

# AUTOMATED SCHEDULER SOFTWARE BASED ON METRO UI DESIGN FOR MACE TELESCOPE

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## Abstract

MACE Scheduler software generates automated schedule for the observations of preloaded high energy gamma-ray sources. The paper presents the design of MACE Scheduler software covering; source rise/set time calculation algorithms; auto and manual schedule generation; various data visualizations provided for schedule and source visibility reports. The schedule generation for a specific period is automated using a filter workflow. The sources are selected for scheduling by processing the sources through a series of customizable user defined filters; source visibility filter, priority filter, priority resolution filter. The workflow provides flexibility to apply any user tailored filter criteria that can be loaded dynamically using XML schema. Loosely coupled design allowed decoupling the astronomical timing calculation algorithms from schedule preparation workflow. Scheduler provides metro UI based interface for source filtering workflow generating auto-schedule, updating the generated schedules. Tree-map visualization helped to represent hierarchical multi-dimensional schedule information for the selected date range. WPF flat UI control templates focused more on content than chrome.

## INTRODUCTION

Major Atmospheric Cherenkov Experiments (MACE) Telescope (Fig. 1) is a very high energy gamma-ray telescope set up by BARC, at Hanle, Ladakh, India for the study of gamma-ray emissions from various cosmic sources in the energy region of 20GeV-10TeV. The MACE

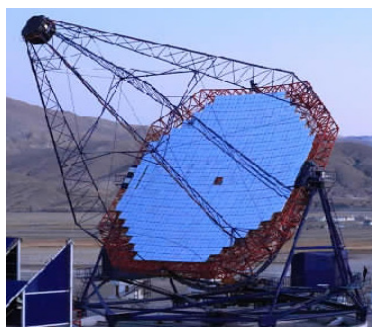


Figure 1: MACE Telescope.

Telescope Control System is a distributed control system which comprises of functionally diverse subsystems like Drive Control system, for moving the telescope towards specific sources at proper orientation; Mirror Alignment system, to focus the Cherenkov

light onto the camera; CAMERA system, which recognizes the onset of cosmic events of interest and records the signal acquired. It also consists of Sky Monitoring system, which quantifies the sky transparency level and checks the tracking accuracy of the telescope during observation; Data Archiving System (DAS), and Weather Monitoring system (WMS).

The MACE Operator console holds the responsibility for integrated control and monitoring of these subsystems to

conduct a successful observation run. Prior to the experiment an observation schedule selecting astronomical sources to be observed and the configuration of the various subsystems for the experiment is prepared by Astrophysicists.

The start-up sequence from the Operator console powers on the various subsystems in the required sequence and initialise the system and experiment configurations in each subsystem. This is done by running a sequence of commands (Fig. 2) from MACE Operator Console (OC), to bring the different subsystems to a ready state from where data acquisition can be started. These operation sequences are categorized into Initial run, Observation run, and Shut down run having associated pre-setup actions, experiment configuration, data acquisition and final shut down procedures respectively [1, 2]. The time required to carry out the initial run is accounted (X hours). The system automatically completes these activities and the Operator console starts the experiment X hours before the first observation.

Subsystem	Command	Status
CAMERA	LoadExpConfig	Success
CAMERA	ApplyHV	Success
LCS	Load_Config	Success
LCS	Get_Config	Success
DAS	SetFilingParam	Success
DAS	StartDAQ_DAS	Success
SKMS	Load_Obs	Success
TCU	StartTrack	Success
SKMS	Start_Obs	Success

Figure 2: Observation Command Sequence.

## MACE SCHEDULER

The successful operation of the MACE Telescope for observing various high energy gamma celestial source by recording the Cherenkov events produced, highly depends on the schedule.

MACE Scheduler provides an interface to the Astrophysicists to generate observation schedule, which is required to streamline the observations of various sources with MACE telescope. A typical schedule contains 5-10 sources It is the scheduler's task to create a realisable schedule that will then be used in the observations. The challenge is to select one of those possible schedules, which will lead to good results. The schedule file thus created consists of a set of different sources (astronomical) and their coordinates along with the time of observation. Scheduler software generates date-wise schedules and stores in a configured centralized location.

MACE OC loads the schedule file for the current date and picks one source at a time to conduct the Observation Run, wherein respective source co-ordinates are sent to the Drive Control System for positioning the telescope towards the source and data acquisition is done as per the time spec-

ified in the schedule. The schedule also chooses the experiment configuration to be loaded for each of the observation run.

### Design Basis

The scheduler software is designed to provide the following functionalities:

- It should provide facility to select the schedule duration, which can be planned for day, lunation, up to a year or any specified period
- It should provide default source list with default Azimuth and Zenith coordinates
- It should have a provision for manual schedule generation for the selected input configuration
- It should have a provision for selecting the visible astronomical sources to be observed
- The user should be able to automate the schedule preparation by using a filter set for selecting the sources
- It should provide various timing plots for Sun, Twilight, Moon Rise set times for deciding the dark period (the time span during which, there will be no background illumination from sun, moon, twilight) for observation
- It should provide report generation facility.

### Software Architecture

Scheduler software has been developed following layered architecture as shown in Fig. 3. Presentation layer handles user interface and implements custom controls, calendar controls, and tree map data visualization control. Application layer implements scheduler core modules like dark-period calculation and auto-scheduling controller and manual scheduling controllers. Algorithm layer implements rise and set time calculation algorithms for various celestial objects. Each layer defines an interface for the services it requires from the lower layer. The main aim of layered design [3] is the separation of concerns among the components. Application layer modules do not depend on lower layer concrete modules, instead they depend on the abstractions following Dependency Inversion principle. This helps to build loosely coupled software.

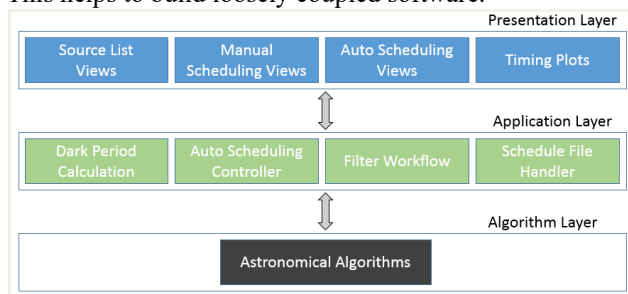


Figure 3: Software Architecture.

## SOFTWARE DESIGN

### Algorithms

The software implements the following astronomical algorithms [4, 5]:

- Calculating Rise/Set time for Sun, Moon and any custom source with defined coordinates
- Calculating Moon Phase
- Calculating the dark period for any day
- Calculating Azimuth and Zenith, given source coordinates and location

Astronomical algorithms are implemented following Adapter design pattern [6] (Fig. 4) and defines an algorithm interface for the application and makes it compatible with various algorithm implementations.

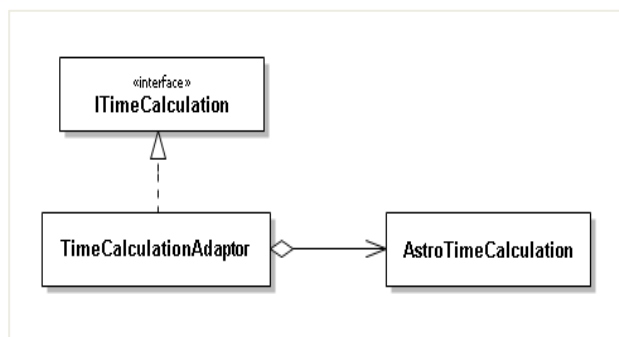


Figure 4: Adaptor Design Pattern for Astronomical Algorithms.

### Source List

The source list is organized into catalogues of various types (Optical, Gamma-ray etc.) and each source catalogue contains various source list with positional information (Right Ascension (RA) and Declination (DEC)) and priority. The source list data is stored in user configurable csv format. Source view provides the selected sources visibility information, polar view for Azimuth trend and Zenith trend plot for 24 hours of the selected day (Fig. 5). Selected source zenith trend plotted along with dark period helps to decide the observation period for the day.

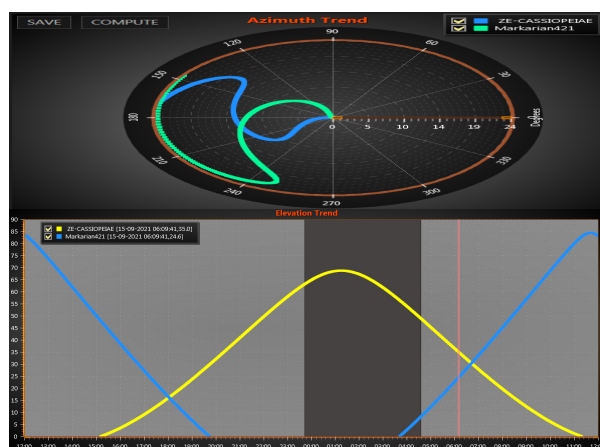


Figure 5: Selected source's azimuth and elevation trend along with dark period.

### Schedule Generation

The main responsibility of MACE Scheduler software is to enable the user to generate observation schedules for the

selected period and selected location. The software provides two modes for schedule generation; Auto, manual modes.

### Auto-Schedule Generation

Observation Schedule is automated by filtering and ordering the sources based on the user-defined criteria and scheduling the ordered sources as per the dark period window. Each source is configured to have a default scheduling period. Dark time available for the selected date is allotted to the ordered sources as per the source configured period.

The following are the steps for the auto-schedule generation.

- 1. Input** Location coordinates (Latitude & Longitude), time zone, date selection, observation duration and source list are taken as input for auto-schedule generation
- 2. Sources Selection** The sources are grouped into 4 categories; Optical (OP), Galactic (GA), Extra-Galactic (EG) and Positional (PO). The required source group or all groups or any user interested sources can be selected for scheduling
- 3. Source Filtering** The sources are filtered and ordered from all the selected source list. To enable the user to control how the sources are filtered, a source reduction workflow has been created. The workflow projects intermediate filter results, enabling the user to see each filter output.

FilterContainer (Fig. 6) acts a Filter Factory that creates Filter Objects and builds filter workflow. Strategy Design Pattern helped to load the selected filters dynamically. The design adapts to new custom filters.

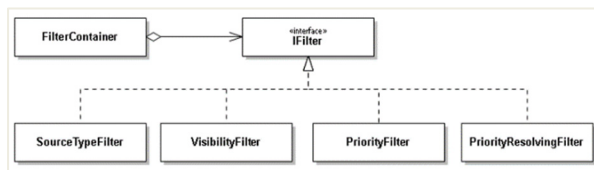


Figure 6: Filter Container.

The workflow consists of the following filters. Each filter takes input from previous filter and produces source list for the next filter input

- **Source Type Filter** The selected source list can further be filtered based on the source type (OP, GA, EG and PO)
- **Visibility Filter** Source observation is normally carried out during dark period. Hence the source should be visible within the dark period for the selected day. Rise/set time of previously filtered sources is calculated and checked if the source visible period overlaps with the dark time span. Thus, visibility filter produces a set of sources that can be observed during dark period.

- **Priority Filter** Each source is assigned a user-defined priority. Previously filtered sources will be ordered based on the priority. User can change the priority while building the workflow.
- **Priority Resolver** The same priority sources in the ordered source list can be resolved using a priority resolved criteria. Currently used criteria for resolving the priority is set time. The source that sets first is given more priority
- **Custom user filter** The workflow provides flexibility to apply any user tailored filter criteria. The user can define any customized filter and load it dynamically through structured XML schema as shown in Fig. 7.

For example, consider the following filter criteria: Source Azimuth > 50 and having 45 < Zenith < 90

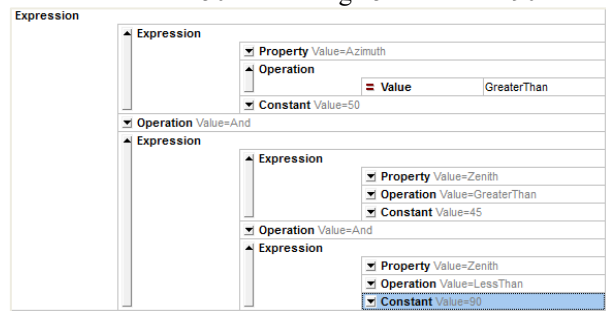


Figure 7: Custom Filter Expression.

Custom filters help to extend the software with various filter criteria depending on the requirements

- **Final Source List & Schedule Generation** The source list will be finally reduced to an ordered list for scheduling the observations depending on the Dark Period availability and a schedule for the selected day will be generated (Fig. 8)

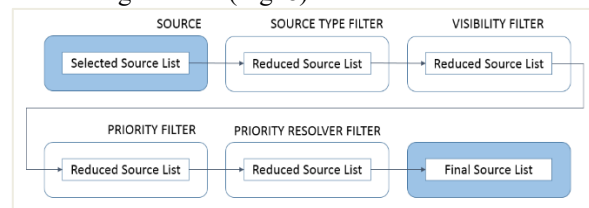


Figure 8: Filter Workflow.

### Manual Schedule Generation

The software also provides manual mode for schedule generation. For the selected day, the visible sources having overlap with Dark Period are selected for scheduling. For the selected source, depending on the tracking mode (Wobble, On/Off), configuration is set. Rise Time plot (Fig. 9) displays Rise and Set timing for Sun, Twilight period, Moon and Dark Period. It also shows the selected source rise/set timings. The plot helps to properly schedule the sources as per the available dark time span. The software provides custom user control to select observation time span up to minute. Rise time plot shows scheduled/added observations



Figure 9: Rise set time plot.

The following Fig. 10 shows manual schedule generation UML sequence diagram [7].

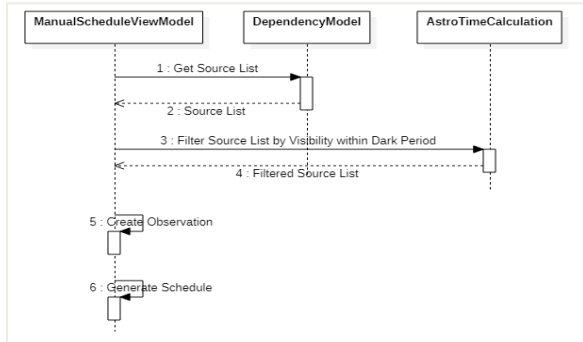


Figure 10: Manual Schedule Generation.

### Reports

The software provides different views for visualizing Sun, Moon, selected source visibility and schedule data. Schedule and visibility data can be exported to readable txt/excel formats. Visibility report (Fig. 11) contains dark period for the day and selected sources visibility for the selected date range.

NAME	01-09-2021	02-09-2021	03-09-2021
BLACK PERIOD	20:03-00:48	20:01-01:41	20:00-02:40
AL-ANDROMEDAE	23:21-04:04	23:17-04:00	23:13-03:56
BE-CASSIOPEIAE	00:20-03:10	00:16-03:06	00:12-03:02

Figure 11: Visibility report.

A schedule file contains the following information; Sources being observed, observation time span, dark time available, tracking mode information and configuration to be used. Schedule reports contain day-wise scheduled sources with the observation time span. Schedule information is shown in matrix layout, where each row contains date-wise scheduled sources. However, the matrix data is difficult to comprehend (Fig. 12) as the date range and number of sources observed increases.

10-09-2021	OP-ZE-CYGNI	08:41 09:11	GA-0FGLJ1958.1+2848	09:11 09:41	EG-BLLacertae	09:41 10:11
11-09-2021	OP-ZE-CYGNI	09:18 09:48	GA-0FGLJ1958.1+2848	09:48 10:18	EG-BLLacertae	10:18 10:48
12-09-2021	OP-ZE-CYGNI	10:00 10:30	OP-ZE-PEGASI	10:30 11:00	EG-BLLacertae	11:00 11:30
13-09-2021	OP-ZE-CYGNI	10:48 11:18	OP-ZE-PEGASI	11:18 11:48	OP-BE-ANDROMEDAE	11:48 12:18
14-09-2021	OP-ZE-CYGNI	11:42 12:12				

Figure 12: Schedule Report.

To get better insight into the scheduling statistics tree map control (Fig. 13) has been developed. Tree map view [8] helps to flatten the hierarchical information and

presents multi-dimensional data. The view highlights the source has with highest scheduling period and positions it to the top left as indicated by the size of the block. For each source block, the date on which it got the highest schedule period is indicated by the size of date block. Color shows the dark period duration. The color intensity of a block is proportional to the dark period available to it.

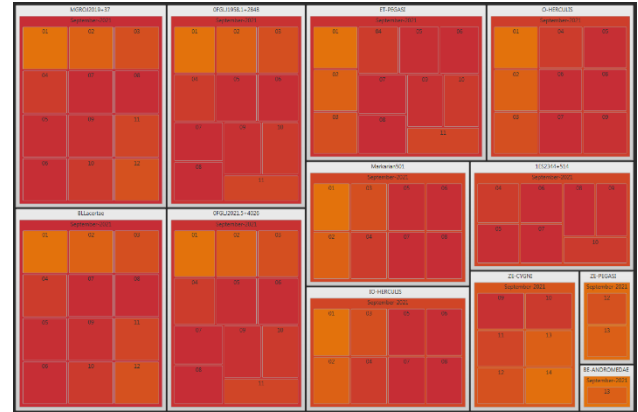


Figure 13: Schedule Info tree map visualization.

### Metro/Flat UX [9]

Scheduler user interface design has been developed following simple visual appearance, allowing the user to focus on content rather than chrome (colours, shadows etc.). Interface/custom control design has been inspired by Microsoft Design Language (MDL). It is also referred as Flat Design, which follows minimalistic approach using simple shapes, colours and icons for creating UI controls that are informative, thus avoiding the UI overload that comes from the visual effects. Flat UI design has been followed throughout the scheduler software.

### General Implementation

UI has been developed in WPF framework [10] and astronomy algorithms have been developed in C# following MVVM [11] architectural style, separating user interface logic from the application logic. Custom controls (ex: Custom Calendar control, auto schedule filter workflow control) are created by defining control templates to configure the control look and UX. Separating view logic from application logic helps to reduce coupling and improves application testability and maintainability. The following Fig. 14 shows the custom calendar control with orange markers to indicate if the schedule is prepared for that day.

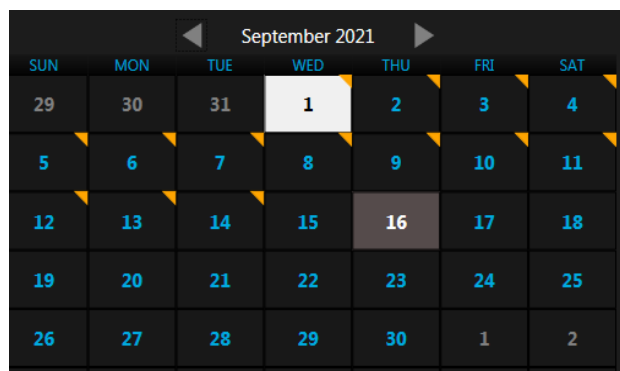


Figure 14: Custom calendar control.

## CONCLUSION

MACE Scheduler can automate the schedule generation through filter workflow for the selected date range and location. The software provides intuitive user interface for scheduling manual observations. The software consists of timing plots showing the available Dark Period and Sun, Moon, Selected Source's rise/set times, allowing the user to take a quick decision on schedule duration and time. The software design allows the scheduler extend to any custom developed astronomy algorithms. The software provides reports view using matrix form and tree map visualization for showing multi-dimensional schedule information. Schedule and Visibility information can be exported to readable format. MACE telescope has become fully operational in 2020 and scheduler has been used for preparing observations

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## REFERENCES

- [1] S. Srivastava, A. Jain, P. M. Nair, P. Sridharan, "MACE camera controller embedded software: Redesign for robustness and maintainability", ELSEVIER Publications, Astronomy and Computing, Volume 30, January 2020, <https://doi.org/10.1016/j.ascom.2019.100358>
- [2] Shikha Srivastava, Anushri Jain, Janhavi Deshpande, Mahesh Punna, Preeti M. Nair, Padmini S., "Design of Data Acquisition, Run-Control & Monitoring Software for MACE Telescope", National Symposium on Gamma Ray Astronomy-2020.
- [3] Mark Richards (2015), "Software Architecture Patterns", O'Reilly Media, Inc, ISBN: 9781491924242.
- [4] Duffett-Smith, P., "Practical Astronomy with your Calculator (3rd ed.)", Cambridge University Press, 1989. doi:10.1017/CB09780511564895
- [5] Jean Meeus, "Astronomical Algorithms (2nd ed.)", Willmann-Bell, 1998, ISBN-10:0943396611, ISBN-13:978-0943396613.
- [6] John Gamma, Erich Helm, Richard Johnson, Ralph Vlissides, "Design Patterns: Elements of Reusable Object-Oriented Software", Addison Wesley, 1994, pp. 139ff. ISBN 0-201-63361-2.
- [7] [www.uml-diagrams.org/sequence-diagrams.html](http://www.uml-diagrams.org/sequence-diagrams.html)
- [8] <https://en.wikipedia.org/wiki/Treemapping>
- [9] <https://www.microsoft.com/design/fluent/>
- [10] <https://docs.microsoft.com/en-us/dotnet/desktop/wpf/introduction-to-wpf>
- [11] <https://docs.microsoft.com/en-us/archive/msdn-magazine/2009/february/patterns-wpf-apps-with-the-model-view-viewmodel-design-pattern>