DOCKS, a growing software suite for space mission prototyping

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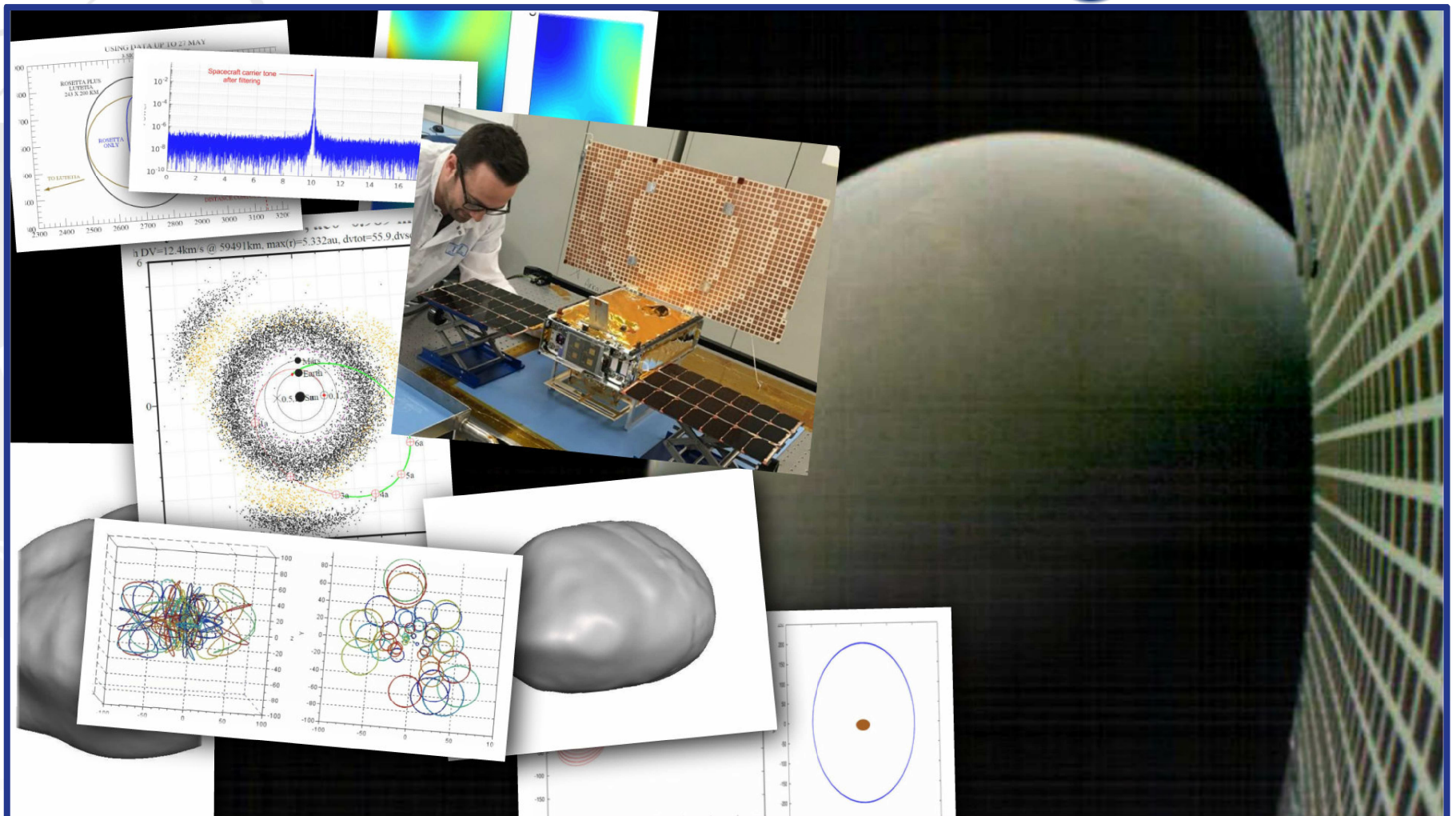
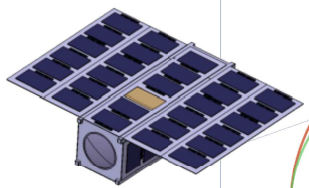
C²ERES, *the space pole of PSL University Paris*

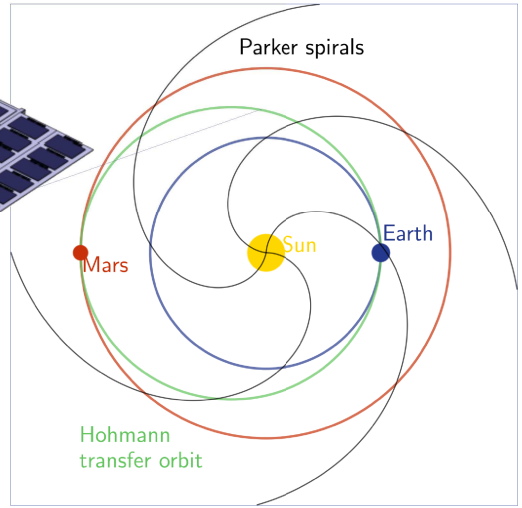
3rd OSCW, Athens, 14-16 oct. 2019

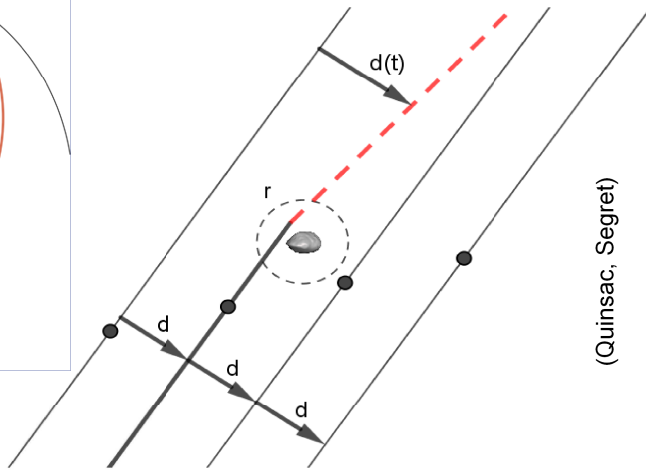
From LEO to Interplanetary CubeSats

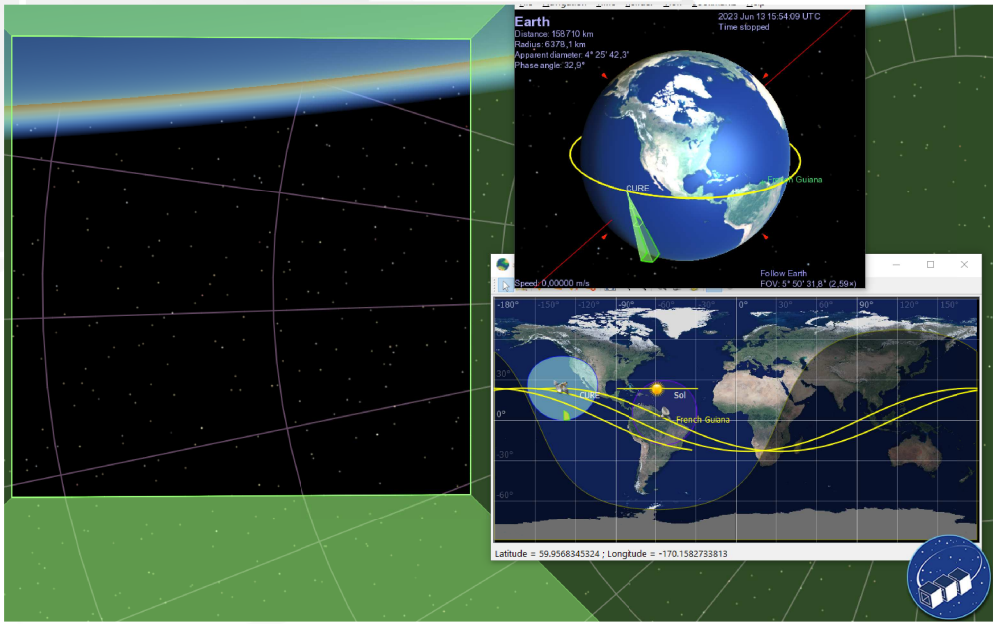


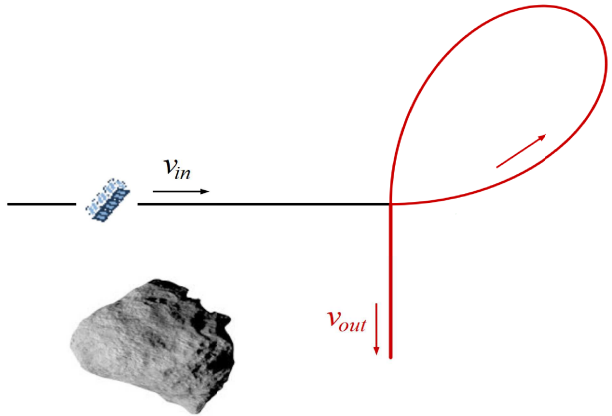
sources :
NASA MarCO
JIVE VLBI
ESA ROSETTA
CNES MMX
Etude NOIRE
MAT
CelestiaMotherlode



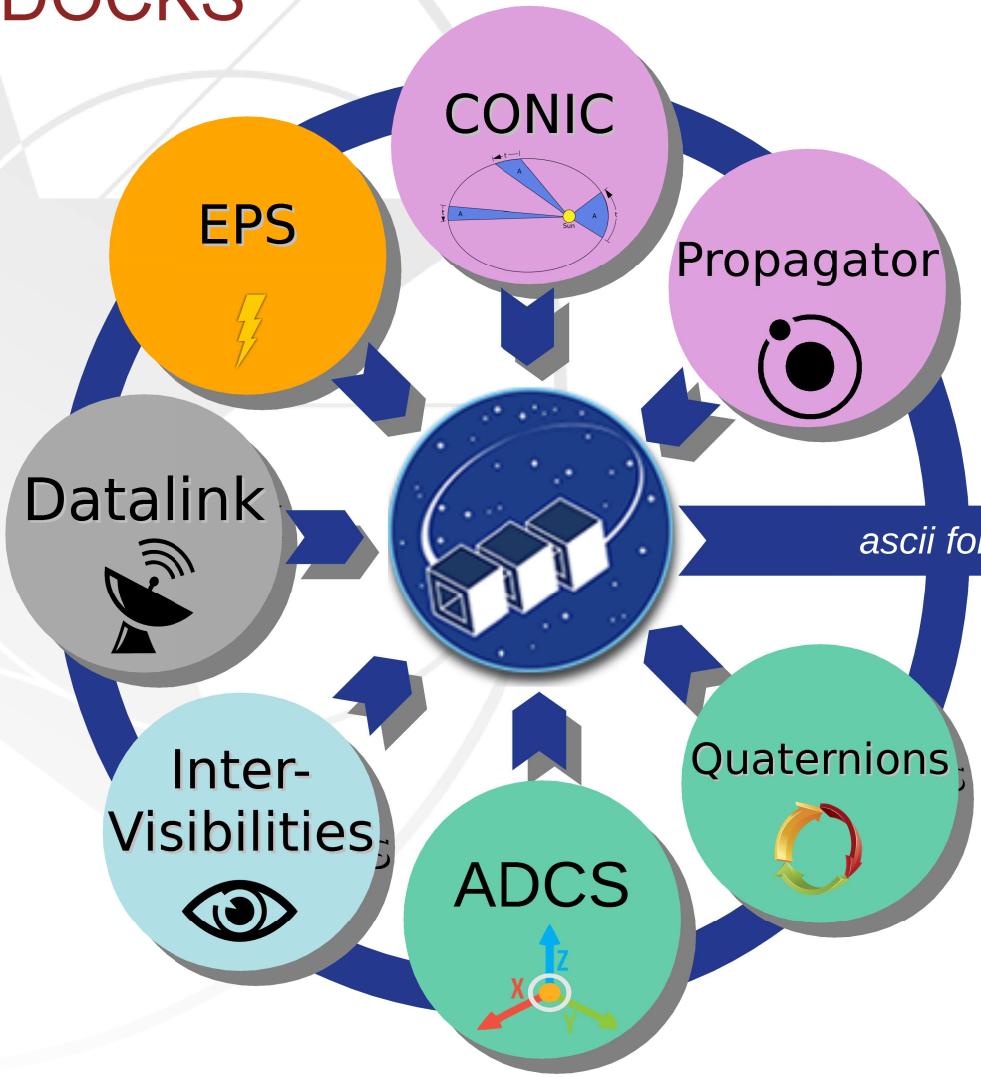

Parker spirals
Mars
Sun
Earth
Hohmann
transfer orbit


d(t)
r
d
d
d
(Quinsac, Segret)

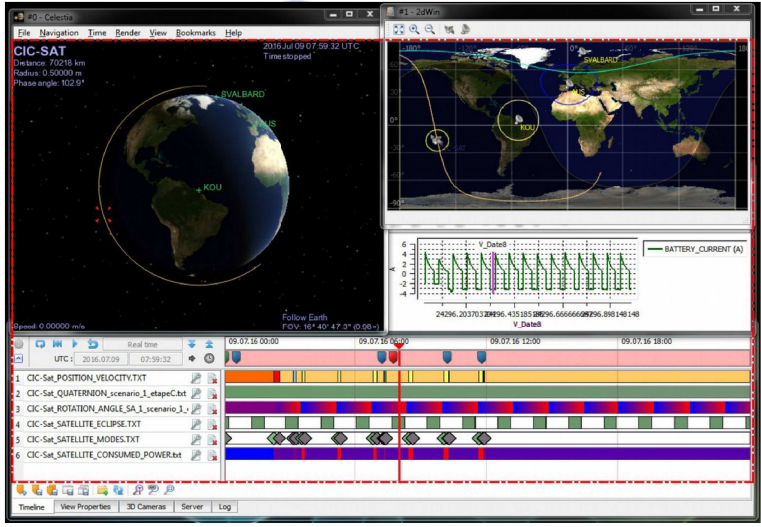

Earth
Distance: 158710 km
Radius: 6378,1 km
Apparent diameter: 4° 25' 42,3"
Phase angle: 32,9°
2023 Jun 13 15:54:09 UTC
Time stopped
CURE
French Guiana
Follow Earth
FOV: 5° 50' 31,8" (2,59×)
Speed: 0,00000 m/s
Sol
Latitude = 59,9568345324 ; Longitude = -170,1582733813


v_{in}
v_{out}

DOCKS



ascii formats to VTS © CNES



CNES

VTS
Version 3.3.1 Build 7809 Arch 32bits

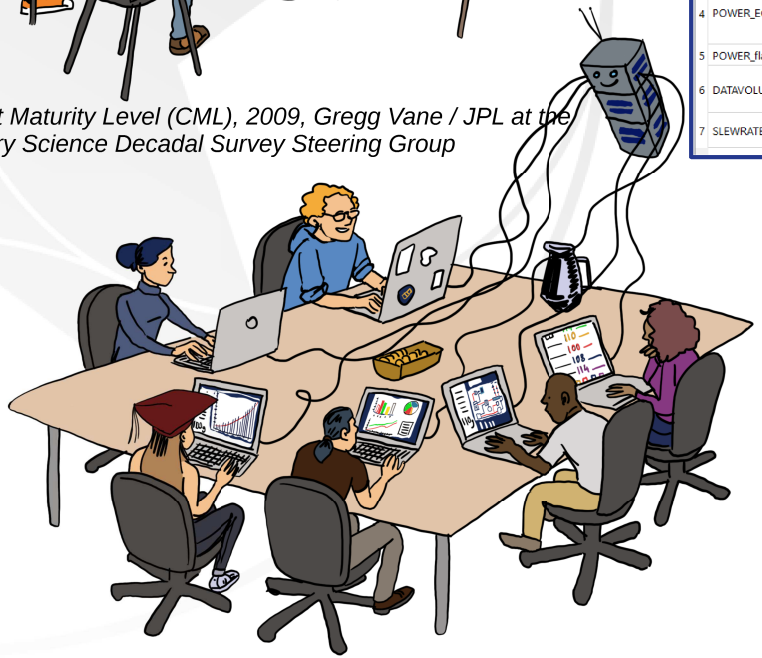
DOCKS helps and structures your CubeSat project, for you to focus:

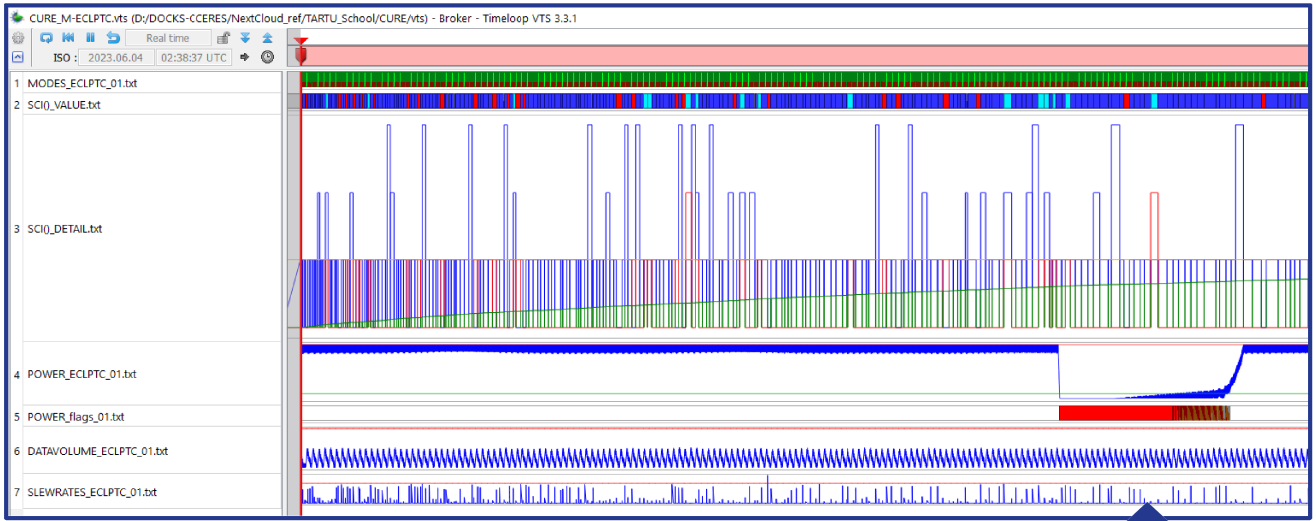
- on the scientific coverage
- on the engineering sizing

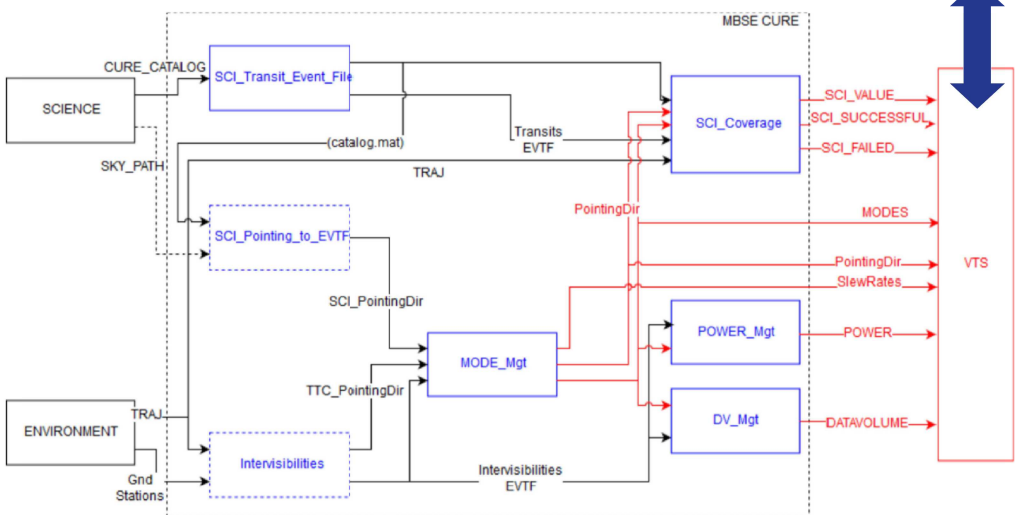
… from the early design up to AIT/AIV

MBSE: Model-Based System Engineering

Concept Maturity Level (CML), 2009, Gregg Vane / JPL at the Planetary Science Decadal Survey Steering Group



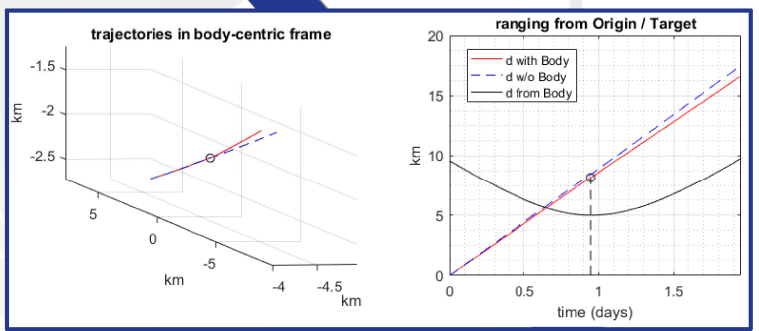




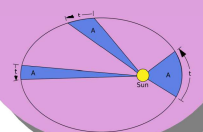
DOCKS: 2 modules for trajectories

Done
To be done

Propagator



CONIC



Deep space trajectories

- Cruise / RdV / ProxOps
  - Forward / Backward propagation
  - Adaptive time-step
    - Runge-Kutta or Runge-Kutta-Fehlberg
    - Accuracy-driven adaptive step
  - Continuous propulsion
- Proximity Operations
  - Spherical Harmonics **or** other
  - Cross-check scientific models
  - Drag / comets…
- Validations
  - Based on planets and asteroids
  - Still some issues in special contexts
  - Cross-checking welcome!

Earth-vicinity: link to CNES' STELA

Keplerian engine: "CONIC"

DOCKS: Energy and Datalink

Done
To be done

Inter-Visibilities

EVTF_INTERVISIBILITY_ECLPTC_01.txt

```
1  CIC_MEM_VERS = 1.0
2  CREATION_DATE = 2019-07-31T22:06:14.953
3  ORIGINATOR = DOCKS / CCERES / LabEx ESEP
   - Paris Observatory - PSL University Paris
4
5  META_START
6
7  COMMENT = Intervisibility for orbit :
   TRAJ_Ecliptic_01.txt, resampled at
   10-second intervals
8
9  USER_DEFINED_PROTOCOL = NONE
10 USER_DEFINED_CONTENT = CHRONOGRAMS
11 USER_DEFINED_SIZE = 1
12 USER_DEFINED_TYPE = STRING
13 USER_DEFINED_UNIT = [n/a]
14 TIME_SYSTEM = UTC
15
16 META_STOP
17
18 60096    2950.0  ECLIN00001
19 60096    3010.0  COMIN00011
20 60096    3600.0  COMEG00011
21 60096    5090.0  ECLEG00001
22 60096    8740.0  ECLIN00001
23 60096    10870.0 ECLEG00001
```

EVTF

EPS

Datalink

Intervisibilities with…

- Sun, Ground station(s)
- Output = “Event File” (**EVTF**)
- Adaptive time accuracy

EPS module

- Solar arrays mounting, cells & battery techno
- Mode strategy
- Quaternions & Intervisibilities
- GUI

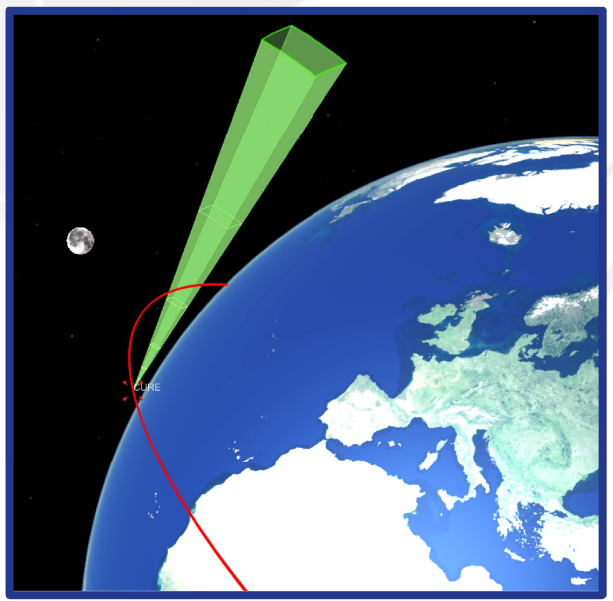
Datalink (to come)

- Primitive modeling with intervisibilities
- Mode strategy
- Output = “Datavolume on board”
- Quaternions (if relevant), Atmospheric loss

DOCS: Orientations

Done
To be done

Quaternions



ADCS

“Easy-Quaternions” module

- (to be released)
- 3-degree simple pointing strategies
- Output
  - “directions” or “quaternions” in VTS formats
  - slew-rates

“Non-easy quaternions” module

- 4th degree of freedom
- Coupling with Mode strategy

Generic ADCS simulator

- Not “Earth-limited”
- Standard control laws and filtering to be tuned
- Library of known actuators and sensors
- Coupling with continuous propulsion

DOCKS: development

Done
To be done

What is done yet

- Free licenses
- Modular architecture
  - Python 3.x / Anaconda 3
    - astropy / polyastro / calceph
  - “docks-tools” module
- Multi-OS
  - Ubuntu 18.04
  - MS-Windows 10
- Distribution
  - public Gitlab
  - releases with install routines
  - support by mail

What *we* will do next

- Multi-OS:
  - Mac OS & Debian
  - Intensive testing in all OS
- Trajectories
  - Sensitivity analyses => Accuracy-driven
  - Propulsion arcs
- Energy: Initial GUI
- MBSE management
  - Timeline, Links and updates in the models
  - User’s configuration management
- “drop & run” service for heavy computation
  - Propagations (~50 it./s, per basic perturbation)
  - ADCS

(.../...)

YOU & DOCKS: what *YOU* could do :)

Skills	A - Top Priority	B - High Priority	C - Interesting!
USER	*Report bugs*	*Report boring use*	*Request features*
Scientist / Engineer	*Challenge Propagator's or EPS' performances*	*Add a model (Propagator or Datalink)*	*Module for Thermal analysis*
IT enthusiast	*User-friendly GUI*	*Reading from GMAT/STK*	*Wizards*
Open Source enthousiast	*Tutorials & Citations*	*"Modules' datasheet"*	*Templates*

- Contact / Support (Gitlab): **docks.contact@obspm.fr**
- Partnering: cceres.psl@obspm.fr
- Keep in touch: subscribe to "cceres.new@obspm.fr"

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Thank you!

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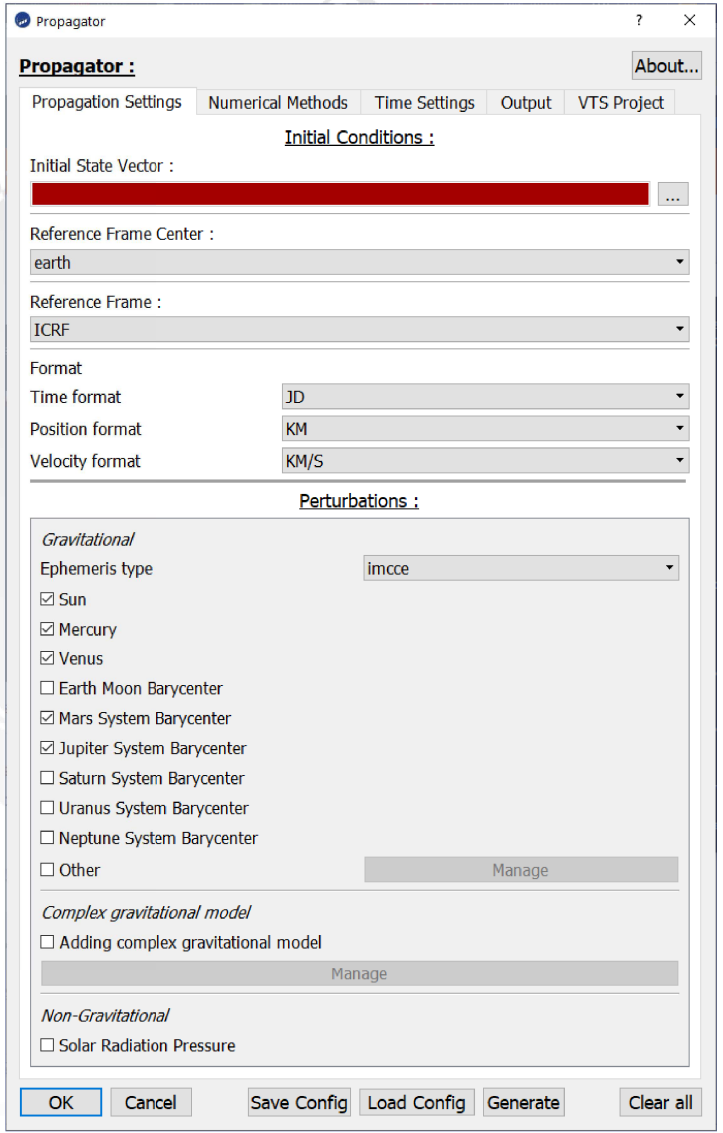
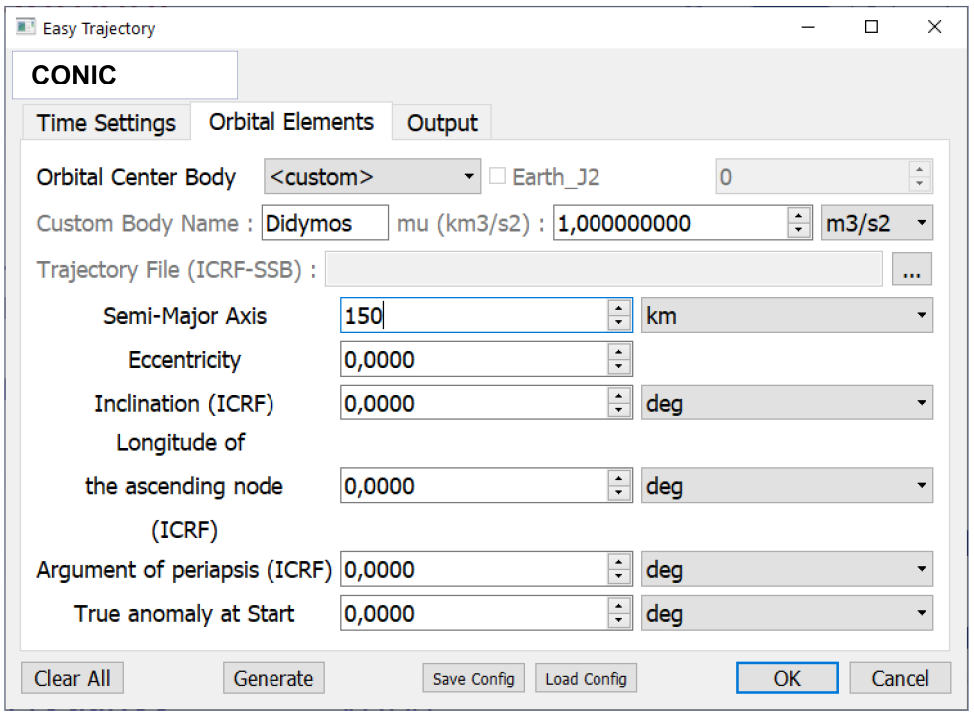
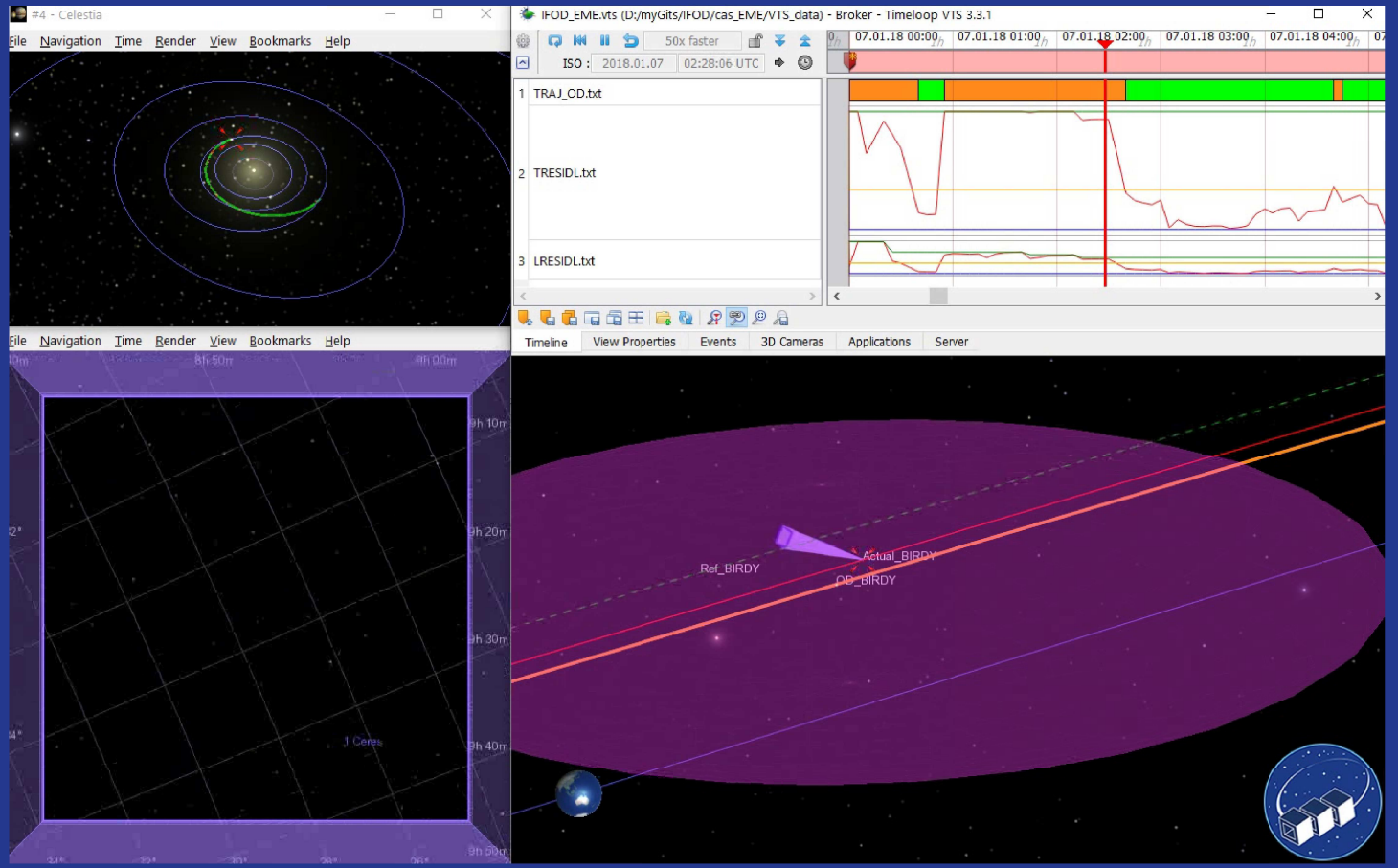
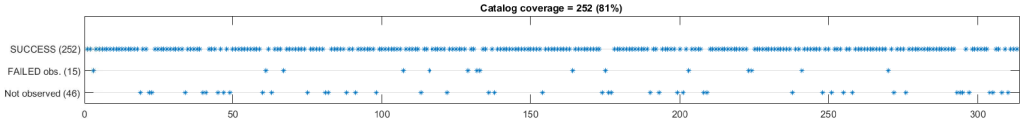

Propagator
Propagator :
About...
Propagation Settings
Numerical Methods
Time Settings
Output
VTS Project
Initial Conditions :
Initial State Vector :
Reference Frame Center :
earth
Reference Frame :
ICRF
Format
Time format
JD
Position format
KM
Velocity format
KM/S
Perturbations :
Gravitational
Ephemeris type
imcce
Sun
Mercury
Venus
Earth Moon Barycenter
Mars System Barycenter
Jupiter System Barycenter
Saturn System Barycenter
Uranus System Barycenter
Neptune System Barycenter
Other
Manage
Complex gravitational model
Adding complex gravitational model
Manage
Non-Gravitational
Solar Radiation Pressure
OK
Cancel
Save Config
Load Config
Generate
Clear all

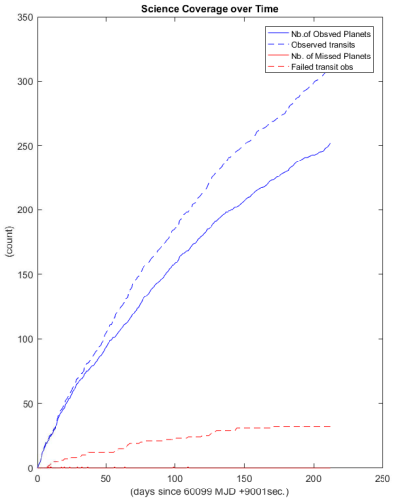

Easy Trajectory
CONIC
Time Settings
Orbital Elements
Output
Orbital Center Body
<custom>
Earth_J2
0
Custom Body Name :
Didymos
mu (km3/s2) :
1,000000000
m3/s2
Trajectory File (ICRF-SSB) :
Semi-Major Axis
150
km
Eccentricity
0,0000
Inclination (ICRF)
0,0000
deg
Longitude of the ascending node (ICRF)
0,0000
deg
Argument of periapsis (ICRF)
0,0000
deg
True anomaly at Start
0,0000
deg
Clear All
Generate
Save Config
Load Config
OK
Cancel

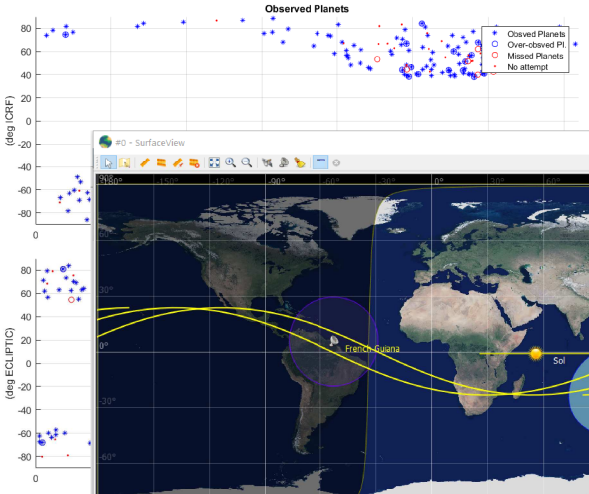
Récapitulatif : UKF, 3 objets d'avant-plan

- Départ de la Terre
- Milieu de croisière
- Arrivée à Mars

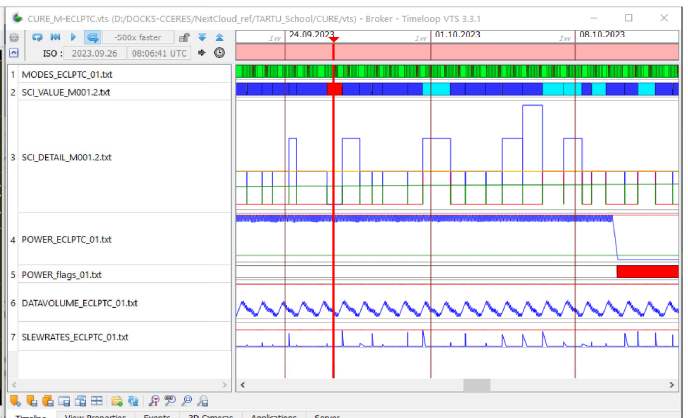


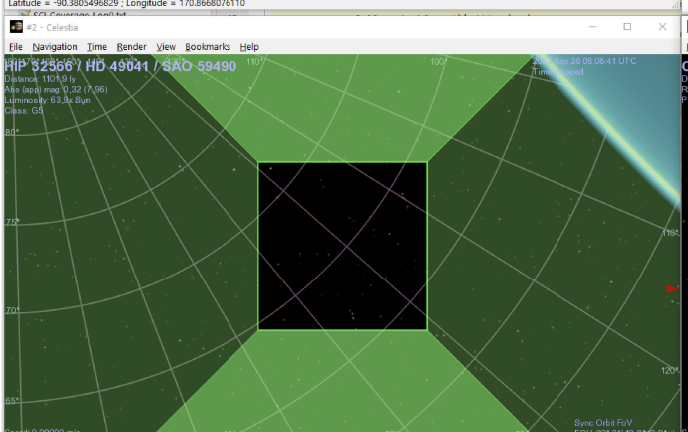

Catalog coverage = 252 (81%)
SUCCESS (252)
FAILED obs. (15)
Not observed (46)
0
50
100
150
200
250
300

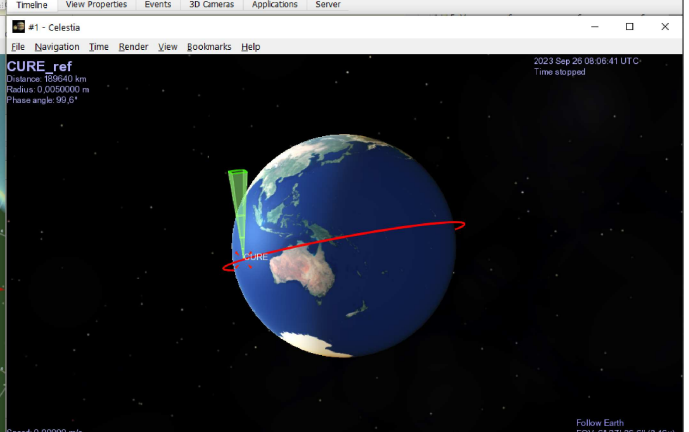

Science Coverage over Time
Nb.of Obsved Planets
Observed transits
Nb. of Missed Planets
Failed transit obs
(count)
(days since 60099 MJD +9001sec.)

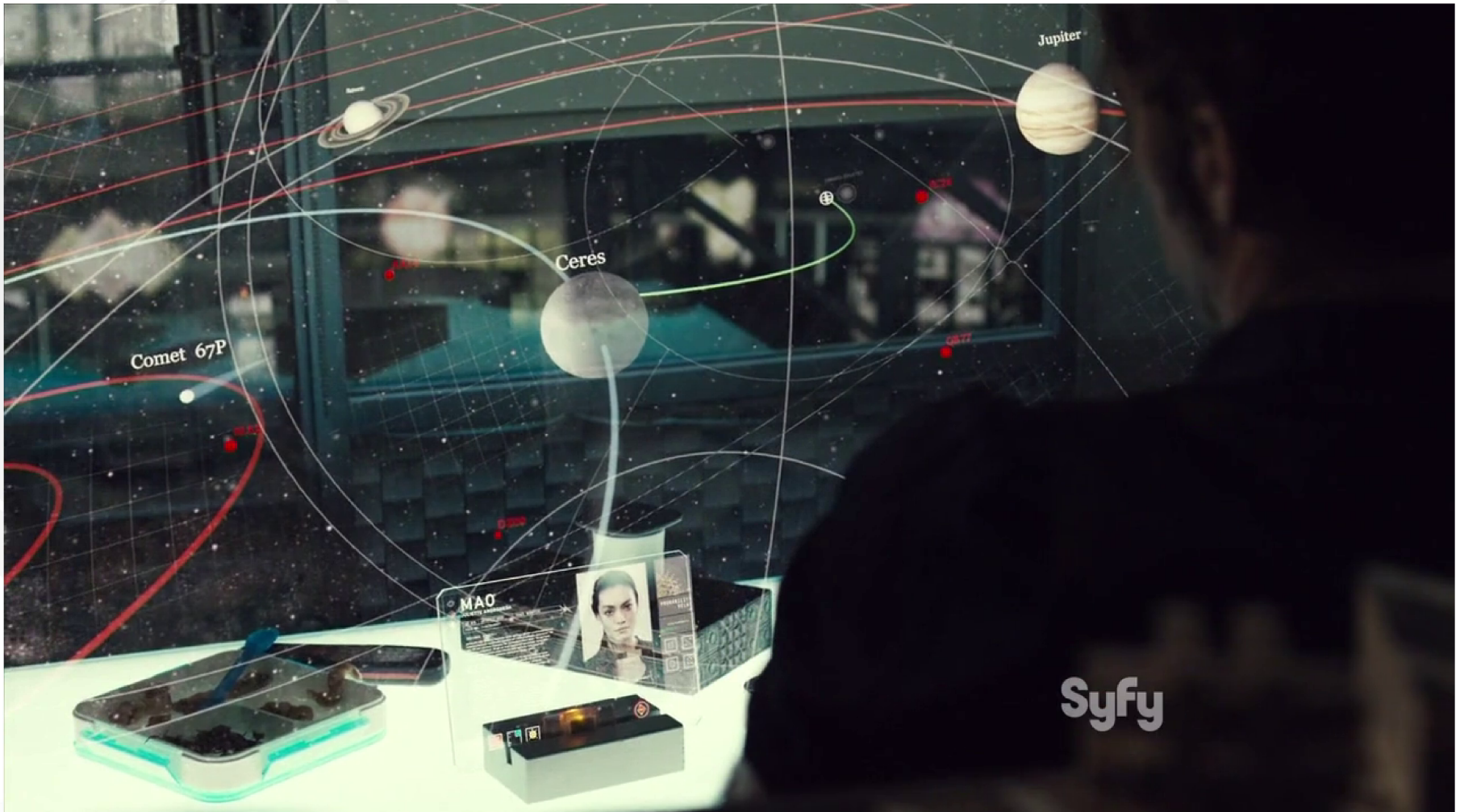

Observed Planets
Obsved Planets
Over-obsved Pl.
Missed Planets
No attempt
(deg ICRF)
(deg ECLIPTIC)

#0 - SurfaceView
French Guiana
Sol
CURE
Latitude = -90.3805496829 ; Longitude = 170.8668076110


CURE_M-ECLPTC.vts (D:/DOCKS-CCERES/NextCloud_ref/TARTU_School/CURE/vts) - Broker - Timeloop VTS 3.3.1
MODES_ECLPTC_01.txt
SCI_VALUE_M001.2.txt
SCI_DETAIL_M001.2.txt
POWER_ECLPTC_01.txt
POWER_flags_01.txt
DATAVOLUME_ECLPTC_01.txt
SLEWRATES_ECLPTC_01.txt
Timeline
View Properties
Events
3D Cameras
Applications
Server


#2 - Celestia
File Navigation Time Render View Bookmarks Help
HIP 32566 / HD 49041 / SAO 59490


#1 - Celestia
File Navigation Time Render View Bookmarks Help
CURE_ref
CURE



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