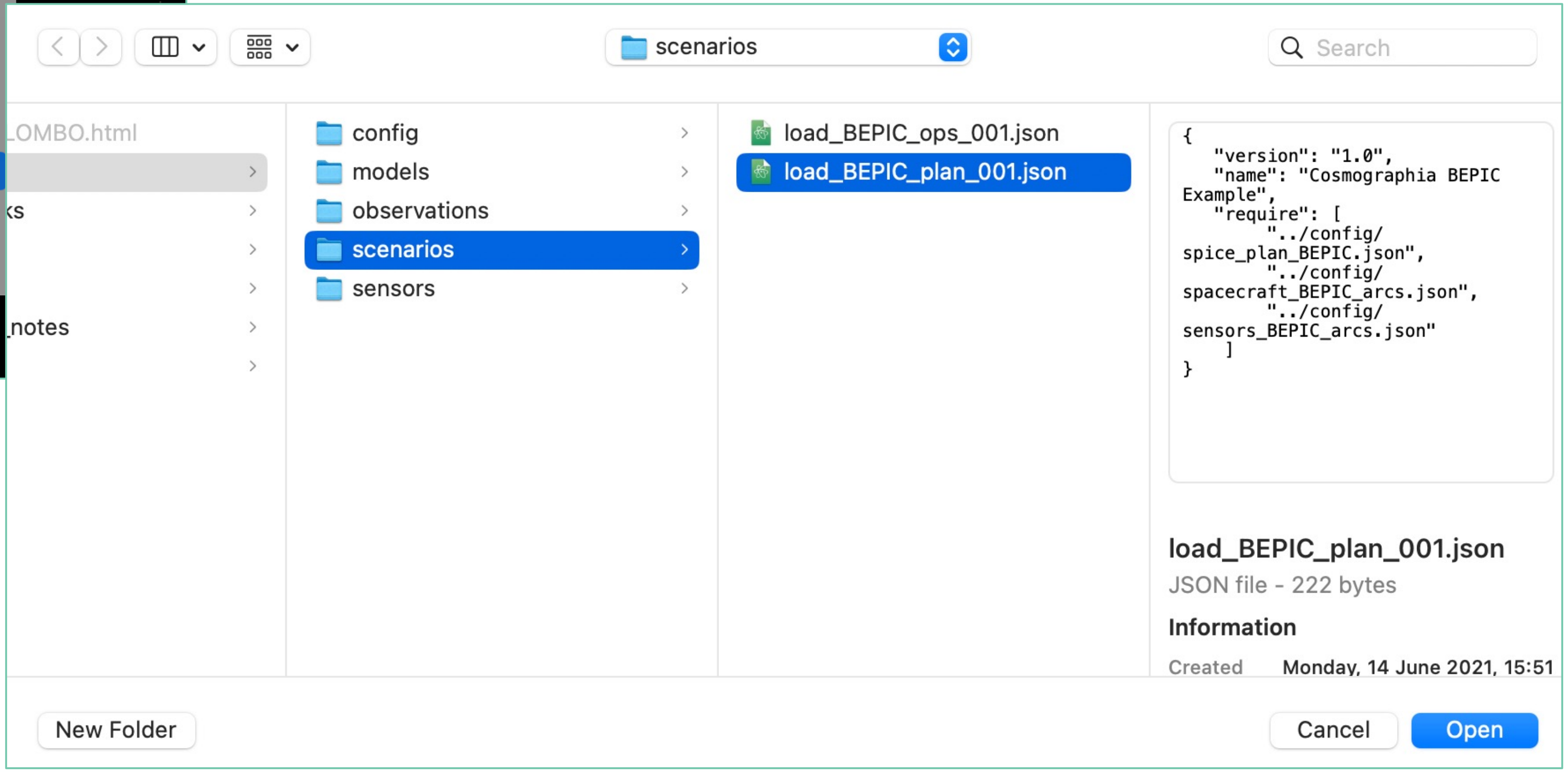
Loading the mission scenario

- In Cosmographia, hit File at the top-bar menu and select **Open Catalog… (cmd + o)**

As in SPICE, loading multiple catalog will result in the last one overriding the previous one.

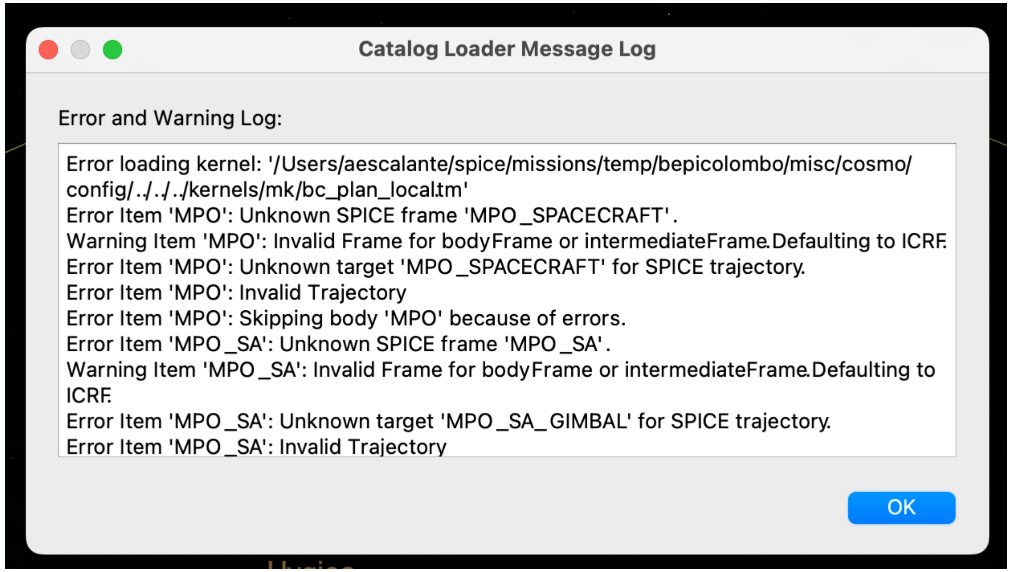
To unload a catalogue click Unload Catalog (cmd + w)





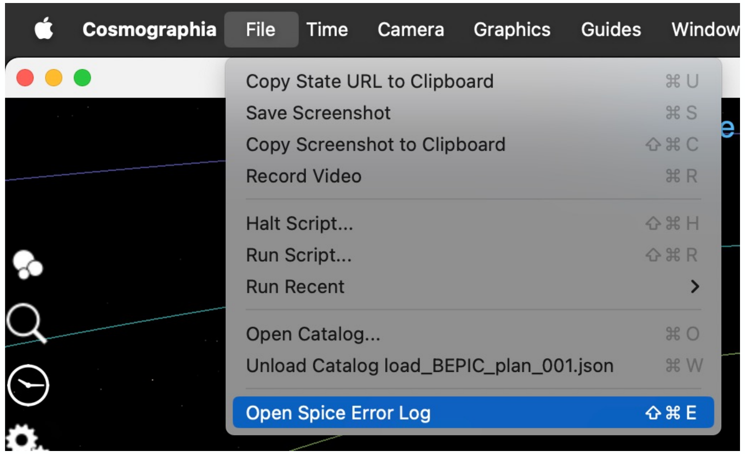
Loading the mission scenario

- If the meta-kernel was not properly configured, you will get an error like:



Make sure that the meta-kernel *_local.tm exists and the PATH_VALUES are properly set.

If it is properly set and still get an error, you can check the Spice Error Log



- In addition, to check that the meta-kernel is properly set it is properly set, you can use **BRIEF** utility to make sure it is working. It is included in the meta-kernel but can also be downloaded from:
    - https://naif.jpl.nasa.gov/naif/utilities.html
- >> brief kernels/mk/bc_plan_local.tm

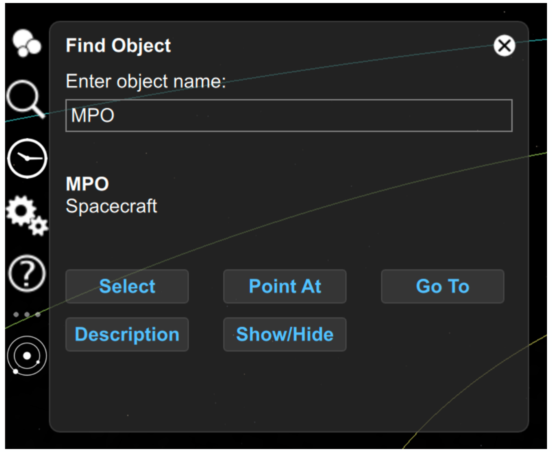
Loading the mission scenario

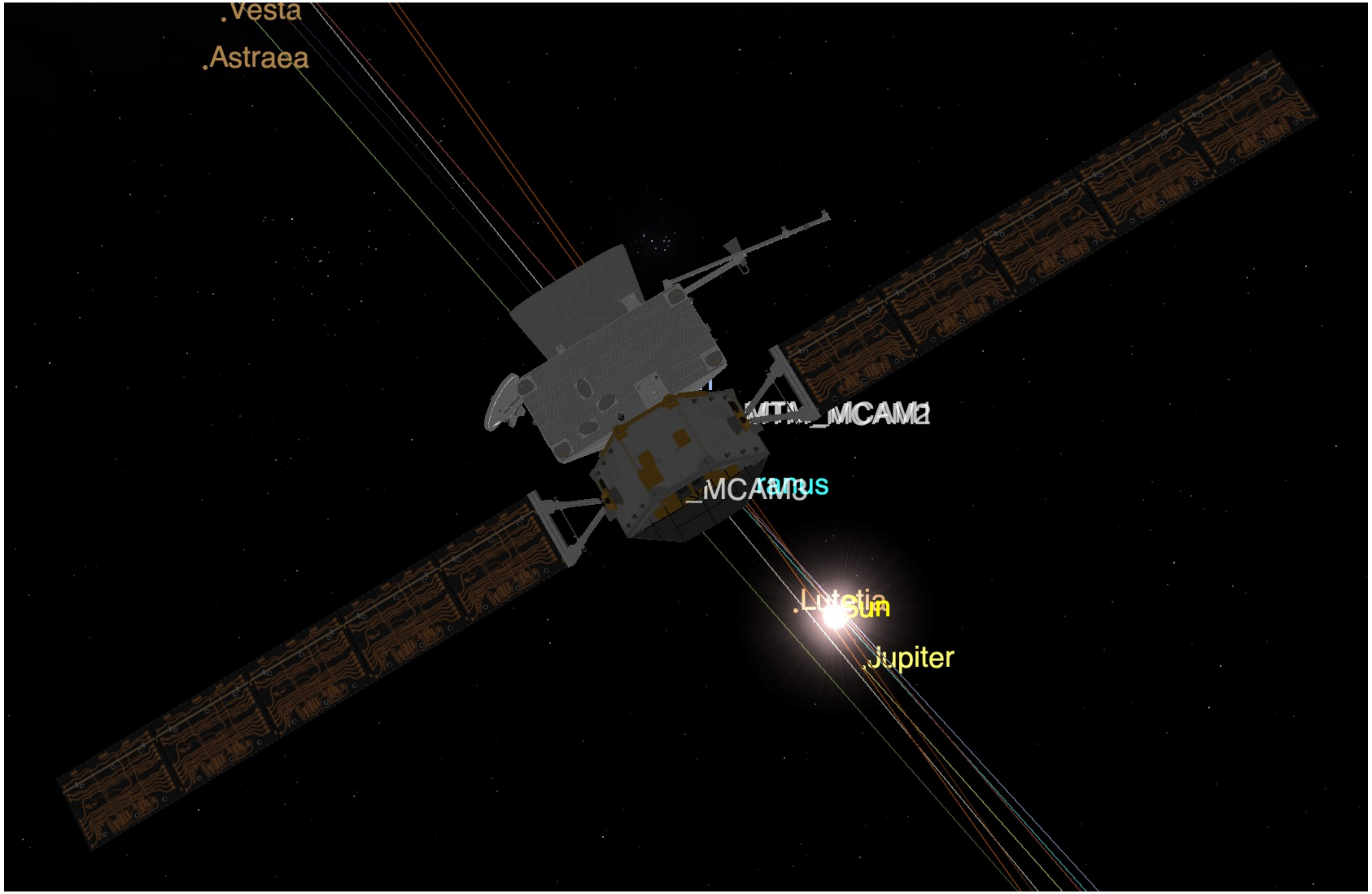
```
(base) ESAC01111205:bepicolombo aescalante$ brief kernels/mk/bc_plan_v413_20231111_001_local

BRIEF -- Version 4.1.0, September 17, 2021 -- Toolkit Version N0067


Summary for: /Users/aescalante/spice/missions/temp/bepicolombo/kernels/spk/de432s.bsp

Bodies: MERCURY BARYCENTER (1)  SATURN BARYCENTER (6)   MERCURY (199)
        VENUS BARYCENTER (2)    URANUS BARYCENTER (7)   VENUS (299)
        EARTH BARYCENTER (3)    NEPTUNE BARYCENTER (8)  MOON (301)
        MARS BARYCENTER (4)     PLUTO BARYCENTER (9)    EARTH (399)
        JUPITER BARYCENTER (5)  SUN (10)
        Start of Interval (ET)              End of Interval (ET)
        -----------------------------       -----------------------------
        1949 DEC 14 00:00:00.000            2050 JAN 02 00:00:00.000


Summary for: /Users/aescalante/spice/missions/temp/bepicolombo/kernels/spk/earthstns_itrf93_

Bodies: DSS-13 (399013)*  DSS-26 (399026)*  DSS-45 (399045)*  DSS-63 (399063)*
        DSS-14 (399014)*  DSS-34 (399034)*  DSS-53 (399053)*  DSS-65 (399065)*
        DSS-15 (399015)*  DSS-35 (399035)*  DSS-54 (399054)*
        DSS-24 (399024)*  DSS-36 (399036)*  DSS-55 (399055)*
        DSS-25 (399025)*  DSS-43 (399043)*  DSS-56 (399056)*
        Start of Interval (ET)              End of Interval (ET)
        -----------------------------       -----------------------------
        1950 JAN 01 00:00:00.000            2150 JAN 01 00:00:00.000


Summary for: /Users/aescalante/spice/missions/temp/bepicolombo/kernels/spk/earthstns_jaxa_20

Bodies: USUDA (399700)*   MISASA (399701)*
        Start of Interval (ET)              End of Interval (ET)
        -----------------------------       -----------------------------
        1950 JAN 01 00:00:00.000            2050 JAN 01 00:00:00.000
```

```
(base) ESAC01111205:bepicolombo aescalante$ brief kernels/mk/bc_plan_local.tm

BRIEF -- Version 4.1.0, September 17, 2021 -- Toolkit Version N0067


================================================================================

Toolkit version: N0067

SPICE(NOSUCHFILE) --

The first file '/Users/aescalante/spice/missions/temp/bepicolombo/kernels/ck/bc
_mpo_magboom_default_s20191107_v02.bc' specified by KERNELS_TO_LOAD in the file
kernels/mk/bc_plan_local.tm could not be located.

A traceback follows.  The name of the highest level module is first.
BRIEF --> FURNSH --> ZZLDKER

================================================================================
```

Loading the mission scenario

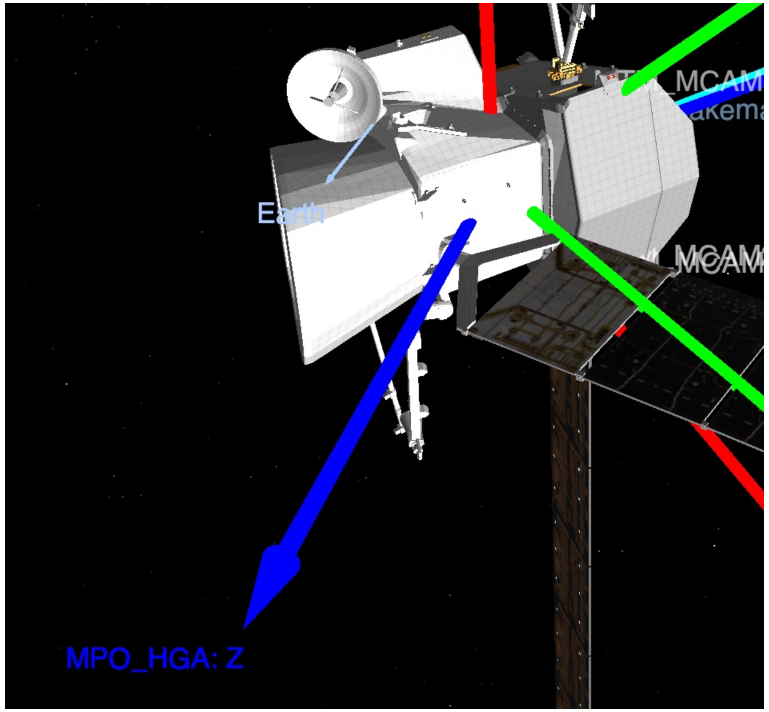
- If everything was fine, you should now see your mission in Cosmographia:

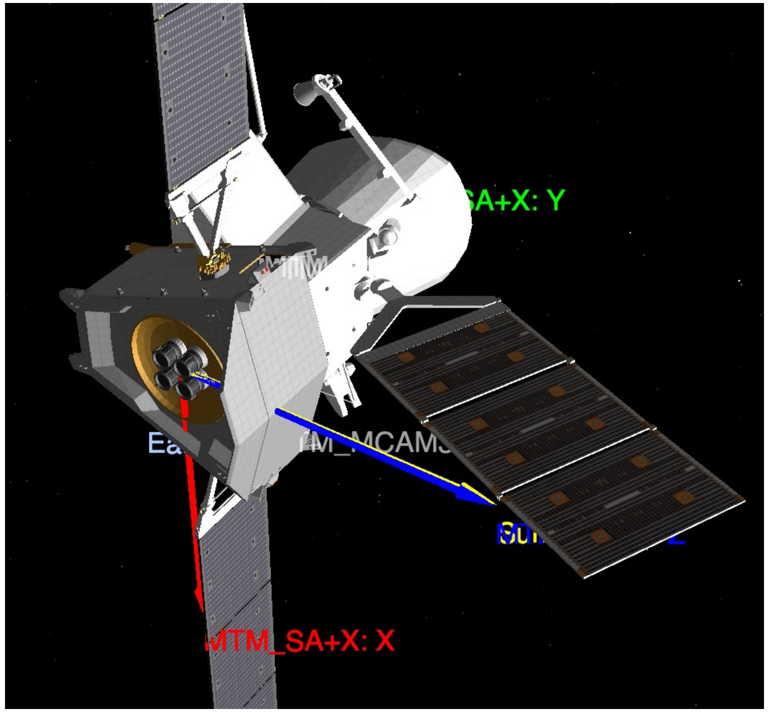


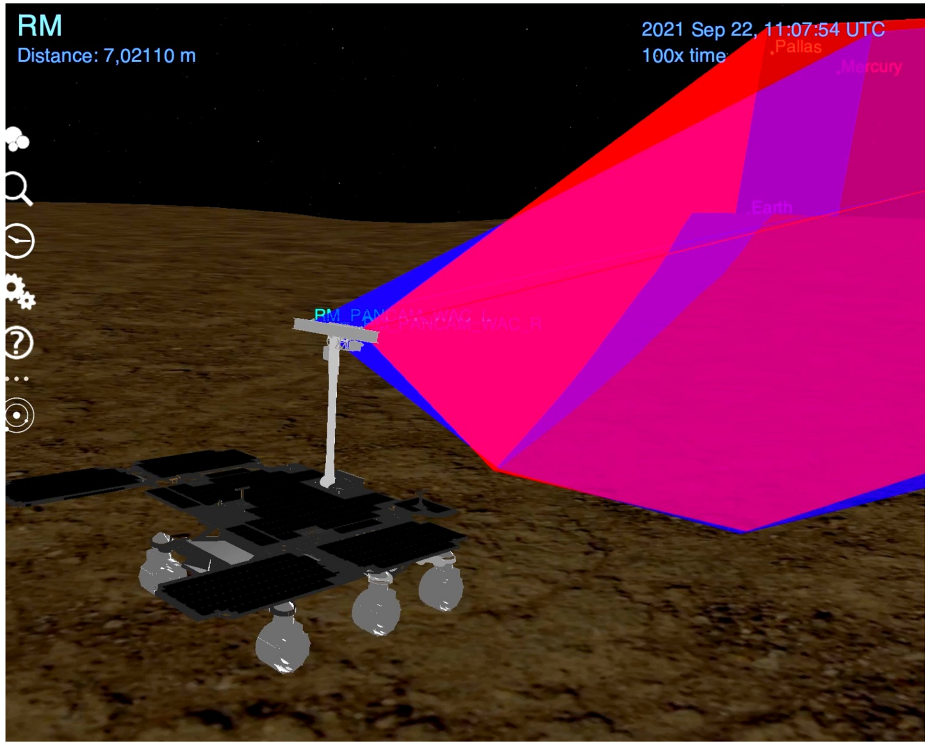


Visualizing the spacecraft

- For some missions, we only have a single (fixed) model of the spacecraft, so you would not see the Solar Arrays or Antenna rotating.
- However, you can display the Solar Arrays reference frames based on telemetry data and see how that fits the Sun Direction.
- For missions with a full model composed of different parts you may see the movement in Cosmographia.







Catalog Configuration Files

- The scenario catalog file we have loaded points to a predifined set of catalog files loading the SPICE kernels and defining the spacecraft, but there are more catalog files that can be loaded.
- Under misc/cosmo/config we have the base catalogs to load:
  - spice_{mk_reference}*.json catalogs, to load the SPICE kernels
  - spacecraft_{missions}*_arcs.json catalogs define the bodies in the scene.

spice_ops_BEPIC.json

```
{
    "version": "1.0",
    "name": "Cosmographia BEPIC Example",
    "spiceKernels": [
        "../../../kernels/mk/bc_ops_local.tm"
    ]
}
```

spacecraft_hera_arcs.json

```
        ]}},
    {
        "class": "spacecraft",
        "name": "HERA",
        "startTime": "2022-01-01 01:00:00.000  UTC",
        "arcs": [
            {
                "center": "DIDYMOS",
                "trajectory": {
                    "type": "Spice",
                    "target": "HERA_SPACECRAFT",
                    "center": "DIDYMOS"
                },
                "bodyFrame": {
                    "type": "Spice",
                    "name": "HERA_SPACECRAFT"
                }
            }
        ],
    "geometry": {
      "type": "Mesh",
      "source": "../models/3ds/hera_sc_bus_v01.3ds"
    },
```

spacecraft_hera_arcs.json

```
{
    "version": "1.0",
    "name": "Cosmographia MPO Example",
    "items": [
{
        "class": "spacecraft",
        "name": "DIDYMOS",
        "startTime": "2022-01-01 01:00:00.000  UTC",
        "arcs": [
            {
                "endTime": "2033-06-23 00:00:00.000  UTC",
                "center": "Sun",
                "trajectory": {
                    "type": "Spice",
                    "target": "DIDYMOS",
                    "center": "Sun"
                },
                "bodyFrame": {
                    "type": "Spice",
                    "name": "DIDYMOS_FIXED"
                }
            }
        ],
      "geometry": {
        "type": "Globe",
        "radii": [
                0.39167,
                0.39167,
                0.29195
            ]
      },
```

Spacecraft Catalog Files

- We can have multiple arcs with different centers for the same body and multiple bodies in the same file.

spacecraft_BEPIC_arcs.json

```
{
   "version": "1.0",
   "name": "Cosmographia MPO Example",
   "items": [
      {
         "class": "spacecraft",
         "name": "MPO",
         "startTime": "2018-10-19 02:05:26.295 UTC",
         "arcs": [
            {
              "endTime": "2025-12-20 09:16:09.343 UTC",
              "center": "Sun",
               "trajectory": {
                  "type": "Spice",
                  "target": "MPO_SPACECRAFT",
                  "center": "Sun"
               },
               "bodyFrame": {
                  "type": "Spice",
                  "name": "MPO_SPACECRAFT"
               }
            },
            {
               "center": "Mercury",
               "trajectory": {
                  "type": "Spice",
                  "target": "MPO_SPACECRAFT",
                  "center": "Mercury"
               },
               "bodyFrame": {
                  "type": "Spice",
                  "name": "MPO_SPACECRAFT"
               }
            }
         ],
         "geometry": {
```

spacecraft_BEPIC_arcs.json

```
      },
      {
         "class": "spacecraft",
         "name": "MMO",
         "startTime": "2018-10-19 02:05:26.295 UTC",
         "arcs": [
            {
               "center": "Sun",
               "endTime": "2025-12-20 09:16:09.343 UTC",
               "trajectory": {
                  "type": "Spice",
                  "target": "MMO",
                  "center": "Sun"
               },
               "bodyFrame": {
                  "type": "Spice",
                  "name": "MMO_SPACECRAFT"
               }
            },
            {
               "center": "Mercury",
               "trajectory": {
                  "type": "Spice",
                  "target": "MMO",
                  "center": "Mercury"
               },
               "bodyFrame": {
                  "type": "Spice",
                  "name": "MMO_SPACECRAFT"
               }
            }
         ],
```

Spacecraft Catalog Files

- Object label and trajectory visual aspect can be configured

spacecraft_BEPIC_arcs.json

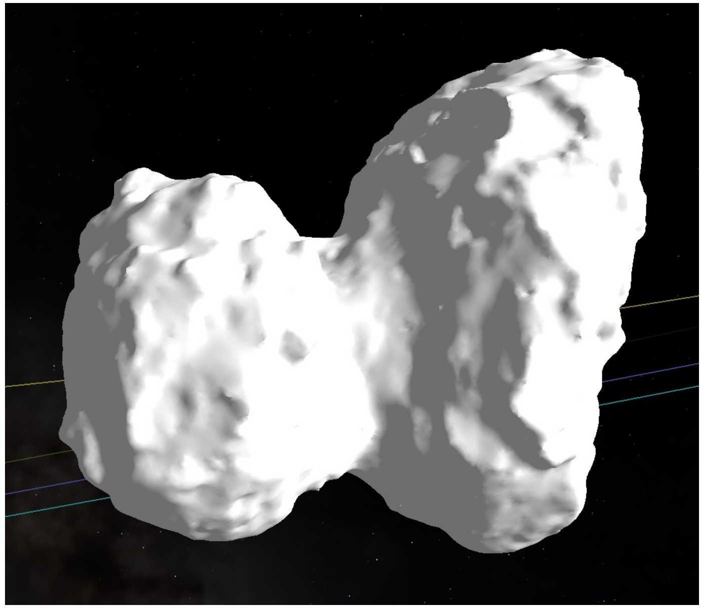
```
"geometry": {
  "type": "Mesh",
  "size": 0.0033,
  "meshOffset": [0, 0, 0.0002],
  "source": "../models/hd/mpo.3ds"
},
"label": {
  "color": [
    1,
    1,
    1
  ]
},
"trajectoryPlot": {
  "color": [
    1,
    0,
    0
  ],
  "lineWidth": 5,
  "duration": "2 d",
  "lead": 0.25,
  "fade": 0.0,
  "sampleCount": 500
}
```

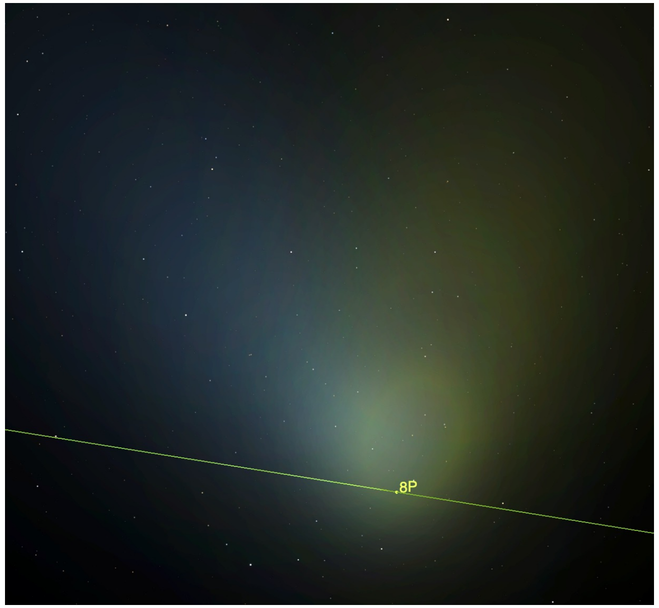
- Time Switched geometry for MMO before and after appendix deployment

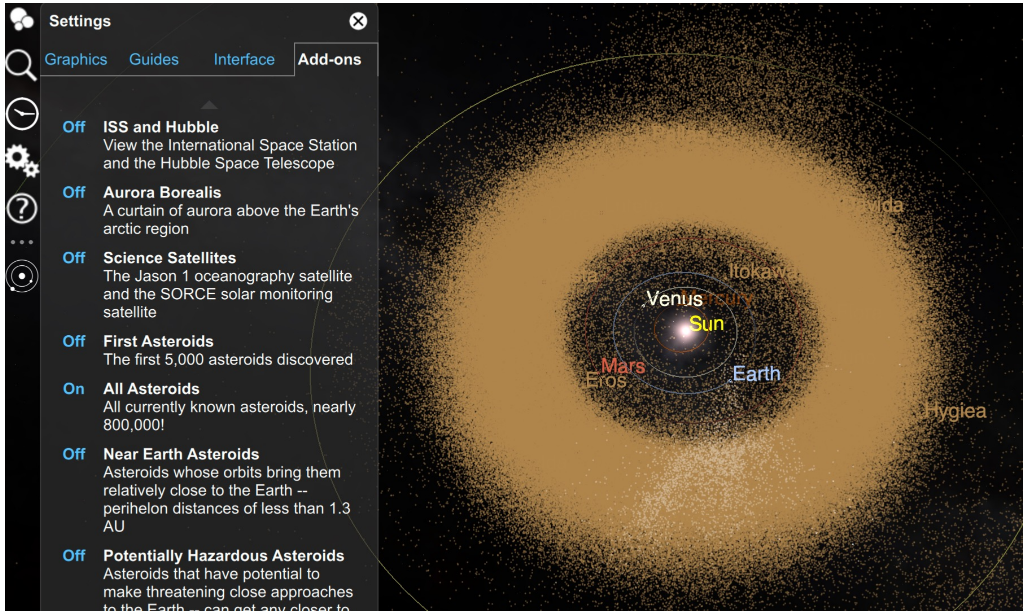
```
      "bodyFrame": {
         "type": "Spice",
         "name": "MMO_SPACECRAFT"
      }
    }
  ],
"geometry": {
  "type": "TimeSwitched",
  "sequence": [
  {
      "startTime": "2018-10-19 02:05:26.295 UTC",
      "geometry": {
        "type": "Mesh",
        "meshOffset": [0, 0, -0.2],
        "size": 0.001,
        "source": "../models/hd/mmo.3ds"
      }
  },
  {
      "startTime" : "2025-12-20 09:16:09.343 UTC",
      "geometry": {
        "type": "Mesh",
        "size": 0.015,
        "source": "../models/hd/mmo_m.3ds"
      }
  }
```

Spacecraft Catalog Files

- In these files we define:
  - The body target and center (observer) and body fixed frame
  - The body geometry: Mesh/DSK, Globe, Ring, Particle System, Keplerian Swarm, Time Switched
    - Scale and Offset
  - Label and Trajectory plot options.







Sensor Catalog Files

- For every sensor defined in the Instrument Kernels, there is a corresponding **sensor catalog** file under:
  - misc/cosmo/sensors

if anything is missing, let us know!

sensor_BEPIC_MPO_AUX.json
sensor_BEPIC_MPO_BELA_RECEIVER-MERCURY.json
sensor_BEPIC_MPO_BELA_TRANSMITTER-MERCURY.json
sensor_BEPIC_MPO_MERTIS_TIR_PLANET-MERCURY.json
sensor_BEPIC_MPO_MERTIS_TIR_PLANET-VENUS-OBS.json
sensor_BEPIC_MPO_MERTIS_TIR_PLANET-VENUS.json
sensor_BEPIC_MPO_MERTIS_TIR_SPACE-MERCURY.json
sensor_BEPIC_MPO_MERTIS_TIR_SPACE-VENUS-OBS.json
sensor_BEPIC_MPO_MERTIS_TIR_SPACE-VENUS.json
sensor_BEPIC_MPO_MERTIS_TIR-MERCURY.json
sensor_BEPIC_MPO_MERTIS_TIS_PLANET-MERCURY.json
sensor_BEPIC_MPO_MERTIS_TIS_SPACE-MERCURY.json
sensor_BEPIC_MPO_MERTIS_TIS-MERCURY.json
sensor_BEPIC_MPO_MGNS-MERCURY.json
sensor_BEPIC_MPO_MIXS-C-MERCURY.json
sensor_BEPIC_MPO_MIXS-T-MERCURY.json
sensor_BEPIC_MPO_PHEBUS_75-MERCURY.json
sensor_BEPIC_MPO_PHEBUS_100-MERCURY.json
sensor_BEPIC_MPO_PHEBUS_SLIT_75-MERCURY.json
sensor_BEPIC_MPO_PHEBUS_SLIT_100-MERCURY.json

sensor_BEPIC_MPO_SERENA_ELENA-MERCURY.json
sensor_BEPIC_MPO_SERENA_MIPA-MERCURY.json
sensor_BEPIC_MPO_SERENA_PICAM_00_30-MERCURY.json
sensor_BEPIC_MPO_SERENA_PICAM_30_60-MERCURY.json
sensor_BEPIC_MPO_SERENA_PICAM_60_90-MERCURY.json
sensor_BEPIC_MPO_SERENA_PICAM-MERCURY.json
sensor_BEPIC_MPO_SERENA_STROFIO-MERCURY.json
sensor_BEPIC_MPO_SIMBIO-SYS_HRIC_FILTERS-MERCURY.jso
sensor_BEPIC_MPO_SIMBIO-SYS_HRIC-MERCURY.json
sensor_BEPIC_MPO_SIMBIO-SYS_STC_FILTERS-MERCURY.jsor
sensor_BEPIC_MPO_SIMBIO-SYS_STC_FPA-MERCURY.json
sensor_BEPIC_MPO_SIMBIO-SYS_STC-MERCURY.json
sensor_BEPIC_MPO_SIMBIO-SYS_VIHI-MERCURY.json
sensor_BEPIC_MPO_SIXS-P-MERCURY.json
sensor_BEPIC_MPO_SIXS-X_PLAN-MERCURY.json
sensor_BEPIC_MPO_SIXS-X-MERCURY.json
sensor_BEPIC_MPO_STR-MERCURY.json
sensor_BEPIC_MTM_MCAM1-EARTH.json
sensor_BEPIC_MTM_MCAM1-MERCURY.json
sensor_BEPIC_MTM_MCAM2-MERCURY.json
sensor_BEPIC_MTM_MCAM3-EARTH.json
sensor_BEPIC_MTM_MCAM3-MERCURY.json

sensor_BEPIC_MMO_MPPE_ENA_CRUISE-VENUS-OBS.json
sensor_BEPIC_MMO_MPPE_ENA_CRUISE-VENUS.json
sensor_BEPIC_MMO_MPPE_ENA-MERCURY_VENUS.json
sensor_BEPIC_MMO_MPPE_ENA-MERCURY.json
sensor_BEPIC_MMO_MPPE_HEP-ELE_CRUISE-VENUS-OBS.json
sensor_BEPIC_MMO_MPPE_HEP-ELE_CRUISE-VENUS.json
sensor_BEPIC_MMO_MPPE_HEP-ELE-MERCURY.json
sensor_BEPIC_MMO_MPPE_HEP-ION-MERCURY.json
sensor_BEPIC_MMO_MPPE_MEA_CRUISE-VENUS.json
sensor_BEPIC_MMO_MPPE_MEA1_CRUISE-VENUS.json
sensor_BEPIC_MMO_MPPE_MEA2_CRUISE-VENUS.json
sensor_BEPIC_MMO_MPPE_MIA_CRUISE-VENUS.json
sensor_BEPIC_MMO_MPPE_MIA-MERCURY.json
sensor_BEPIC_MMO_MPPE_MSA_CRUISE-VENUS.json
sensor_BEPIC_MMO_MPPE_MSA-MERCURY.json
sensor_BEPIC_MMO_MPPE-LEP_CRUISE-VENUS-OBS.json
sensor_BEPIC_MMO_MPPE-LEP_CRUISE-VENUS.json
sensor_BEPIC_MMO_MPPE-LEP-MERCURY.json
sensor_BEPIC_MMO_MSASI.json
sensor_BEPIC_MMO_SSAS.json

Sensor Catalog Files

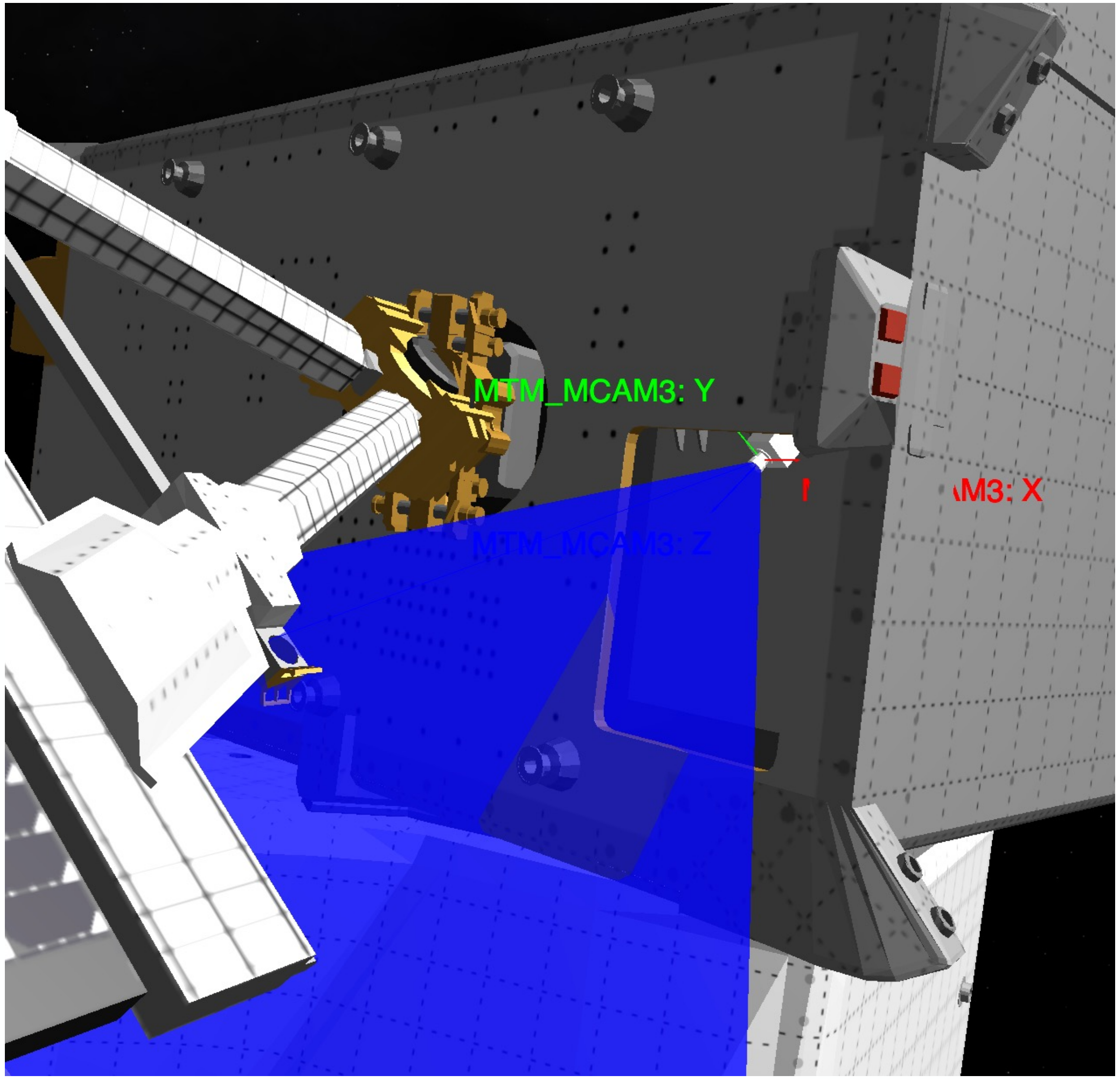
- It is possible to visualize the Field-of-view of the instruments defined in the Instrument Kernels (IK) of the SPICE Kernel Dataset
- bc_mtm_mcam_v05.ti

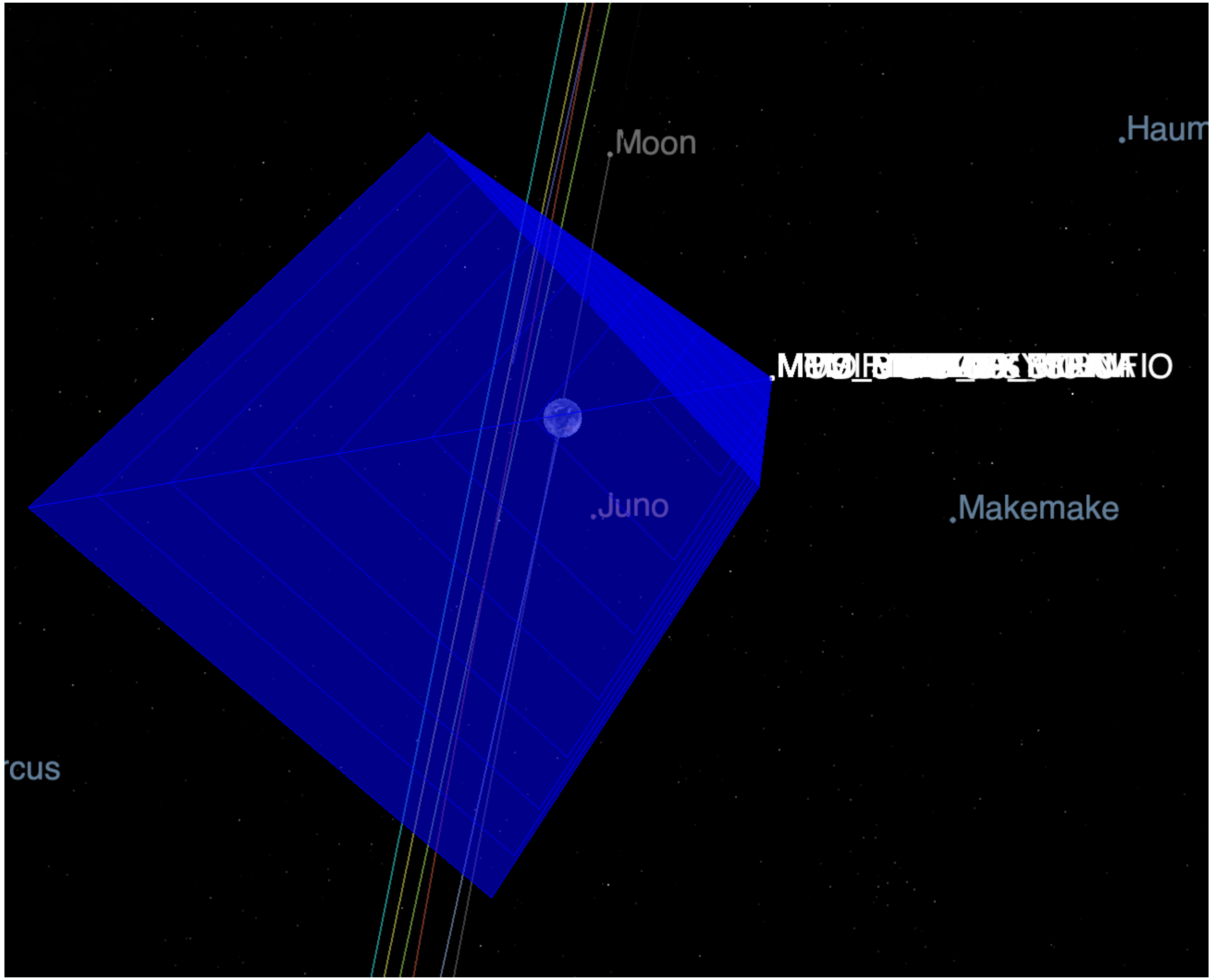
```
INS-652970_NAME              = 'MTM_MCAM3'
INS-652970_BORESIGHT         = ( 0.0, 0.0, 1.0 )
INS-652970_FOV_FRAME         = 'MTM_MCAM3'
INS-652970_FOV_SHAPE         = 'RECTANGLE'
INS-652970_FOV_CLASS_SPEC    = 'ANGLES'
INS-652970_FOV_REF_VECTOR    = ( 0.0, 1.0, 0.0 )
INS-652970_FOV_REF_ANGLE     = ( 30.18 )
INS-652970_FOV_CROSS_ANGLE   = ( 30.18 )
INS-652970_FOV_ANGLE_UNITS   = 'DEGREES'
```

- sensor_BEPIC_MTM_MCAM3-EARTH.json

```
{
  "version": "1.0",
  "name": "Cosmographia BEPIC Example",
  "items": [
    {
      "class": "sensor",
      "name": "MTM_MCAM3_FOV",
      "parent": "MTM",
      "center": "MTM_MCAM3",
      "trajectoryFrame": {
        "type": "BodyFixed",
        "body": "MTM"
      },
      "geometry": {
        "type": "Spice",
        "instrName": "MTM_MCAM3",
        "rangeTracking": true,
        "target": "Earth",
        "range": 500,
        "frustumColor": [
          0.0,
          0.0,
          1.0
        ],
        "frustumOpacity": 0.3,
        "gridOpacity": 0.8,
        "footprintOpacity": 0.8,
        "sideDivisions": 125,
        "onlyVisibleDuringObs": false
      }
    }
  ]
```

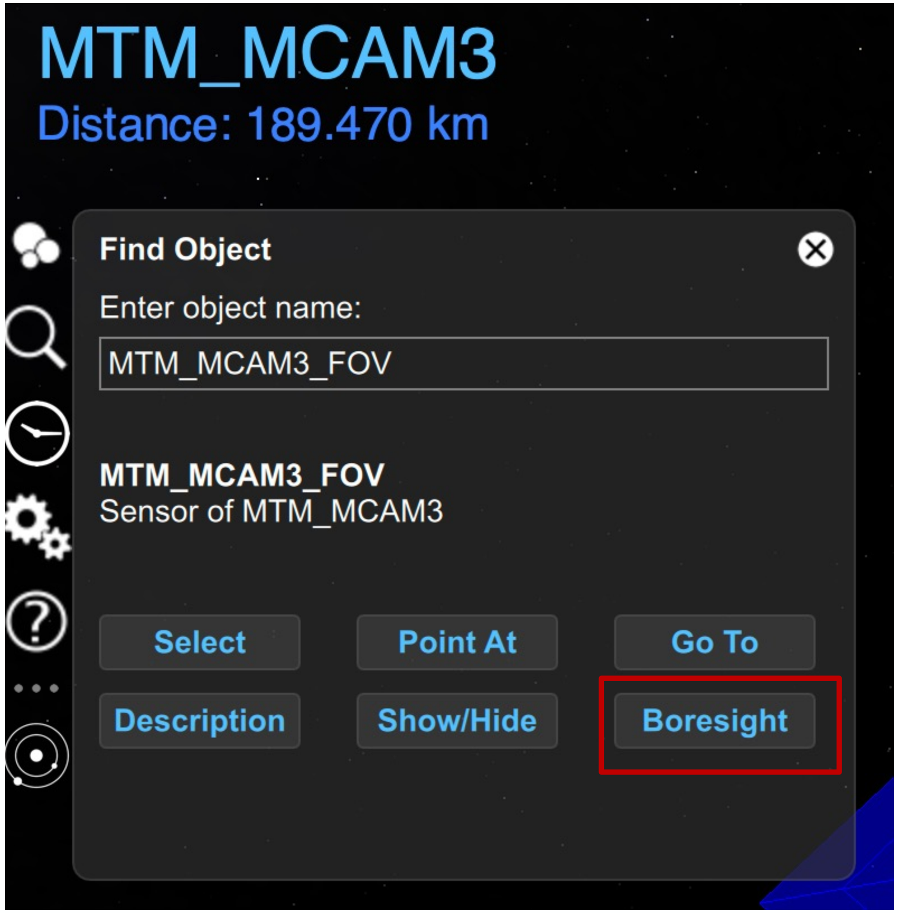
Sensor Catalog Files

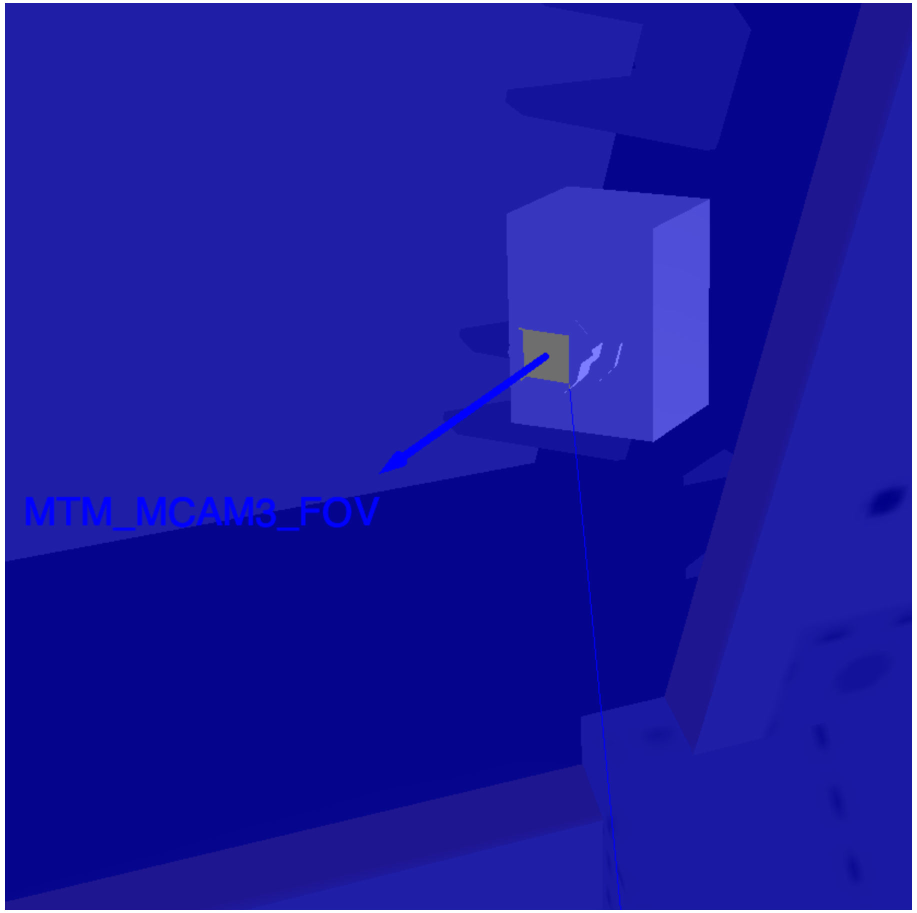




Sensor Catalog Files

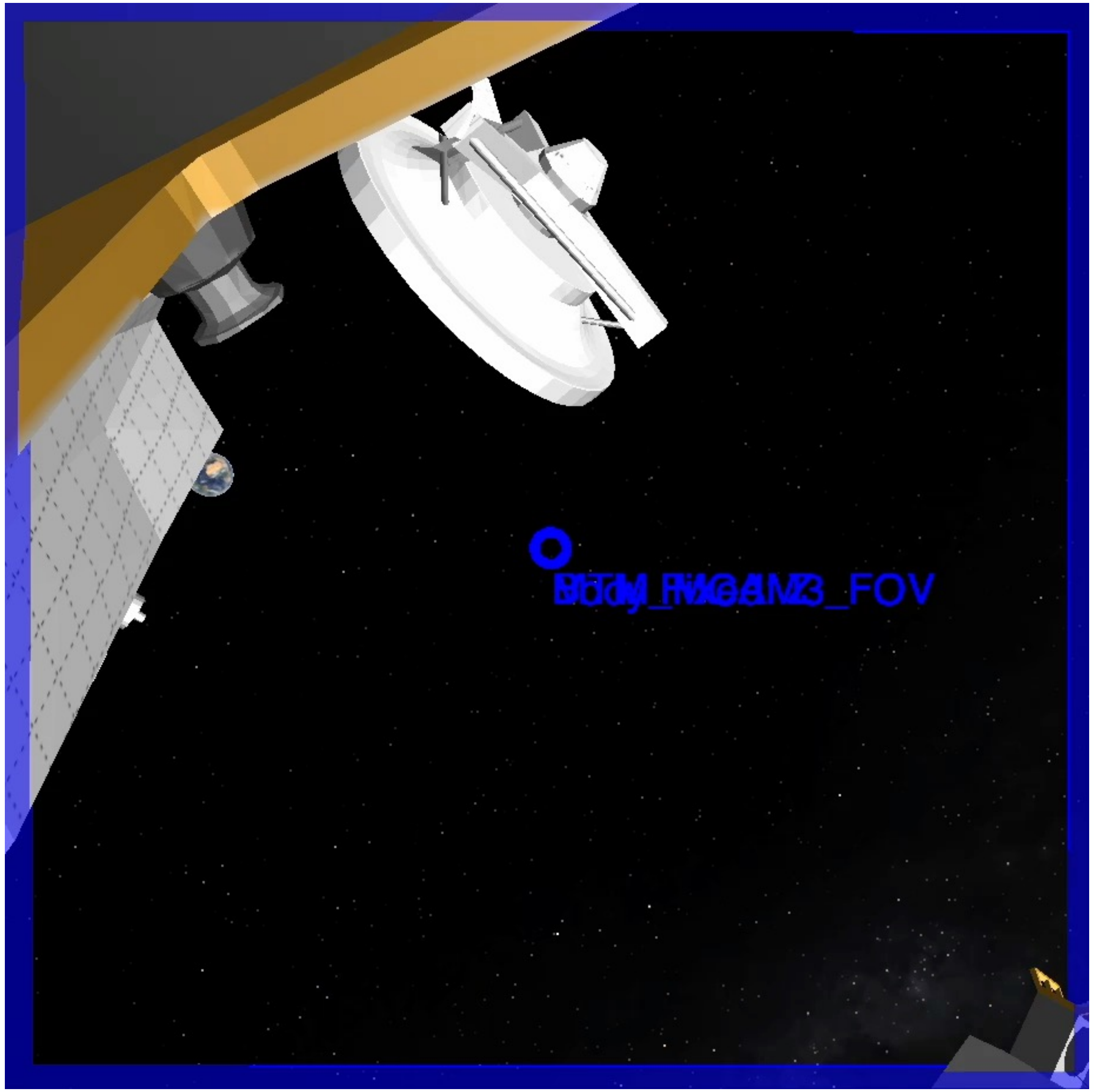
- It is possible to display the boresight of the loaded sensor by typing its name in the Find Object menu





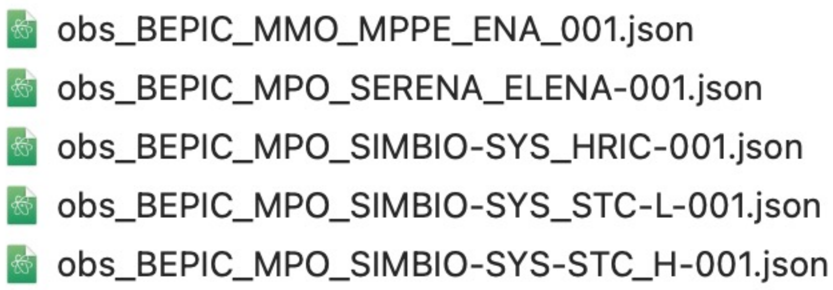
→ THE EUROPEAN SPACE AGENCY

Sensor Catalog Files

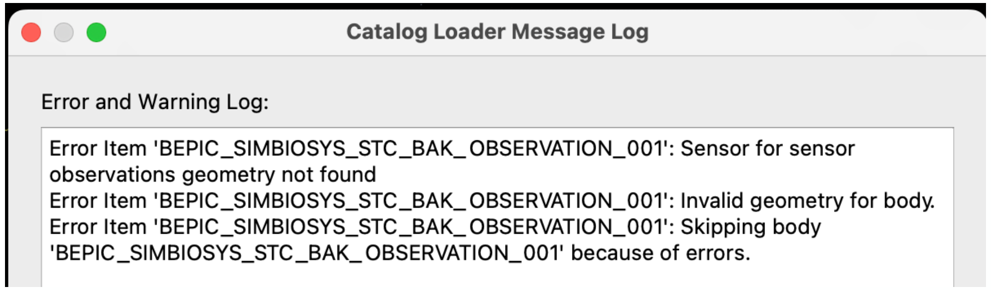


Observation Catalog Files

- Once a sensor catalog has been loaded, the instrument is defined in the Cosmographia scene.
- It is possible now to visualize the footprint of the instrument on a given target with the **observation catalog**
- These are located under:
  - misc/cosmo/observations

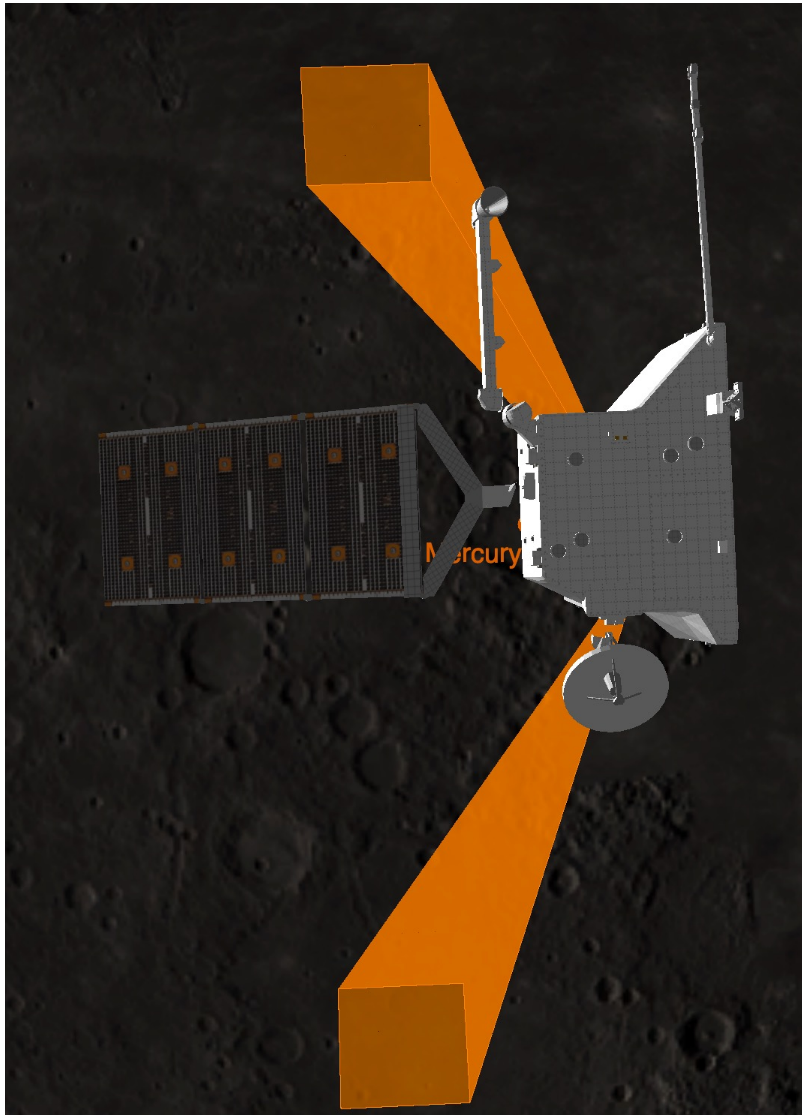


- If there is a one-to-one correspondance between sensor catalog and instrument sensor, there may be multiple observation catalogs for a given instrument, each of them for different use cases.
- NOTE: remember to always load the sensor catalog before the observation catalog, otherwise you will get an error



→ THE EUROPEAN SPACE AGENCY

Observation Catalog Files



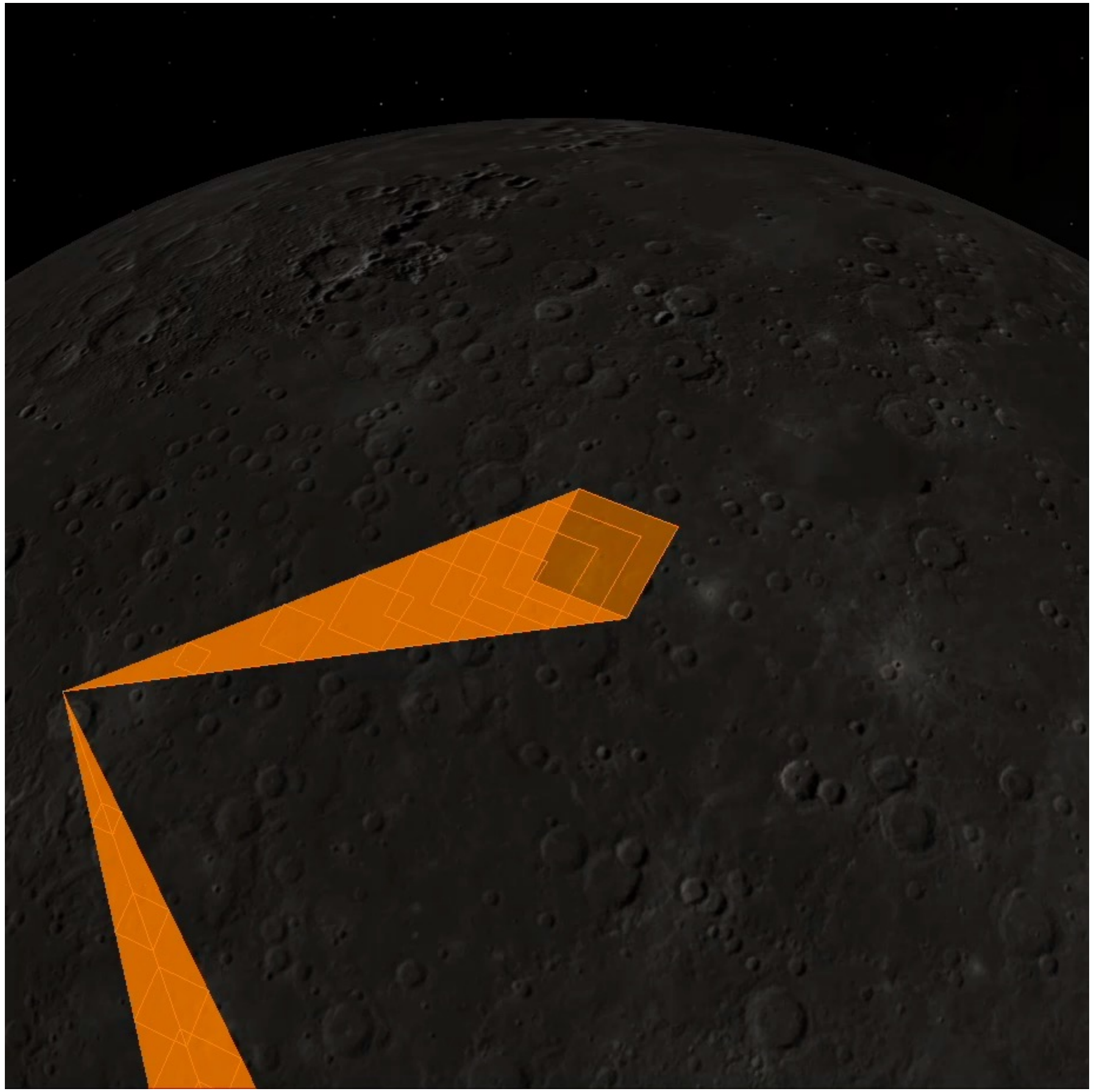
sensor_BEPIC_MPO_SIMBIO-SYS_STC-MERCURY.json

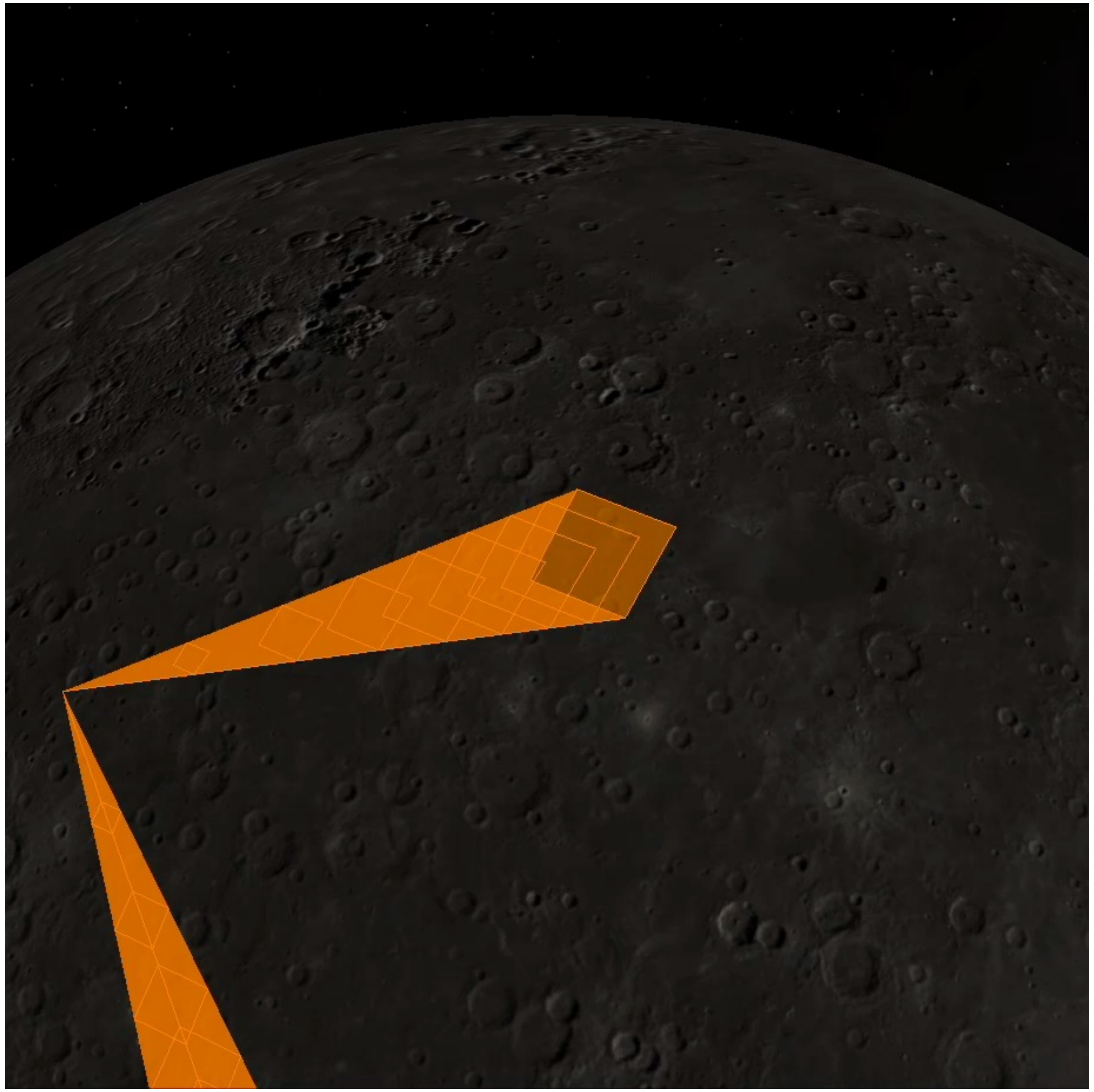

```
{
    "version": "1.0",
    "name": "Cosmographia BEPIC Example",
    "items": [
        {
            "class": "sensor",
            "name": "MPO_SIMBIO-SYS_STC-L",
            "parent": "MPO",
            "center": "MPO_SIMBIO-SYS",
            "trajectoryFrame": {
                "type": "BodyFixed",
                "body": "MPO"
            },
            "geometry": {
                "type": "Spice",
                "instrName": "MPO_SIMBIO-SYS_STC-L",
                "rangeTracking": true,
                "target": "Mercury",
                "range": 500,
                "frustumColor": [
                    1.0,
                    0.549019608,
                    0.0
                ],
                "frustumOpacity": 0.3,
                "gridOpacity": 0.8,
                "footprintOpacity": 0.8,
                "sideDivisions": 125,
                "onlyVisibleDuringObs": false
            }
        },
        {
            "class": "sensor",
            "name": "MPO_SIMBIO-SYS_STC-H",
            "parent": "MPO",
            "center": "MPO_SIMBIO-SYS",
            "trajectoryFrame": {
```


obs_BEPIC_MPO_SIMBIO-SYS_STC-L-001.json


```
{
    "version": "1.0",
    "name": "Cosmographia BEPIC Example",
    "items": [
        {
            "class": "observation",
            "name": "BEPIC_SIMBIOSYS_STC_BAK_OBSERVATION_001",
            "center": "Mercury",
            "trajectoryFrame": {
                "type": "BodyFixed",
                "body": "Mercury"
            },
            "bodyFrame": {
                "type": "BodyFixed",
                "body": "Mercury"
            },
            "geometry": {
                "type": "Observations",
                "sensor": "MPO_SIMBIO-SYS_STC-L",
                "groups": [
                    {
                        "startTime": "2026-04-17 13:16:00 UTC",
                        "endTime": "2026-04-17 13:17:00 UTC",
                        "obsRate": 1
                    }
                ],
                "footprintColor": [
                    1.0,
                    0.549019608,
                    0.0
                ],
                "footprintOpacity": 0.5,
                "showResWithColor": false,
                "alongTrackDivisions": 500,
                "shadowVolumeScaleFactor": 1.75,
                "fillInObservations": true
            }
        }
    ]
}
```

Observation Catalog Files



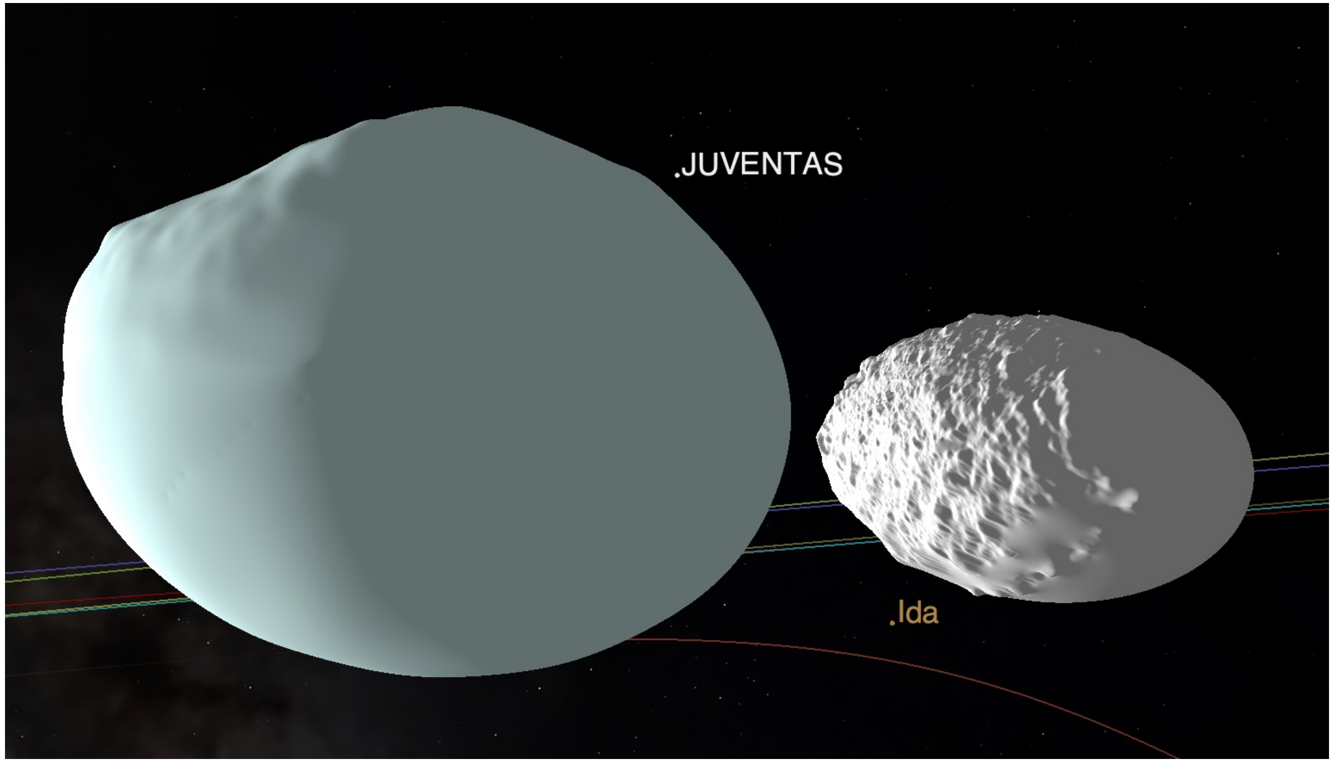


Shape Models and DSKs

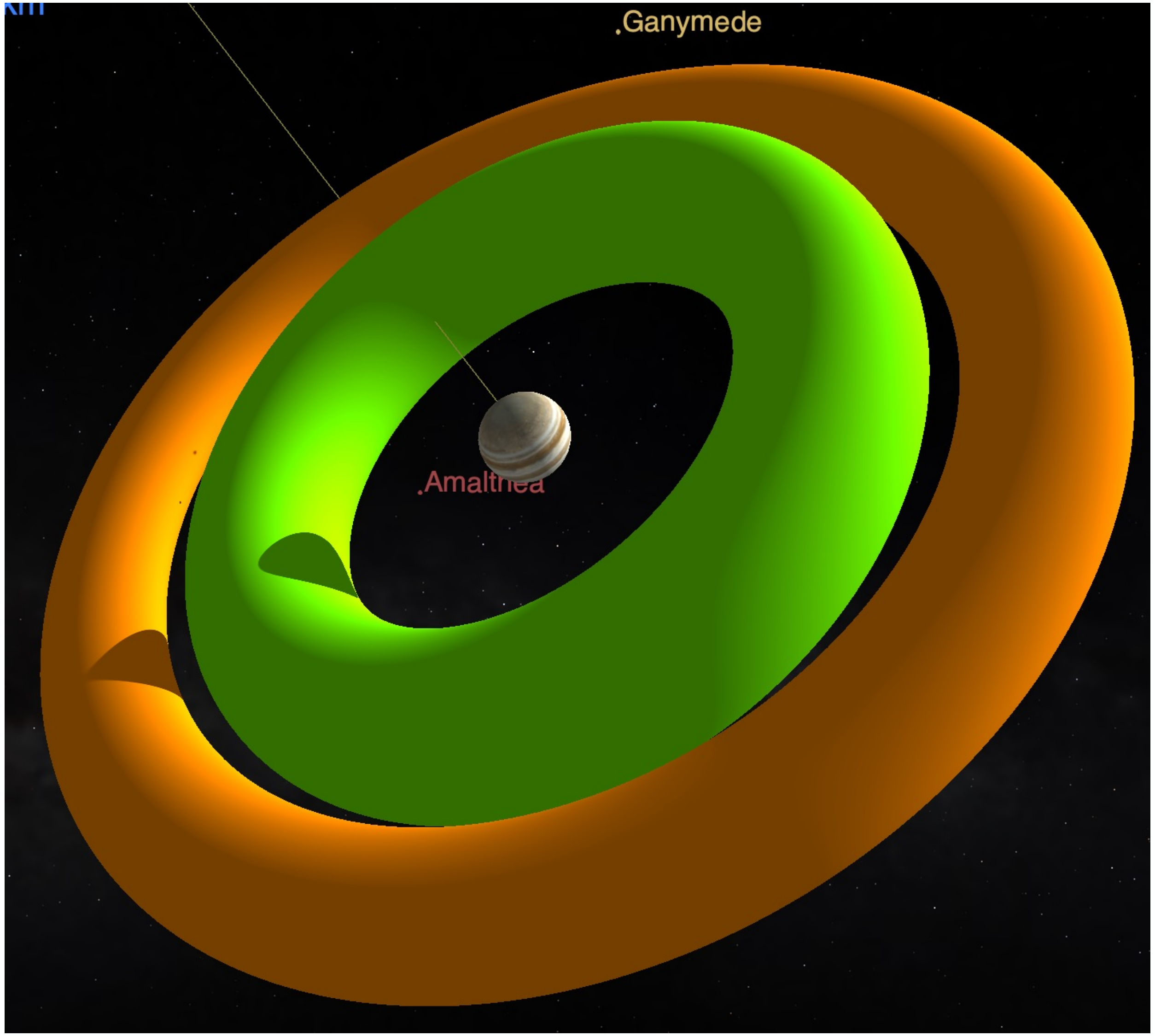
- For some missions, there are shape models avaialable different than the loaded by default.
- In some cases the models are quite heavy or intended for a specific use case.
- These are spacecraft catalog files and are available in:
  - misc/cosmo/config

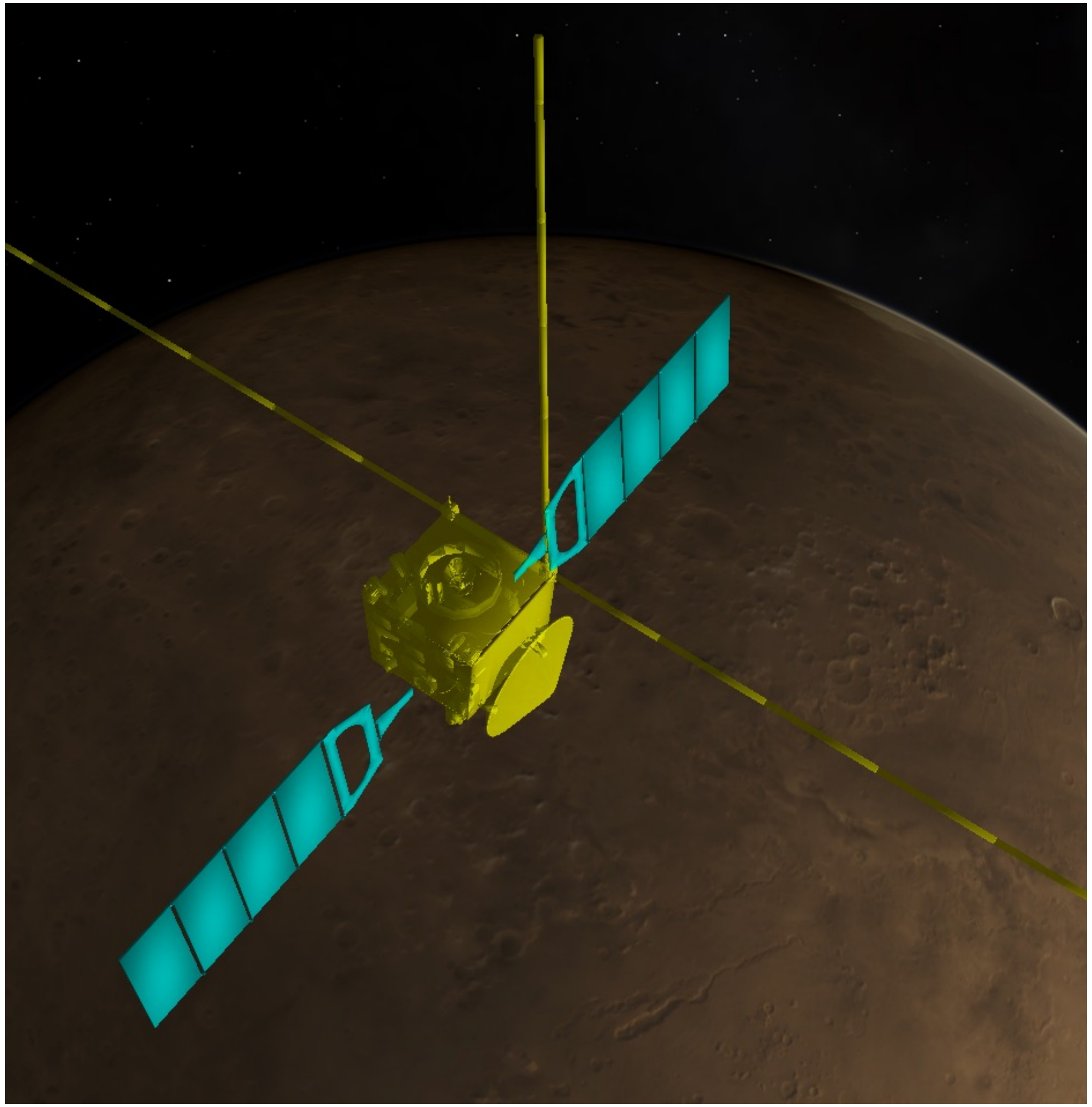
spacecraft_didymos_DSK_arcs.json

```
{
   "version": "1.0",
   "name": "Cosmographia MPO Example",
   "items": [
{
         "class": "spacecraft",
         "name": "DIDYMOS",
         "startTime": "2022-01-01 01:00:00.000  UTC",
         "arcs": [
            {
               "endTime": "2033-06-23 00:00:00.000  UTC",
               "center": "Sun",
               "trajectory": {
                  "type": "Spice",
                  "target": "DIDYMOS",
                  "center": "Sun"
               },
               "bodyFrame": {
                  "type": "Spice",
                  "name": "DIDYMOS_FIXED"
               }
            }
         ],
      "geometry": {
        "type": "DSK",
        "kernel": "../../../kernels/dsk/g_01165mm_spc_obj_didy_0000n00000_v003.bds",
        "color": [ 0.9, 1.0, 1.0 ],
        "opacity": 1.0
      },
```



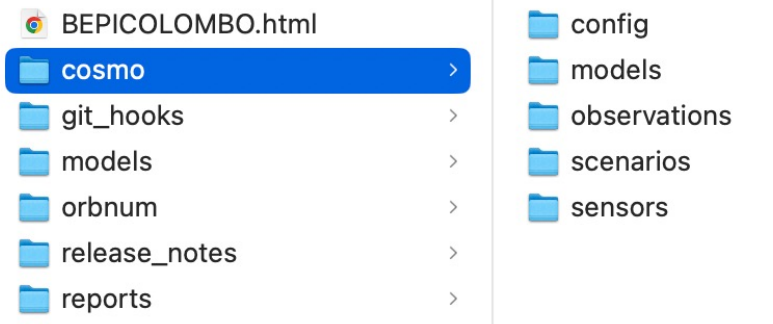
Shape Models and DSKs





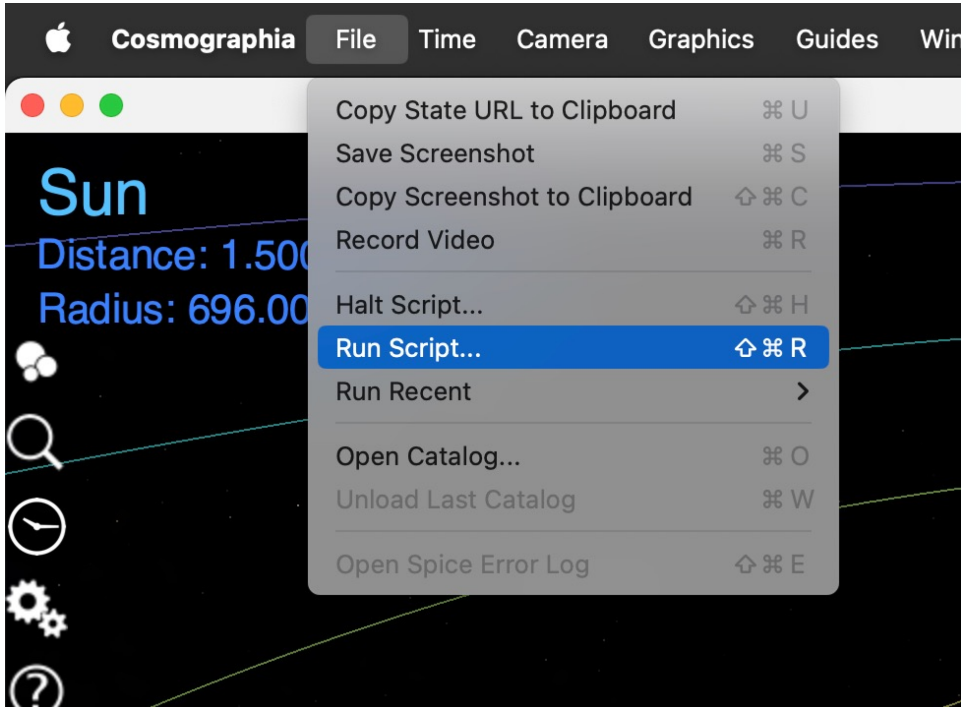
Summary

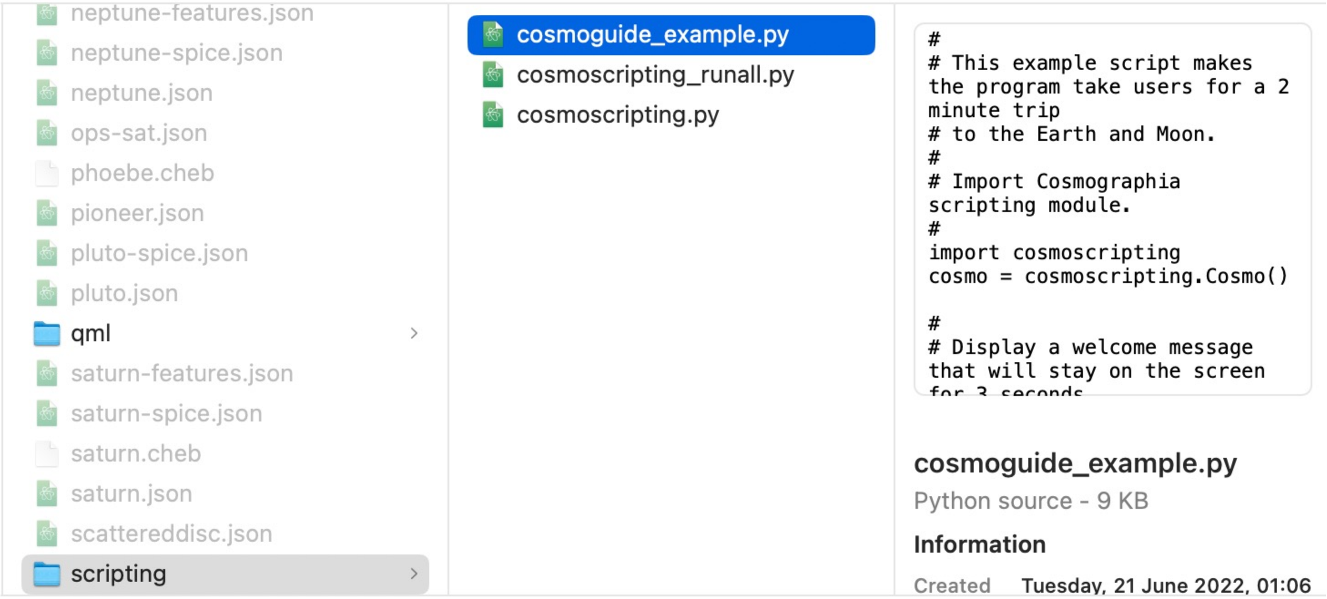
- The SPICE Kernels and Cosmographia configuration for a given mission are distributed together from BitBucket and our operational FTP/HTTPS
- To load the mission scenario into Cosmographia:
    - Create local copy of the meta-kernel: **mv kernels/mk/bc_plan.tm kernels/mk/bc_plan_local.tm**
    - Update the PATH_VALUES in the local meta-kernel with the absolute path to your kernels directory
        - **PATH_VALUES = ('/Users/aescalante/spice/missions/bc/bepicolombo/kernels')**
    - OR, install the amazing **git hook** so you do not have to worry every time you do a git pull
        - cd [SKD_PATH]
        - misc\git_hooks\skd_post_merge\install_hook_windows.bat (.sh for Mac and Linux)
- The most important catalog to load is the **scenario catalog** for the meta-kernel you want
    - spacecraft catalog and spice catalog are under config directory
    - sensor catalogs load the field-of-view of IK defined instruments
    - observation catalogs plot the footprint of sensors
    - models directory contains 3D models and textures of objects



Cosmographia Scripting

- Cosmographia allows the execution of Python scripts to automate some processes.
  - Python 2 for Mac and Linux – Cosmographia 4.1 (or previous versions)
  - Python 3 for Windows, Mac and Linux – Cosmographia 4.2 (or newer)





JUICE Cosmographia Plugin

The **Cosmographia JUICE plugin** is a software that adds extra features to the Cosmographia tool allowing an easy 3D visualisation of the JUICE spacecraft manoeuvres and instrument pointing.

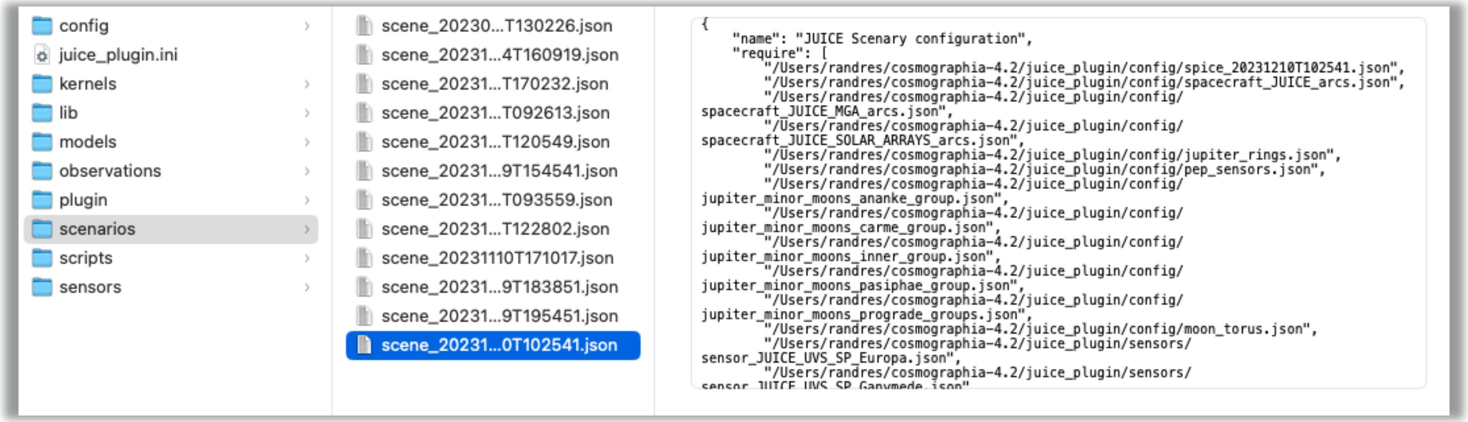
The package deals with the tedious build-up of Cosmographia catalogue files, hiding the low-level details and providing a turn-key solution for quick and easy visualization of JUICE pointing

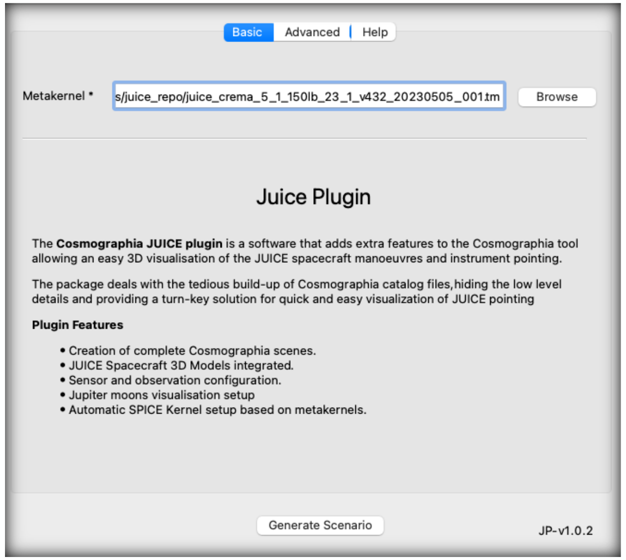
- Creation of complete Cosmographia scenes.
- Automatic SPICE Kernel setup based on metakernels.
- JUICE Spacecraft 3D Models integrated.
- Sensor and observation configuration.
- Load individual CKs

https://www.cosmos.esa.int/web/juice/cosmographia-plugin

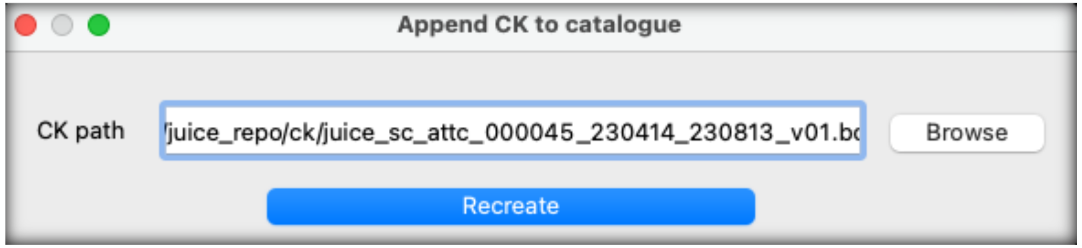
Scene loading based on metakernels

- The JUICE plugin deals with the preparation of the catalogues and spice configuration. The user selects a valid JUICE metakernel and the scene is prepared.



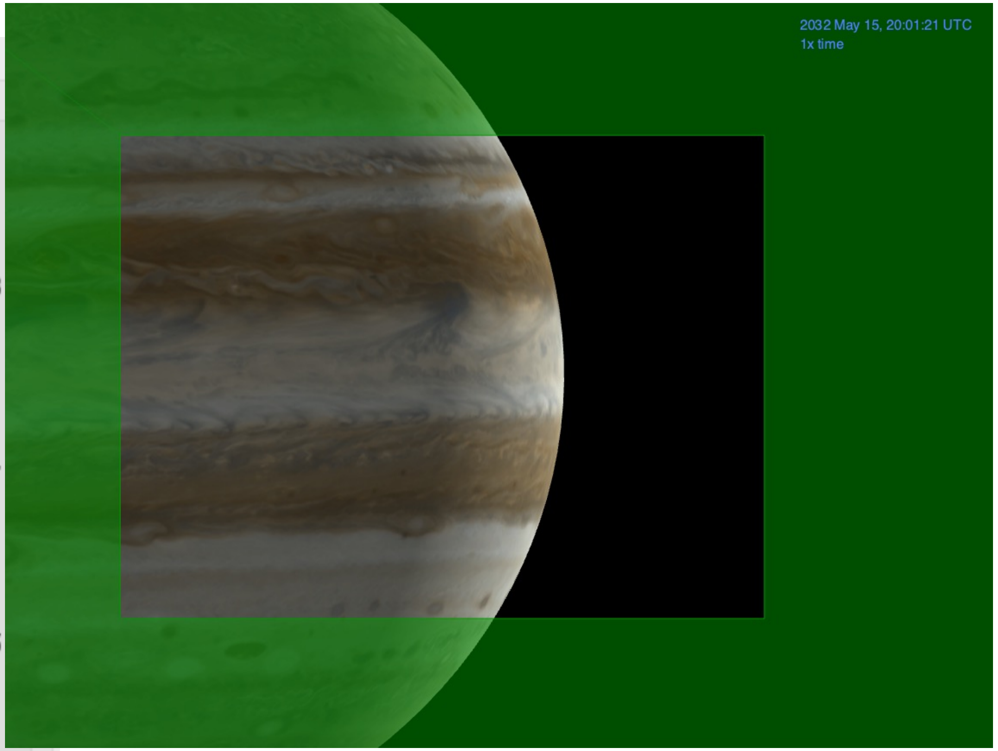


- After the scene loading, the kernel set can be updated adding new attitude kernels



Sensors

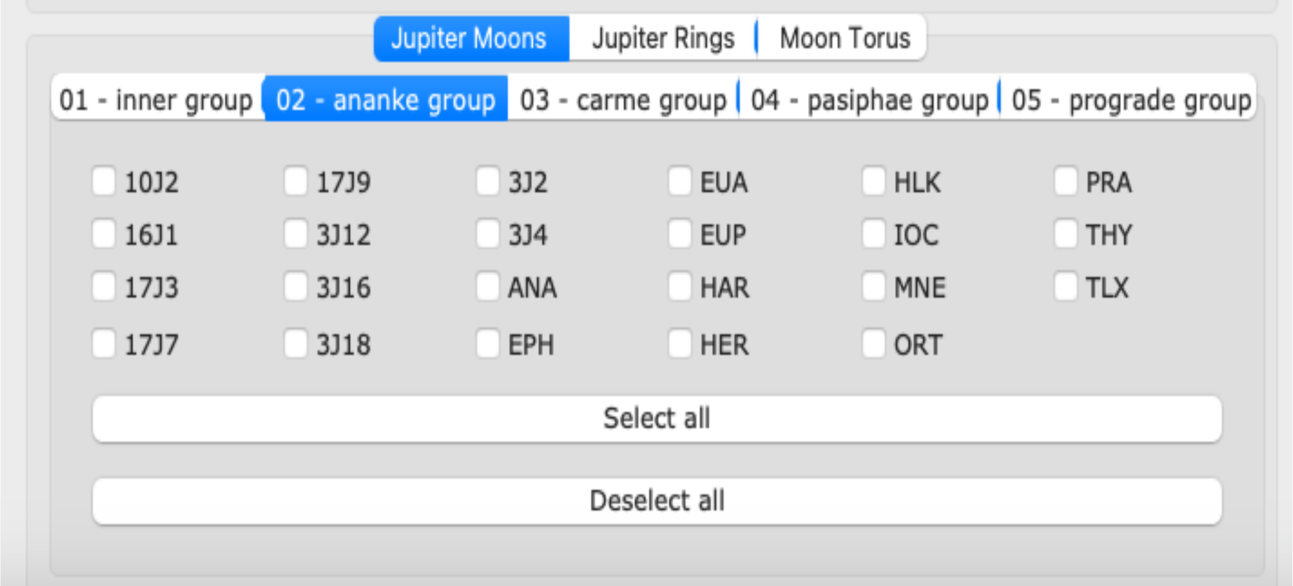
- The JUICE plugin helps with the preparation of the sensor catalogues, creating them on the fly.
- After loading, a dedicated UI allows to identify and activate/deactivate them … and even have a quick look through them

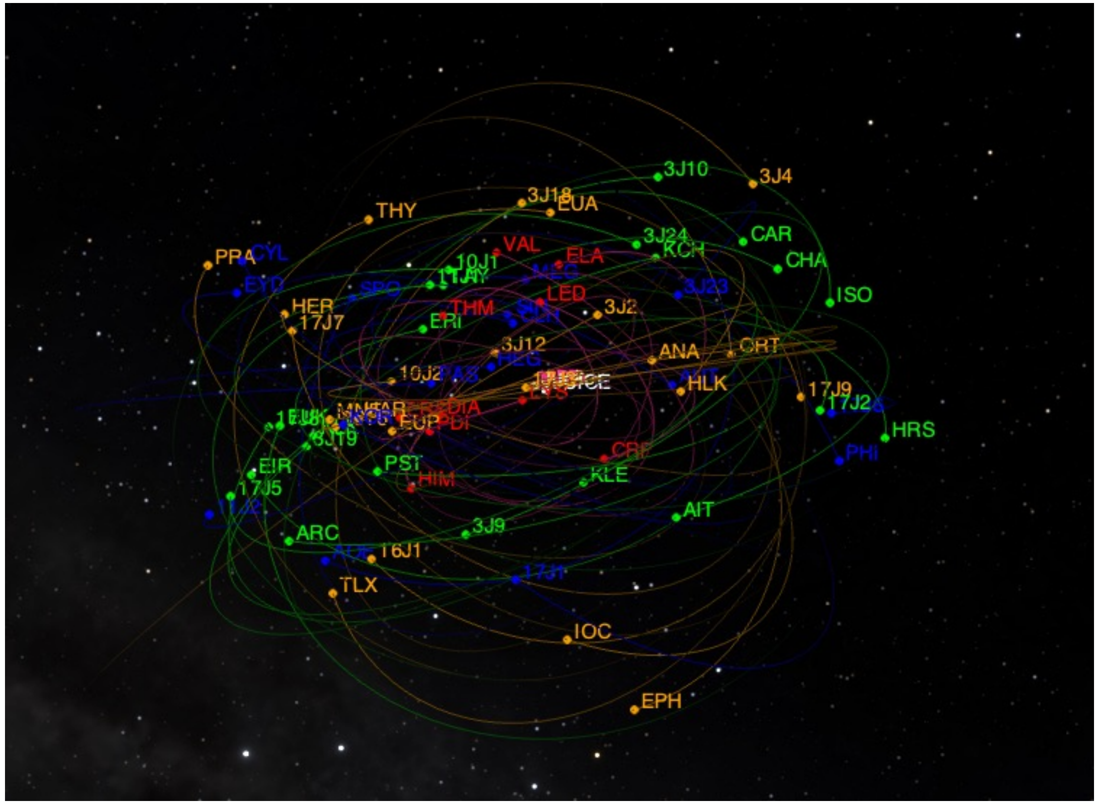


Minor moons and Science models

Accessing and visualising the Jupiter minor moons is a tedious manual process in Cosmographia

- Family colour and moon naming conventions
- UI show/hide feature
- Individual or family selection





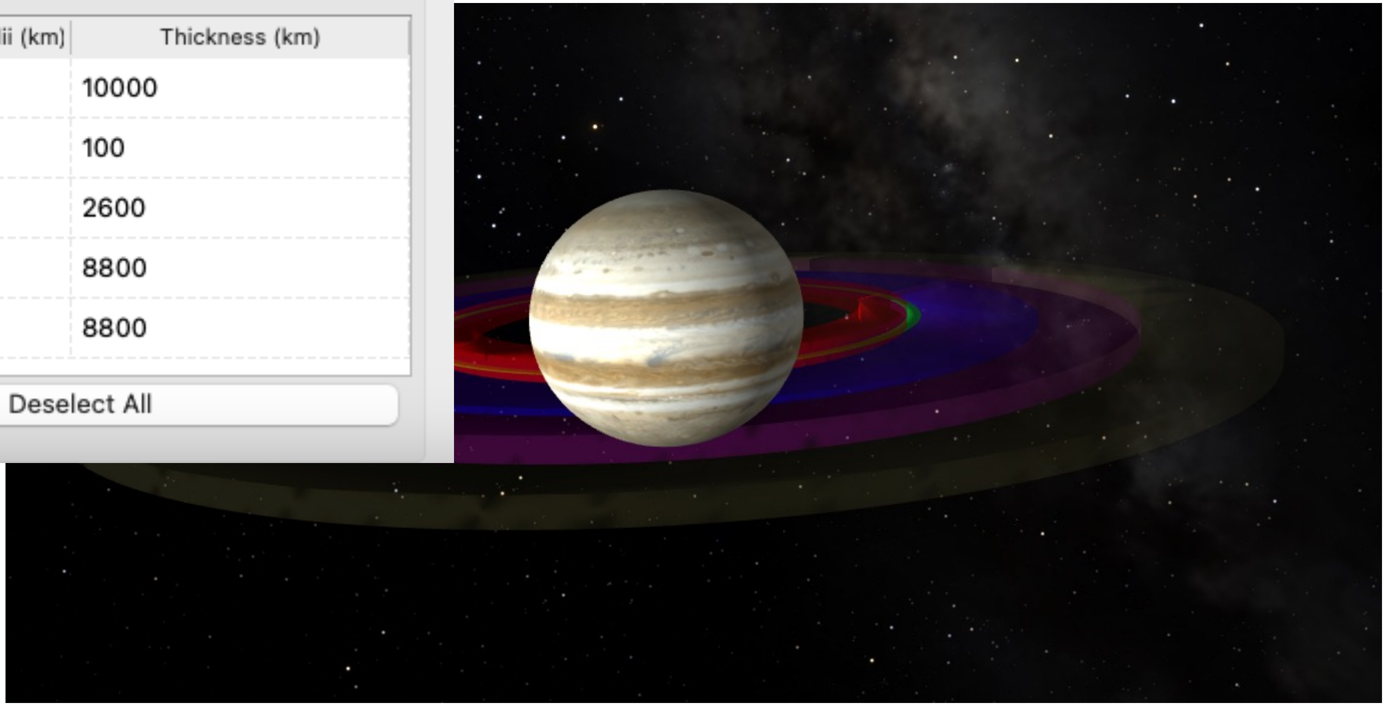
Jupiter Rings

- The Jupiter rings are implemented as a first order approximation mainly for science planning purposes (Pointing Design, Occultation opportunities, etc.). The rings are implemented in JUICE Cosmographia Plugin, the Cosmographia configuration files of the SPICE Kernel data set, the SPICE kernels themselves and in the JUICE Pointing Tool.

Jupiter Moons | Jupiter Rings | Moon Torus

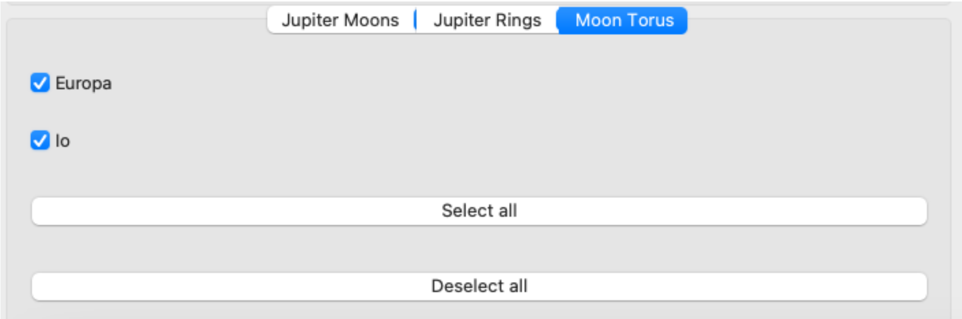
SPICE ID	Name	Color	Internal radii (km)	External radii (km)	Thickness (km)
☑ JUICE_...	Halo Ring		10000	122400	10000
☑ JUICE_...	Main Ring		122400	129100	100
☑ JUICE_...	Amalthea ...		129100	181350	2600
☑ JUICE_...	Thebe ...		181350	221900	8800
☑ JUICE_...	Thebe ...		221900	226000	8800

Select All | Deselect All



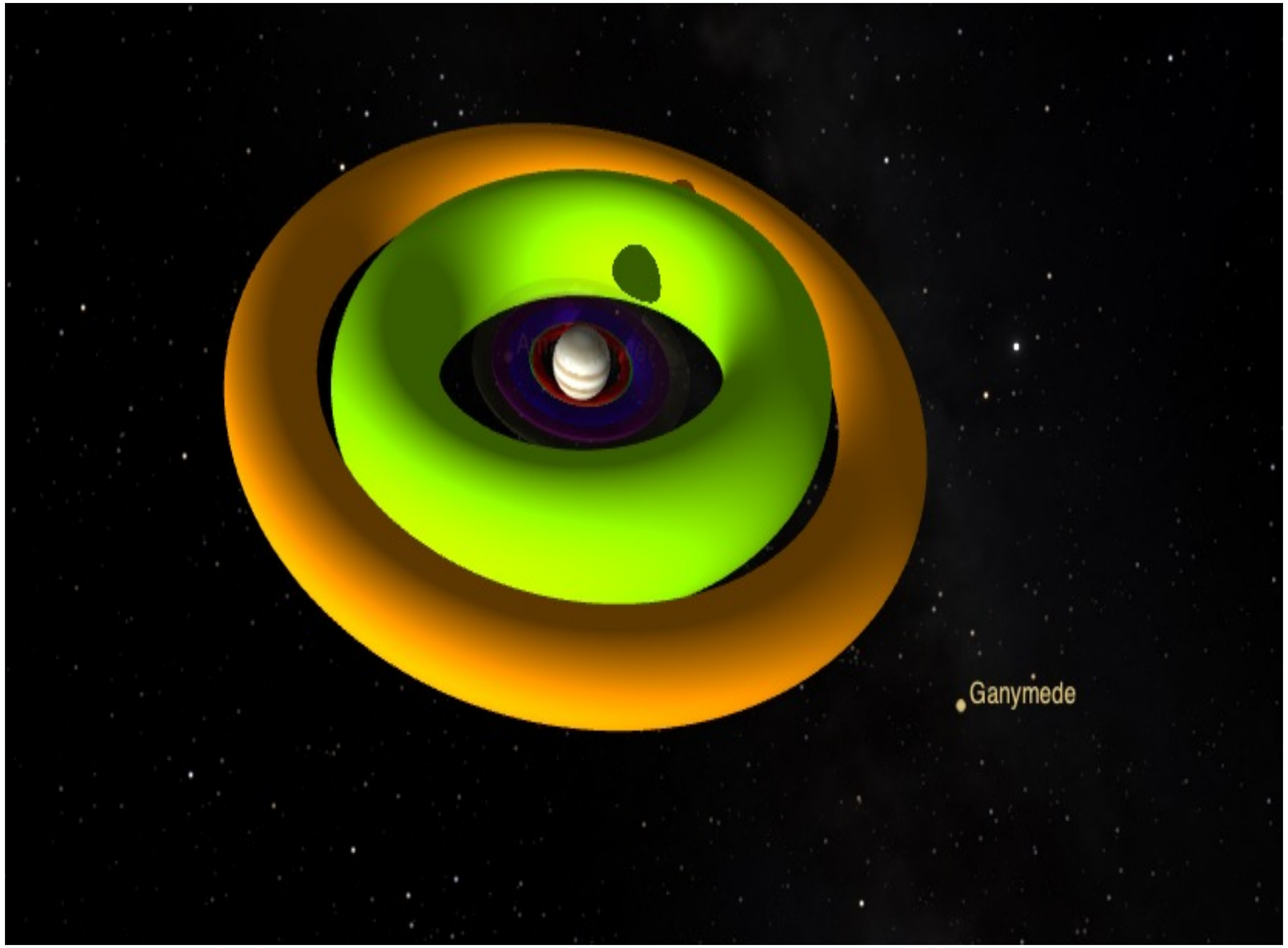
Io and Europa Torii

- The Jupiter and Europa Tori are implemented in the JUICE SPICE kernels, the plugin, and the Cosmographia configuration for science planning activities.



The Io Plasma Torus (IPT) is based on a 2-D model representing a section of the Io Torus based on data from the JUNO mission.

For the Europa Plasma Torus (EPT) The torus is centered on 10.5 RJ (not centred in moon) with an ellipsoidal radius of 1.5 RJ in-plane and 1 RJ out of the plane, where the plane is defined by Europa's orbital plane around Jupiter.



Jupiter Main Aurora and Magnetosphere belts

The Jupiter Main Aurora and Inner, Middle, and Outer Magnetosphere belts are available in the plugin and in the Cosmographia configuration files of the SPICE kernel set for visualization purposes and they show the magnetosphere of Jupiter and aurora. The magnetosphere is generated through the *particle system* option of Cosmographia, with particle positions along magnetic field lines estimated by a model. The aurora position also uses the *particle system*, with locations obtained from the Auroral Ovals files provided by LASP/University of Colorado

Online help

JUICE SOC Tools
1.0
Search docs

- Overview
- Cosmographia Plugin
  - Overview
  - Installation
  - Working with the Plugin
  - Known Issues
- Science Models

» Cosmographia Plugin   View page source

Cosmographia Plugin

SPICE-Enhanced Cosmographia is a visualization program rendering the solar system and its bodies in 3D to create a freely navigable map of the solar syster The program allows manipulation of time and camera (observer) position. It car use SPICE data to visualize trajectory, orientation, and sensors flown on and observations taken by interplanetary spacecraft, to support scientific or engineering analysis, and perhaps even public outreach.

The Cosmographia JUICE plugin is a software that adds extra features to the SPICE-Enhanced Cosmographia tool allowing easy 3D visualization of the JUIC spacecraft manoeuvres and instrument pointing.

Overview

The package deals with the tedious build-up of Cosmographia catalog files, hiding the low level details and providing a turn-key solution for quick and easy visualization of JUICE pointing.

Jupiter Rings

The Jupiter rings are implemented as a first order approximation mainly for science planning purposes (Pointing Design, Occultation opportunities, etc.). The rings are implemented in JUICE Cosmographia Plugin,the Cosmographia configuration files of the SPICE Kernel data set, the SPICE kernels themselves and in the JUICE Pointing Tool.

The Jupiter rings are modelled from [CIT04] as follows:

Name	Color	Internal radii (km)	External rad
Halo Ring	Red (#ff0000)	10000	122400
Main Ring	Green (#00ff00)	122400	129100
Amalthea Gossamer Ring	Blue (#0000ff)	129100	181350
Thebe Gossamer Ring	Magenta (#ff00ff)	181350	221900
Thebe Extension	Orange (#e7ad79)	221900	226000

- Big thanks to Marc Costa
- https://juicesoc.esac.esa.int/help/cosmog/

The backdoor - Getting access to the main window

In the previous section of Cosmographia scripting, we have seen how to execute a Cosmo script and what is the intended flow of the scripting.

With the plugin we wanted a way of interacting with Cosmographia out of this loop. So, we searched for a method of bypassing normal processing and allow us to extend the capabilities.

After analysing the tool and its usage of the Qt framework (pyQt 5), we concluded, that getting access to the main window, and setting up a 'hook' on it (as a menu option for example)

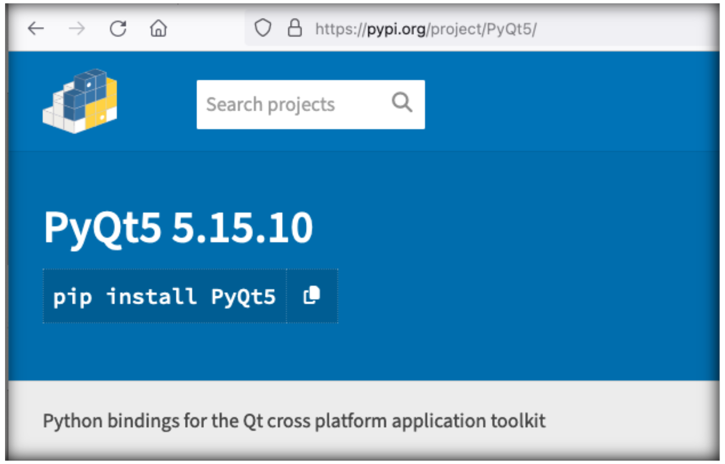
```python
from PyQt5.QtWidgets import qApp

def get_main_window():
    for widget in qApp.topLevelWidgets():
        name = widget.objectName()
        if name == 'mainWindow':
            return widget
    return None
```

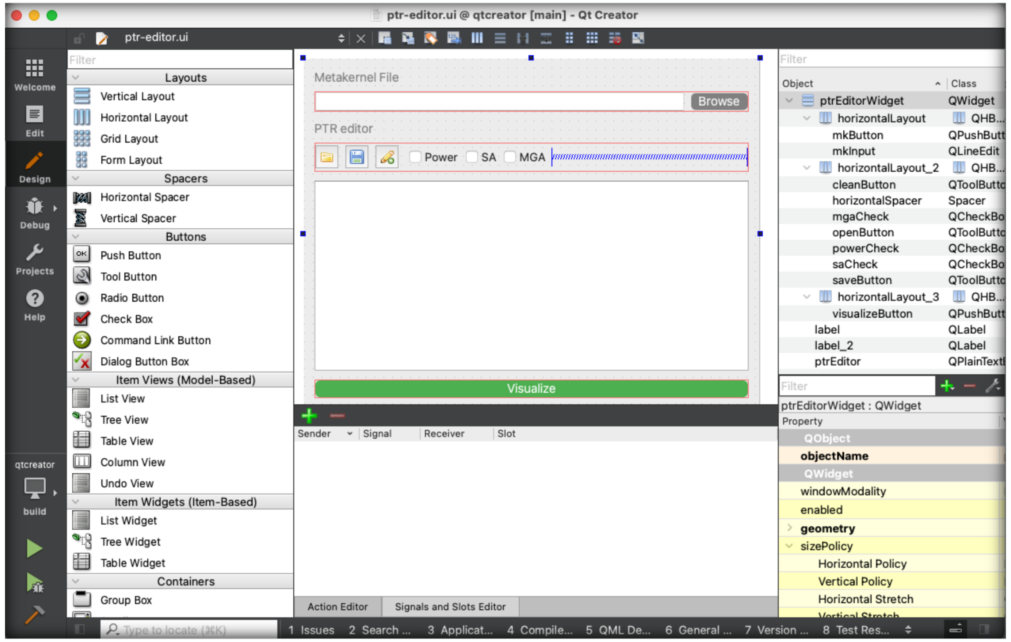
The backdoor – creating an app on top

Adding custom packages to the cosmo scripting (Cosmographia 4.1+)

```python
import cosmoscripting
import os
import sys

cosmo = cosmoscripting.Cosmo()

# prepare and load the libraries
sys.path.append(os.path.abspath(cosmo.scriptDir()))
```

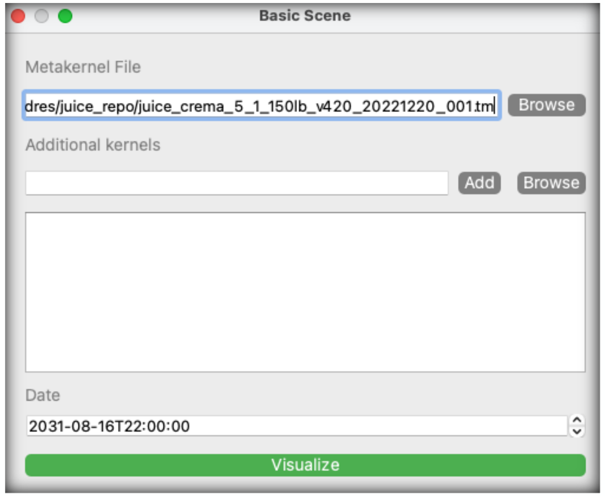
PyQT and Qcreator (UI development)

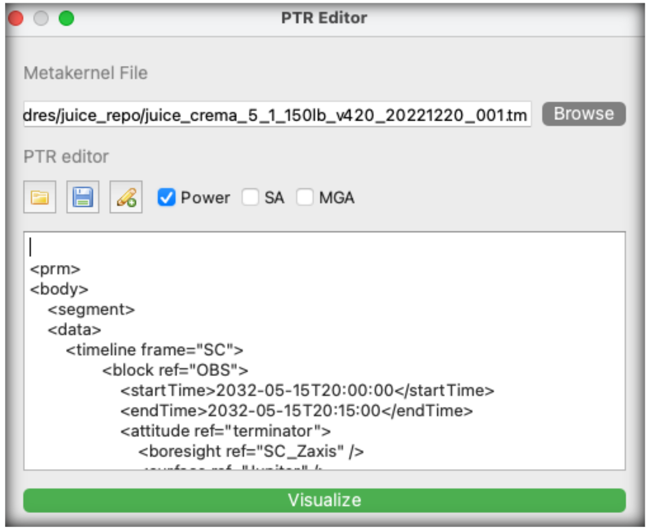


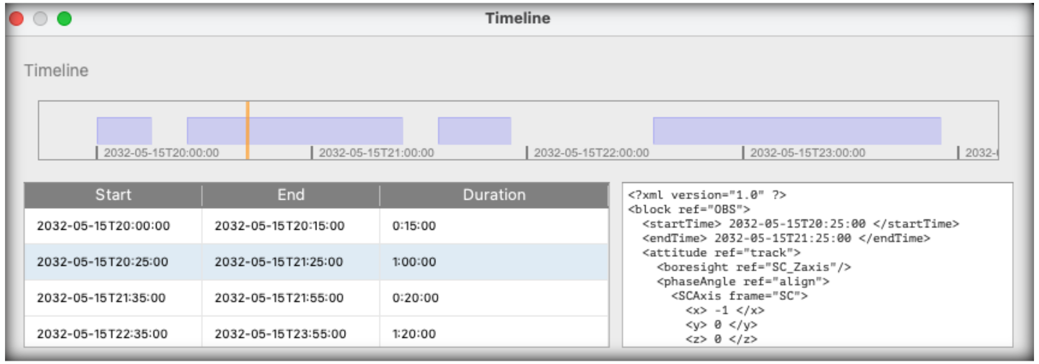


Next Generation

- Limitations for the development have been removed with Cosmographia 4.2
- The experience gained during the juice plugin allows us to extend the capabilites and improve the mission specific usability
- Refactoring is needed to ensure the maintenability and stability







SPICE service is open to implement or support mission specific use cases that can benefit from the Cosmographia capabilities.

Open Discussion

- Thank you very much for following the Cosmographia Training!
- We hope you will now know how to load your missions scenario into Cosmographia, plot reference frames, instruments field-of-views and observations.
- Learn more at the official Cosmographia User Guide: https://cosmoguide.org/

QUESTIONS?