STPA applied to GMACS for Giant Magellan Telescope

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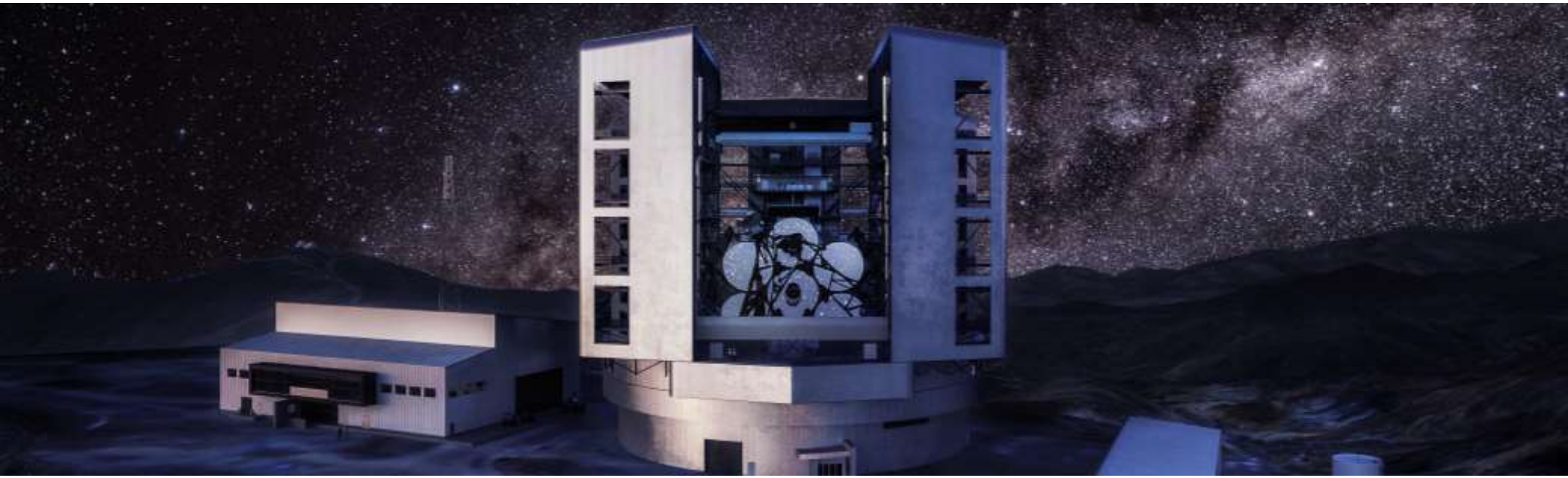

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Agenda

- Giant Magellan Telescope
  - Overview
  - System Engineer & STPA
  - Operation
  - GMACS
- GMACS
  - Components
  - Slit Mask
- STPA applied to GMACS - Slit Mask
  - Losses and Hazards
  - Control Structure
  - Unsafe Control Actions (UCAs)
  - Loss Scenario
  - Safety Constraints
- Conclusion

Giant Magellan Telescope

Overview

- **Giant Magellan Telescope - GMT**
  - One of the largest Gregorian optical-infrared telescope
  - Use seven of the world's largest mirrors
  - Under construction at Las Campanas - Chile,
    - One of the best locations on Earth to sky view.
  - Internacional Consortium
    - 14 leading research institutions representing
      - Australia
      - Brazil
      - Israel
      - South Korea
      - Taiwan
      - United States

GMTO. **About us**. Available at: https://giantmagellan.org/about-us/. Accessed at : 24 jul. 2024.

Giant Magellan Telescope

System Engineer & STPA

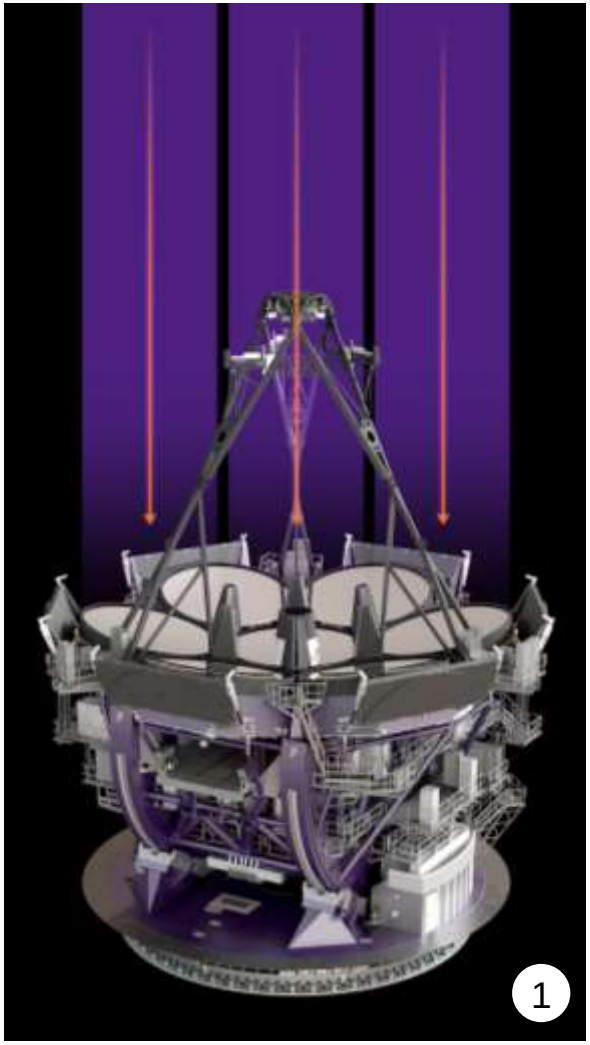
- Systems Engineering
  - Model Base System Engineering MBSE approach
    - Understand the interactions of the components
    - Facilitate communication between the different teams
      - USA, Australia, and Brazil.

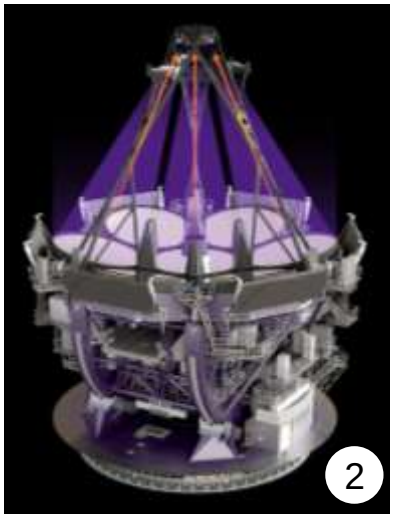
- STPA
  - Recently being applied by the System Engineer team in Brazil
  - Strategic approach for Hazard Analysis
  - Understanding the entire system view
    - Control and feedback mechanisms.
  - Timeline
    - Six months to understand the STPA process
    - Six months to capture most of the hazards associate with the target system

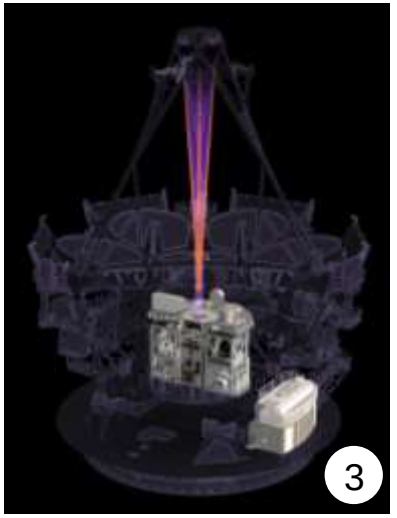
Giant Magellan Telescope

Operation

- **Light collected by GMT**
  - Provides scientific information
  - Analyzed by one or more instruments
- **Instruments**
  - Imager
  - Polarimeter
  - Spectrograph
- **Obtained Information**
  - Speed
  - Age
  - Temperature
  - Mass
  - Abundance of chemical elements





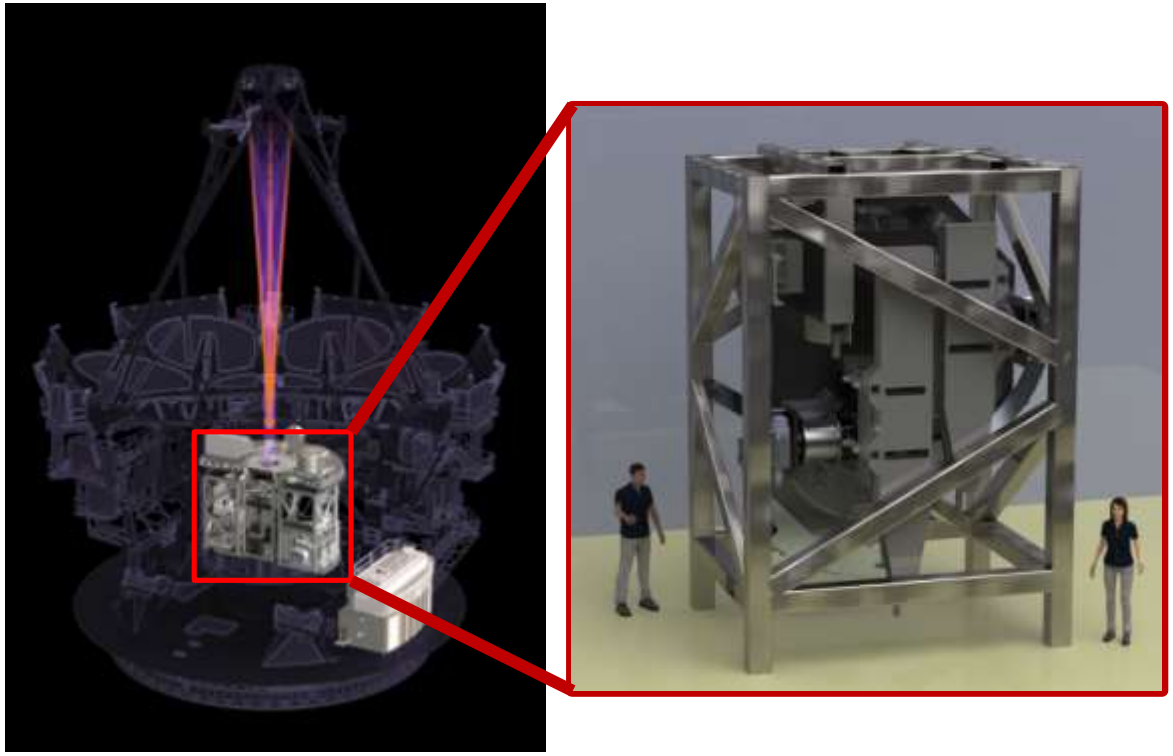


GMTO. **About us**. Available at: https://giantmagellan.org/about-us/. Accessed at : 24 jul. 2024.

Giant Magellan Telescope

GMACS

- **GMACS – GMT Multi-Object, visible, moderately scattered spectrograph**
  - Red and Blue Channels
- **Project (2024)**
  - Preliminary Design Review – Completed
  - Behavior of the components was analyzed
    - Identify
      - Hazards
      - Losses



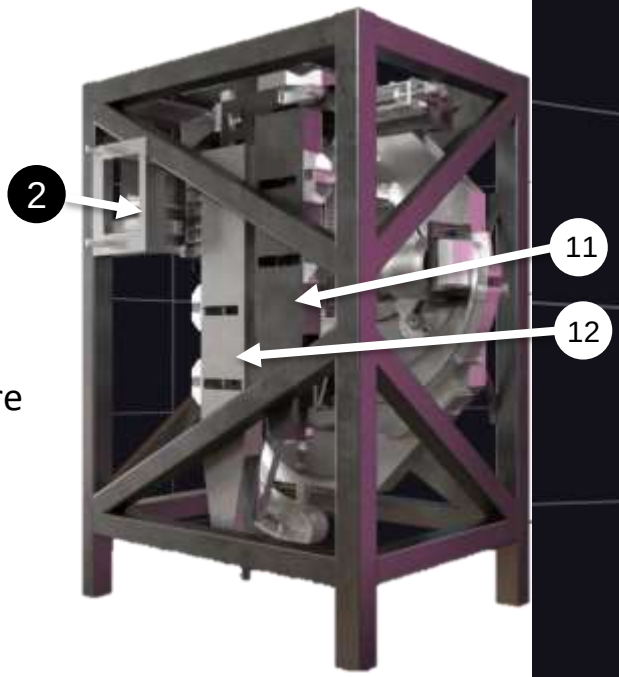
GMTO. **Scientific Instruments**. Available at: https://giantmagellan.org/scientific-instruments/ Accessed at : 24 jul. 2024.

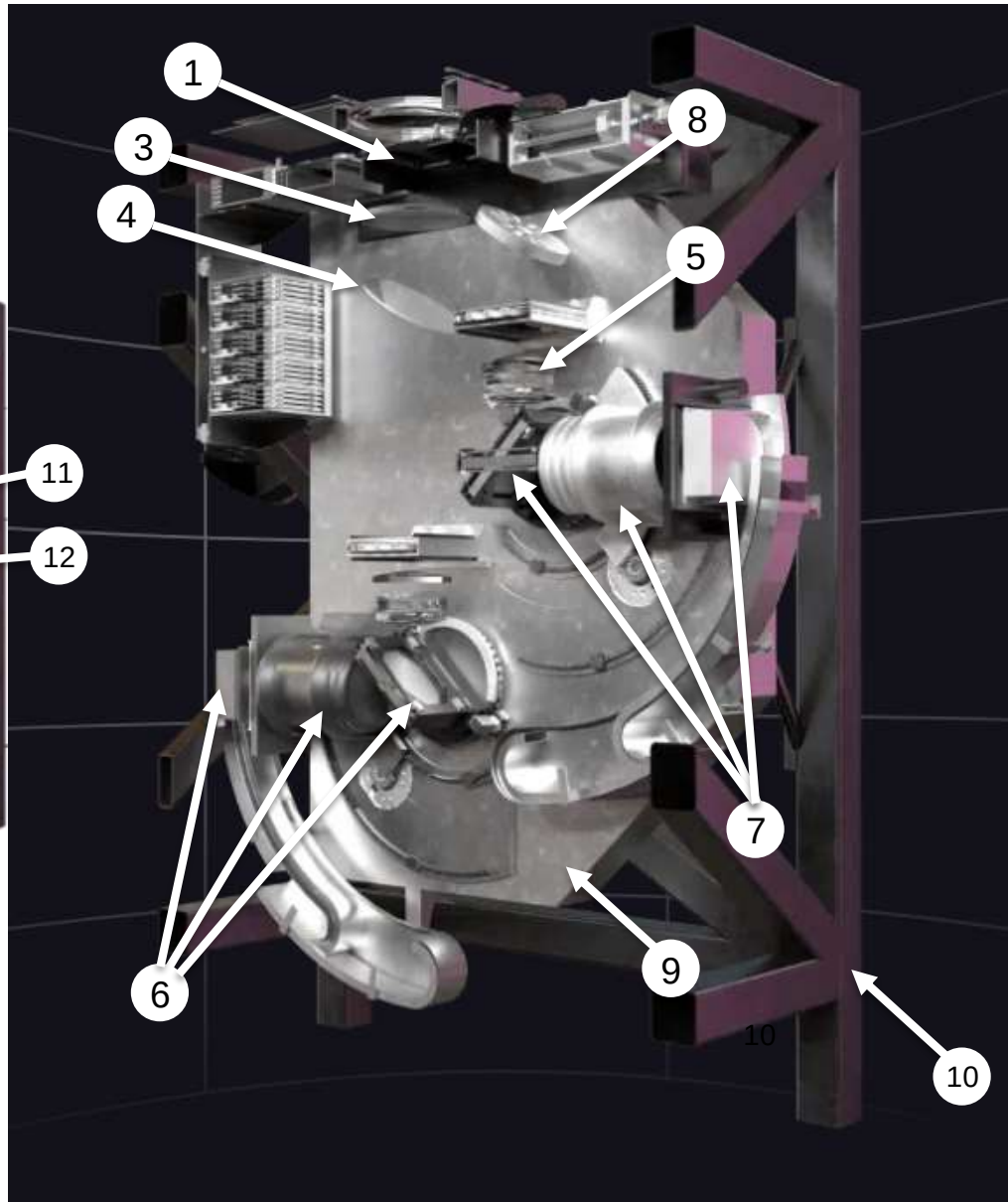
GMACS

Components

The main GMACS components are:

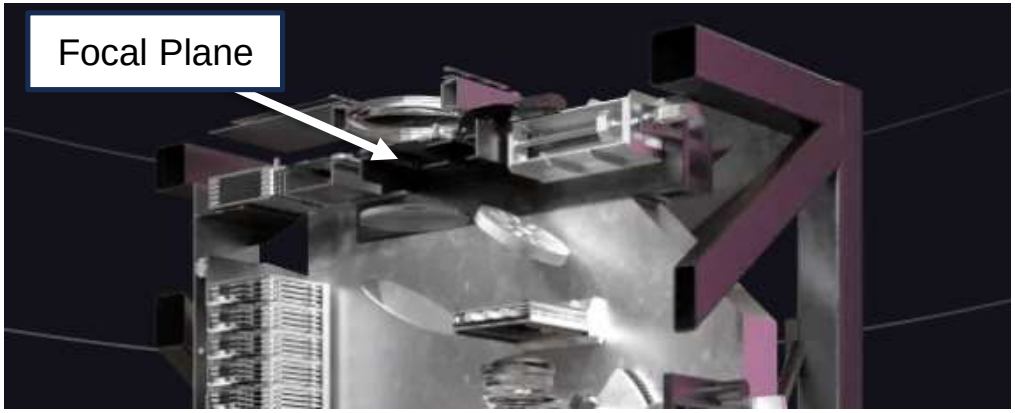
1. Focal plane
2. Slit Mask
3. Field Lens
4. Dichroic
5. Collimator
6. Red channel
   - Grating
   - CCD
   - Camera
7. Blue channel structure
   - Grating
   - CCD
   - Camera
8. Fold Mirror
9. Optical bench
10. Instrument Mount Frame – IMF
11. Red Grating/Filter Cassette
12. Blue Grating/Filter Cassette



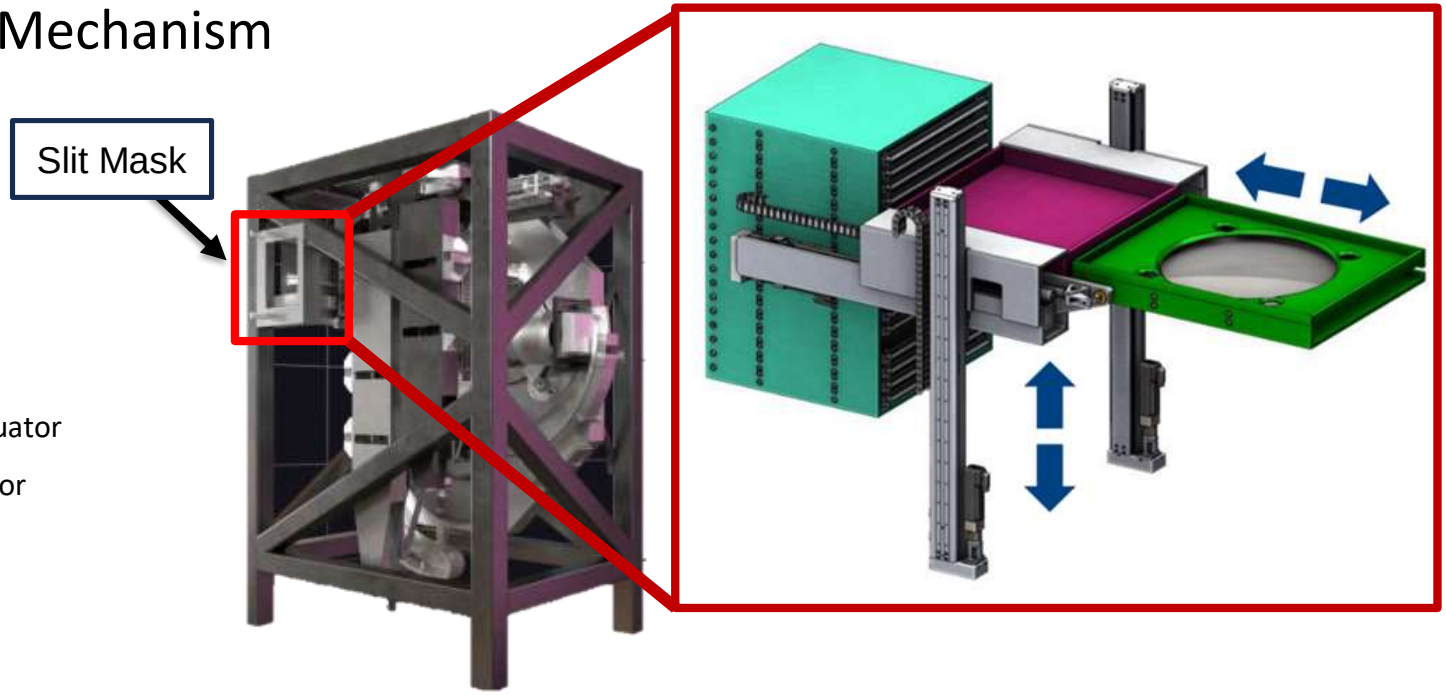


GMACS

Slit-Mask



- Operation of the Telescope
  - Make configuration adjustments
    - Different fields of views
    - 62° Maximum Zenith Angle
- Slit-Mask changing Mechanism
  - Jukebox-style
  - 23 Slit masks
    - Carbon fiber
  - Components
    - Elevator
    - Horizontal linear actuator
    - Vertical linear actuator
    - Clamping



STPA Applied to GMACS – Slit Mask

Losses and Hazards

Losses

L-1: Loss of observation

L-2: Equipment damaged

L-3: Observation delayed

L-4: Maintenance technician injured

Hazards

H-1: The slit mask cannot remove or store the mask [L-1, L-2, L-3]

H-2: The slit mask has not had preventive maintenance plan carried out [L-1, L-2, L-3, L-4]

H-3: The slit mask is inoperative [L-1, L-2, L-3]

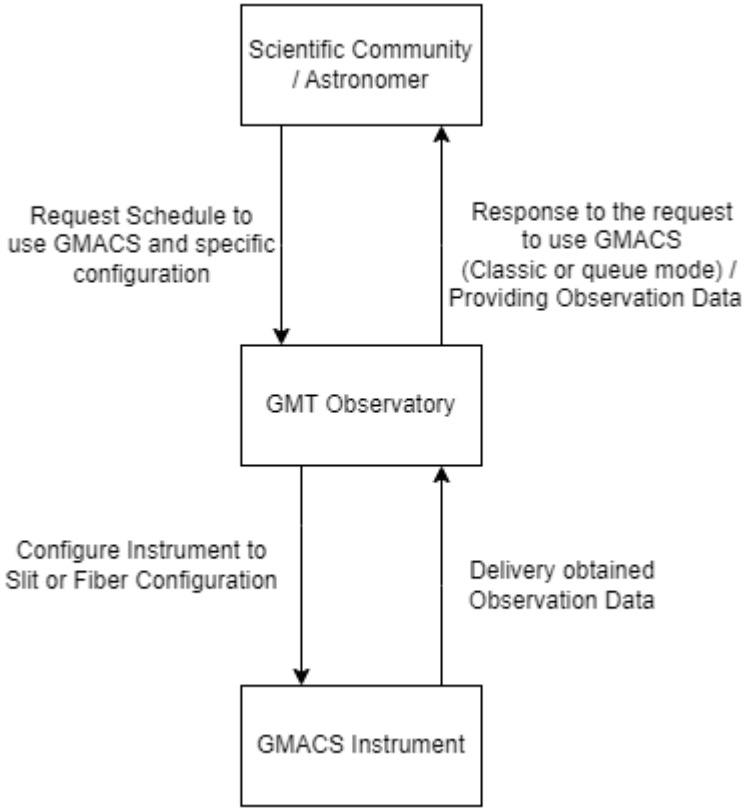
H-4: The slit mask violate the GMACS's stop command [L-2, L4]

STPA Applied to GMACS – Slit Mask

Control Structure

GMT High level Hierarchical Control Structure

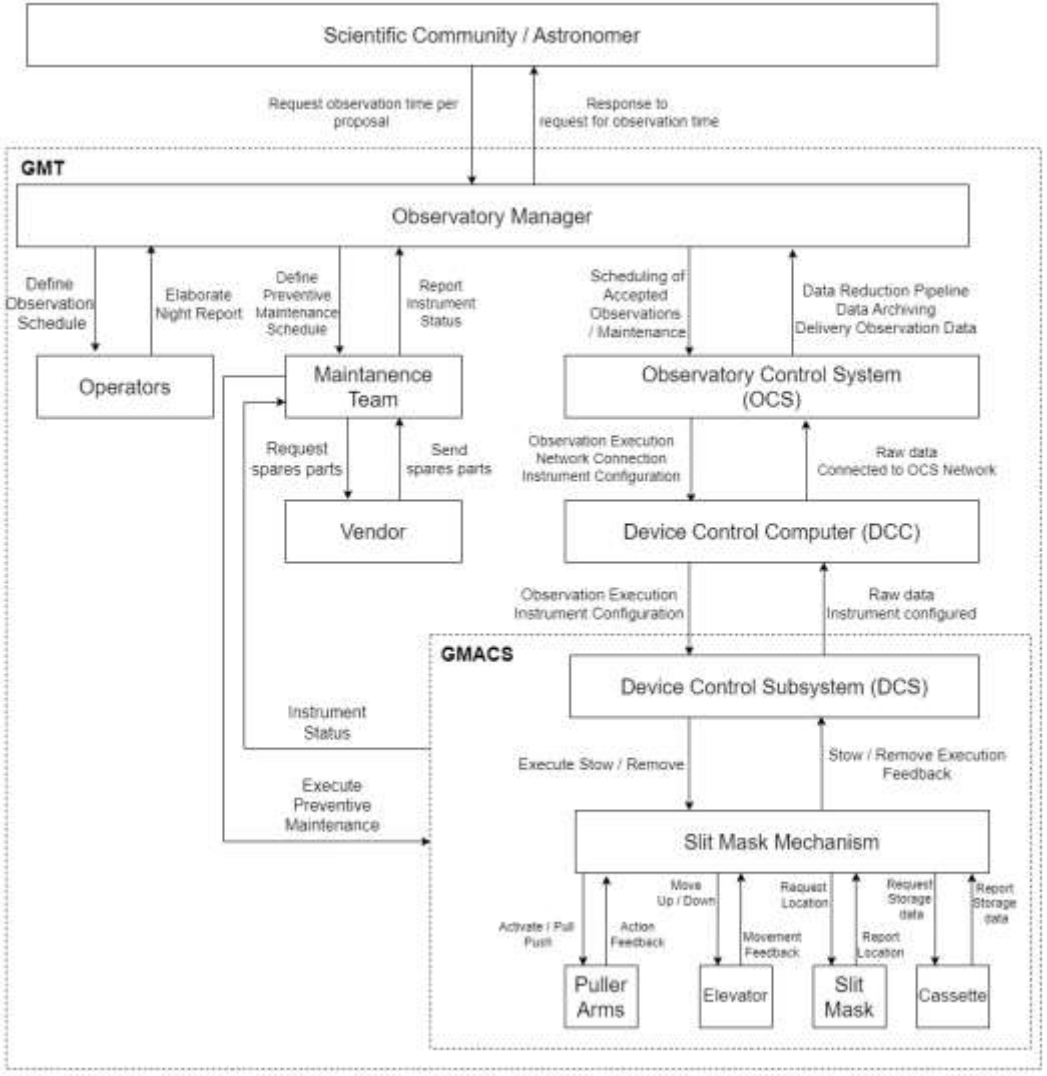
- After the instrument configuration and observation,
- The instrument will send the collected data to the telescope which will perform the data processing
- Finally, the data will be sent to the scientific community and interested astronomers.



STPA Applied to GMACS – Slit Mask

Control Structure

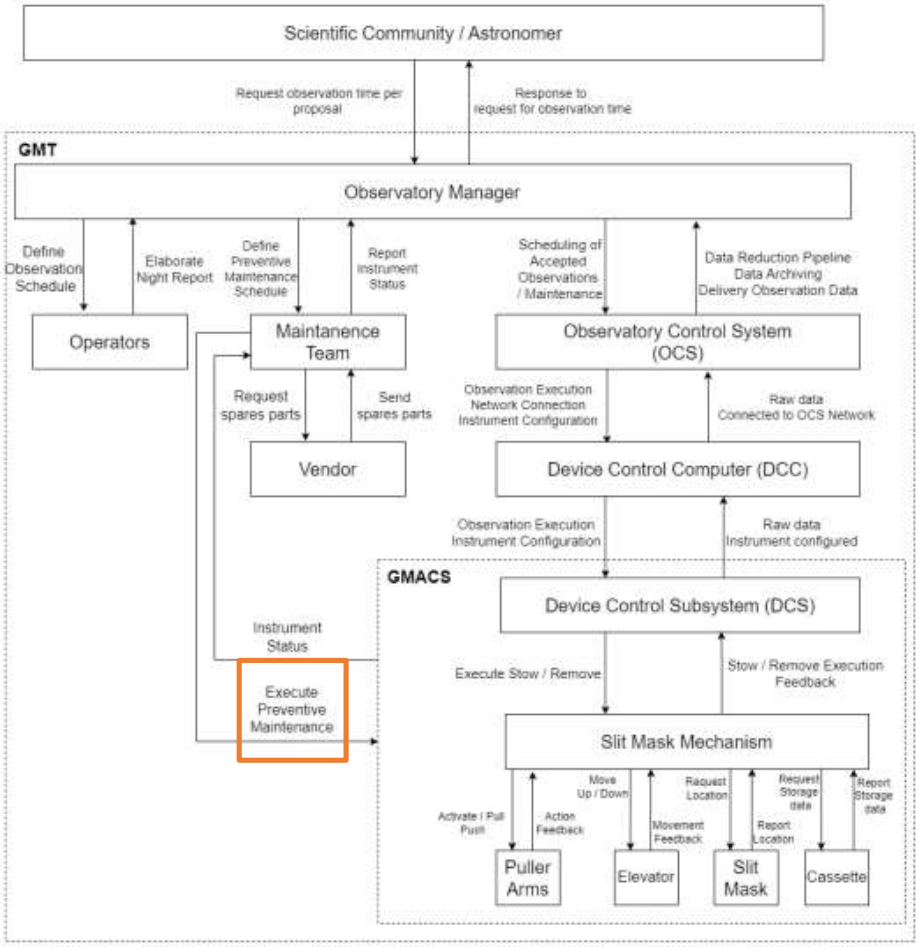
GMT High level Hierarchical Control Structure for Slit Mask Mechanism



STPA Applied to GMACS – Slit Mask

Unsafe Control Actions - UCAs

Identifying UCAs: (Control Action) Execute Preventive Maintenance



UCA-1: The observatory's maintenance team carried out the maintenance in the wrong order in relation to the maintenance plan provided. [H-1, H-4]

UCA-2: Preventive maintenance was interrupted [H-1, H-2, H-3]

UCA-3: The observatory's maintenance team has organized a schedule that is incompatible with the instrument's preventive maintenance plan. [H-1, H-2, H-3, H-4]

STPA Applied to GMACS – Slit Mask

Loss Scenario (UCA-1)

UCA-1: The observatory's maintenance team carried out the maintenance in the wrong order in relation to the maintenance plan provided. [H-1, H-4]

Scenario 1: Preventive maintenance cannot be performed, because there are no spare parts on-site. (H-2 and H-3 occurs)

Scenario 2: Spare parts are not manufactured/supplied by the vendor. (H-2 and H-3 occurs)

Scenario 3: After an earthquake occurs, the mask bearings are found to be warped in the linear guide of the cassette. (H-1 occurs)

Scenario 4: Communication problem between the observatory control system (OCS) and the Device Control Subsystem (DCS). (H-4 occur)

STPA Applied to GMACS – Slit Mask

Safety Constrains

SC-1: Preventive maintenance shall be performed keeping a defined set of spare parts on-site at Las Campanas.

SC-2: Defined spare parts shall be manufactured/supplied in the agreed preventive maintenance cycle.

SC-3: Assure a minimum space room for the technician to perform preventive maintenance on the mechanism (to enter the IMF).

SC-4: Special procedure during maintenance shall be establish when environmental effects (snowfall, earthquake) occurs.

SC-5: The preventive maintenance procedure shall follow the daily schedule to avoid delays, finishing during the day to allow the science activities during the night observation.

Conclusion

Benefits from STPA observed by the SE Brazilian group

(2022-2024):

- Apply STPA: less than 8 hours of training and results started to show.
- More expressive view: the high control structure produces a much clear view of the GAMCS's components and its interactions.
- Software flow of activities: clarification on all interactions of the SW components and the path to execute the instrument configuration/operation (day and night operation).
- Avoids information gaps: helping interaction and communication between teams (software, mechanics, and optics) and, consequently, reducing the complexity of the system.
- Traceability: all elements of the technique (loss, hazard, safety constraints, scenarios) are easy to track during the project life cycle, from the top-down or bottom-up.

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