CTA TOP LEVEL USE CASES: FOR DISCUSSION

A. Bulgarelli and all COOR people

Tools

- **List of functionalities for use cases (Paris F2F meeting):**
  - the simulation tools for writing proposals
    - to check minimum time for observation (to reach desired sensitivity)
    - to check the impact of sky quality
    - the period to observe a source
  - the tool that makes sure to recognise all names of objects, to avoid duplicate GO observations
  - the tool that flags if two GO proposals are close enough that they could both be conducted in the same observing time and data shared
  - the tool that searches multi-wavelength catalogs for counterparts of new transients
  - the tool that automatically adds newly found transients to the catalog
  - the alert tools (giving/receiving)

ACTION LIST

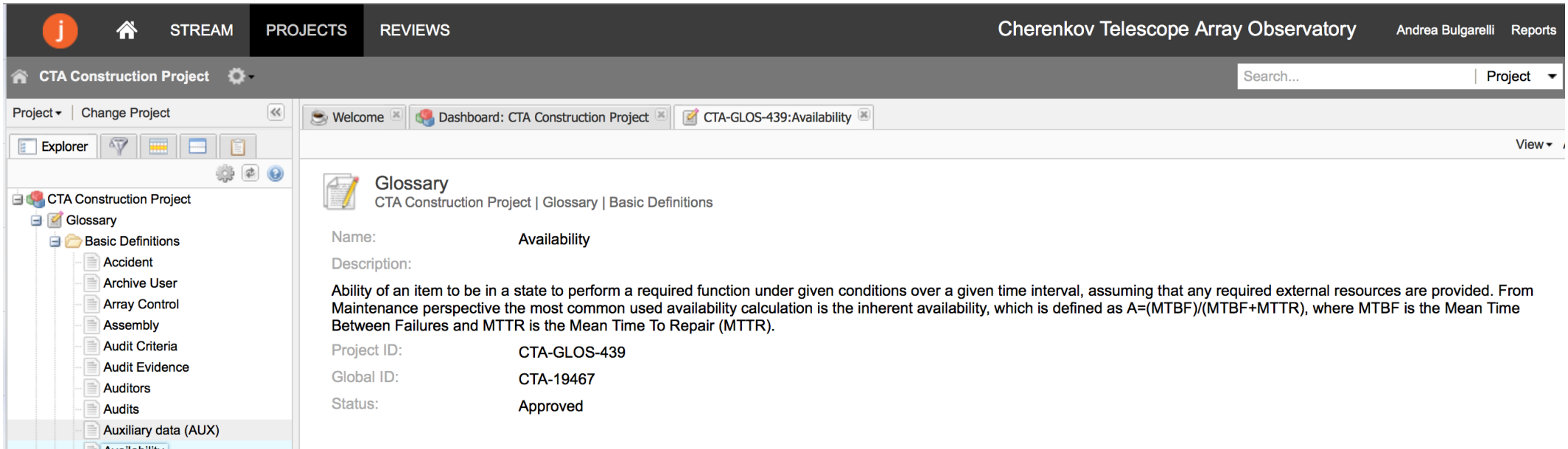
- mailing list
- upload all documents on Top Level Use Cases Sharepoint pages
- **to close V2, for the UC conveners (within two weeks, by the end of July in Jama)**
  - **changes in the main scenario**, based on the main scenario
  - **actor** (for each step)
  - **automation** (what is automated, what is manual, for each step to the main scenario)
  - **context** (clarify better)
  - comments on global CTA scheduler: each use case should take into account if this is needed (global on-line scheduler). Emma will send a short presentation
  - organize in the “open point part” the comment receiveid
    - science-related
      - send them to Stefano for discussion
    - “operations”

ACTION LIST /2

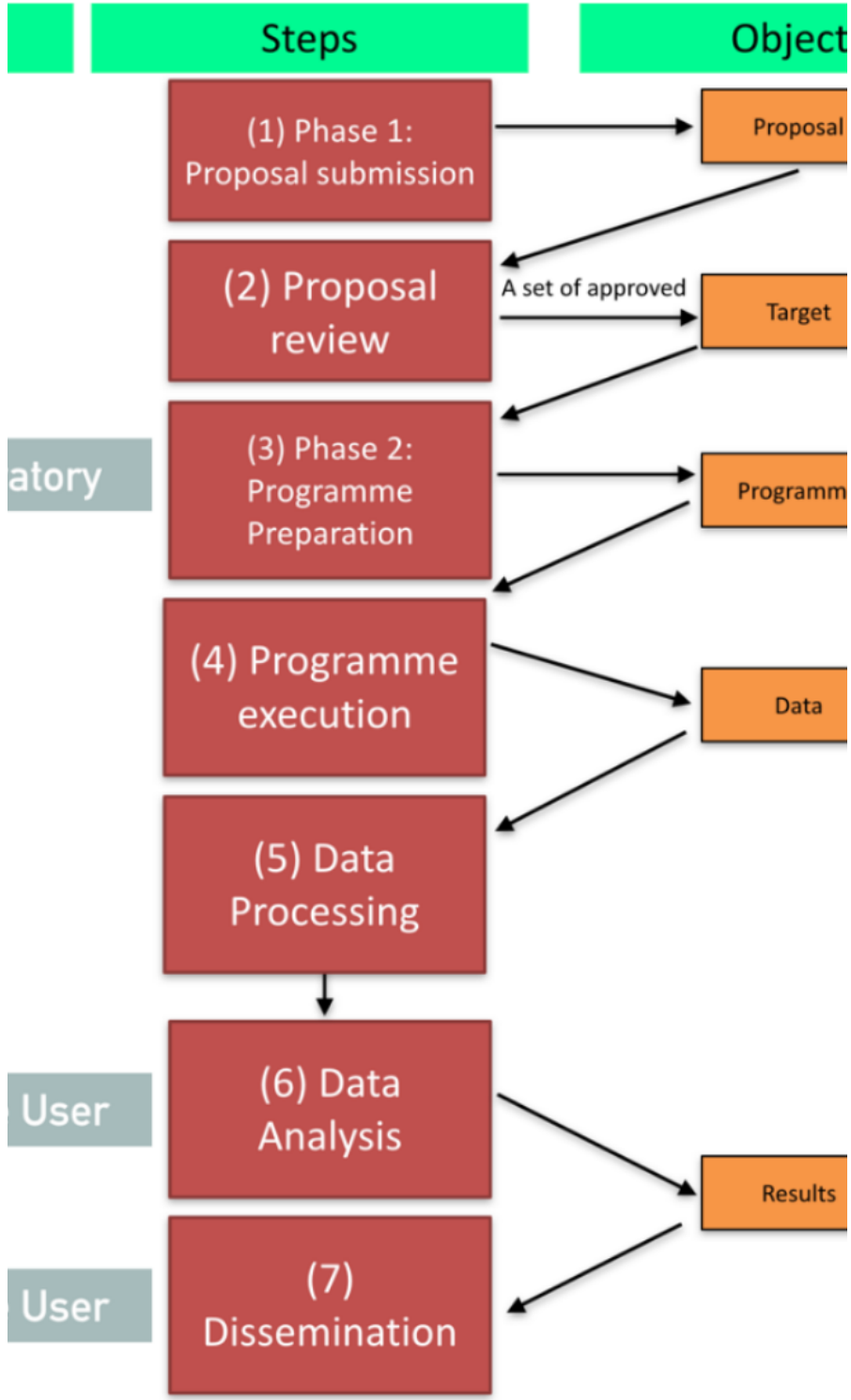
- **New use cases. Daniel Mazin (end of July in Jama)**
  - 009 Observe a point source like source
  - 010 Observe an extended source
- **(Fe, end of July): document of "top level common points"**
  - prioritisation
    - if we mess observations (for many reason), the priorities could change?
  - definition of "science parameters" and their relationship and conditions (general) to stop an incoming observation.
  - tools (see discussion), check USER reqs
- **By the end of September**
  - extract and categorise requirement (check missing requirements)
    - science
    - observatory
    - user

ACTION LIST

- Jamie, Andrea, Bruno, Catherine, all
  - Check definitions and glossary. Missing definitions: serendipitous, transient, …
- Tools: discuss with Jim how to proceed

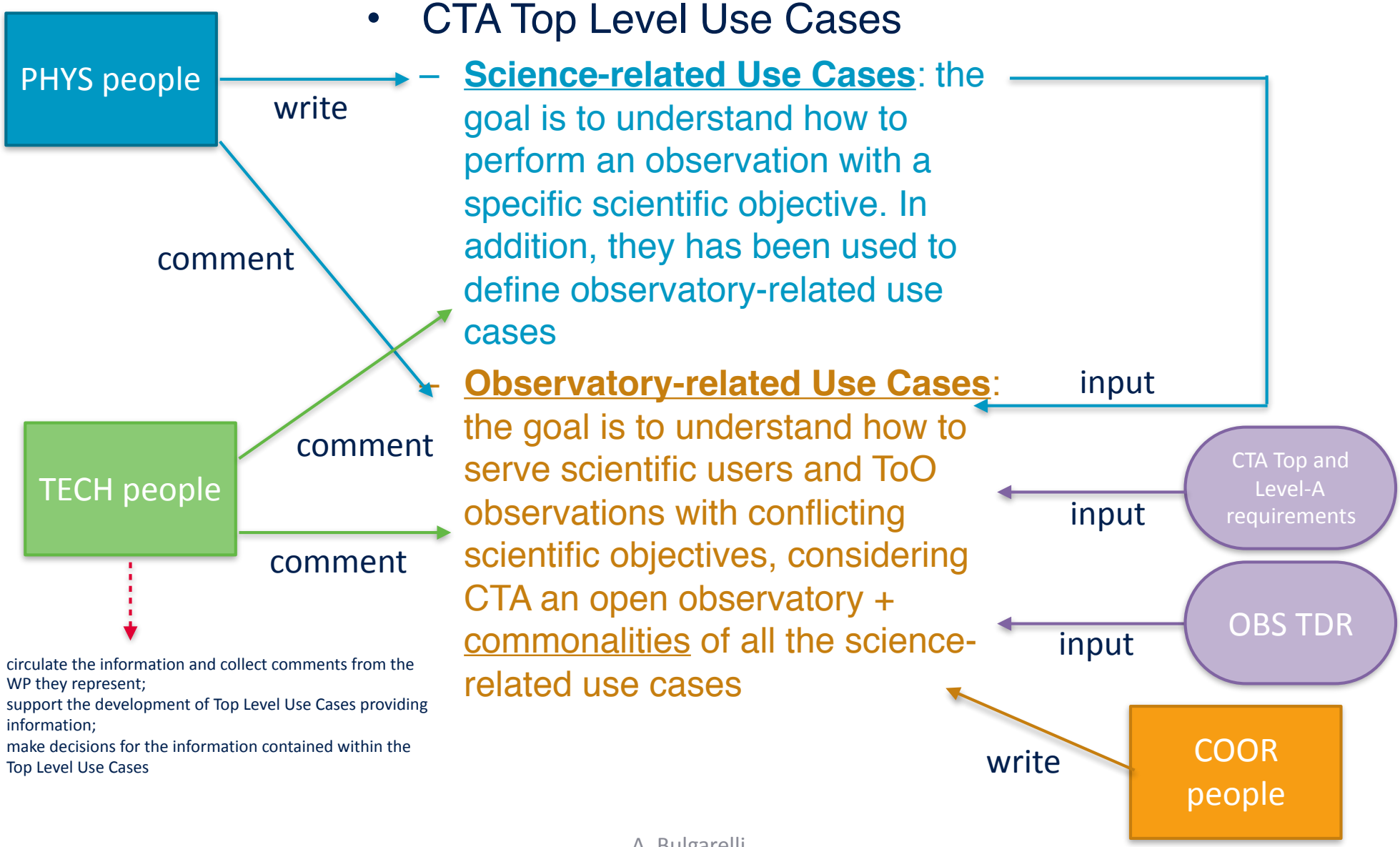


OBSERVATORY-RELATED USE CASE DOCUMENT



Overview

- CTA Top Level Use Cases
  - **Science-related Use Cases**: the goal is to understand how to perform an observation with a specific scientific objective. In addition, they has been used to define observatory-related use cases
  - **Observatory-related Use Cases**: the goal is to understand how to serve scientific users and ToO observations with conflicting scientific objectives, considering CTA an open observatory + commonalities of all the science-related use cases



- circulate the information and collect comments from the WP they represent;
- support the development of Top Level Use Cases providing information;
- make decisions for the information contained within the Top Level Use Cases

UCD AND COMMENTS

- UCD V 1.1
  - https://docs.google.com/document/d/1xtHmyQLBdUL9ywOd2lGoxF83U4sTWqydrCBFZaR00fU/edit?usp=sharing
- Comments
  - https://docs.google.com/document/d/1_7dIVdfD5mC9tube44zB-XzZiZ96rq06-5p4AQ8QOOk/edit?usp=sharing

cherenkov telescope array

Observing objects

Actors

- Observer
  - Guest Observer
  - CTA Consortium Observer
- Observatory
- Archive User
- Systems
  - CTA Telescopes
  - CTA Software
  - CTA Auxiliary Items
  - External Instruments: e.g. external MM/MWL facilities

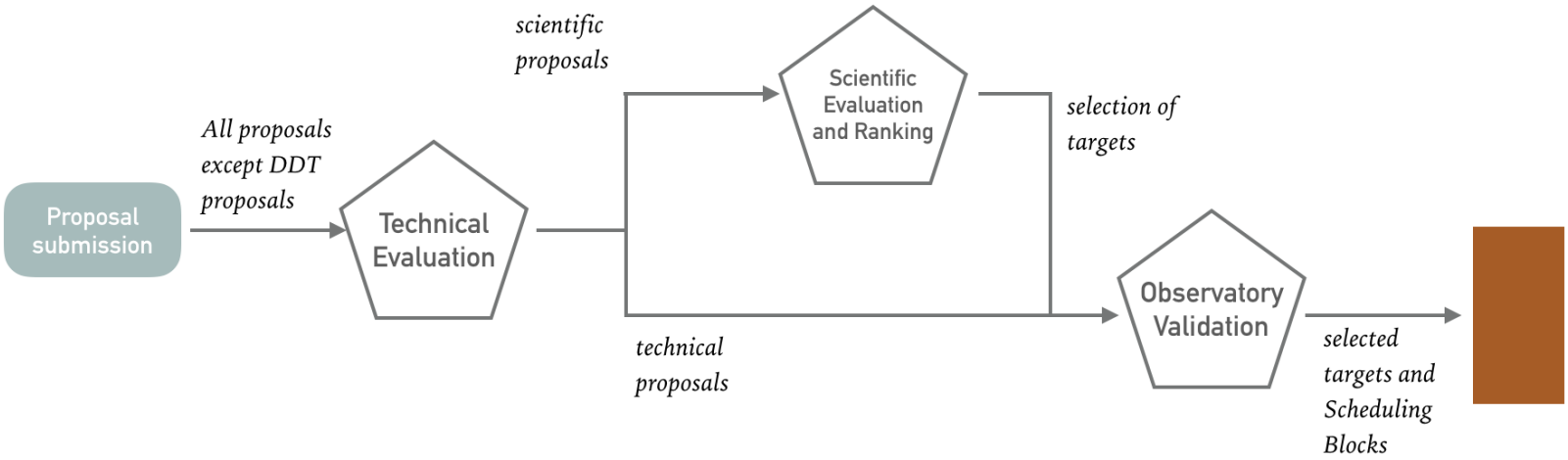
The observing objects

- A **Proposal** contains the description of the observing strategy and associated observing modes. A proposal has
  - Unique Proposal Identification Code
  - AO call identification code
  - Title
  - Abstract
  - Proposal Type
  - Proposal Class (DDT, GO, KSP, CTAO)
  - Principal Investigator and Author list
  - Scientific justification
  - Total Requested Time
  - Experience with Data Analysis
  - (List of) Targets

The observing objects/2

- A **Target** consists of the approved part of the proposal. The Target describe the object(s) or sky position(s) to observe. In order to study the scientific case of the Proposal, each Target being a unique sky position.
  - Target Name
  - ~~Sky coordinates~~
  - ~~Requested Time~~
  - **Observing Mode**
  - Related Proposal Identification
  - Ranking
    - Target class (A,B,C)
    - Target rank (1-10)

see next slide



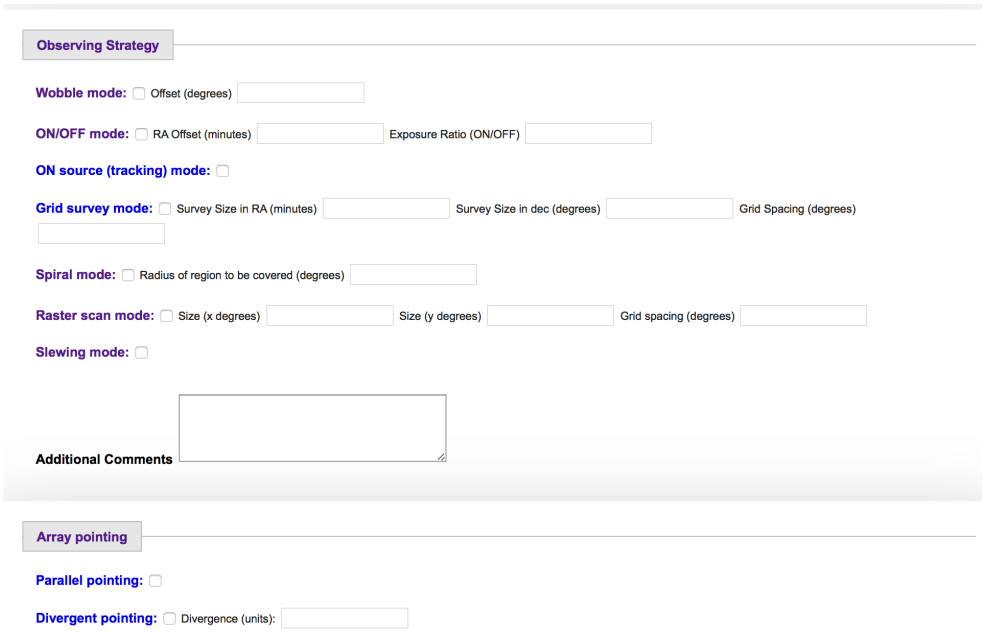
Observing mode definition

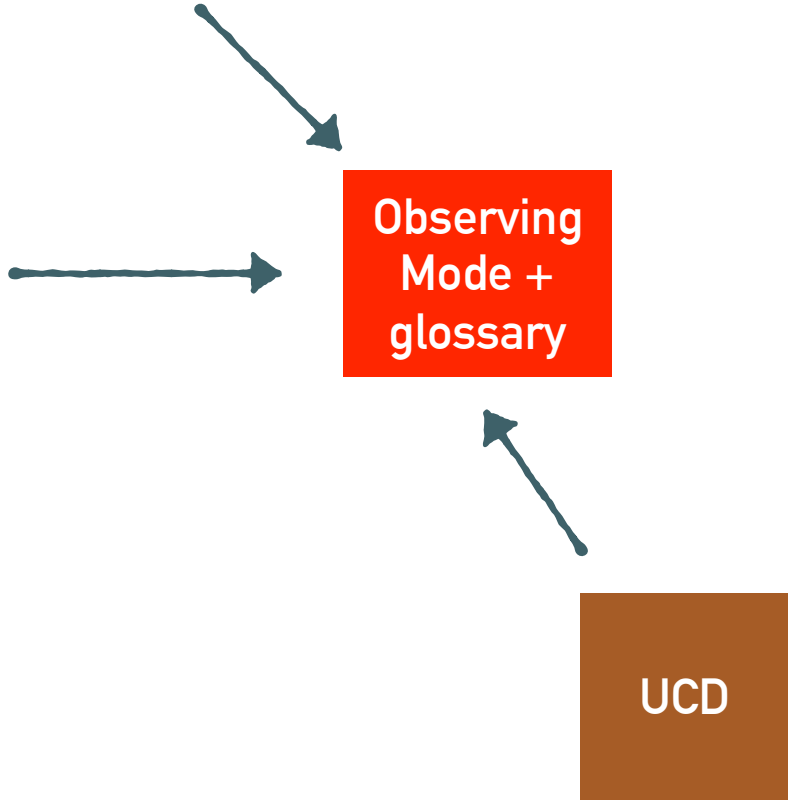
- How to perform an observation -> Define the configuration of the (sub-)array, the observing conditions and constraints for the execution of a Target.
  - Array: N, S, both
  - Pointing coordinates system: Ra-Dec / Alt-Az / Gal
  - Observing strategies (ON/OFF, wobble, survey, etc)
  - Nominal_Pointing: pointing coordinates for the Target
  - Requested_Time: amount of observation time on the Target
  - Requested_SubArray
  - Minimal_Sky_Quality: very good / good / marginal
  - NSB_Range: a range of acceptable values or ranking / any
  - Zenith_Range: minimum and maximum allowable zenith angle during the SB; the SB will not be executed unless this condition is met. It could be possible to have a limited choice - e.g. bounds could be 30, 45, 60 degrees
  - Precision_Pointing: a tick box enabling highest pointing precision (low wind, low temperature gradient); the SB will not be executed unless these conditions are met.
  - Allowed_Time_Range(s): Observation time and epoch and time sequences and/or constraints. Table of observing windows when the observations are allowed (by default the full year, but for multi-wavelength campaigns or periodic sources may be more specific). For ToO observations: maximum duration of an observation, maximum time delay.

This is a common definition present in the observatory-related UCD and used in the science-related use cases

Observing Mode #1 (initial scanning of GW error region)

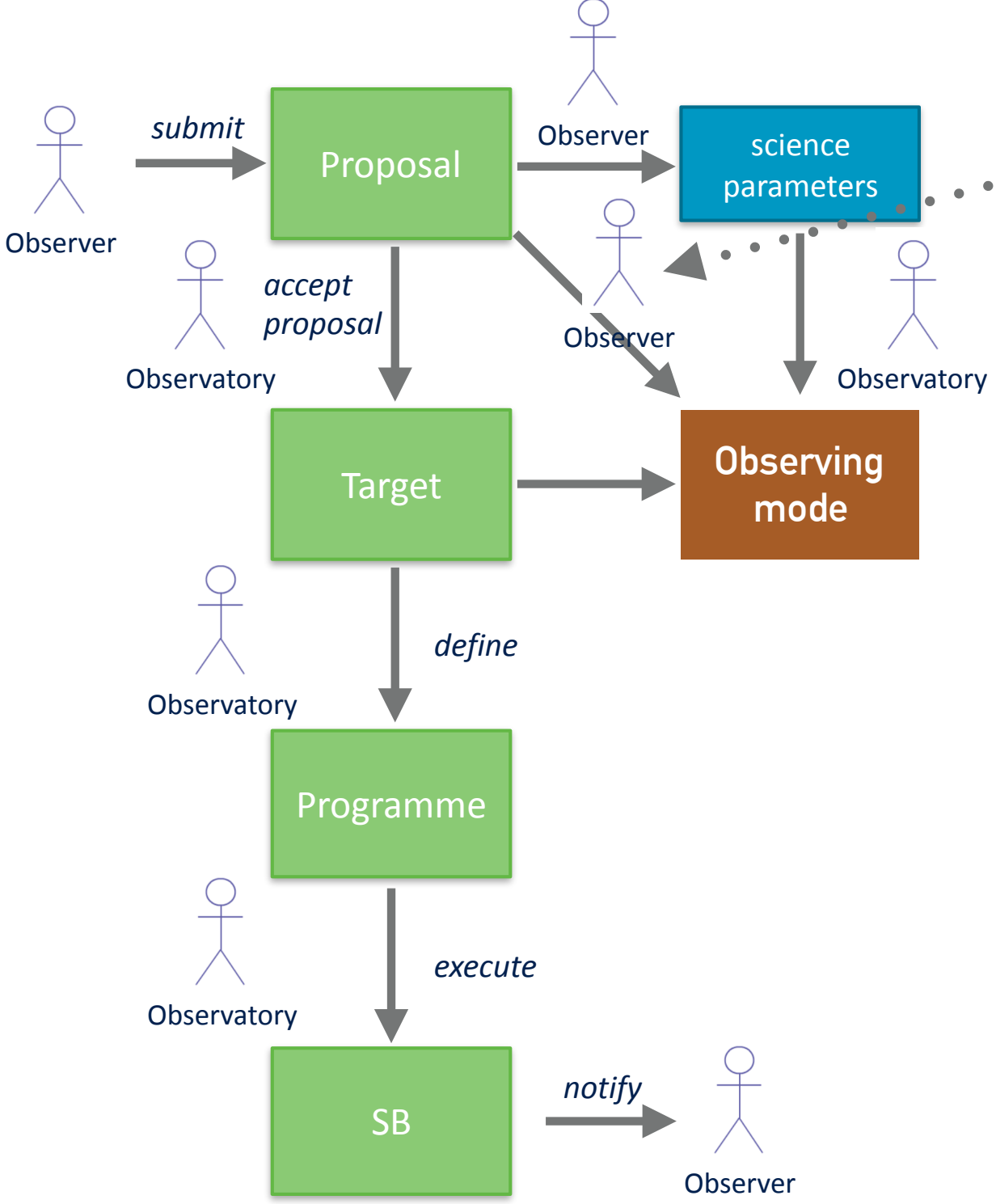
1. Array: both, depending on sky location of error region;
2. Pointing_Coordinate_System: Ra-Dec (based on the GW map)
3. Nominal_Pointing: *pointing coordinates for each target and a field that describes the expected target size (a radius or region-of-interest definition).* The GW error region is a map in HEALPIX format that will need converting into a set of CTA pointings.
4. Pointing_Mode: parallel (=0) / convergent (<0) / divergent (>0) Default is parallel, multiple pointings required. Needs further simulations to see if divergent pointing could be useful.
5. Requested_Telescopes: *number of LST / MST / SST telescopes requested for the run. Or full array, sub-system, sub-arrays.* LSTs + a few MSTs
6. Minimal_Telescopes: *minimum number of LST / MST / SST telescopes required for the run; the run will not be executed unless these telescopes can be provided.* 2 LSTs
7. Minimal_Sky_Quality: perfect / good / marginal. *Specifying atmospheric quality (transmission); the run will not be executed unless these conditions are met.* Marginal (at least early on in the program)
8. NSB_Range: minimal / up to 5 x minimal (~1/2 moon) / any. *Minimum and maximum allowed NSB, mainly due to the moon; the run will not be executed unless these conditions are met. There may be technical reasons to have a non-zero minimal value (off-runs for high NSB regions, technical studies, etc).* up to 5x minimal
9. Zenith_Range: *minimum and maximum allowable zenith angle during the run; the run will not be executed unless this condition is met.* <70deg (from KSP)
10. Precision_Pointing: *conditions enabling highest pointing precision (low wind, low temperature gradient); the run will not be executed unless these conditions are met.* No (we'll pin down the precise source position with EM follow-ups)
11. Allowed_Time_Range(s): *Observation time and epoch. Table of observing windows when the observations are allowed (by default the full year, but for multi-wavelength campaigns or periodic sources may be more specific). For ToO observations: max duration of an observation, maximum time delay.* at least 2h/follow-up (from KSP); max. time delay <2-3h
12. Priority: The GW team will work out the prioritization of the alerts taking into account for example the time delay since the GW alert, the size of the error region, properties of local galaxies within the error regions and the CTA-FoV, etc. ...





The observing objects/3

- Once a **Target** has been created, it has to be described by a **Programme** in order to be scheduled. This is the reason for "Programme Preparation".
  - A *Programme* is a set of *Scheduling Blocks* (at least one)
- A **Scheduling Block** (SB) represents a unit of observation that includes all necessary calibration observations/procedures for the Observatory.
  - A SB may include several observations and calibration sequences.
  - Observations are intended to be run to completion when scheduled, and should only be canceled or aborted when either
    - 1) a ToO alert of higher priority arrives to interrupt it; or
    - 2) observing conditions become so bad that they represent a danger
  - Execution of a scheduled SB will be initiated if the requested conditions are expected to be met.



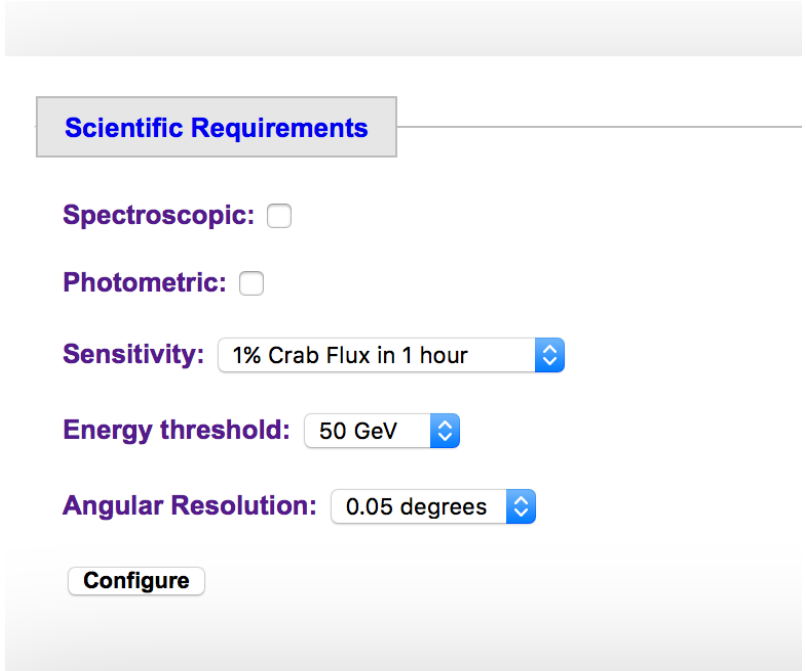
select between a list of templates

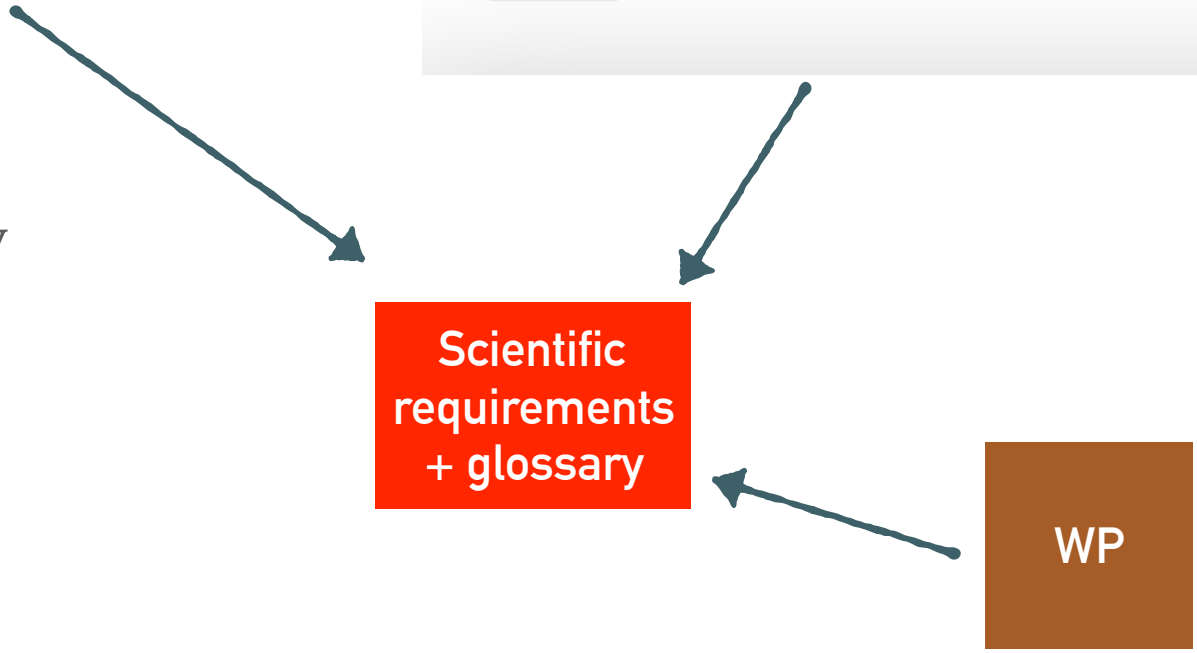
Science-related use cases:

- *list of observing modes*
- *sequence of step (i.e. generation of new programmes) to follow a strategy*

SCIENTIFIC REQUIREMENTS OF A PROPOSAL

- UCD:
  - energy range
  - PSF/Angular resolution
  - energy resolution (per channel)
  - required sensitivity
  - expected morphology of the gamma-ray emitting region
  - systematics





TYPE OF PROPOSALS

- **Standard programme proposals**: planned observation of a sky region that can be achieved within one Announcement of Opportunity (AO)
  - **UC-SCI-009**
  - **UC-SCI-010**
- **Monitoring programme proposals**
  - **UC-SCI-001: Long Term Monitoring of AGN**
  - **UC-SCI-002: Perform an AGN Snapshots**
- **Large programme proposals**: proposals requiring a large amount of observing time, e.g., surveys, to be handled in a coordinated way.
  - **UC-SCI-008: Perform a Survey of a region**

- **Technical proposals**: special data acquisition needed for engineering tests, calibration or performance validation. Special proposals are with calibration sources.
- **Coordinated observation proposals**: proposals with special constraints, to be executed in coordination with other ground-based or space observatories.
- **DDT observation proposals**: observation of a sky region decided by the CTAO Director that is either planned in advance or triggered by an external or internal notification.
  - **UC-SCI-003: Observe a transient discovered with RTA (Real-Time Analysis)**

- **Triggered observation proposals**: proposals for which observing time cannot be allocated in advance
  - **Automatically triggered observations**, for any kind of high priority internal (via RTA) or external (via MWL, MM) alerts, without human intervention
    - **UC-SCI-003: Observe a transient discovered with RTA (Real-Time Analysis)**
    - **UC-SCI-004: Observe a ToO following an alert from gravitational wave observatories**
    - **UC-SCI-005: Observe a ToO following an alert from high-energy neutrino telescopes**
    - **UC-SCI-006: Observe a GRB after external alerts**
  - **Non-automatically triggered observations**, that must be carried out as soon as possible after the Observatory has received the notification (e.g. via Astronomical Telegram or MoUs). A check/filtering is performed before the on-line scheduling. Non-automated observations should also be foreseen during the commissioning phase.
    - **UC-SCI-007: Observe a XRB/gamma binary from external alert**

➤ UC-SCI-003: Observe a transient discovered with RTA (Real-Time Analysis)

Trigger condition

6.1 Main scenario

During the early science period, or 'training' time, the sequence should probably be something like:

0) A serendipitous source is detected with the RTA. [automated]. In case a transient is detected, the Observatory will routinely issue an alert to the community (after the training period) [automated/manual?].

1) Search databases for counterparts [automated] in a catalog. Mechanisms should be in place to check against recent VOEvent/ATELs in the same region. [automated] Decide the class of priority.

2) Interrupt schedule and put LSTs + MSTs [note 1] on any new transient (observing mode #1), while simultaneously getting the first data products (flux, spectrum, light curve) and comparing the initial products to known source templates [note 2] [automated]. If based on this initial analysis the spectral index is very hard (~1 or lower), maybe worth adding in the SSTs at least until we know if there is a cutoff below 10 TeV or not.) (observing mode #2) [automated]

3) Perform observations [automated]

3.1) If source has a known counterpart:

3.1.1) For AGN flare appearing in a couple of hours integration, flux 50-100 mCrab, return to the programmed observation, assess situation the following day (needs to be more specific)
3.1.2) In general, we need to have some clear follow up (see "external ToO" UCs) strategy in each case, that may only be in place after some time 'training' on new transient activity.

3.2) If detection is not associated with known sources: highest priority, observe with full array, and trigger MWL facilities or exploit MoUs. The observation is defined by the "observing mode #3".

Note: gamma-binaries: velocity/photometric measurements should be arranged with regular/ToO proposals submitted to different facilities in advance (ESO,CAHA,ING telescopes, GTC, ...). Perhaps if optical telescopes are available in CTA sites, it will be also of great help. Radio and X-ray measurements would also require to have similar proposals submitted in advance to appropriate observatories (VLA, EVN, Chandra, XMM ....)

4) Determine longer term follow-up strategy and have mechanism to rework the schedule to fit this into the prior observing schedule. [manual]

Note: Overall we did not get very far for individual source classes here, partly because this is still terra incognita. We need to plan/allow for a "training" period as soon as transient detection is possible with RTA.

➤ UC-SCI-004: Observe a ToO following an alert from gravitational wave observatories

Trigger condition

6.1 Main scenario
A list of steps.

1. The Observatory receives an external trigger for a GW alert, monitoring the private stream of GCN notices/VO events. Notify the Operator and the GW team that an alert has been received. The GCN notice/VO event contains the error region (currently in HEALPIX format). A visibility calculator tool automatically translates this information in CTA pointing directions and an automatic decision tree provided by the GW-team decides which array (N and/or S) should be triggered.
2. If parts of the GW error region is reachable and if all constraints are satisfied (zenith angle, weather conditions, alert delay, observation priority, time availability) a new observation (Observing mode #1) is planned automatically. Each site will employ at least 2LSTs for at least 2 hours. The sequence and details of the scheduled pointings are provided by the tool described in Sec. 5. Control system notifies the Operator and the GW team about the starting observations.
3. Control system automatically repoints the LST(s). When the telescopes are in the right position, Control system starts the data taking and proceeds to tile the sky within the available GW error region.
4. The realtime analysis automatically starts the data analysis. The best source data analysis algorithm is selected automatically.
5. The realtime analysis system automatically analyses the data and checks if a new source is detected in each pointing in sequence.
6. If there is no source detection within 2 hours from the start of the observation, control system automatically puts back the LST in the previous (prealert) scheduled configuration. END of GW follow-up
7. If a new source is detected by the realtime analysis, RTA automatically sends an alert to the CTA GW team and notifies control system to schedule a new observation with the full array right away (Observing mode #2a) or once the current search is over (Observing mode #3a). Another possibility would be to point a sub-array of LSTs and/or MSTs towards the new source while continuing mode #1 with the LSTs (Observing mode #4a).
    1. see below for steps to be taken in Observing mode 2a, 3a and 4a
8. If the GW team is informed by the electromagnetic follow-up group of the detection of a potential EM-counterpart during the initial scanning observations #1, new observations with the full array may be requested right away (Observing Mode #2b) or once the current search is over (Observing mode #3b). Another possibility would be to point a sub-array of LSTs and/or MSTs towards the new source while continuing mode #1 with the LSTs (Observing mode #4b).
    1. see below for steps to be taken in Observing mode 2b and 3b
9. If a new source is detected by the Level B analysis within the region scanned in #1: Level B analysis sends an automatic alert to the CTA GW team. The GW team will manually decide if deeper, full-array observations are requested (Observing mode #3c) and define their priority.
10. If the GW team is informed by the LSC-EM follow-up group of the detection of a potential EM-counterpart outside the CTA GW observations: the GW team will manually decide if deep, full-array observations are requested (Observing mode #3d) and define their priority.

➤ UC-SCI-006: Observe a GRB after external alerts

Trigger condition

6.1 Main scenario
1) The short term scheduler receives an external trigger for a GRB, monitoring the stream of Gamma-ray Coordinates Network (GCN) notices or from the VOEvent servers. Notify the Array Operator that an alert has been received.
The Observer can then, after discussion with the BA, manually trigger follow-up. - [human]

1.1) The short term scheduler plans a new Observation. If all constraints are satisfied (zenith angle, weather conditions, alert delay, observation priority, time availability) a new observation is planned using a sub-array of LSTs or the full array. Notify the Array Operator.
Postconditions: a new observation is ready to execute

2) Execute the observation

2.1) Repoint the sub-array of LSTs/full-array. If possible, take data during slewing
Postconditions: the sub-array/full-array is/are repointed and in observation.

2.3) RTA analyses data. RTA receives the external trigger from the scheduler with the position of the GRB, the error box, the timestamp, the new array configuration with the information of the sub-array devoted to the transient follow-up (or of the full array). Based on these information, the best data analysis algorithm is selected.
Postconditions: RTA is up and running

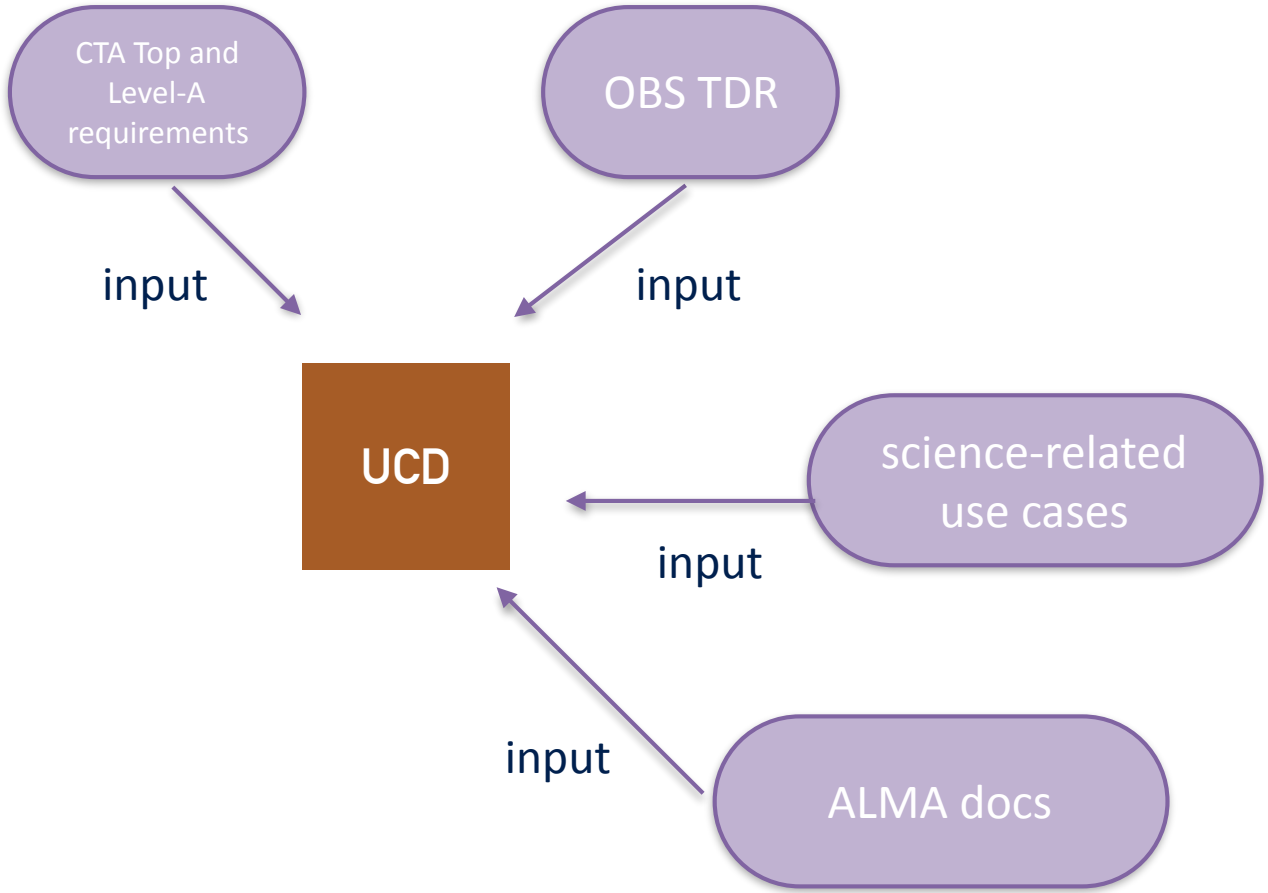
3) RTA analyzes the data and checks if the GRB is detected. RTA also checks for localization. If there is an RTA detection, update and repoint telescopes to the RTA detection position (center of error box).
Feedback to Array Operator and to RTA, BA, transient group (mailing list).

3.0) If there is no detection within the maximum allowed delay, notify the Array Operator and BA, then put back the sub-array/full-array in the previous (pre-alert) scheduled configuration. Send a GCN alert / VOEvent to the external world with the upper-limit.
Postcondition: the Array continues the previous scheduled observations

3.1) If there is a GRB detection, send a GCN alert (automatic) to the external world and notify the scheduler. The scheduler plans to repoint the full array generating a new observation. Alert other site if source is not fading and might become visible for the other site within the next 2 hours.
Postconditions: a new observation is ready to execute

cherenkov telescope array

Observe with CTA


CTA Top and Level-A requirements
OBS TDR
input
input
UCD
science-related use cases
input
input
ALMA docs

Survey a Region Use Case

UC-SCI-008: This use case is a special case of the "Observe With CTA" case with implications on the following: (will become specifications)

- Scheduler
  - must be able to optimize coverage of a large sky region
  - try to get uniform exposure, must be able to go back and fill in gaps when missed, even out exposure.
  - Definition of "flat exposure" needs to be made (is energy and telescope-type dependent)
- User proposal tools:
  - need ability to specify a region instead of a point in space in the proposal
  - should provide way of optimizing the grid spacing (sensitivity, flatness of exposure vs speed of coverage and total observation time)
- Automated analyses (Level A-C):
  - identify unexpected sources (no associated with proposal or known-VHE source catalog)
  - Look for transients (not strictly part of this use case, but related)
  - These are mostly satisfied by other UCs, so are not special to this one

➤ UC-SCI-008: Perform a Survey of a region

1. Prepare Survey Proposal
   a. Select survey region in ICRS or Galactic coordinates (may be a box, or other shape, and may be split into multiple sub-regions)
   b. Optimize grid spacing and geometry (triangular, rectangular, etc) of observations within the survey region for the science case, taking into account minimum flux sensitivity, uniformity, amount of available time.
   c. Make Survey proposal, which may span multiple years, specifying the results of the previous steps
   d. Evaluate Survey proposal for feasibility (determine what can be covered in the given observing season due to observational constraints)
2. Perform survey observations
   a. Implement survey grid into observation scheduler with constraints on zenith angle, expected grid-point coverage, weather, and subarray choice.
   b. [details of scheduling and array control here]
   c. scheduler evaluates current survey coverage
   d. choose grid point that falls within observing constraints and requires further exposure, weighted toward low zenith angle
   e. schedule observation of chosen grid point
   f. the observation are performed by the Observatory
   g. check data quality
   h. search for transients during the survey observation
      i. search for inter-observation (short timescale variability)
      ii. if and only if previous exposures exist of the region of comparable sensitivity, search for differences in detected sources (e.g. look for long-term variability)
      iii. if during an observation transient is detected feed into transient or “serendipitous UC”
3. Perform Science Analysis of Survey : (end-user analysis)
   a. Case 1: Perform survey analysis run-by-run to be later summed and filled into the survey ROI
      i. choose an appropriate WCS (region of interest, coordinate system, and projection covering the whole survey, part of the survey, or the full sky) for the run-wise results.
      ii. choose an appropriate WCS for the full survey ROI(s)
      iii. ...
   b. Case 2: Perform survey analysis on full survey ROI or set of ROIs at once
      i. choose an appropriate WCS for the survey ROI(s)
      ii. ...
      iii. combine multiple observations into a set of survey data cubes that cover the ROI: (counts, on and off exposures, effective area, psf) summing and resampling/mosaicing intermediate per-run outputs.
   c. detect sources within the ROI (or series of sub-ROIs)
   d. search for transients within the ROI in the level C analysis (on many timescale, up to the survey “pass” time)
   e. perform target science analysis on each detected source (spectrum + morphology fit)
   f. produce catalog of detected targets
4. Dissemination of results:
   a. publish catalog of sources internally and evaluate them for follow-up
   b. schedule follow-up observations on interesting hot-spots/sources
   c. publish catalog of sources publically

- UC-SCI-001: Long Term Monitoring of AGN
- UC-SCI-002: Perform an AGN Snapshots

6.1 Main scenario

A list of steps.

1. Prepare proposal
   - 1.1. determine optimal parameters from flux requirements/spectra, using 3 predefined bands
   - 1.2 check feasibility of monitoring cadence
   - 1.3. define communication frequency (from some preset options)
   - 1.4. determine level of unusual (flaring) activity for the target that will be recognized for sending out a ToO (both for CTA and external facilities)
2. Perform observations
   - 2.1. receive notification before observation starts [public short/long term planning a la Xray telescopes]
   - 2.2. check sky conditions, assess if observation feasible
   - 2.3. check hardware conditions, availability of various subarrays
   - 2.4. point telescope(s)
   - 2.5. check for flares during data taking at the end of one observing block (RTA)
   - 2.6. in case of flaring state (as defined above), send alert
   - 2.7. receive email at completion with basic summary
3. perform final science analysis (offline)
   - 3.1. create the best sampled as possible light curve (<< 30mn to 30mn time bin)
   - 3.2. make spectra for each light curve bin when possible
   - 3.3. fit a model to a multiwavelength SED including forward folding in Xray/Gamma and radio/OIR
4. disseminate

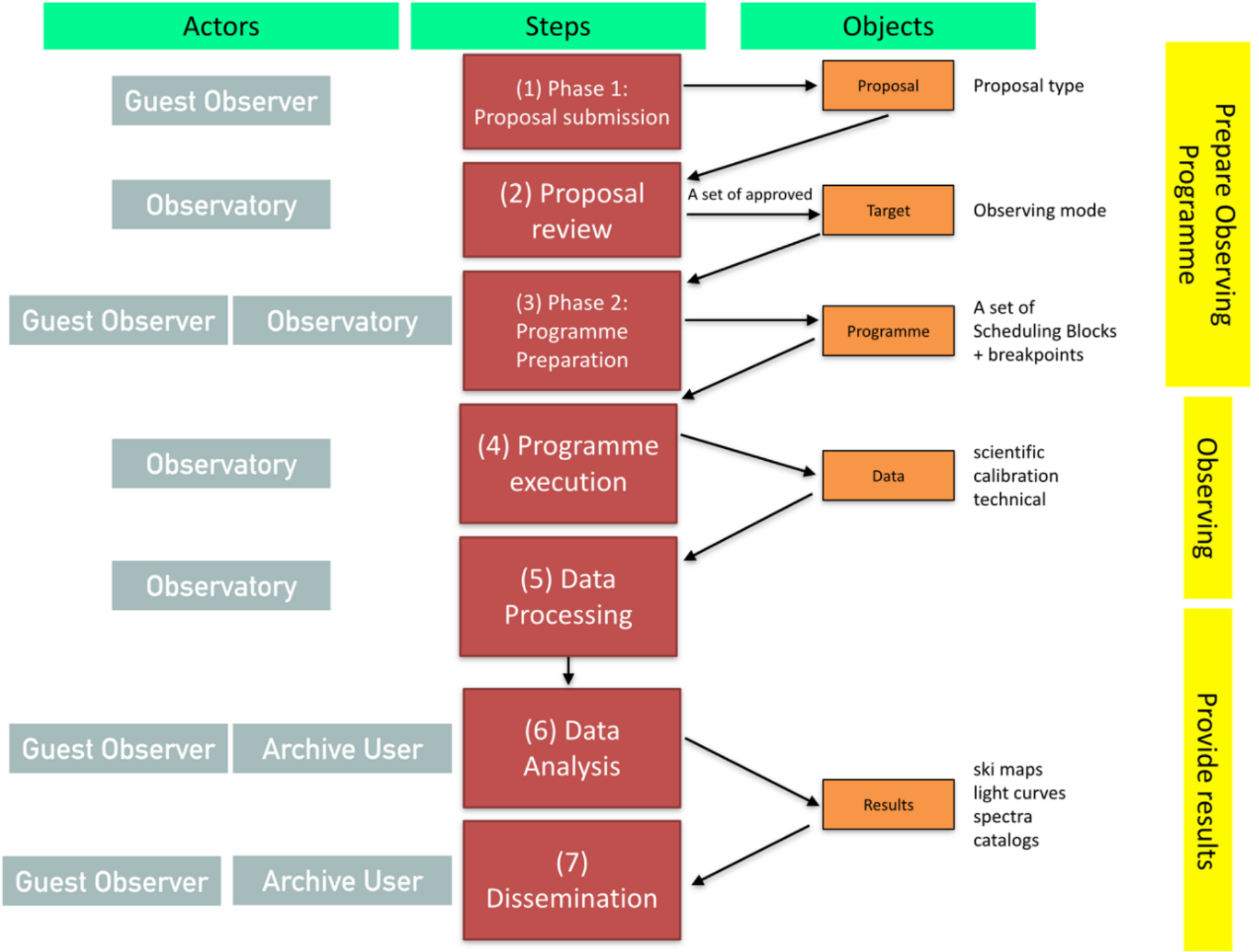
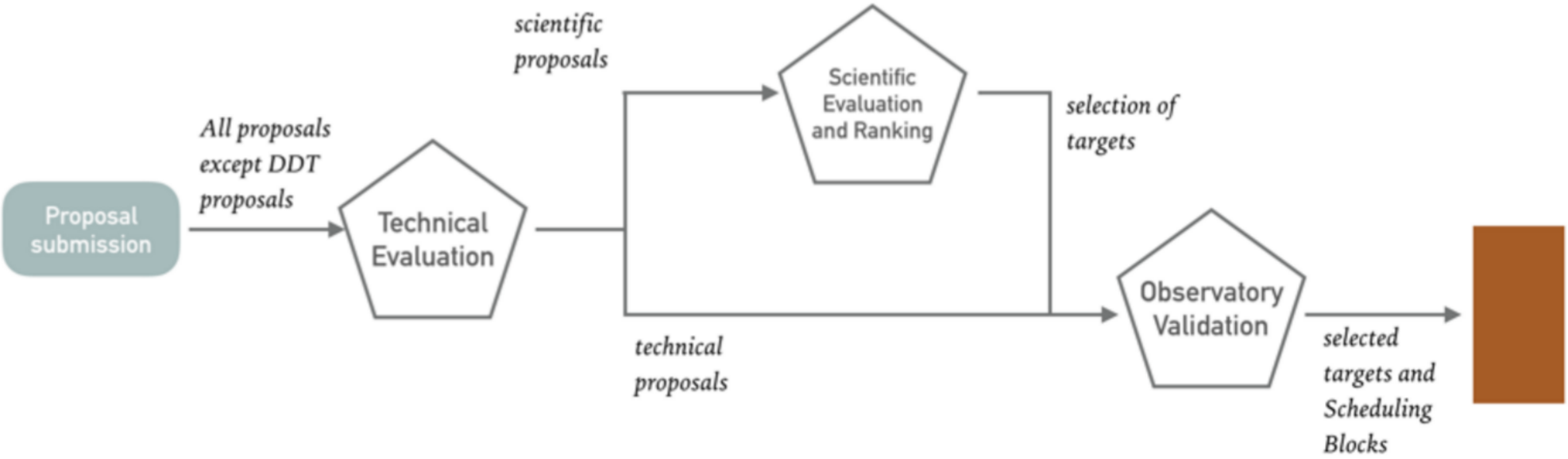
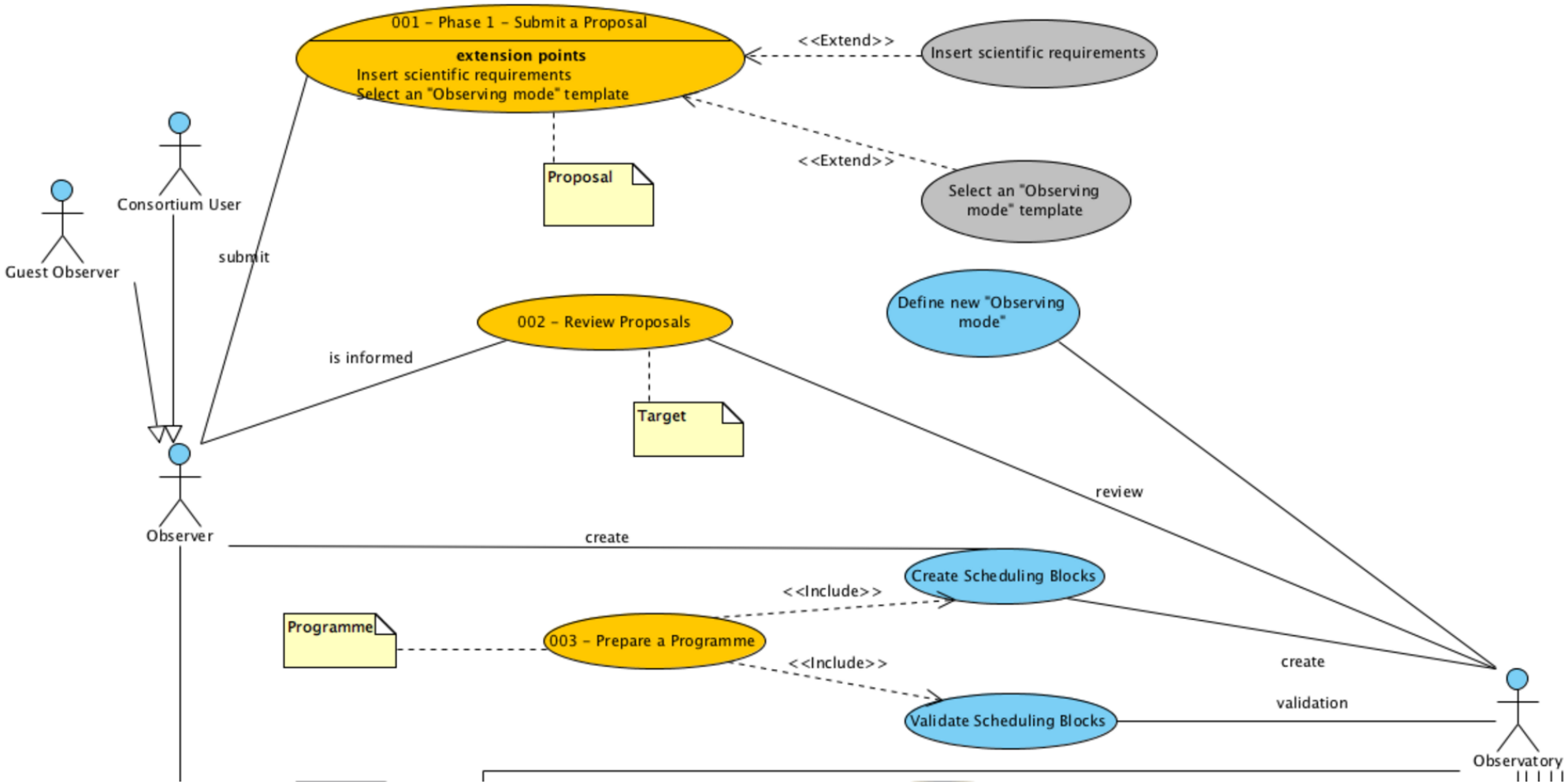
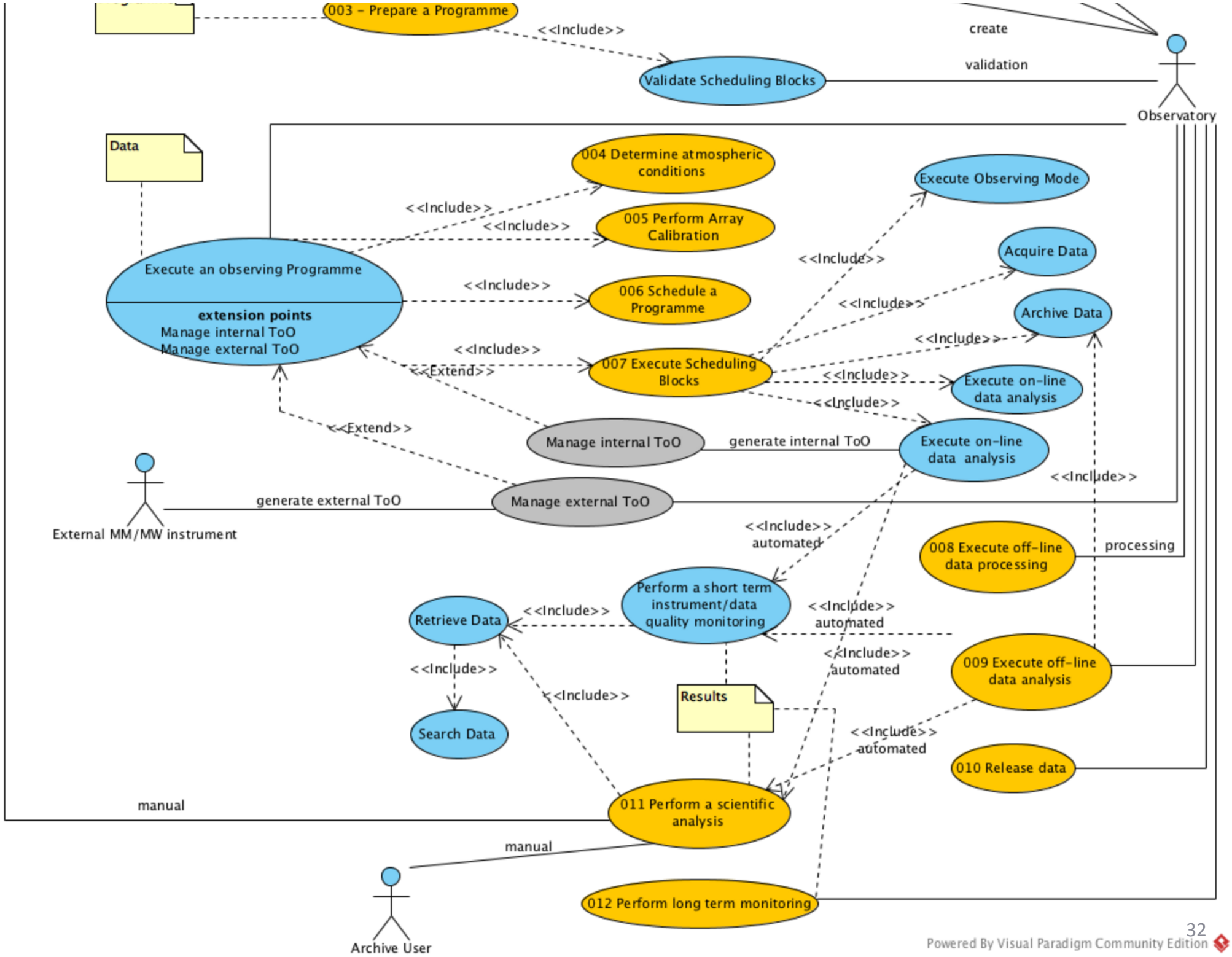


Figure 1: workflow: main actors (see section 3.2), steps and objects (orange)


Proposal submission
All proposals except DDT proposals
Technical Evaluation
scientific proposals
Scientific Evaluation and Ranking
selection of targets
technical proposals
Observatory Validation
selected targets and Scheduling Blocks

UC: Observe with CTA





List of use cases

Proposal submission
UC-CTAO-002 - Phase 1 - Submit a Proposal
UC-CTAO-003 - Define new Observing mode
Proposal review
UC-CTAO-004 - Review Proposals
Programme preparation
UC-CTAO-005 - Phase 2 - Prepare a Programme
Programme execution
UC-CTAO-006 - Determine atmospheric conditions
UC-CTAO-007 - Perform Array Calibration
UC-CTAO-008 - Schedule Programmes
UC-CTAO-009 - Execute Scheduling Blocks
UC-CTAO-010 - Execute Observing mode
UC-CTAO-011 - Acquire data
UC-CTAO-012 - Manage external ToOs
UC-CTAO-013 - Manage internal ToOs
UC-CTAO-014 - Review Programme

Data processing
UC-CTAO-015 - Execute on-line data processing
UC-CTAO-016 - Execute off-line data processing
Data Analysis
UC-CTAO-017 - Execute on-line data analysis
UC-CTAO-018 - Execute off-line data analysis
UC-CTAO-019 - Perform a scientific analysis
UC-CTAO-020 - Perform a short-term instrument/data quality monitoring
UC-CTAO-021 - Perform a long-term monitoring of instruments
Dissemination
UC-CTAO-022 - Release data
Common use cases
UC-CTAO-023 - Archive Data
UC-CTAO-024 - Search Data
UC-CTAO-025 - Retrieve Data