ICE CTA Scheduler

22 June 2016

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Problem Conditions

- Observatory
  - Several subarrays
    - Each subarray contains a number of telescopes (TLCs) of same or different types
    - TLCs can be shared between subarrays (those subarrays will then exclude each other in simultaneous observation, i.e, Subarray1: All TLCs vs Subarray2: LSTs + MSTs)
    - All telescopes are in the same location (lat, long, alt) – No extension of the observatory(ies) considered so far
- Parameters of each target
  - Coordinates
  - Observation time to be achieved
  - Maximum Zenith Angle
  - Subarray assigned
- Slew time between observations of different targets
  - Overhead time of 2 minutes + 1 second per degree
- Observation blocks
  - 1200 seconds (can be configured for each target)
- Long-term Scheduler and Short-term Scheduler (real-time response to bad weather conditions / ToO / etc)

Observation Constraints

- Hard Constraints
  - Visibility constraints
    - Dark hours (global)
    - Maximum Zenith Angle (target)
  - Resource constraints
    - Subarrays that share telescopes cannot observe at the same time
- Soft Constraints
  - Maximize observation time of each night
  - Minimize slew time of each night (time blocks will increase due to consecutive observations)

Optimization Strategies

- Genetic Algorithm (GA)
  - Single objective
    - Maximize the observation time
- Multiobjective Evolutionary Algorithm (MOEA)
  - Two objectives
    - Maximize the observation time
    - Minimize slew time

Comparison between Strategies

- Scenario
  - CTA South: 464 targets (3692.11 hours)
  - 1 year planning based on the KSP programs
  - 4 subarrays and 4 type of telescopes
    - 0: LST + MST + SST
    - 1: LST + MST
    - 2: MST + SST
    - 3: LST
  - Target subarray assigned according its type (not necessarily in agreement with information provided on the KSP):
    - Galactic Survey: L + M + S
    - Extragalactic Survey: L + M
    - Galactic Center Mini Survey: M + S
    - Pevatrons: M + S
    - Others: L
  - Subarray priority randomly assigned each night

Comparison between Strategies

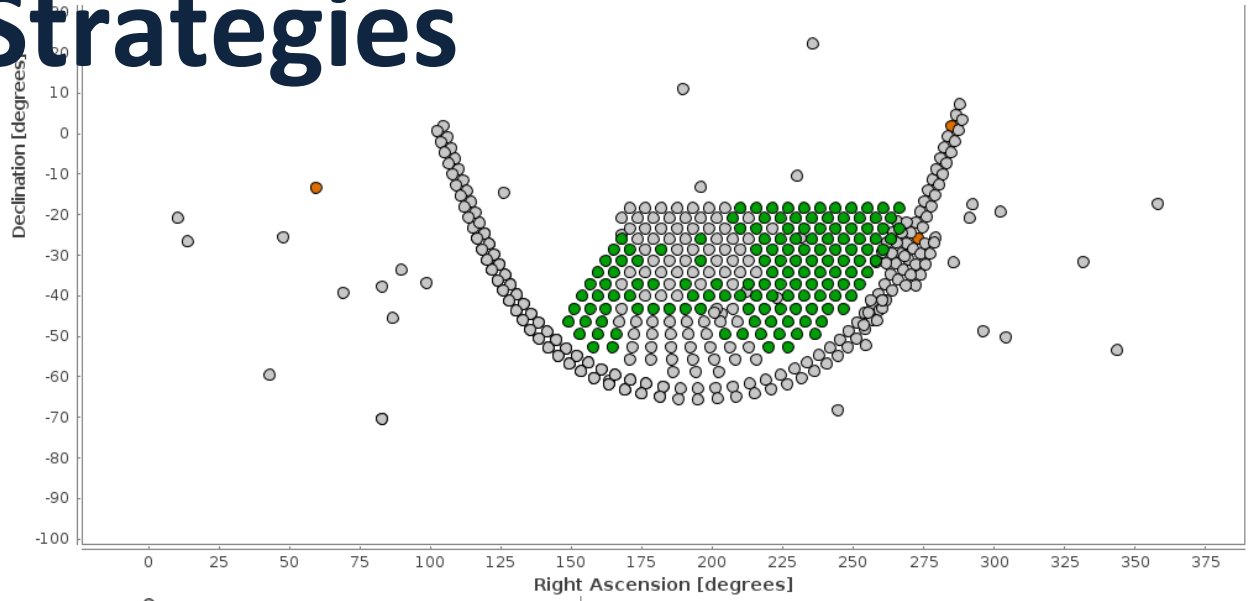
- Results (average of all subarrays)
  - Observation time metric
    - GA: 3609 observations (1168 hours)
    - MOEA: 4271 observations (1359.68 hours)
  - Slew time metric
    - GA: 8.32% of the working time* (104.7 hours)
    - MOEA: 2.62% of the working time* (34.26 hours)

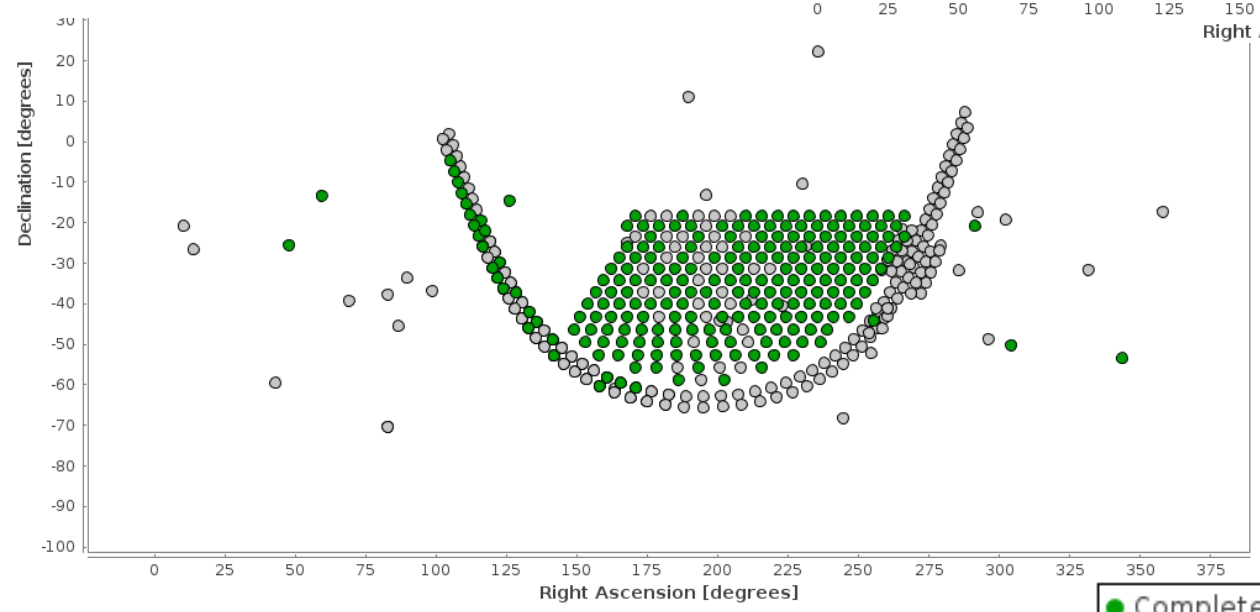
* Working time: slew time + observation time

- Execution time
  - Around 5 hours to simulate the 1 year scenario

Comparison between Strategies

- Target Status
  - GA





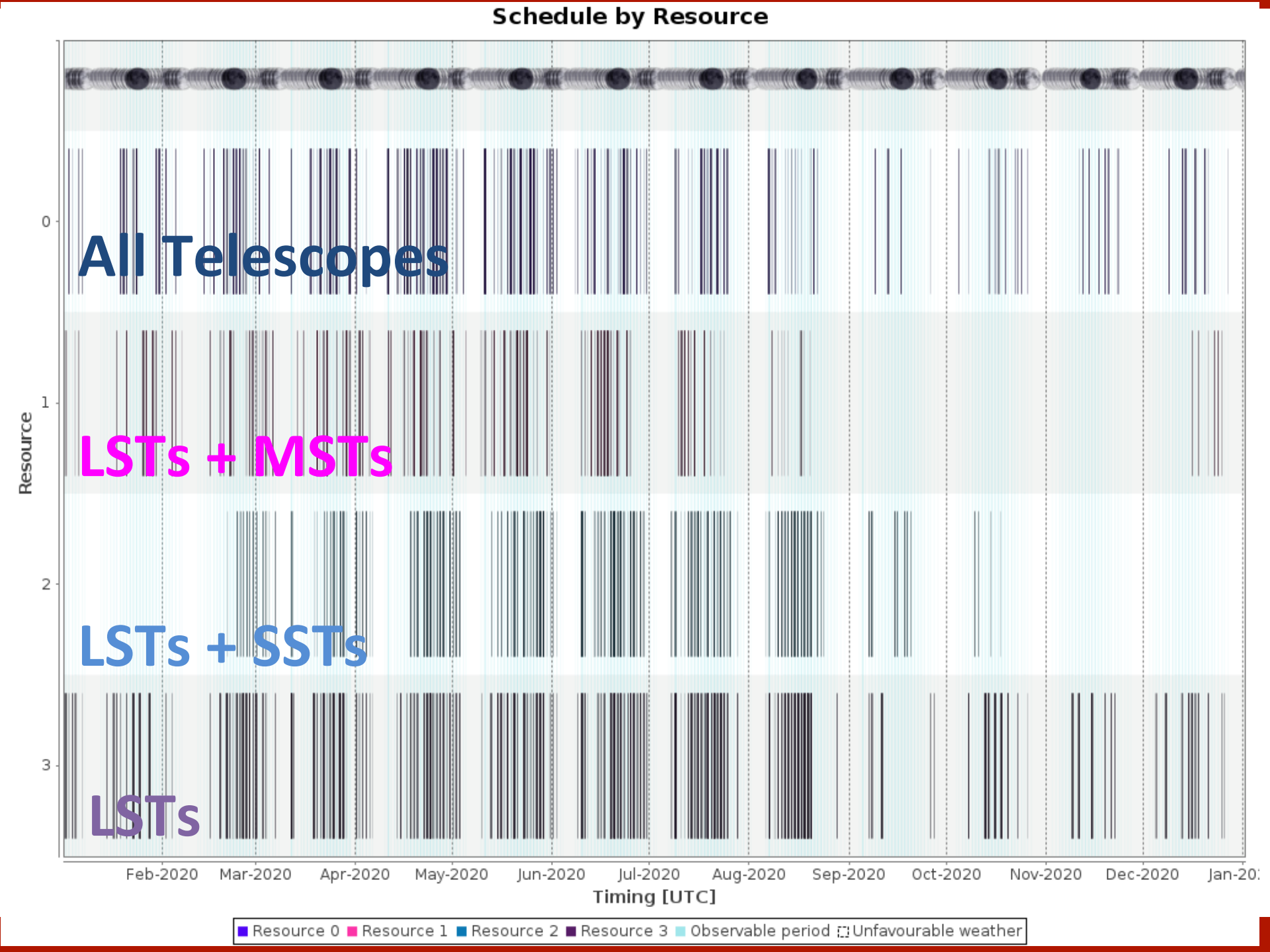
  - MOEA

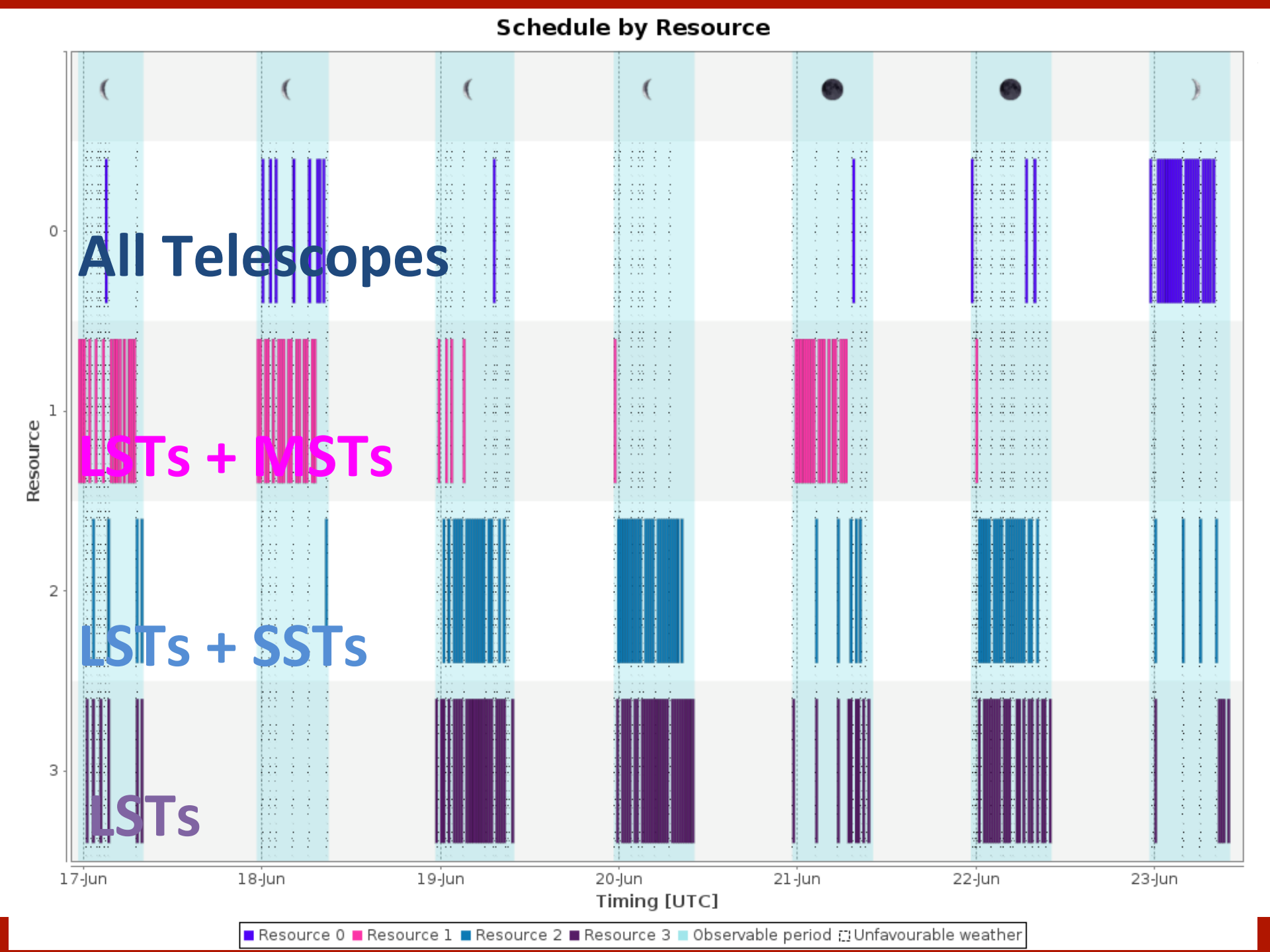
Completed Uncompleted Unplanned Not visible

Comparison between Strategies

- Scientific point of view
  - MOEA allows to complete more objects than GA because it better optimizes the working time

Target Type	Subarray	#Targets	GA #Planned (#Completed)	MOEA #Planned (#Completed)
GAL	0 (L + M + S)	170	168 (0)	170 (25)
EXP_GPS	1 (L + M)	231	231 (140)	231 (197)
GCMinil	2 (M + S)	20	20 (0)	20 (0)
Pevatron	2 (M + S)	5	5 (0)	5 (1)
Others	3 (L)	38	37 (0)	38 (6)


Schedule by Resource
All Telescopes
LSTs + MSTs
LSTs + SSTs
LSTs
Resource
0
1
2
3
Feb-2020
Mar-2020
Apr-2020
May-2020
Jun-2020
Jul-2020
Aug-2020
Sep-2020
Oct-2020
Nov-2020
Dec-2020
Timing [UTC]
Resource 0
Resource 1
Resource 2
Resource 3
Observable period
Unfavourable weather


Schedule by Resource
All Telescopes
LSTs + MSTs
LSTs + SSTs
LSTs
Resource
0
1
2
3
17-Jun
18-Jun
19-Jun
20-Jun
21-Jun
22-Jun
23-Jun
Timing [UTC]
Resource 0
Resource 1
Resource 2
Resource 3
Observable period
Unfavourable weather

Conclusions

- The proposed scheduler is able to schedule several subarrays simultaneously
- The scheduler allows flexibility in the definition of:
  - Hard constraints
  - Optimization strategy (soft constraints and optimization algorithm)
  - Scenario (targets, subarrays…)
- Optimization Algorithm (GA vs MOEA)
  - MOEA optimizes better the working time than GA
    - Slew time is reduced and more time is available for observing (near 70 hours in one year)
- Further work
  - Define priority objects
  - Consider the priority in the Optimization Algorithm of the scheduler
  - Response to ToO