THESEUS Mission Observation Simulator (MOS)

ESA THESEUS Study Team

THESEUS Conference – March 2021

THESEUS science objectives flow-down

1. **THESEUS Science Requirements Document (SciRD)** covers the **Level 0 objectives** *[mission statement(s)]* and its flow-down **into Level 1 requirements** *[THESEUS science objectives, unrelated to a specific implementation of the mission]*
2. **Mission Requirement Document (MRD)** during Phase A covers the flow-down

    a) from Science requirements Level 1 (SciRD) **into mission requirements Level 2 (MRD)** *[THESEUS req. related to the implementation of the THESEUS, and driving the mission design (binding)]*

    b) **from mission Level 2 into lower levels requirements** for SC, Payload and Ground Segment and Operations

3. During Phase A: payload Consortium (inst. teams) and ESA Industrial partners aim at designing against the level 3 requirements of the MRD → assessment of the technical and programmatic feasibility of THESEUS mission requirements

4. Due to the nature and definition of the THESEUS main science objectives *[i.e. number of GRBs (long and short) and transients/variable X-ray sources]* **a Mission Observation Simulator (MOS)** was introduced to **"make the connection" between Science "figure of merit" (SciRD level 1) and mission efficiency (MRD level 2)**

MOS background

- Introduced in Dec-2018 right after the Phase 0 (ESA CDF) as an engineering fidelity tool to be used during Phase A with the main objectives:
  1) allow validation (by analysis) of Science objectives (level 1) in terms of figure of merit/mission efficiency within the high level system design capabilities
  2) identify system drivers and consolidate MRD requirements allocations for
     - ✓ Observation scenario (e.g. reference SC pointing law), agility, Field of Regards, down-times, etc…
     - ✓ Support the science driving modes definition and operational constraints (e.g. exclusion angles)
     - ✓ Science and trigger data availability requirements
  3) Provide inputs for decision making (closing trade-offs) by the relevant parties and support yellow book preparation
- Not intended to substitute or fulfil the tasks of a fully-fledged mission simulator (high fidelity)
- During Phase A, MOS was implemented by ESA supported with inputs from THESEUS Science Study Team (TSST) and Payload Consortium

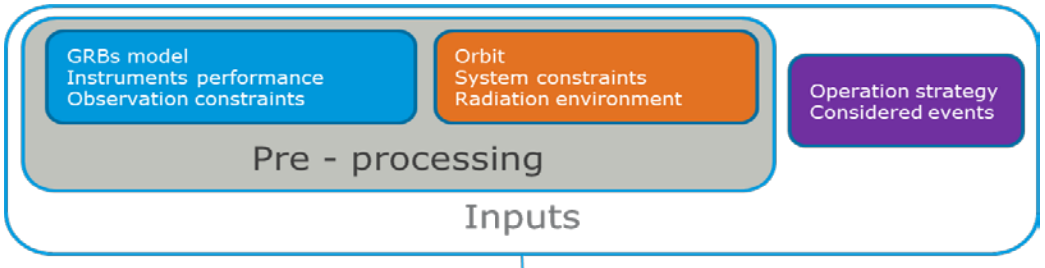
Overall MOS scheme

- MOS **only simulates the Science Operation Phase** based on science driven modes definition, neglecting the other SC modes or mission phases

- The majority of generic routines (orbit propagator, event finding algorithm, astrodynamics computations, etc.) come from a validated collection of libraries available in the Flight Dynamic Division (OPS-GF) at ESA/ESOC.

- The software in Python and with a modular architecture:
  - ✓ **Sky model (TTST)** and containing functions to extract relevant characteristics for the simulation;
  - ✓ **Instruments** response functions and constraints
  - ✓ **Radiation environment and Orbit:** propagate the SC orbit and pre-process it, computing orbital events (eclipses, SAA passages, visibility windows);
  - ✓ **Spacecraft:** collection of functions and data related to spacecraft characteristics (e.g. spacecraft agility, FoR, or down times due to thermal or pointing constraints);
  - ✓ **Reference pointing strategies** during survey mode, as well as definition of SC attitude during the different operational science modes

- Simulator; core of the MOS, uses the functionality and information in the other modules to build a mission profile and propagate it in time

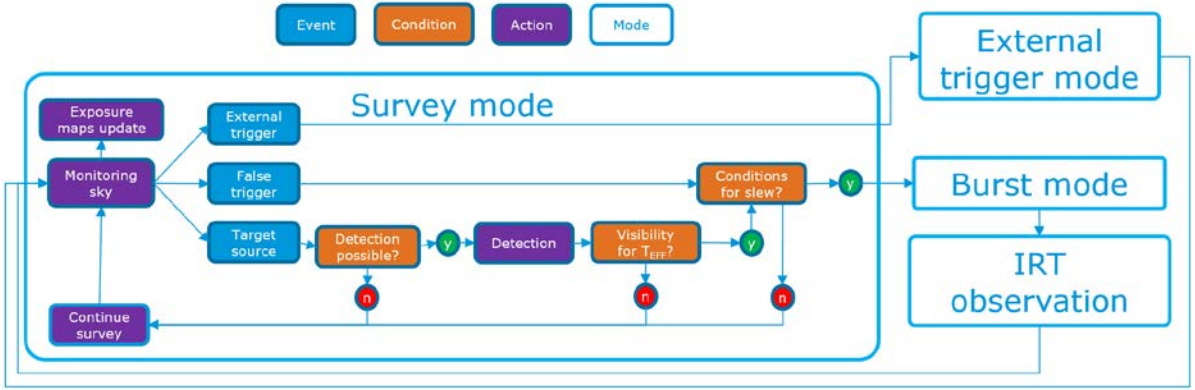


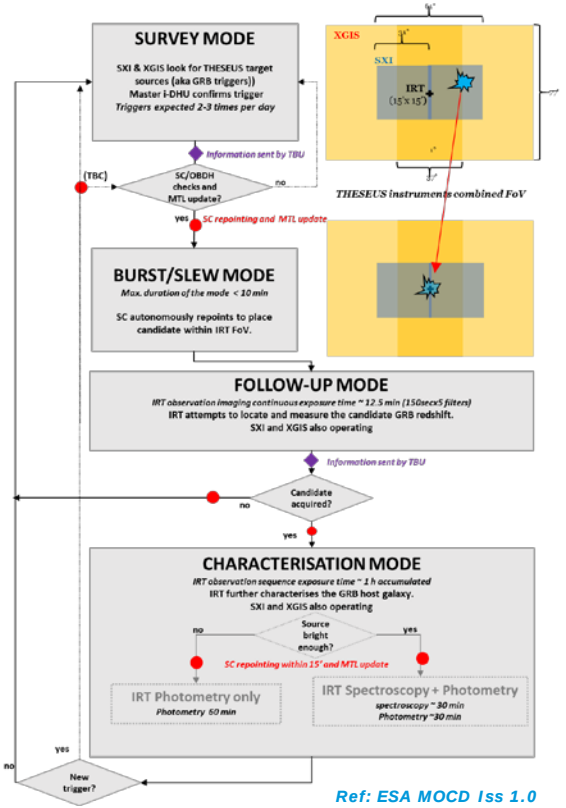
Number of GRBs	
SciRD Vr 2.1	Required *[Goal]*
THS-SCI-R-101 long at z≥6	40 *[100]*
THS-SCI-R-103 short	30 *[80]*
over in-orbit nominal mission lifetime	

- Distribution of GRBs
- Granularity of Inst. Responses
- Exposure maps
- Impact of different parameters
- Etc..

Number of transients and/or X-Ray variable sources		
SciRD Vr.2.1	Required	Remark
THS-SCI-R-110	300 over in-orbit lifetime	on-board or off-line data processing

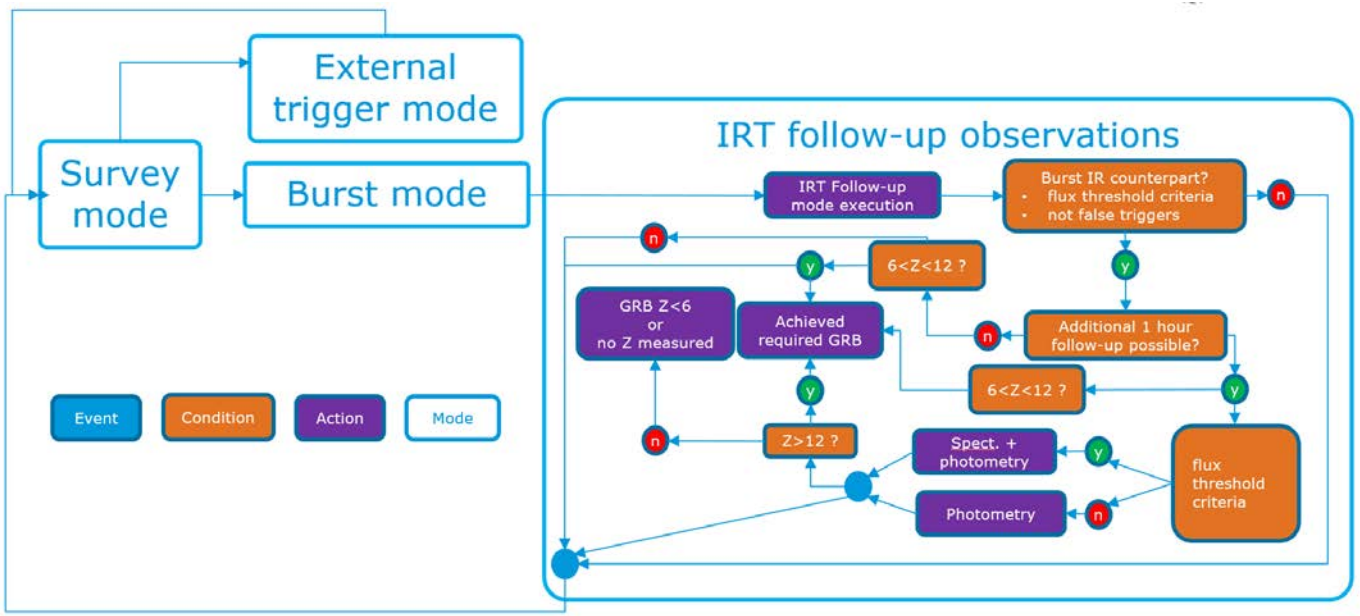
Example MOS modes flow / logic (1 / 2): survey mode overview





Ref: ESA MOCD Iss 1.0

Example MOS modes flow / logic (2 / 2)
IRT observation overview



MOS history of runs and trade-space

MOS runs	(3) Issue 0: EP TSTT#4 Oct 2019	(4a) Towards Issue 1: EP Telcon Jun 2020	(4b) Towards Issue 1: DYN Telcon Jun 2020	(5a) Issue 1: EP TSST#5 Jul 2020	(5b) Issue 1: DYN TSST#5 Jul 2020	(6a) Issue 2.1: EP TSST#6 Oct 2020	(6b) Issue 2.1: DYN TSST#6 Oct 2020
Survey pointing law	Fixed Ecliptic	Fixed Ecliptic	2 slews per orbit (60 deg tilt)	Fixed Ecliptic	2 slews per orbit (60 deg tilt)	Fixed Ecliptic	2 slews per orbit (60 deg tilt)
Declination range [deg] of achieved GRB [%]	0-55 ~36%	0-30 ~4% 30-55 ~33%	0-30 ~53% 30-55 ~39%	0-30 ~4% 30-55 ~30%	0-30 ~50% 30-55 ~39%	0-30 ~4% 30-55 ~29%	0-30 ~51% 30-55 ~36%
Number of SXI cameras (SXI quadrant condition)	4 (YES)	4 (NO)	4 (NO)	2 (NO)	2 (NO)	2 (NO)	2 (NO)
Mission lifetime [yr]	3	3	3	4	4	4	4
IRT Follow-up duration	7 min	12.5 min	12.5 min	12.5 min	12.5 min	12.5 min	12.5 min
GRB model (FITS file) and XGIS trigger effic/sensitivity [version]	FITS file (v05) *Trig.eff. (V3.0)*	FITS file (v06) *Trig.eff. (V5.0)*	FITS file (v06) *Trig.eff. (V5.0)*	FITS file (v06) *Trig.eff. (V5.1)*	FITS file (v06) *Trig.eff. (V5.1)*	FITS file (v06b) *Trig.eff. (V5.2)*	FITS file (v06b) *Trig.eff. (V5.2)*
XGIS location accuracy [of triggers]	≤7 arcmin	Only follow to z<6 50% z>6 20%	Only Follow z<6 50% z>6 20%	Always slew but within IRT FoV cond. z<6 75% z>6 50%	Always slew but within IRT FoV cond. z<6 75% z>6 50%	Always slew but within IRT FoV cond. z<6 75% z>6 50%	Always slew but within IRT FoV cond. z<6 75% z>6 50%
Other MOS condition/assumption changes from "Inputs to the MOS"	SC Agility mode Inputs to MOS Vr 3.0	Vr 4.1	Vr 4.1	Vr 4.2	Vr 4.2	Vr 4.5 Teff 50% (was 100%) IRT threshold 0.017 mJy (was 0.02)	Vr 4.5 Teff 50% (was 100%) IRT threshold 0.017 mJy (was 0.02)
Output	**Results and presentation of results have evolved and supported the needs of TSST / ESA discussions and trades in order to allow decision making and ultimately MOS (Dec 2020 Iss 2.2) has provided more than 18 specific outputs that have serve THESEUS science working groups for Yellow book scientific analysis**						

ACKOWLEDGMENTS

- **Amedeo Rocchi** (ESA Study Team-ESOC) creator and brain behind the model
- **Payload Consortium (Instrument teams)** in general and in particular Sandro Mereghetti and Enrico Bozzo
- **THESEUS Science Study Team** led by Lorenzo Amati/Matteo Guainazzi and instruments PIs for their patience and support throughout more than 2 years of “interdependency”

More details about the THESEUS Mission Observation Simulator of Phase A:

1) *“ESA THESEUS Mission Operations Concept Document (MOCD)”-Iss 1.0 Annex 1 [ESA-TSS-EST-MIS-OD-001]*
2) *“Consortium inputs to the ESA Mission Science Operations Simulator (MOS)” Iss 4.5 [THS-UoG-ADM-TN-0001]*
3) *ESA Study team for any questions and TSST for any results/outcome provided by the MOS*

THANKS