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on behalf of the Institute of Space Sciences (IEEC – CSIC) team

Artificial Intelligence for the CTA Observatory Scheduler

ICE
Institute of Space Sciences
(IEEC-CSIC)

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Acknowledgments

Álvaro García
"AI for the ECHO Mission Scheduler"

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Outline

- CTA Observatory
- Operational model
- Use case model
- Scheduling algorithm design
- Analysis and performance
- Summary

CTA Observatory

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CTA Observatory

- New generation ground-based very high energy gamma-ray instrument
- Community
  - 1000 scientists
  - 186 institutes
  - 28 countries
- Schedule
  - 2010-2014 Preparatory phase
    - Prototyping
  - 2014-2018 Construction phase
  - > 2018 Operation phase

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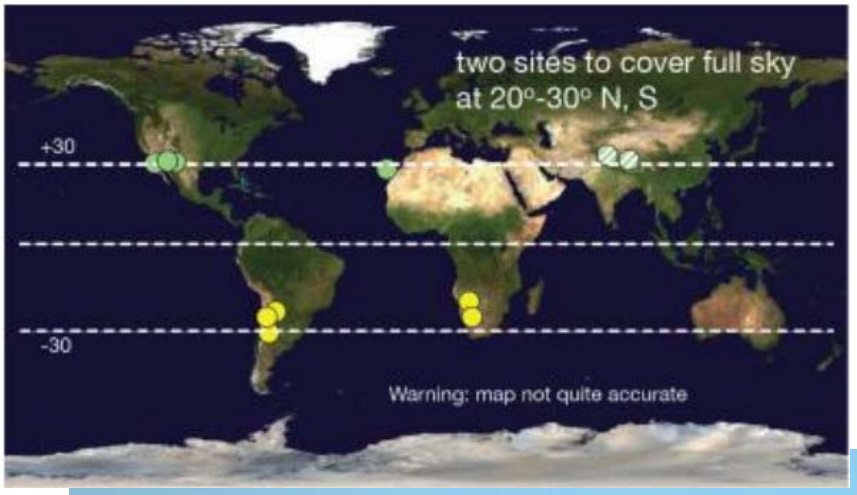
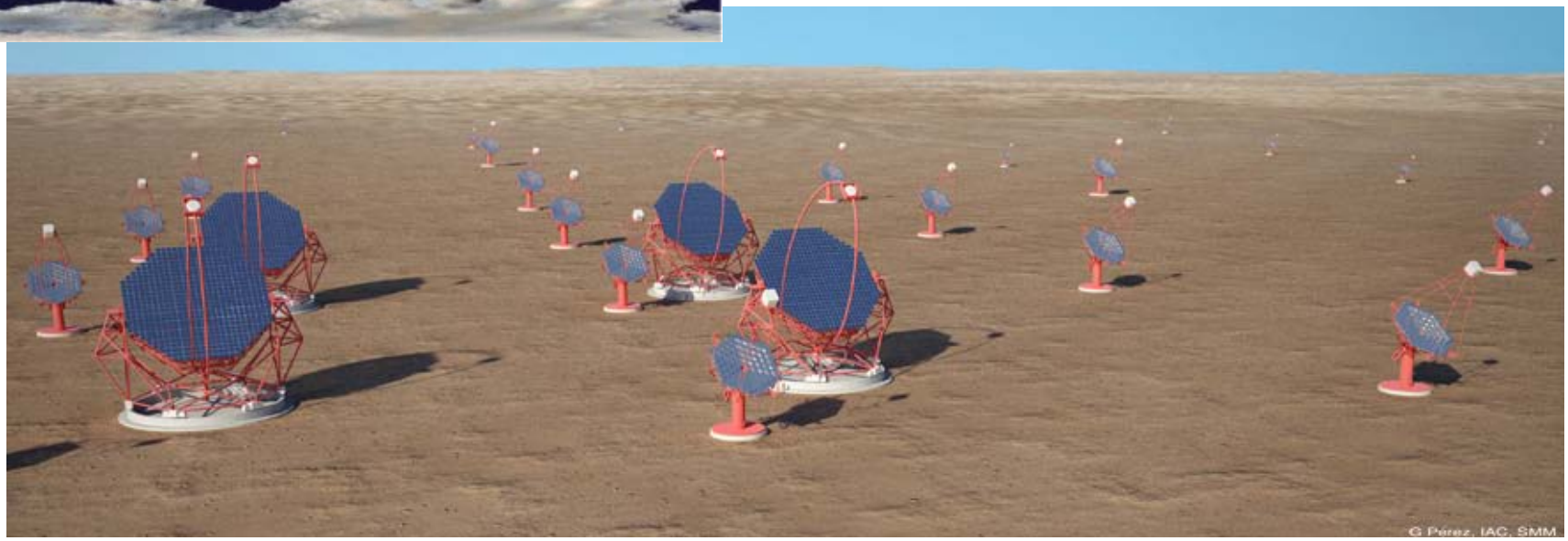
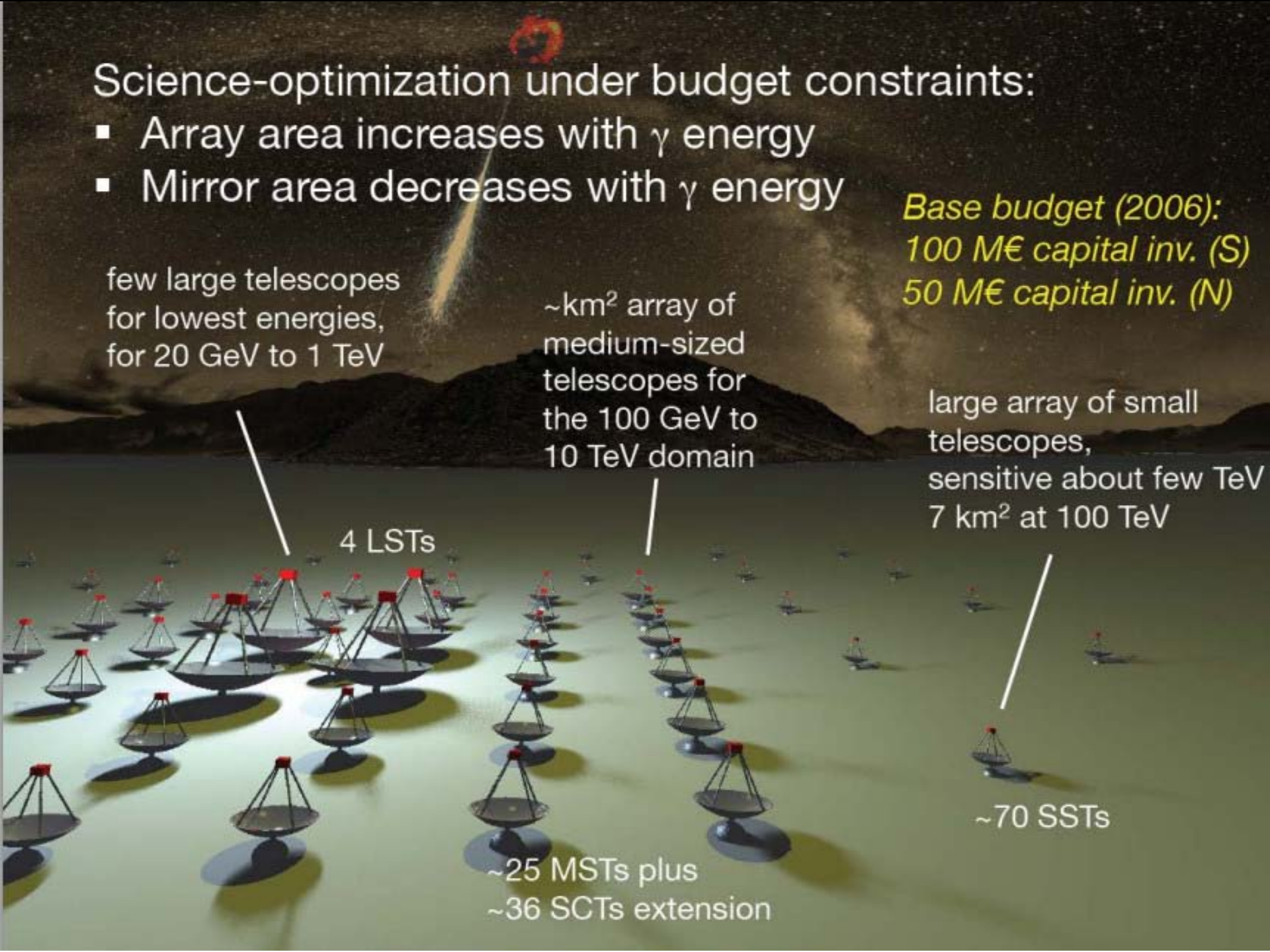
CTA Observatory



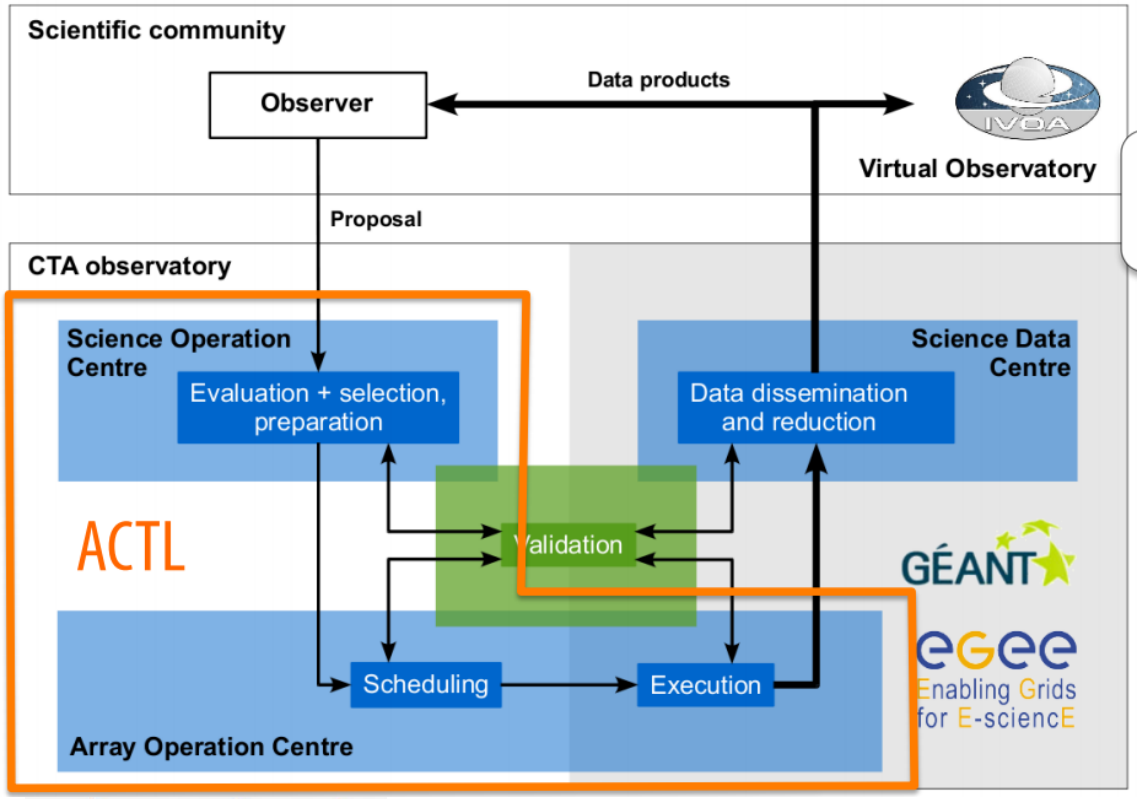
- Two sites (North/South)
  - Under selection
- 20-70 Telescopes

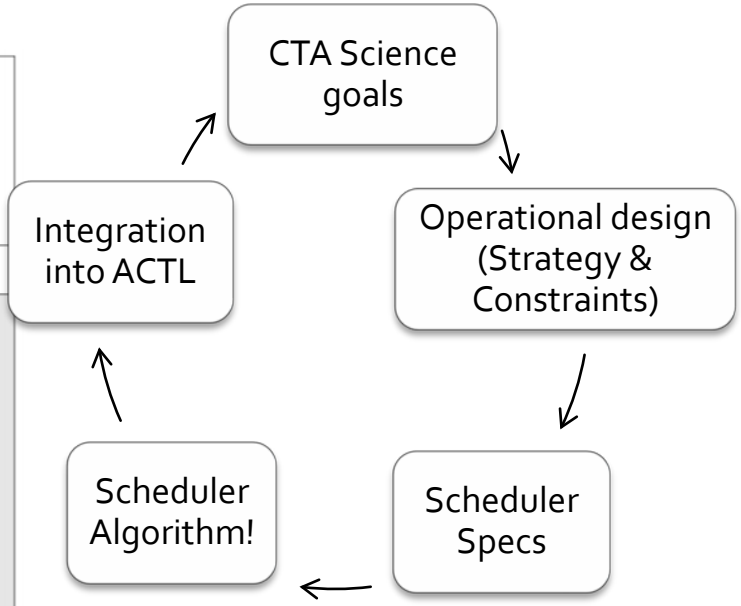



Science-optimization under budget constraints:
Array area increases with γ energy
Mirror area decreases with γ energy
Base budget (2006):
100 M€ capital inv. (S)
50 M€ capital inv. (N)
few large telescopes
for lowest energies,
for 20 GeV to 1 TeV
~km² array of
medium-sized
telescopes for
the 100 GeV to
10 TeV domain
large array of small
telescopes,
sensitive about few TeV
7 km² at 100 TeV
4 LSTs
~70 SSTs
~25 MSTs plus
~36 SCTs extension

Operational model

- **Operational approach → Open Observatory**





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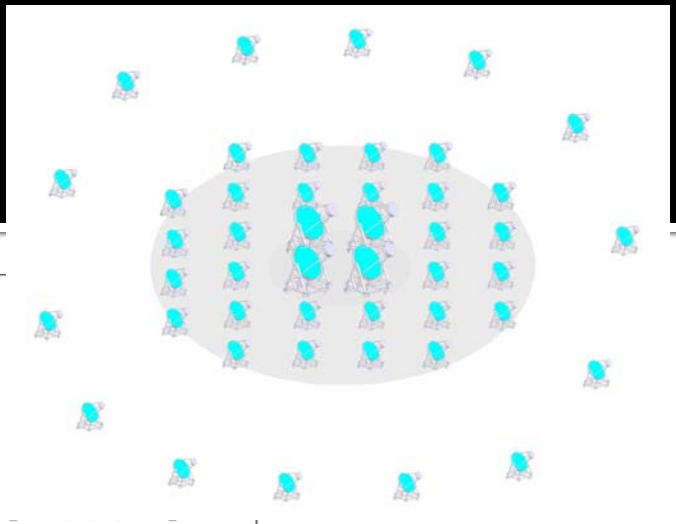
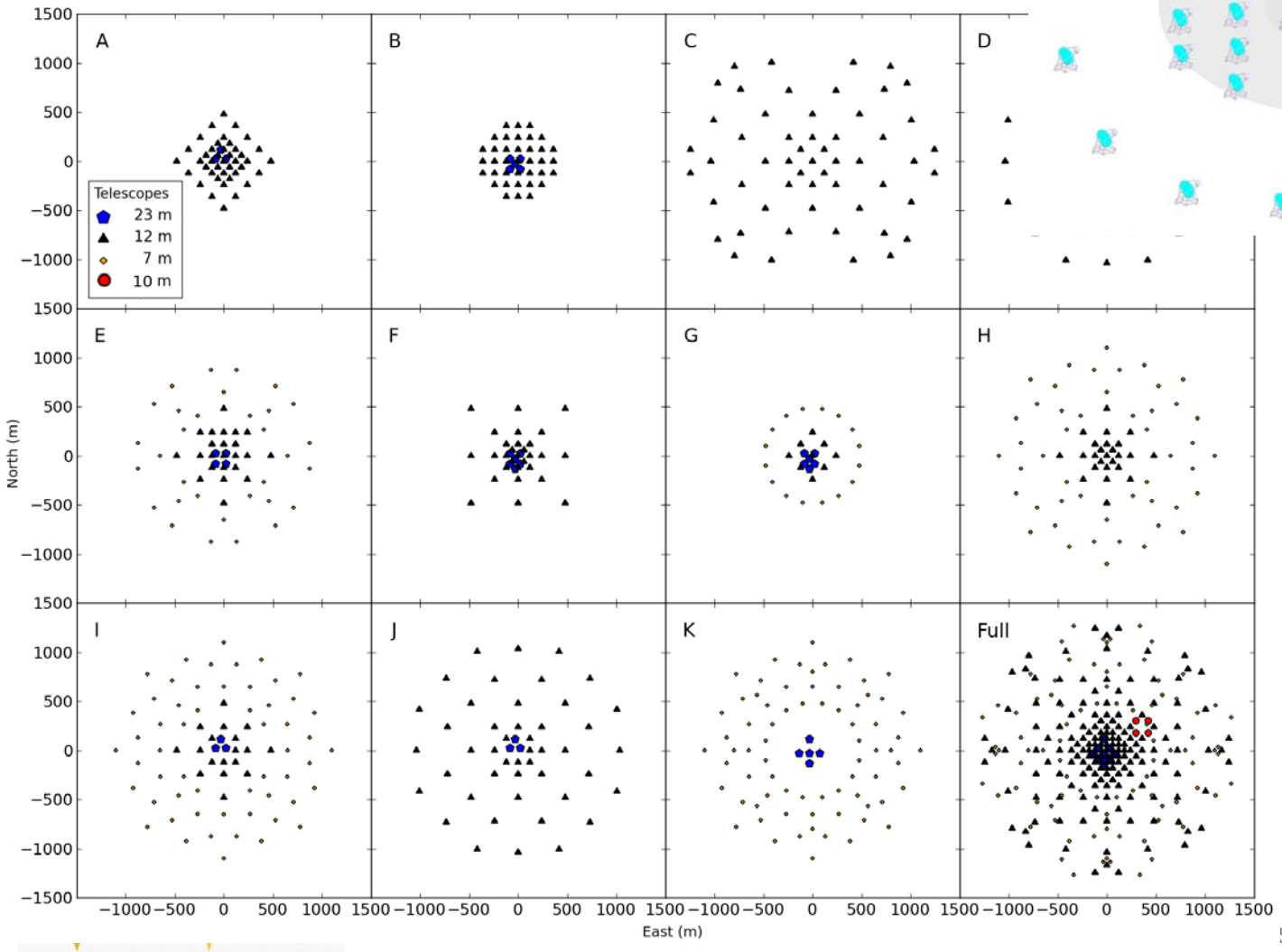
Operational model

- Scheduling cycles
  - Long-term → Static
  - Short-term → Dynamic-fast response (< 10 sec), ToO (< 1 sec)
- Observation strategy
  - Observation modes
  - Sub-array definition & telescope operation model
  - Task (& SBs) definition and execution constraints → Science & Calibrations
  - Time scheduling modes (monitoring, ToO,…)
- Planning modes and control
  - Interactive, automatic, simulation
- Inputs & Outputs
  - Pending tasks, housekeeping
  - Short- and long-term planning

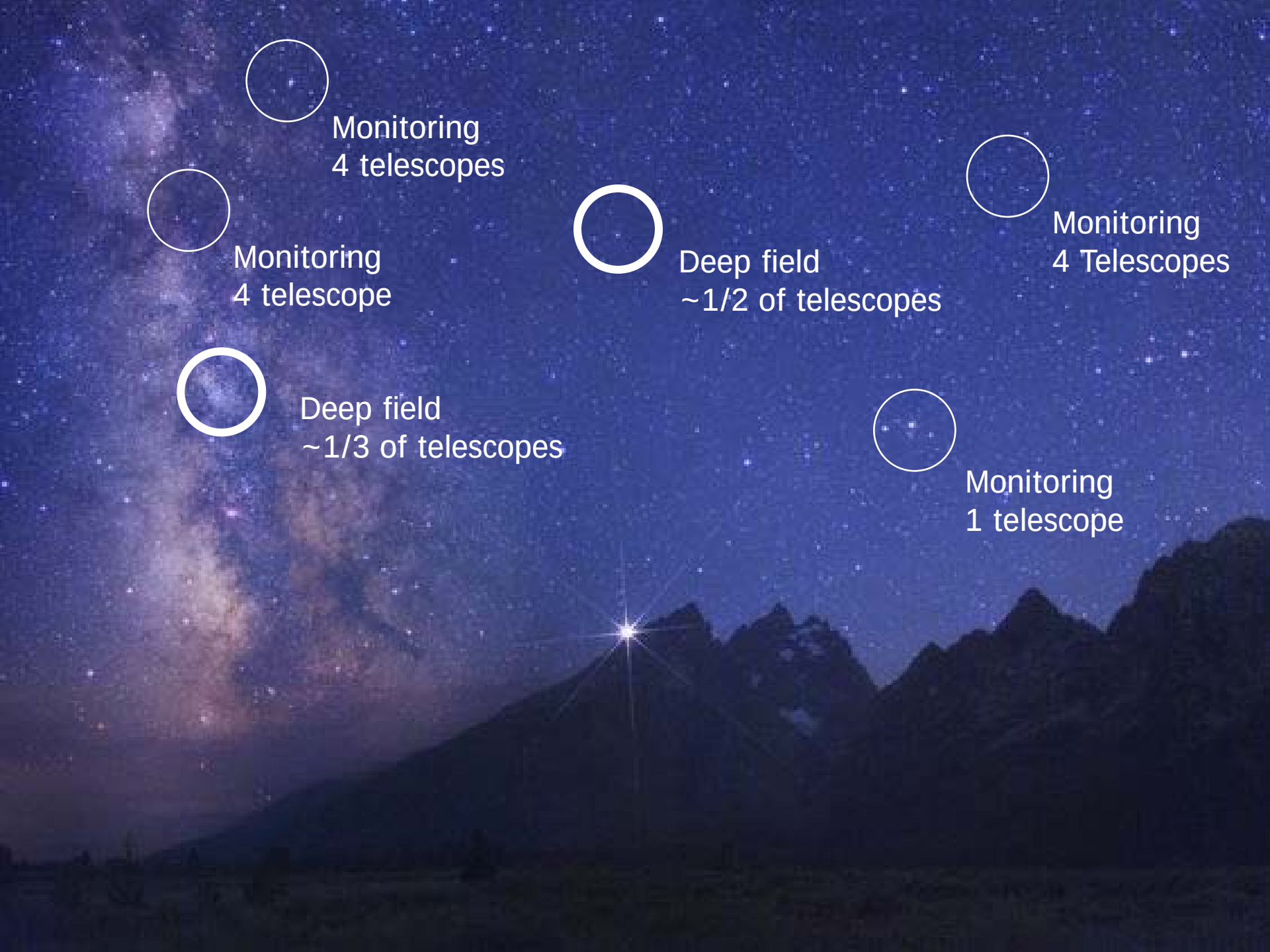
Operational model





CTA observation modes

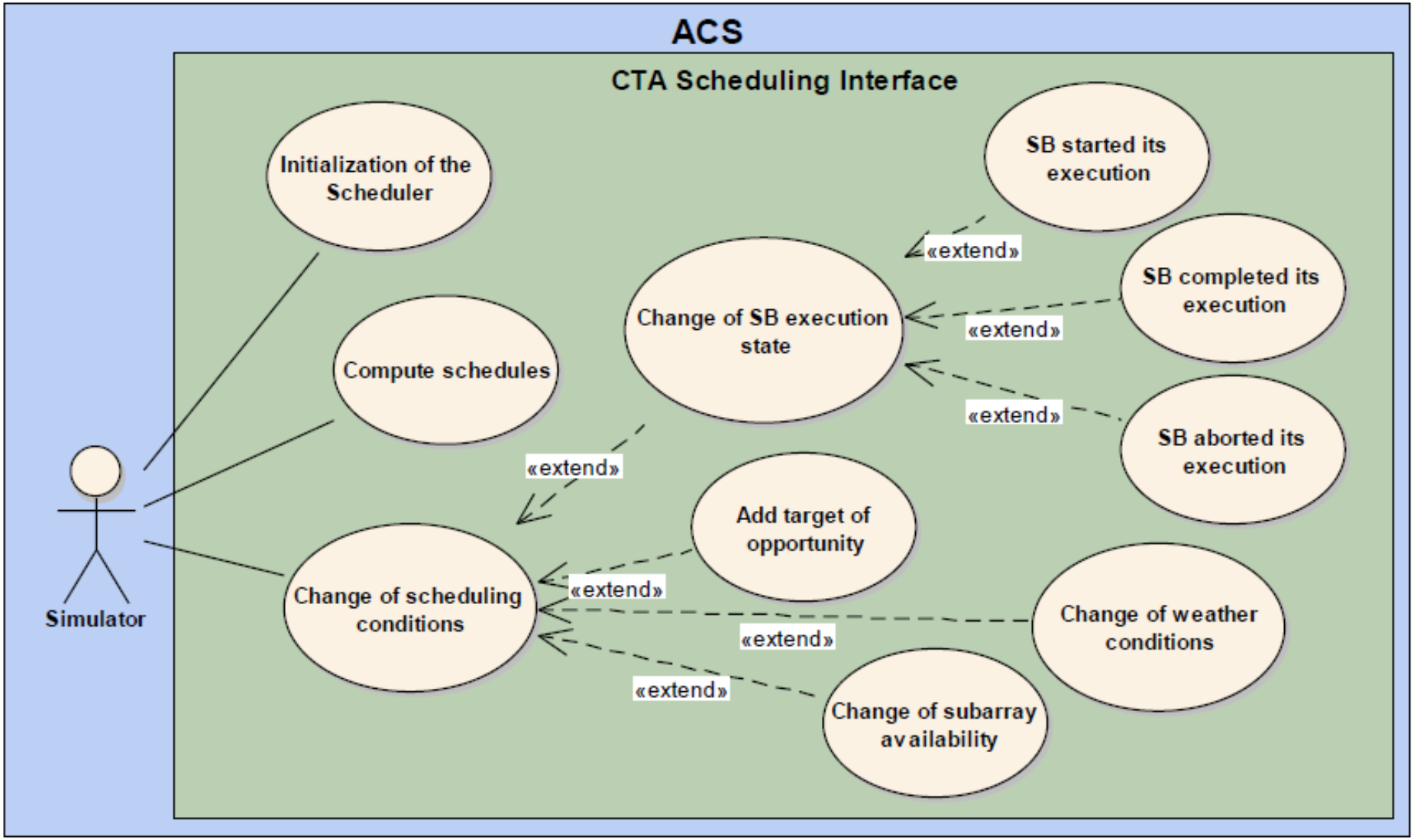
- Very deep field


Monitoring
4 telescopes
Monitoring
4 telescope
Deep field
~1/2 of telescopes
Monitoring
4 Telescopes
Deep field
~1/3 of telescopes
Monitoring
1 telescope

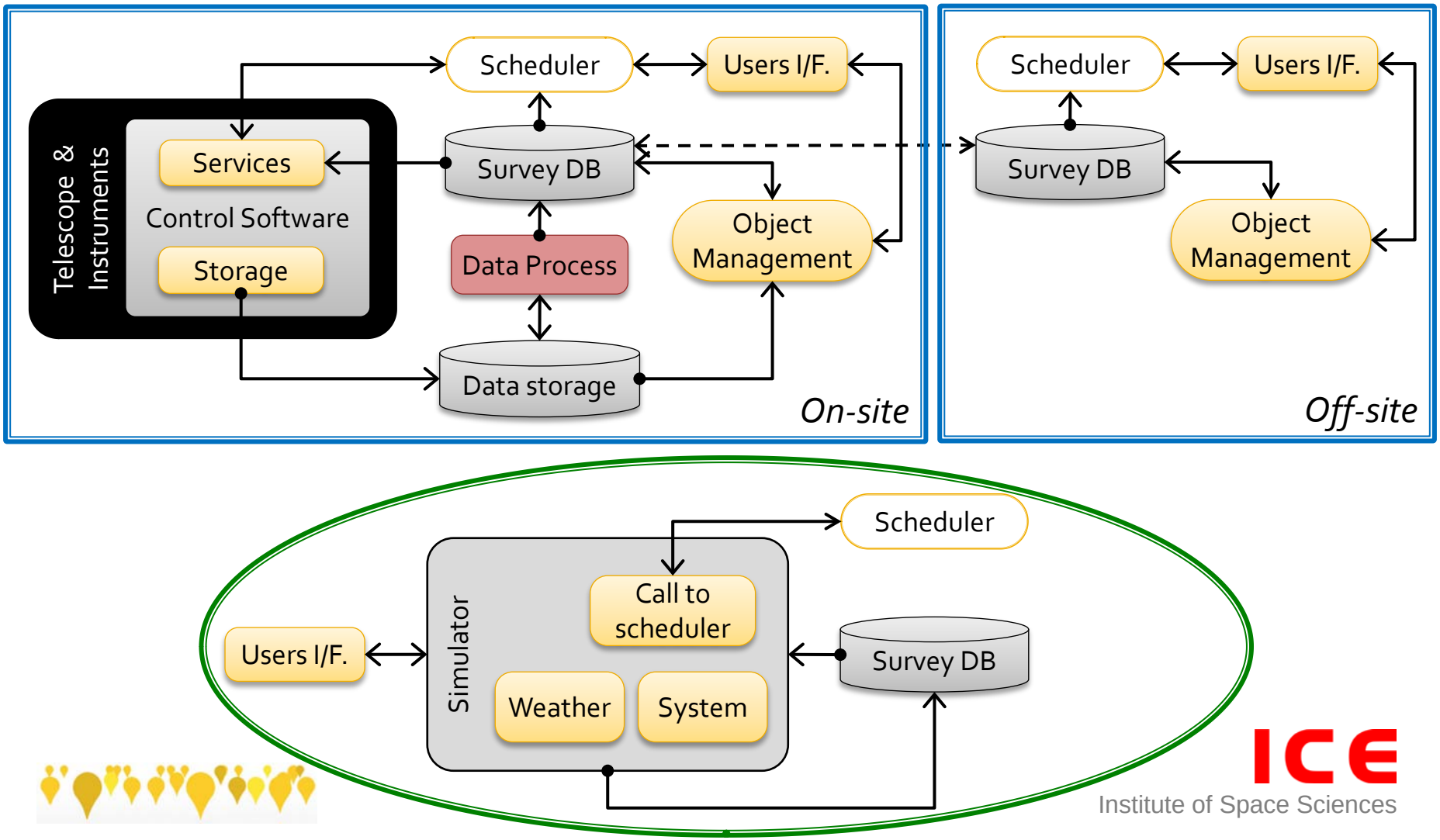
CTA observation modes

Survey mode:
>25% sky at better than current sensitivity in ~1 year

Use Case model



Scheduling algorithm design



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Scheduling algorithm design

- Objectives
- Priorities or *soft constraints*
- Merit functions or *hard constraints*

➔ **Selection of algorithm**

Objectives	
Minimize	Operation downtime
	Time overheads
Maximize	Allotted time to scientific tasks
	Scientific priority
	Task completion

Constant priorities	Short-term	Long-term
Scientific priority		
Executive priority		
Scheduling block priority		

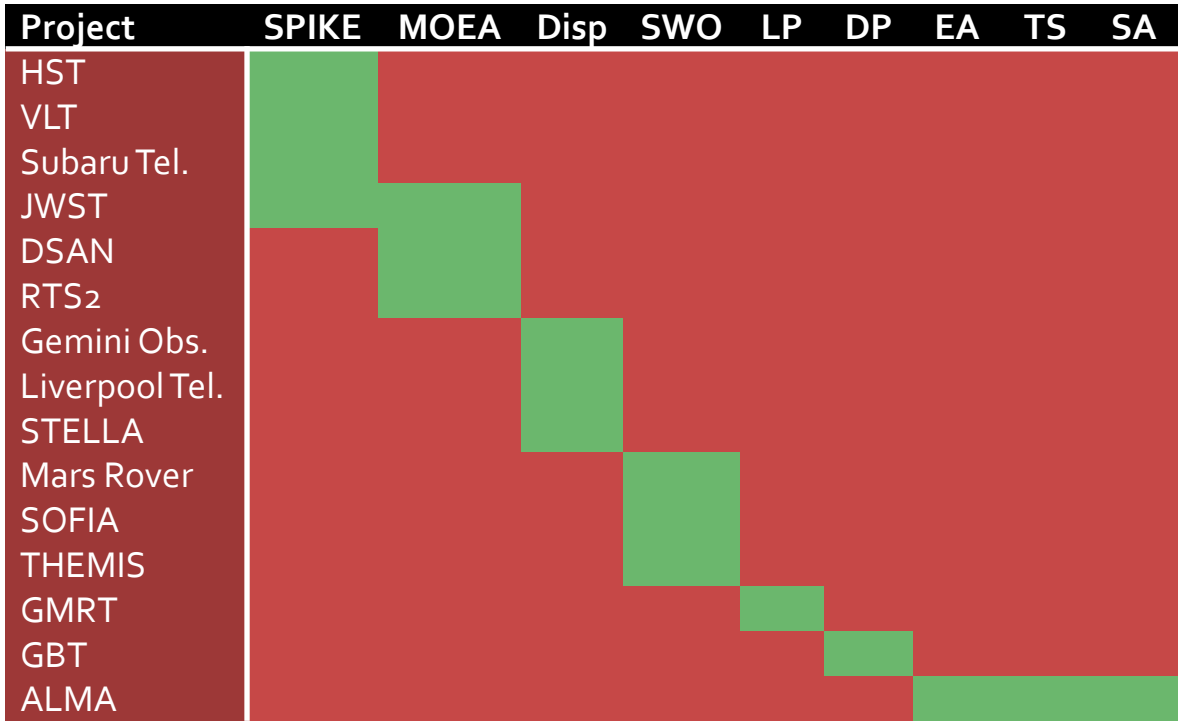
Temporal priorities	Short-term	Long-term
% of project completion		
Stringency factor		

Scheduling algorithm design

Merits	Short-term	Long-term
Min expected data quality	?	?
Operation mode & arrays configuration		
Min sky darkness		
Tasks dependences	?	?
Target visibility & max ZA		
Avoidance areas		
Time constraints & monitoring		
Environment conditions		
System conditions & current configuration		
Calibration required	?	?

Scheduling algorithm design

- Selection
  - Algorithms used in astronomical observatories
  - Job-shop
  - **Flexible job-shop**



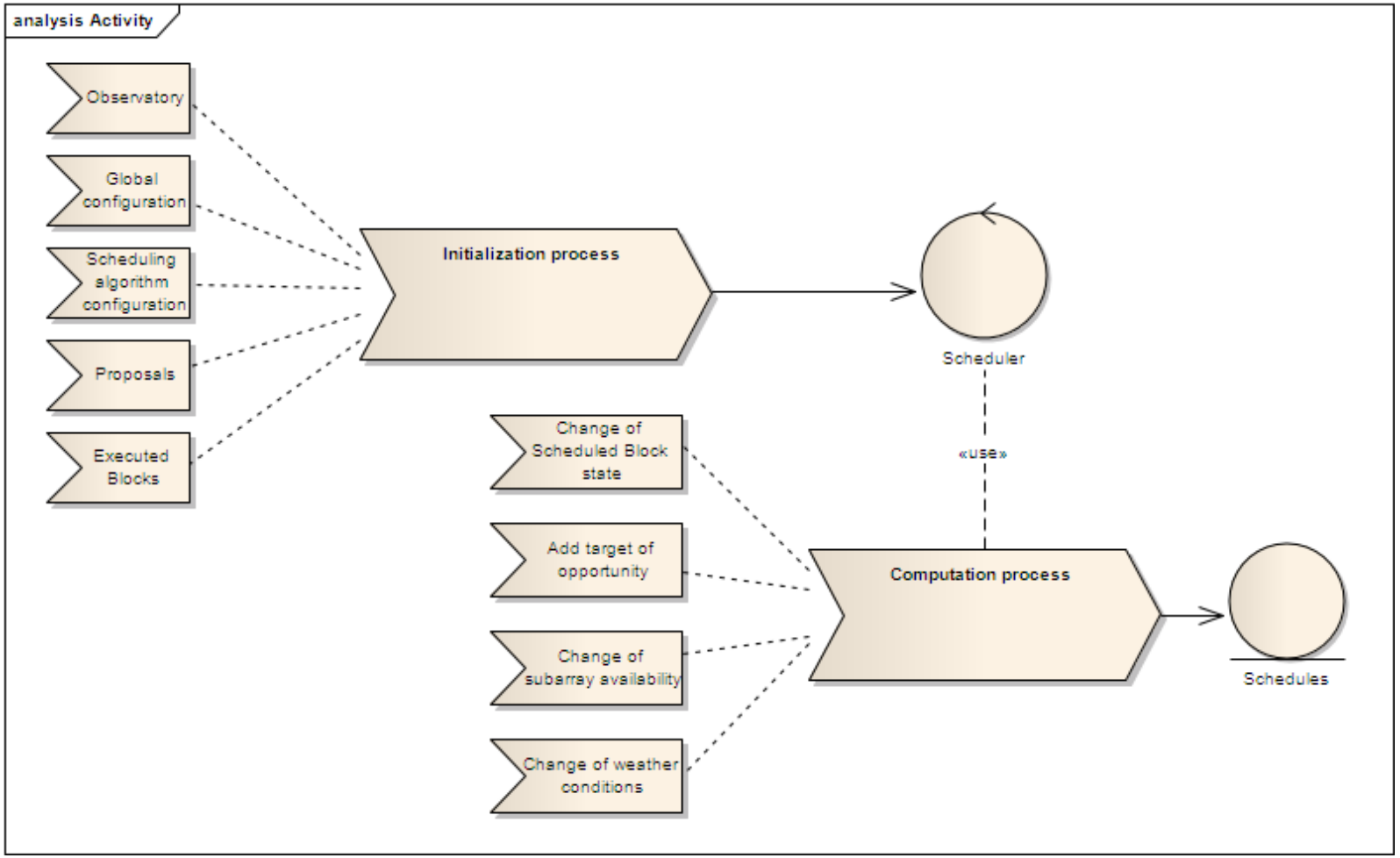
MOEA (Multi-Objective Evolutionary Algorithm),Disp (Dispatcher), SWO (Squeaky Wheel Optimization), LP (Linear Programming), DP (Dynamic Programming), EA (Evolutionary Algorithm), TS (Tabu Search), SA (Simulated Annealing).

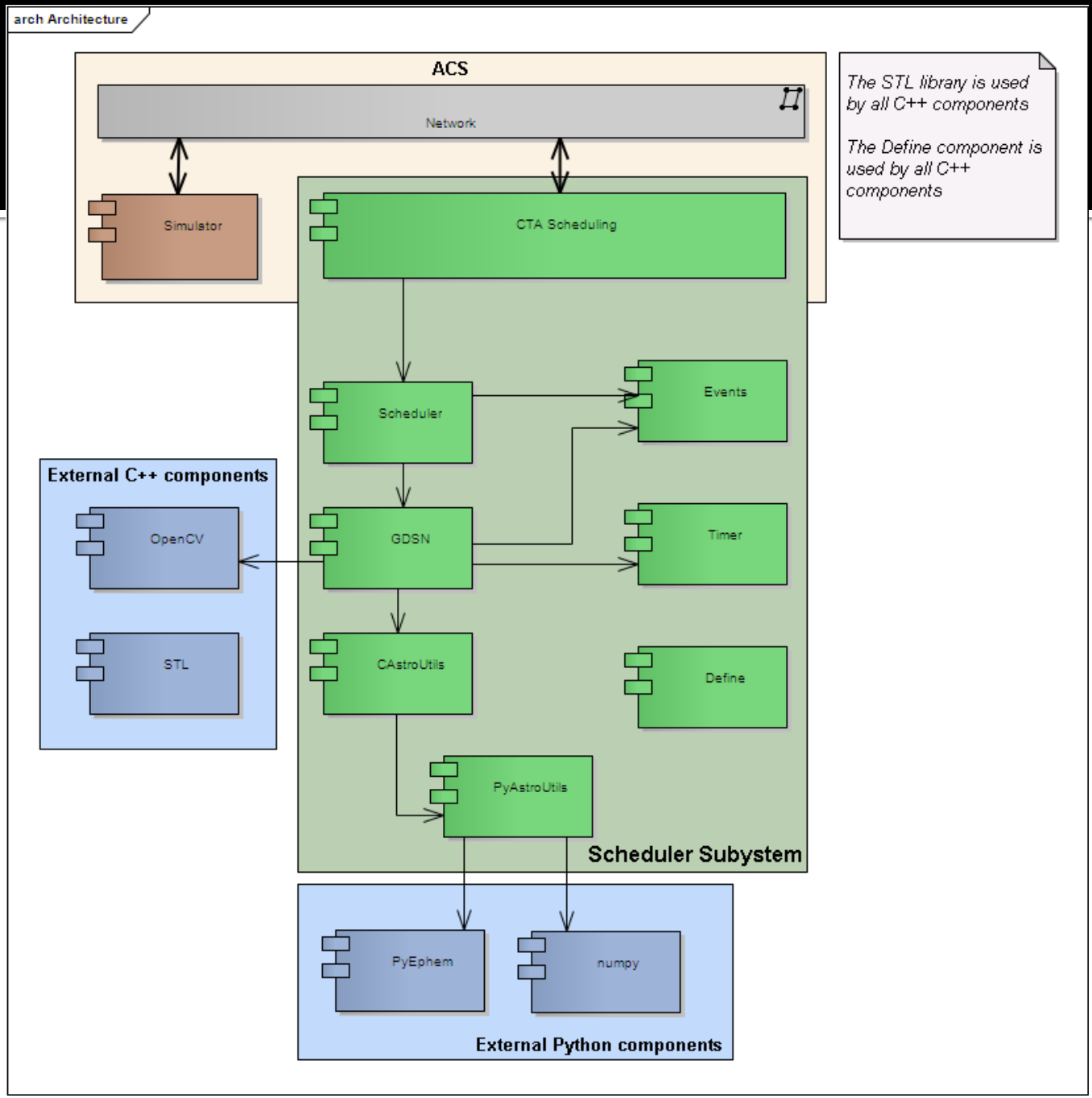
➔ **"Research on schedulers for astronomical observatories", Colomé et al., SPIE, Amsterdam 2012**

Scheduling algorithm design

- Prototype implementation ➔ SPIKE-based algorithm (GDS neural network & CSP) + ACO
  - Scheduling conditions can be changed during execution without the need to start from scratch
  - It may optimize an entire night, week, month, etc., for all kind of time and resource constraints and remove conflicts
  - Optimize more than one objective with no lost of information
- Scheduling process
  1. Initialization phase ➔ Objectives to optimize and specification of constraints and priorities
  2. Long-term planning for a full period ➔ Recomputed every morning
  3. Long-term planning ➔ Input for the short-term
  4. Most optimized schedule is returned ➔ Tasks (SBs) + Execution time
  5. Short-term planning ➔ Schedule updated based on system events

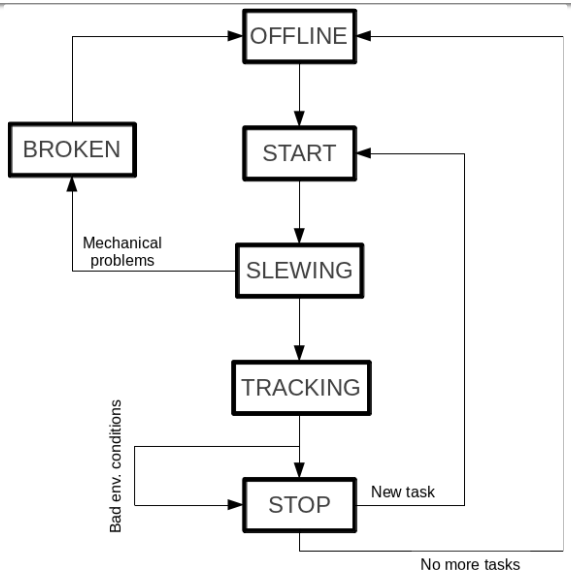
Scheduling algorithm design




arch Architecture
ACS
Network
Simulator
CTA Scheduling
Scheduler
Events
GDSN
Timer
CAstroUtils
Define
PyAstroUtils
Scheduler Subystem
External C++ components
OpenCV
STL
PyEphem
numpy
External Python components
The STL library is used by all C++ components
The Define component is used by all C++ components

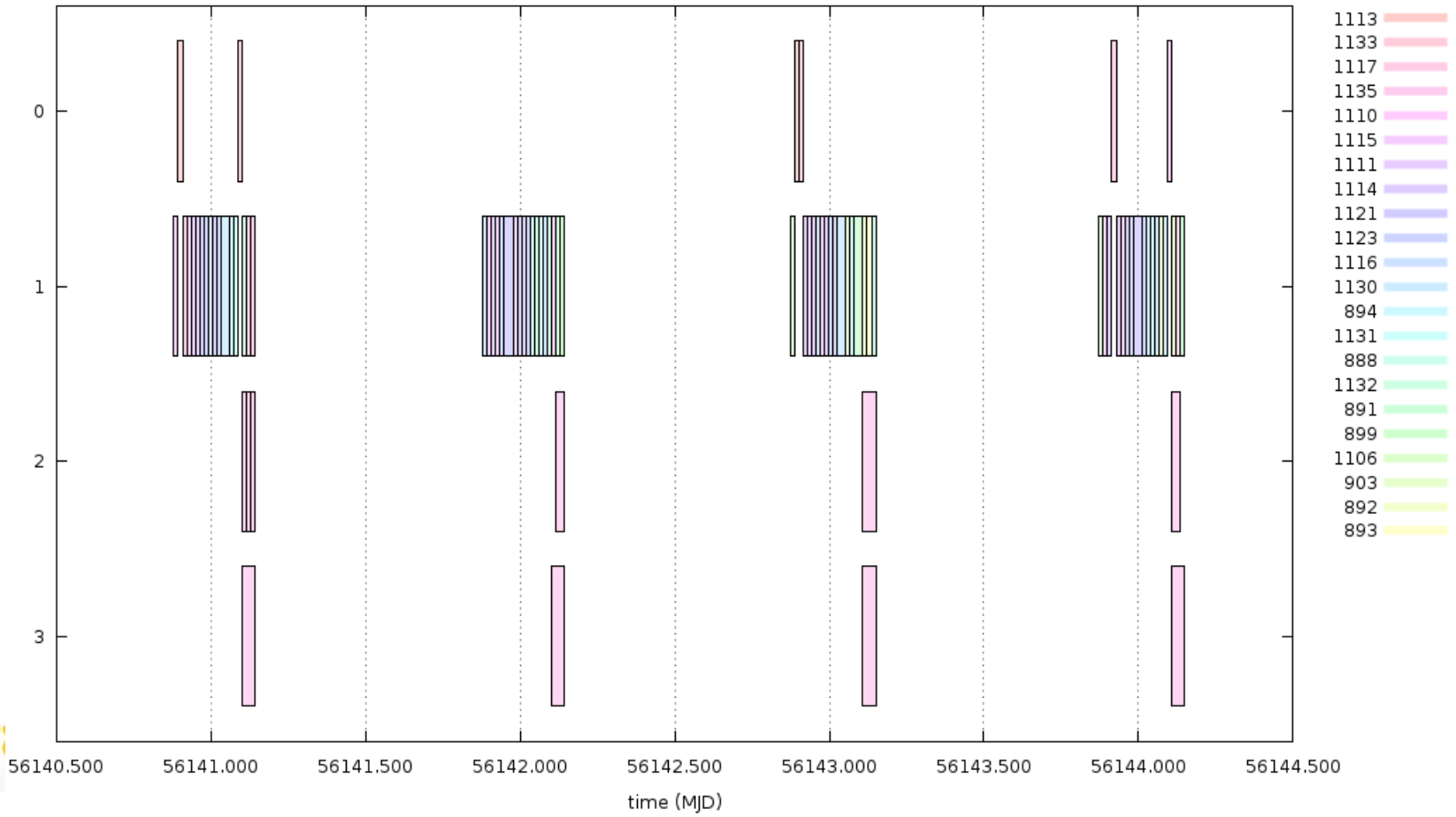
Analysis & performance

- Simulator design
  - Input
    - Scientific projects & executed SBs
    - Schedule ← Scheduler
    - Configuration (system & algorithm)
  - Simulated processes
    - Long- and short-term simulation
    - Change on system configuration → array subsets, telescope states
    - System health → error occurrence likelihood
    - Weather conditions → real data
  - Output for analysis
    - Proposals execution report → proposals completion for scientific return
    - Telescope/subarray operation report → science scheduled time for operation efficiency

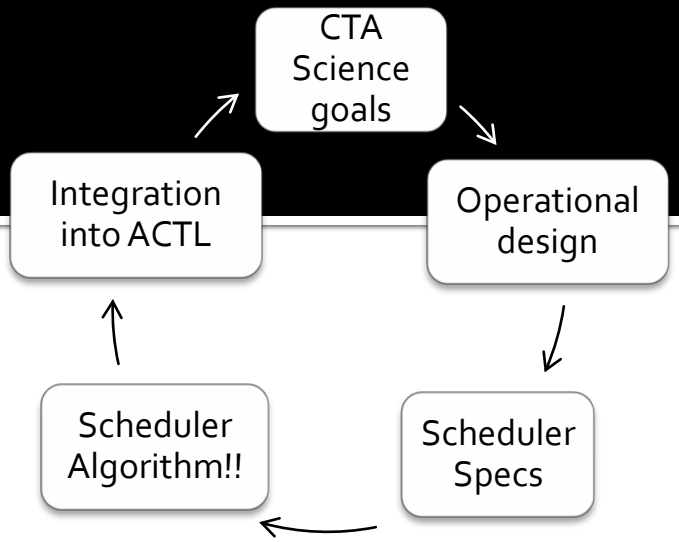


Analysis & performance

- Long-term (4 days) planning



Summary



- CTA Observatory ➔ Open observatory
  - Operational design under definition
- Scheduler for CTA
  - Multi-objective optimization
  - Long- & Short-term planning
  - Observation constraints (max. ZA, sky brightness, time constr., ToO)
  - Input (tasks + system housekeeping)
  - Output (long-, short-term planning)
  - Algorithm ➔ Flexible Job-Shop ➔ GDSN + CSP + ACO
- Analysis and tests to evaluate requirements coverage and performance
- **Next steps**:
  - Specifications update and development of the Operative Version
  - Improve system model & science programs ➔ Improve simulations & analysis
  - Test other algorithms (i.e., MOEA)

Artificial Intelligence for the CTA Observatory Scheduler

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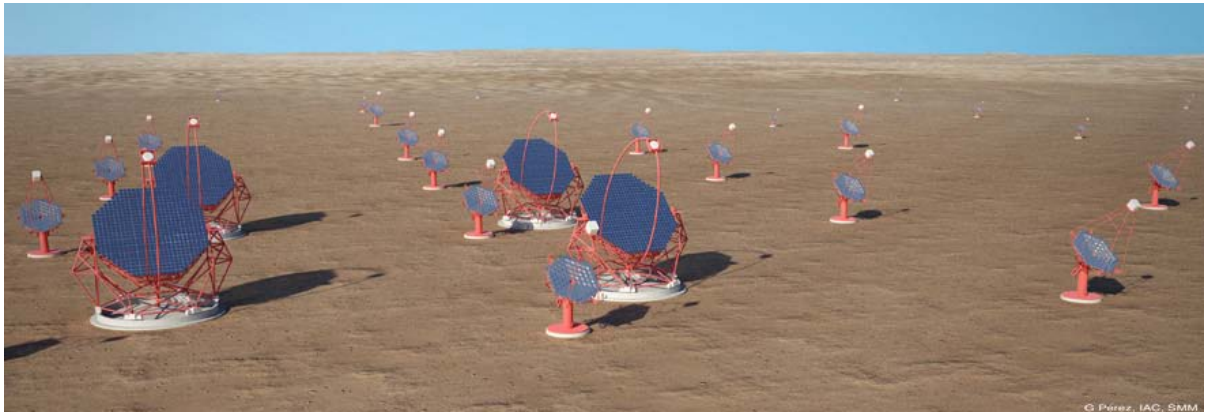

cta
cherenkov telescope array

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