Report

Short-term visit supported by Europlanet NA1
Created by: Iaroslav Iakubivskyi et al

Purpose of trip:

Visiting Paris Observatory in order to use their tools and concurred engineering facility to assess the feasibility of CubeSat-esque satellite to support ARIEL mission in creating the observation catalogues.

Problem:

The ephemerides of potential targets are not well known, hence the creation of detailed catalogues is required the latest by year 2026.

Solution:

CubeSat-esque satellite to assess observations of transits and better to characterize ephemerides. Mission name: Cubesat for Refining Ephemerides (CURE). Mission time 2022-2024.

Tools:

Key Elements :

The MBSE approach is to provide the project CURE with an early assessment of the overall performance of a mission design: identification of exoplanets in the future ARIEL catalog whose CURE will be able to confirm the ephemerides during its operation lifetime.

A lifetime for CURE as of the 2nd semester 2023 is considered. Two main observation concepts, "P" and "M", are summarized into a subcatalog of exoplanets, CURE_CATALOG, and a sequence of pointings in the lifetime, SKY_PATH, for each concept. An event file TRANSIT_EVTF lists all possible observations in the lifetime and serves as a reference of the scientific coverage. The model SCI_Coverage, in OCTAVE, is the core of the CURE MBSE and produces detailed or synthetic results in terms of successful or failed observations, some of them being displayed as a VTS project.

An additional layer of models is desirable and shall address the engineering aspects of the mission design: overall MODE Management, DATAVOLUME management and early POWER assessment. Some useful routines, in OCTAVE and PYTHON, are provided to help develop these models (not included).

An "MBSE sheet" summarizes the objects and models available yet.

Tools that are considered important for this week:

- CURE-SANDBOX
    - PROMESS_CURE Cloud
    - VTS folder sharing
- PROMESS computers:
    - Firefox: 3 bookmarks, Personal Webmail
    - VTS
    - OCTAVE
- Personal computers:
    - Internet access
    - adding a Fix in VTS
    - OCTAVE

=> ok, all tools were checked “operational”, smooth!
=> SCIENCE case discussion was possible to clarify what is at stake. It appeared suggestions:

- if other missions cannot make good follow up to Ecliptic poles, why not concentrate CURE to these observations?
- Uncertainty metrics involves Transit Mid-time Error, Error on Period and n, number of transits since last observation. This uncertainity is at the center of CURE’s goal
- Multiple orbital configurations should be considered from the very beginning to figure out what is at stake
- 2 main approaches to produce a “successful observable”:
    - A) observation of each event INGRESS and EGRESS independantly considering that each of them is usefull, then “Orbit Duration” (OD, as requested in the CURE_Catalog) should be minimized to cover Ingress OR Egress, no both => a “successful observation” is reached if a stable pointing lasts at least OD over an event.
    - B) observation as long as possible before, during and after the transit to gather as many points as possible all over the light curve of the transit => a “successful observation” is reached if “sufficient” (TBD) observation is obtained all over the transit.

Agenda:

Agenda			
Session		plenary	Goal
Welcome	Mo.from 9:30		Building 15, Ground floor: PROMESS room: Coffee & Tea
Stakes	Mo.10:00-12:00	X	CURE for ARIEL (V.CdF), MBSE & tools, roles & deliveries, logistics
(visits & lunch)			C^{2}ERES facilities, Castle – Parc – Buildings, Restaurant

Tools	Mo.14:00-16:00		Set-up & takeover with very primitive models
(+ coffee/tea break)			
Models.1	Mo.16-00-18:00		SCI FLY&GND / Power / DV / Mode: needs for models & metrics
Mission.1	Mo.18:00-18:30		Identification of main SCIENCE and ENGINEERING options
Mission.2	Tu.09:30-11:00	X	SPIRAL => brainstorming on the options
Models.2	Tu.11:00-12:30		Models & Metrics development
Mission.3	Tu.14:00-16:00	X	SPIRAL => arbitrations on the options and their requirements
(+ coffee/tea break)			
Models.3	Tu.16:00-18:30		Models & Metrics development + special focus on Optics
Optics.1	We.09:30-11:00	X	“P Concept” discussion with JM Reess
Wrap-up.1	We.11-12:30	X	Statement by SCI > STM > MTM > TLR > Timeline > Systems > Risks
Mission.4	We.14:00-16:00	X	SPIRAL => need for models & metrics
(+ coffee/tea break)			
Models.4	We.16:00-18:30		Models & Metrics development
Optics.2	Th.09:30-11:00		Models & Metrics development // 2nd Optics session for “M concept”
Models.5	Th.11:00-12:30		Preparation of statements of each one’s perimeter for final Wrap-up
Mission.5	Th.14:00-15:30	X	SPIRAL => challenges and to-do-list
(+ coffee/tea break)			
Wrap-up.2	Th.16:00-17:30	X	Aggregate updated parts in the models
Diner	Thursday	X	Logistics to be set up
Farewell visit	Fr.08:50-11:30	X	Meeting at the entrance of Paris Observatory, 77 Ave Denfert Rochereau – Metro/RER B Denfert-Rochereau Visits of Great Galery (9h-10h), Cassini room, Arago dome + Lunch
Wrap-up.3	Fr.13:00-17:30	X	Final Wrap-up => DANJON room @ Paris - Statement by SCI > STM > MTM > TLR > Timeline > Systems > Risks - What to do next? - Collective statement on the needs in future PROMESS campaigns

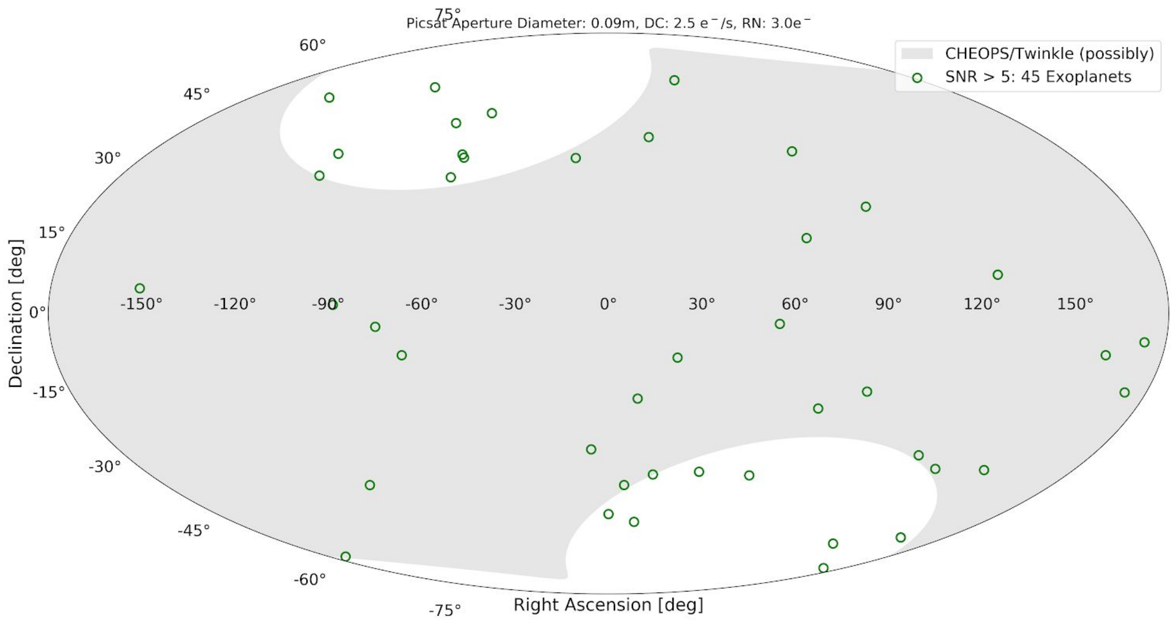
Participants:

Attendee	Institution	Role	Perimeter
Vincent Coudé du Foresto Pierre Drossart	PO	PI CURE & co-I	(attending “Stake” & “Wrap-up” sessions)
Anna Aret	TO	Co-I CURE	Preparatory Ground Observations
Clovis Gédor	PO	IS	Instrument Scientist, concept M
Vincent Lapeyrère	PO	IS	Instrument Scientist, concept P
Billy Edwards	UCL	IS	Instrument Scientist, concept M

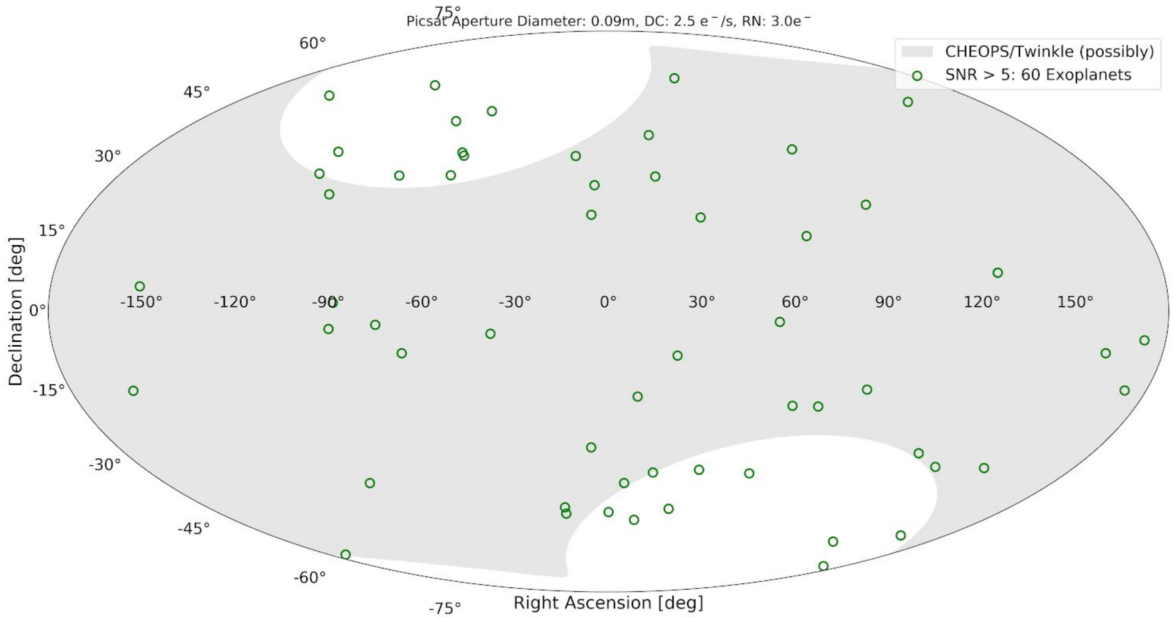
Andris Slavinskis	TO	PM	PM, STM, Risk Management
Iaroslav Iakubivskyi	TO	SE	MTM/TLR, Timeline (modes)
Janis Dalbins	TO	Design	Power, TT&C, ADCS
Sébastien Durand	C²ERES	MBSE	Orbits, Stations, tool support
Boris Segret	C²ERES	MBSE	Animation, modeling support
Jean-Michel Reess	PO	Expert	Optics, attending We.am

Results:

Observational targets with 9cm FoV:



Observational targets with two apertures, each 9cm:



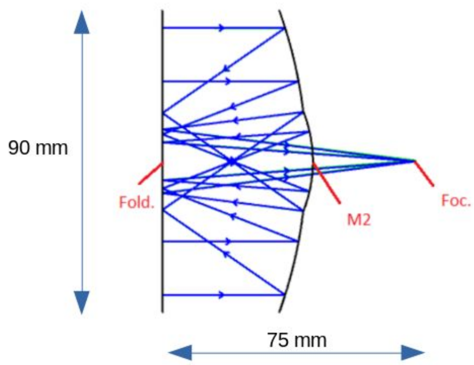
Credit: B.Edwards

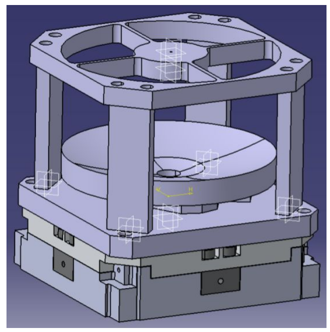
Potential instrument:

Imager:

Credit: M.Pajusalu

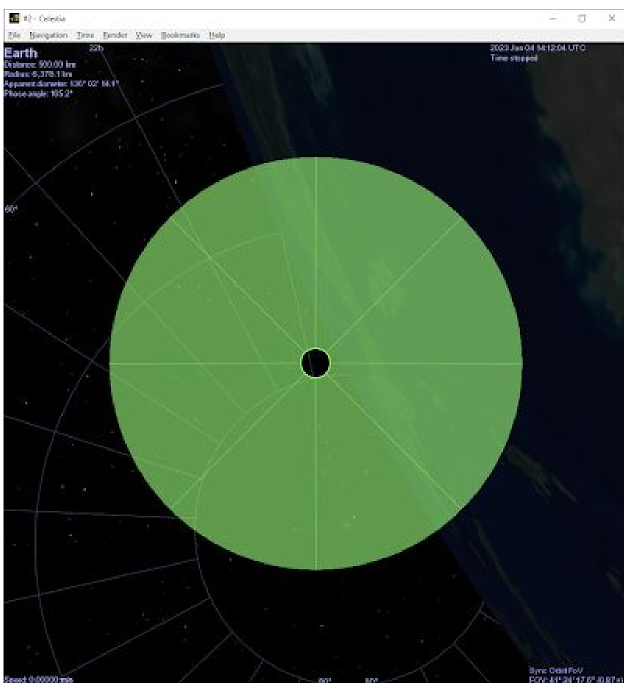
Fiber based:

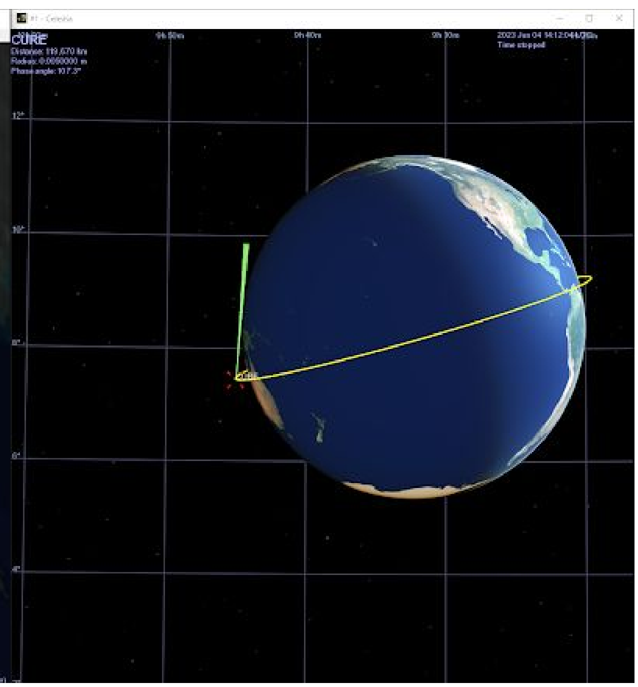


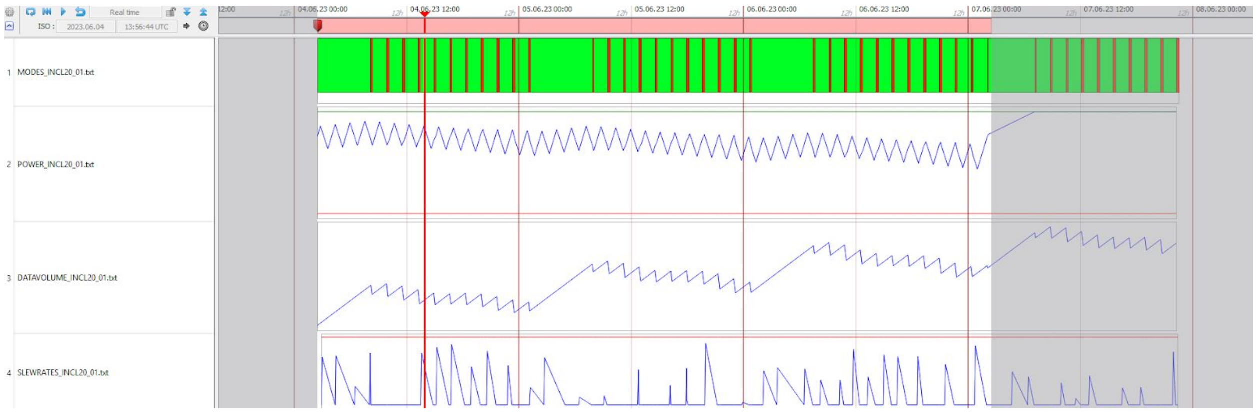


Credit: Paris Observatory

Orbits, observation, telemetry, power etc:



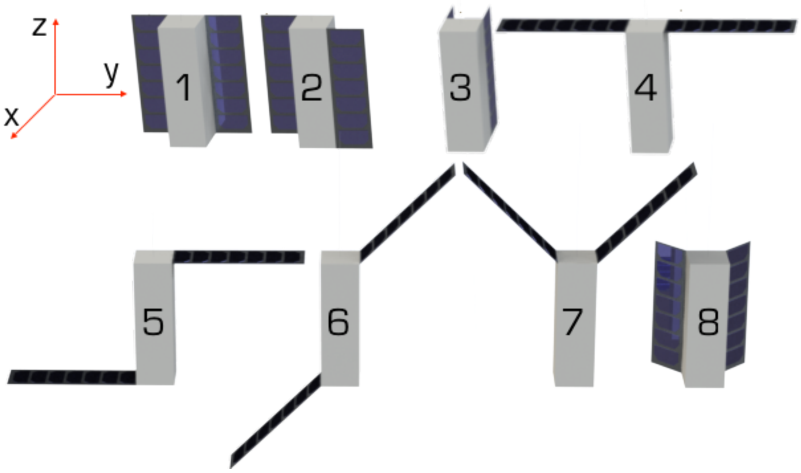




Battery	
Capacity	33.8 Wh
Number of cells	4
Operation temperature	0-20 C
Volume	0.1 U
Mass	155 g

Power consumption			
Subsystem/Instrument	Stand by, mW	Nominal, mW	Peak, mW
Instrument	200	2000	2500
OBC for Instrument	300	1750	1750
EPS	20	250	250
ADCS and OBC	600	2900	2900
UHF TX	30	3600	3600
UHF RX	20	300	300
Star tracker	200	950	2900
Magnetic coils	0	1000	2000

Solar panels			
Number of cells	16 on panels and 6 on body	28 on panels and 6 on body	16 on deployables and 2 on body
Efficiency	29% and 80% DCDC	29% and 80% DCDC	29% and 80% DCDC
Cell area	0.0704 m^2	0.1088 m^2	0.054324 m^2
Power generation @1AU	22.8 W	35.2 W	18.2 W
Avarage power generation	17.1 Wh	26.4 Wh	13.65 Wh
Configuration	**2 deployables**	**2 double deployables**	**2 deployables and short side**



Parameter	Value								Unit
	Space - Earth (9,6k baud)				Earth - Space (9,6k baud)				
Elevation angle	80	50	30	10	80	50	30	10	
	Satellite				**Transmitter**				
Transmitter power	30				47				dBm
Transmitter losses	2				2				dB
Transmitter antenna gain	2				16				dBi
Antenna pointing error	2				2				dB
Equivalent isotropically radiated power (EIRP)	28				59				dBm
	Losses								
Distance (zenith 500 km)	507	637	909	1695	507	637	909	1695	km
Free space loss	138.59	140.57	143.66	149.07	138.59	140.57	143.66	149.07	dB
Atmospheric loss	2				2				dB
Polarisation loss	1.5				1.5				dB
Total loss	142.09	144.07	147.16	152.57	142.09	144.07	147.16	152.57	dB
	Receiver				**Satellite**				
Receiver antenna gain	16				2				dBi
Noise temperature	340				336				K
Boltzmann constant	-198.60				-198.60				dBm/K/Hz
Received power	-98.09	-100.07	-103.16	-108.57	-81.09	-83.07	-86.16	-91.57	dBm
Data rate	9600	9600	9600	9600	9600	9600	9600	9600	baud
SNR per bit (Eb/N0)	35.37	33.39	30.30	24.89	52.42	50.45	47.35	41.94	dB
Required Eb/N0 for 2FSK modulation (G3RUH)	18				18				dB
Link budget reserve	17.37	15.39	12.30	6.89	34.42	32.45	29.35	23.94	dB

Modes				
Mode numenclature	Mode name	Description	Running systems	Power Consumption, mW
SCIE	SCIENCE	Observaring targeting star during required time	Instrument (nominal) ADCS and OBC (nominal) EPS (nominal) UHF RX (nominal)	8150
TX00	Tranmission	Transmitting data after observations if needed	UHF TX (nominal) all REST (STAND BY)	5150
STTC	Science and transmission	Observing targeting star with stability and transmitting data	Instrument (nominal) ADCS and OBC (nominal)	11450
SAFE	Safe			
IDLE	Idle			
BOOT	Boot			
SLEW	Slewing			
SPRE	Science preparation			

Mass budget:

Part	Mass, g
Structure	900
Deployables	370
Bus+batteries	600
2 RWs + support	250
Antenna	100
Instrument	1000
Star tracker	150
Total	3370
20% margin	4044

Conclusions:

The week was extremely productive and team reached goals of the workshop as well as enhanced collaboration between different institutions in EU.