Lessons at C²ERES with an MBSE approach for scientific nanosatellites

Boris Segret
LESIA, PSL Université / Observatoire de Paris, France

MBSE & C.E. for “Mission Profile”

DOCKS

Timeloop 3.3

VTS

"Ozone"

14 nanosat “ideas” supported

Topics covered

- Astrochemistry
- Space Geodesy
- LF Radio-astronomy (2)
- High Power Computing
- Space Weather
- Meteorites
- Plasma
- Exo-planetelogy (2)
- Atmospheres (3)
- Stellar physics

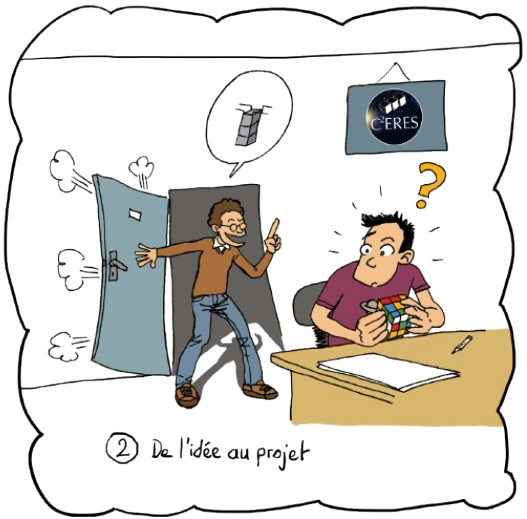
e.g. CURE

C²ERES is an ecosystem to support emerging ideas

- Financial (small money)
- Reviews
- System Engineering
- Tools, COTS & tooling

Support...	Financial	Reviews	S.E.	Tools
Nb.of Projects	9	3	9	9

From the idea to the project



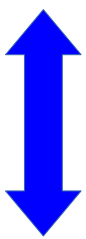
Concept Maturity Level

- CML 1: Cocktail Napkin
- CML 2: Key numbers for feasibility
- CML 3: Options in a mission profile
- CML 4: Base-line Design
- CML 5+ in interaction with agencies

A scientific idea

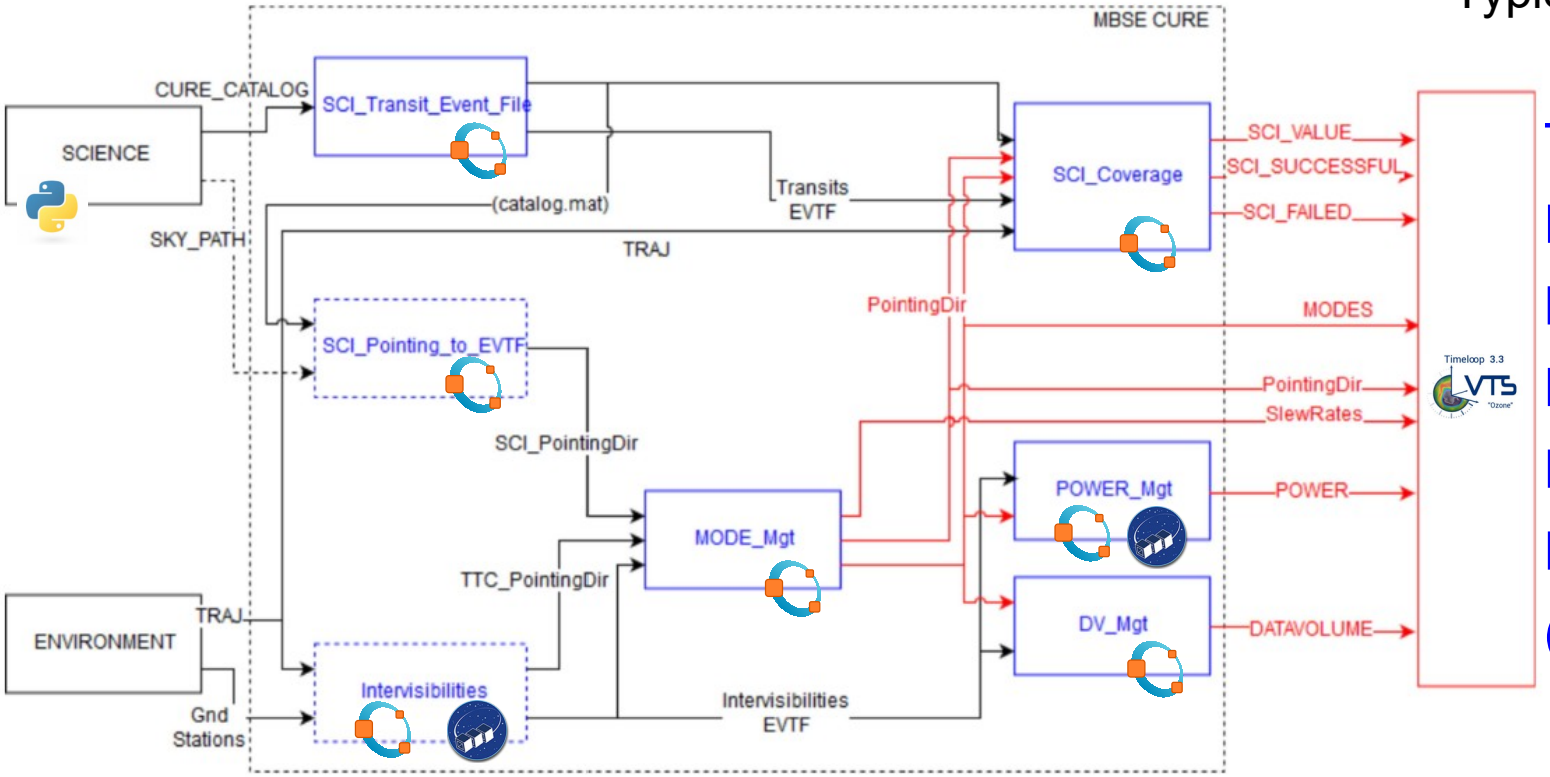
- Measurement concept
- Minimum Coverage

Scientific Coverage



Mission Profile

Building an MBSE architecture



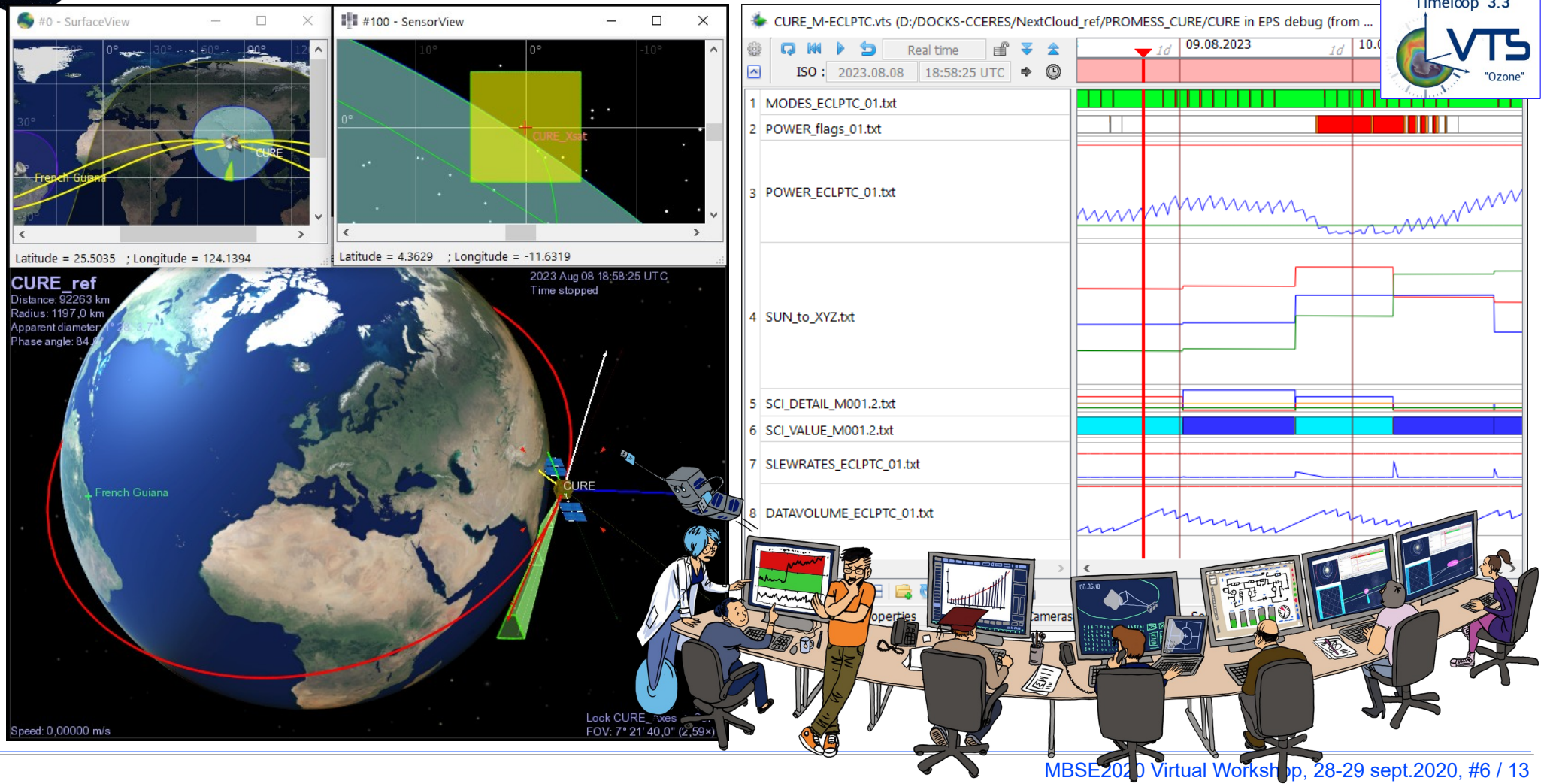
Typical sequence:

- Trajectory
- Events => Event File
- Modes (Sc., TTC...)
- Pointing
- Data Volume
- Power
- (science coverage)

=> output to VTS

DOCKS (in python)
Python
Octave (or Matlab™)

Output to CNES' VTS free software



Scientific Coverage

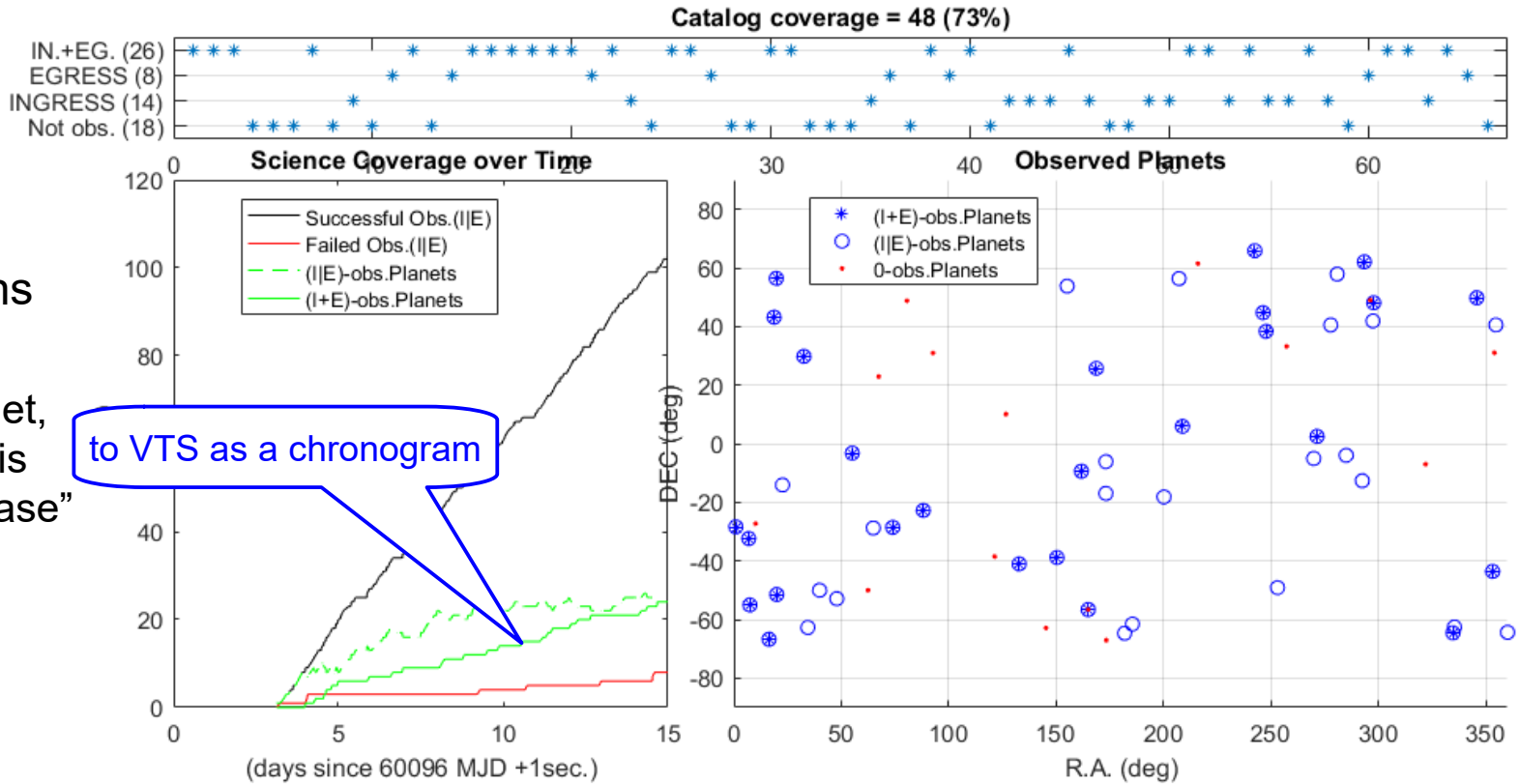
Details & Summary

- Outside of VTS, with specialized tools
- Summary to VTS:
  - quantitative
  - cumulative

Check the conditions for observations

- If conditions are met, science coverage is assumed to “increase”
- No “instrument simulator”

to VTS as a chronogram



Coding the models: early 1st version, then update

Trajectory

- DOCKS @ C²ERES
- CNES STELA (Earth's orbit)
- imported to VTS' CIC

Events / DOCKS

- Ground Stations
- Eclipses
- Special events: combined DOCKS & external tool

=> "EVTF" (event file)

MODES

- EVTF => Octave
- Data rate (up/down)
- Energy consomption

Pointing

- Tracking, Inertial, Slews...
- Slew rate
- (DOCKS in future)

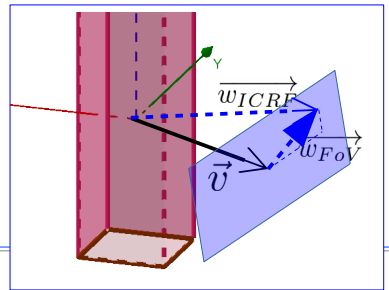
=> Quaternion file

=> VTS chronogram

Data Volume

- EVTF => Octave
- No "data link" budget here

=> VTS chronograms



Power / DOCKS

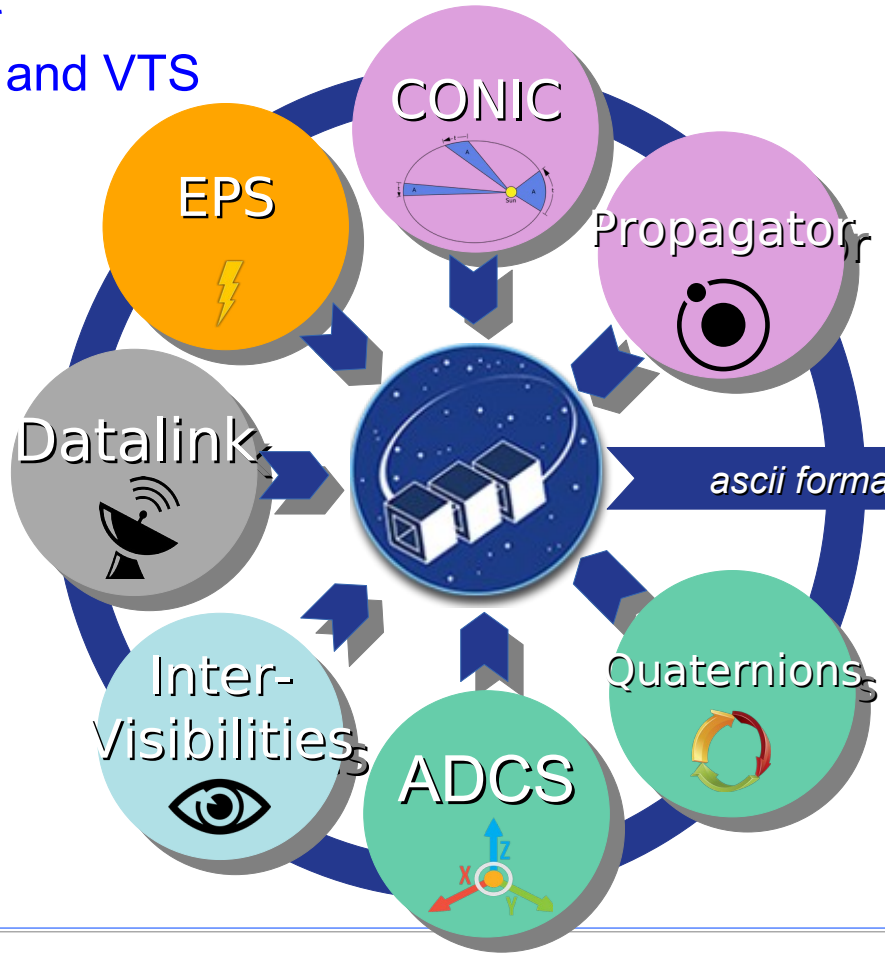
- Fixed solar panels
- Techno & Thermal basic models
- Modes & Quaternions are needed

=> VTS chronograms

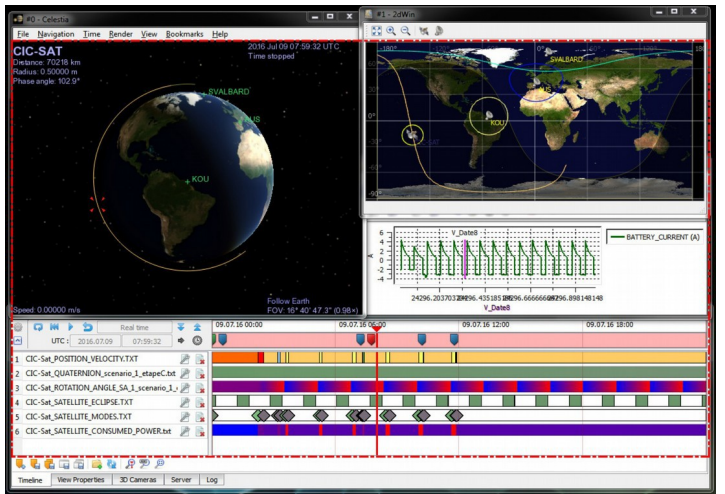
DOCKS development

"CCSDS" format

used in DOCKS and VTS



ascii formats to VTS © CNES



VTS Version 3.3.1 Build 7809 Arch 32bits

CELESTIA

"Only Free Software" policy

Deploying an MBSE architecture

MBSE can do a lot, but it needs:

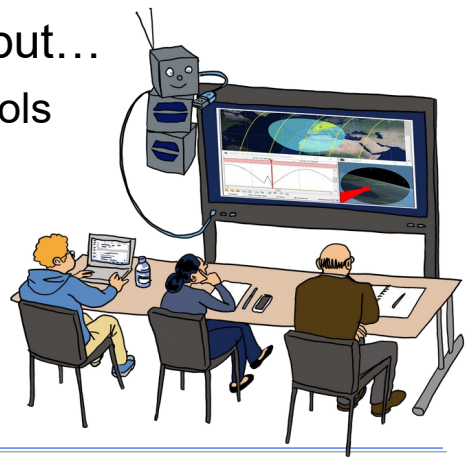
- NUMBERS => chronograms
- Tools
- Training
- Standards
- Methodology

… i.e. a “culture”!

and culture change takes time

Feedback from 5 projects

- Model for scientific coverage
  - 1st priority
  - Most difficult
- MBSE architecture
  - Initial version by C²ERES
  - Take over by Project’s System Engineer
  - Training on tools: VTS, DOCKS
- Other models: simple but…
  - Interfaces with own tools
    - Input reading
    - Output formating
  - Skills nice-to-have
    - Flight dynamics
    - Quaternion algebra



MBSE: Lessons for our Nanosats

Benefits

Mission profile is urgent, even more than...

- Trajectory design, ...
- Mechanical design, ...

- Fits well for a Nanosat proposal in phase 0
  - Science vs. System budgets
  - Explaining and distributing workpackages
  - Tolerant with own tools
  - Early visible results, easy updates
- Good to structure a project until phase E (?)
  - Review support for phases B, C, D
  - Interface with “New Space” industry
  - Preparation for phase E (same tools?)
- **open** standards only, **free** license only
  - because it’s possible (for nanosats!)
  - because of interoperability

Gaps

- CAD models to be imported (cmod / 3ds)
  - If needed (from CML4+)
  - From CubeSat catalogs
- ASCII outputs is a must (CCSDS principles)
  - VTS’ CIC to be enlarged & documented
  - Need for multi-OS (Linux, MS-Win… and Mac)
  - XML not easy for direct coding
- Skills in Math & Physics still necessary (surprise!)

Risks

- Decrease documents & forms for New Space
  - MBSE **is** self-explanatory
  - MBSE should **not** complicate the design process
- Avoid any proprietary tool
  - MS-docx,xlsx,OneDrive “at 7€/m only” are **not** necessary and break the interoperability chain
- Need for a unified / unifying new tool ???

MBSE: broader feedback

Interoperability is a MUST

Mission profile focused

- Needed early
- Frequently updated
- Files / Config. versionning
- Review support

… with people

- Scientific team, Engineers, Industry
- not only for System Engineers

… with computers

- **open** standards only, **free** license only
- ASCII preferred (CCSDS principles)
- multi-OS (Linux, MS-Win… and Mac)

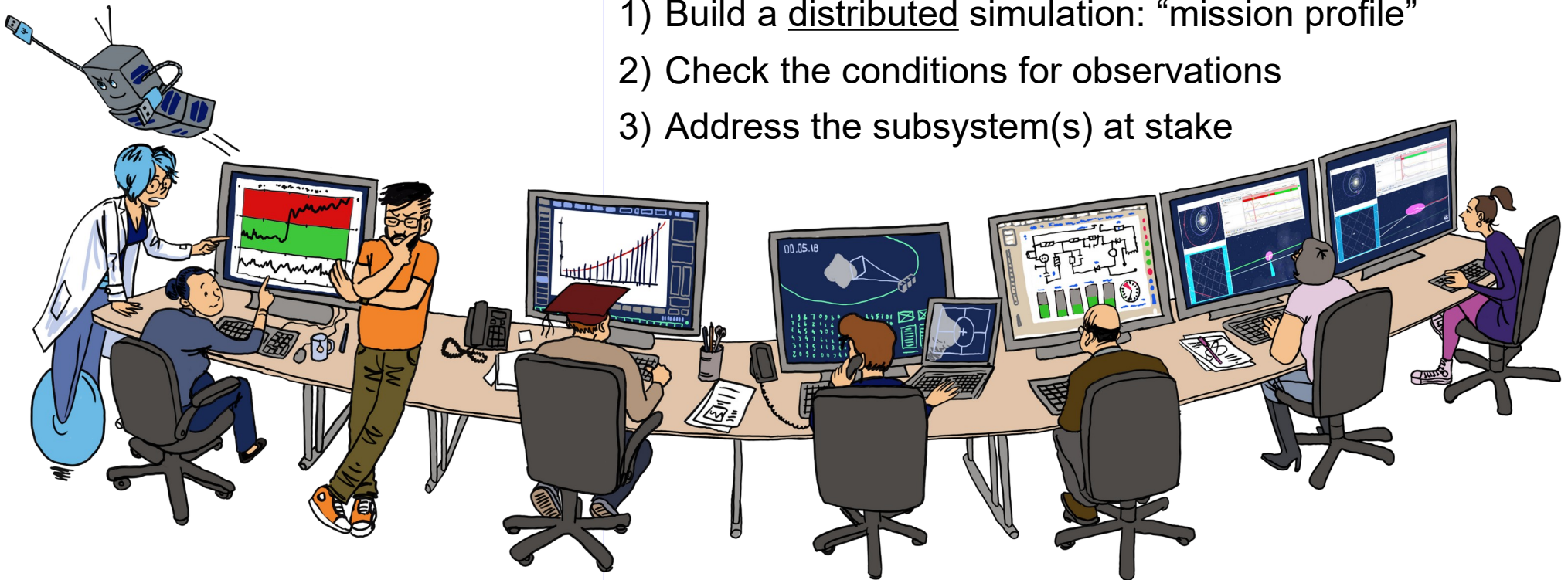
… with next tasks

- AIT/AIV acceptances
- Operations (and commissioning)

Model-Based System Engineering

How to maximize the Science coverage?

1) Build a distributed simulation: “mission profile”
2) Check the conditions for observations
3) Address the subsystem(s) at stake



boris.segret@observatoiredeparis.psl.eu