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National Centre for Radio Astrophysics

Monitoring and Control System for Giant Metrewave Radio Telescope

User Requirement Specifications

March, 2013

Version 2.0

Notice

National Centre for Radio Astrophysics (Tata Institute of Fundamental Research)

Monitoring and Control System for Giant Metrewave Radio Telescope

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Document Details

Name	Version Number	Description
User Requirements Specification of Monitoring and Control system for Giant Metrewave Radio Telescope	2.0	This document contains the user requirements and system requirements of Monitoring Control (M&C) system being developed for the Giant Metrewave Radio Telescope (GMRT)

Revision Details

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Many	NA	NA	Initial release
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Added use cases and system requirements under section 2	NA	NA	Remaining use cases and relevant system requirements are added
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• ***Table 6*** and ***Table 44*** (Last row added)			
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					diagrams under ***2.1.20*** and ***2.1.29*** • The requirements sheet under section ***2.3*** • ***Table 6*** and ***Table 44*** (Last row added)	
2.0	28-Mar-13	Baseline document	NA	NA	Updated ***Figure 5, Figure 7, Table 4 , Table 6*** and ***A.6.*** Status of all the use cases is changed to Accepted. Updated summary of ***2.1.33*** and ***2.1.34.***	NA

About this Document

Purpose

The purpose of this document is to lay down the user requirements of the M&C system for GMRT. This document also includes the system level requirements of the M&C system. This document is meant for the users and stakeholders of the M&C system and Tata Consultancy Services (TCS) project team.

Intended Audience

This document will help:

- The NCRA to understand and approve the requirements of the proposed application, as adequate to meet its stated business needs.
- The project team to design and develop the application using the requirements as a basis, as well as to plan and manage all project resources thereof.
- The acceptance testing team to develop test data and test the application.
- The maintenance team to understand all aspects of the application and maintain it.

Organisation of this Document

Information in this document has been organised as follows:

Table 1: Organisation of the Document

Chapter	Description
Introduction	This section provides the general information about the NCRA, GMRT and M&C systems.
Requirements	This section details out the user and system level, functional and non-functional requirements of the M&C system.
Information Technology Plan	This section describes the infrastructure upgrades/ preferred technologies for implementing the M&C system.
Appendix	This section describes the user interface, deployment and training requirements of the M&C system.

Typographical Conventions

The following table gives the details of the typographical conventions used in the document:

Table 2: Typographical Conventions

Type of Information	Formatting Convention
Cross-reference	Fields with cross-reference appears in bold italics. For example, ***System Requirements***
Filenames	Names of files are in italics. For example, *system.mdb*

References

The following table gives the details of the references used for this document:

Table 3: References

Sr No	Title	Author	Version
1.	User requirement specification of the GMRT control and monitoring system	NCRA (JPK)	1.1
2.	A Control and Monitoring system for the GMRT: Description and Requirements	NCRA (J. Kodilkar, R. Balasubramanian)	1
3.	Chapter 18: An Overview of the GMRT	Jayaram N. Chengalur	NA
4.	Response to the Questionnaire from various stakeholders	NCRA and TCS	1.1
5.	Basics of Radio Astronomy (JPL D-13835)	NASA (Diane Fisher Miller)	NA
6.	ISA – 18.02 – 2009, Management of Alarm Systems for the Process Industries	ISA (International Society of Automation)	18.02

How to Use this Document

The following points are to be considered while using this document.

- M&C, System, M&C system are interchangeably used in this document and imply the same meaning.
- It is recommended that the user is acquainted with Unified Modelling Language conventions.
- For efficient requirement management, the system level requirements have been captured in an MS EXCEL sheet which is embedded as objects in section **2.3** of this document.
- It is highly recommended the user before reading the use cases, refers to section **A.6** of Appendix. The appendix provides detailed explanation of the use case fields and conventions used in the use case tables.

Contents

Total number of pages in this document (including cover page) is 180.

List of Figures

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List of Abbreviations

Table 4: List of Abbreviations

Abbreviation	Expanded Form
ABC	Antenna Base Computer
ADC	Analog to Digital Convertor
AGC	Automatic Gain Controller
ANTCOM	Antenna Base Computer
AZ	Azimuth
BB	Baseband
BPF	Band Pass Filter
CB	Common Box
CEB	Central Electronic Building
CMC	Central Monitoring and Control
COMH	Communication Handler
COTS	Commercial off the shelf
DAS	Data Acquisition System
DDC	Digital Down Conversion
DEC	Declination
EL	Elevation
FE	Front End
FFT	Fast Fourier Transform
FilRF	Filter RF
FPS	Feed Positioning System
GAB	GMRT Analog Backend
GAC	GMRT Array Combiner
GCC	GMRT Co-ordination Committee

Abbreviation	Expanded Form
GMRT	Giant Metrewave Radio Telescope
GSB	GMRT Software Backend
GTAC	GMRT Time Allocation Committee
IF	Intermediate Frequency
IST	India Standard Time
LMC	Local Monitoring and Control
LNA	Low Noise Amplifier
LO	Local Oscillator
LST	Local Sidereal Time
LTA	Long Term Acquisition
M&C	Monitoring and Control
MCM	Monitoring and Control Module
MCM	Monitoring and Control Module
MTAC	Maintenance Time Allocation Committee
NCRA	National Centre for Radio Astrophysics
OF	Optical Fiber
PA	Phased Array
PAPS	Post Amplifier and Phase Switch
PET	Power Equalisation Tool
PT	Phasing Tool
RA	Right Ascension
RF	Radio Frequency
RFI	Radio frequency Interference
RCB	Rabbit Control Board
RMC	Remote Monitoring and Control

Abbreviation	Expanded Form
SFBB	Switched Filter Bank and Bypass
SKA	Square Kilometre Array
TCS	Tata Consultancy Services
TM	Telescope Manager
TIFR	Tata Institute of Fundamental Research
URS	User Requirements Specification
UT	Universal Time
WBS	Work Breakdown Structure

1. Introduction

This chapter gives a brief overview of the project and GMRT.

1.1. Background

The National Centre for Radio Astrophysics (NCRA) of the Tata Institute of Fundamental Research (TIFR) is a premier Indian research institute in the area of Astronomy and Astrophysics. NCRA has built a unique, world class facility of GMRT for conducting research in the radio astronomy. GMRT is located near Pune (Khodad) in India, has an array of antennas operating at metre wavelengths. At the time it was built, it was the world's largest interferometric array. NCRA is also keen in investigation of a variety of radio astrophysical problems ranging from nearby solar system to the edge of the observable Universe. It has various active research programmes in the areas of astronomy and astrophysics, which includes studies of the sun, interplanetary scintillations, pulsars, Interstellar medium, active galaxies and cosmology. These research programs are being conducted using GMRT.

NCRA strives to keep the GMRT equipped with the latest tools and technologies so that the GMRT is highly available and provides the accurate results for the science observations. As a continued effort, NCRA is presently focusing on upgrading the various aspects of GMRT such as increase in the operational bandwidth of GMRT, hardware upgrades and so on. The proposed M&C system upgrade is one of such initiatives of NCRA.

NCRA is representing India, in an international programme in radio astronomy called Square Kilometre Array (SKA) for building the most sensitive radio telescope network. The NCRA has indicated to be a lead organisation in handling the Telescope Manager (TM) work package for SKA. NCRA would like to showcase its capabilities in handling of TM WBS by upgrading the existing M&C system to gain sufficient experience for handling of certain critical aspects of TM architecture like scalability, availability and challenges due geographical separations. The proposed M&C system implementation would act as a precursor to the TM for SKA.

As a first step towards the proposed M&C system implementation, NCRA has invited TCS to identify and document the user requirements of M&C system for GMRT.

Proposed M&C system aims at:

- Providing a modern, versatile M&C system to GMRT
- Leveraging the technology trends to upgrade the present hardware and software setups of GMRT
- Showcasing the capabilities of NCRA for handling the TM for SKA
- Supporting the increase in bandwidth of GMRT from 32 MHz to 400MHz

1.2. Scope

The scope of this document is as described below:

1.2.1. Scope Inclusion

Scope of this document is to document:

- The user requirements of the M&C system for GMRT
- System requirements of the M&C system for GMRT

1.2.2. Scope Exclusion

- The requirements of the system that may be developed to test the M&C system are not documented in this document.
- The requirements pertaining to the modification of existing external interfacing systems are not documented in this document.

1.3. Domain Information

Radio astronomy is a subfield of astrophysics that studies the radio frequencies emitted by the celestial objects. Several observations have identified a number of different sources of radio emission from celestial objects. These include stars and galaxies, as well as entirely new classes of objects, such as radio galaxies, quasars, pulsars and masers. The discovery of the cosmic microwave background radiation that provided compelling evidence for the Big Bang was made through radio astronomy.

The basis of modern astronomical research is the synchrotron radiations emitted by the celestial sources, as a result of non-thermal emission phenomenon. These radiations fall in wavelength ranging from a few millimetres to nearly 100 metres and can penetrate the Earth's atmosphere. Although these wavelengths have no discernible effect on the human eye or photographic plates, they do induce a very weak electric current in a conductor such as an antenna.

Radio telescopes needed to capture these radiations need to be extremely large for receiving signals with high signal-to-noise ratio. Also, since angular resolution is a function of the diameter of the telescope in proportion to the wavelength of the electromagnetic radiation being observed, radio telescopes had to be much larger.

To achieve even higher resolution and sensitivity, modern radio telescopes generally use an array of antennas (instead of one huge antenna). In most of the radio telescopes, antennas are parabolic (dish-shaped) reflectors that can be pointed toward any part of the sky. They gather radiations and reflect them to a central focus, where the radiation is concentrated. The weak current at the focus can then be amplified by a radio receiver so that it is strong enough to measure and record. The radio signals coming from this array of antennas can be processed in a way to achieve the same results as a single huge antenna would provide.

The ground-based astronomical instruments can detect the electromagnetic spectrum in the optical wavelengths (0.4 microns- 0.7 microns) and occasional infrared wavelengths in dry and high mountain sites and radio wavelengths in ~1 cm to ~10 m. Celestial bodies exhibit the electromagnetic radiations in radio regime. This is because of to various reasons such as:

- Thermal radiations from the accelerating electrons due to proton mass,

- Non-thermal radiation: Due to electron movements in the spiral magnetic field (synchrotron radiation)
- Spectral-line emissions: Due to hyperfine transition in the hydrogen atom, higher transition between Rydberg levels and the plasma oscillations and so on.

The Meter-wavelengths of synchrotron emission are predominant and can be captured using low-frequency telescopes, such as GMRT.

A brief overview of GMRT is continued in the following section.

1.4. System Overview

The GMRT consists of an array of 30 antennas. Each antenna is 45 m in diameter and constructed over 18 m tower in height. These antennas are distributed in a region of about 25 Km diameter forming a rough Y shape. The rough geographic placement of these antennas (Array configuration) is depicted in ***Figure 1***.

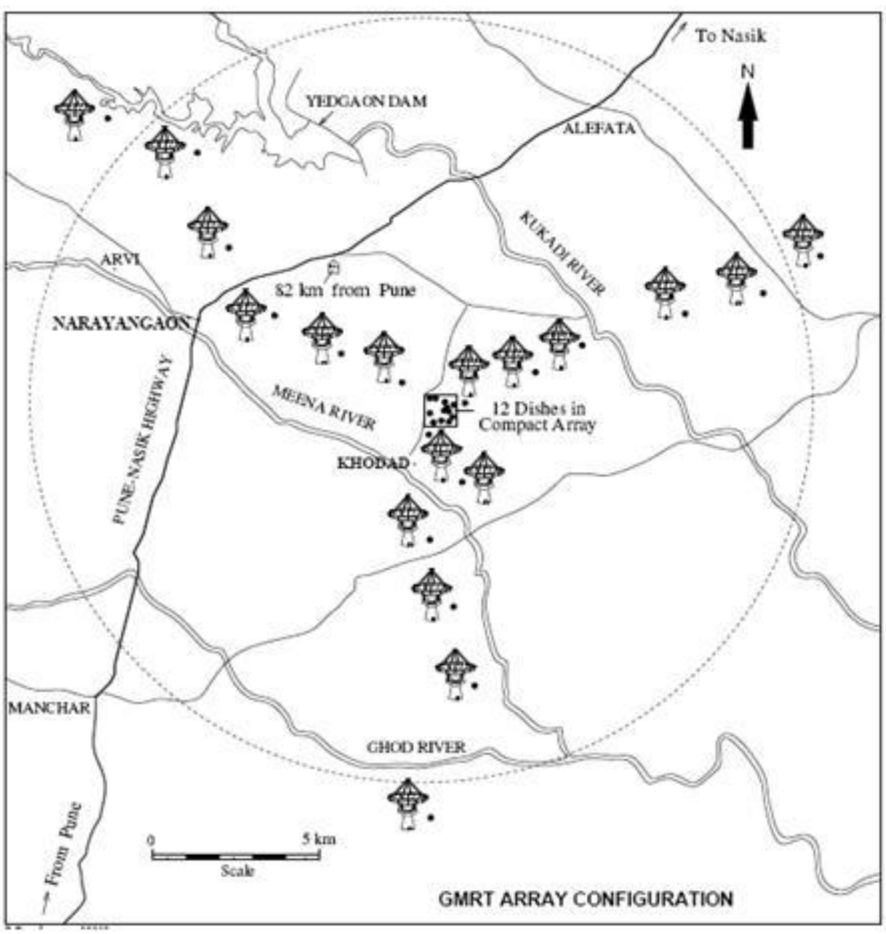

Figure 1: Geographic Placement of the GMRT Antenna

In principle, GMRT operates at frequencies ranging from 50 MHz to 1450 MHz and supports a full bandwidth of 32[1]MHz. This represents GMRT as a unique observatory in the world, facilitating the low frequency observations.

Each of these antennas is steerable in azimuth (AZ) and elevation (EL). Antennas are equipped with four different feeds, capable of turning antennas to five different frequencies (one feed is co-axial; the operating frequencies of the feeds are 150MHz, 233MHz, 325MHz, 610MHz and 1420MHz).

GMRT is a complex assembly of electronic and electro-mechanical subunits. Conducting an observation using GMRT involves co-ordinated control of all these subunits. For example, antennas have to track the selected source continuously, front-ends have to be tuned to the chosen frequency band, all the amplifiers along the signal path have to be set up to deliver high signal to noise ratio, and local oscillators (LO) have to be tuned to select the desired frequency and so on. Also, the system needs to be monitored continuously to ensure safe and reliable operations while conducting science observation.

All these tasks are presently being controlled and monitored automatically by software. Details are provided in ***1.5.1***.

1.5. Existing GMRT System

This section explains the present setup of GMRT with the help of entire receiver chain / subsystems and associated control system.

1.5.1. Receiver Chain and Subsystems

Capturing, interpreting and storing the Radio Frequency (RF) emissions from the celestial source are a multistage processing activity. Processing is performed by various subsystems at the Antenna Base and Central Electronic Building (CEB). The subsystems are controlled using the control and monitoring system. This is described with the help of entire receiver chain and subsystems of GMRT in ***Figure 2***.

The subsystems and their associated control systems present at the Antenna Base are Front End (FE) system, Antenna Base Receiver (ABR), Optical Fiber Transmitter, Sentinel System, Feed Positioning System (FPS), Servo Control Computer (SCC), Antenna Based Computer (ABC) and Monitoring and Control Modules (MCM). These are described in detail in the subsequent sections.

1.5.2. Front End

FE has two parts: FE box and Common Box (CB). The FE system receives dual polarised RF signals from the GMRT feeds. The lower bands below 1000 MHz have dual circular polarisation channels (Right hand circular and left hand circular polarisation) and L-band (1000 MHz to 1500 MHz) has dual linear polarisation channel (vertical and horizontal polarisation). These two channels have been conveniently named as channel 1 and channel 2 (CH1 and CH2). The FE can be configured for either dual polarisation observation at a single frequency band or single

[1] GMRT subsystems are being upgraded to support a total bandwidth of 400MHz.

polarisation observation at two different frequency bands. The polarisation channels can be swapped in common box. The front end has RF termination and noise injection facilities. Any band of the receiver can be switched OFF whenever not in use. The operations of FE are controlled by the control and monitoring system through MCM 5.

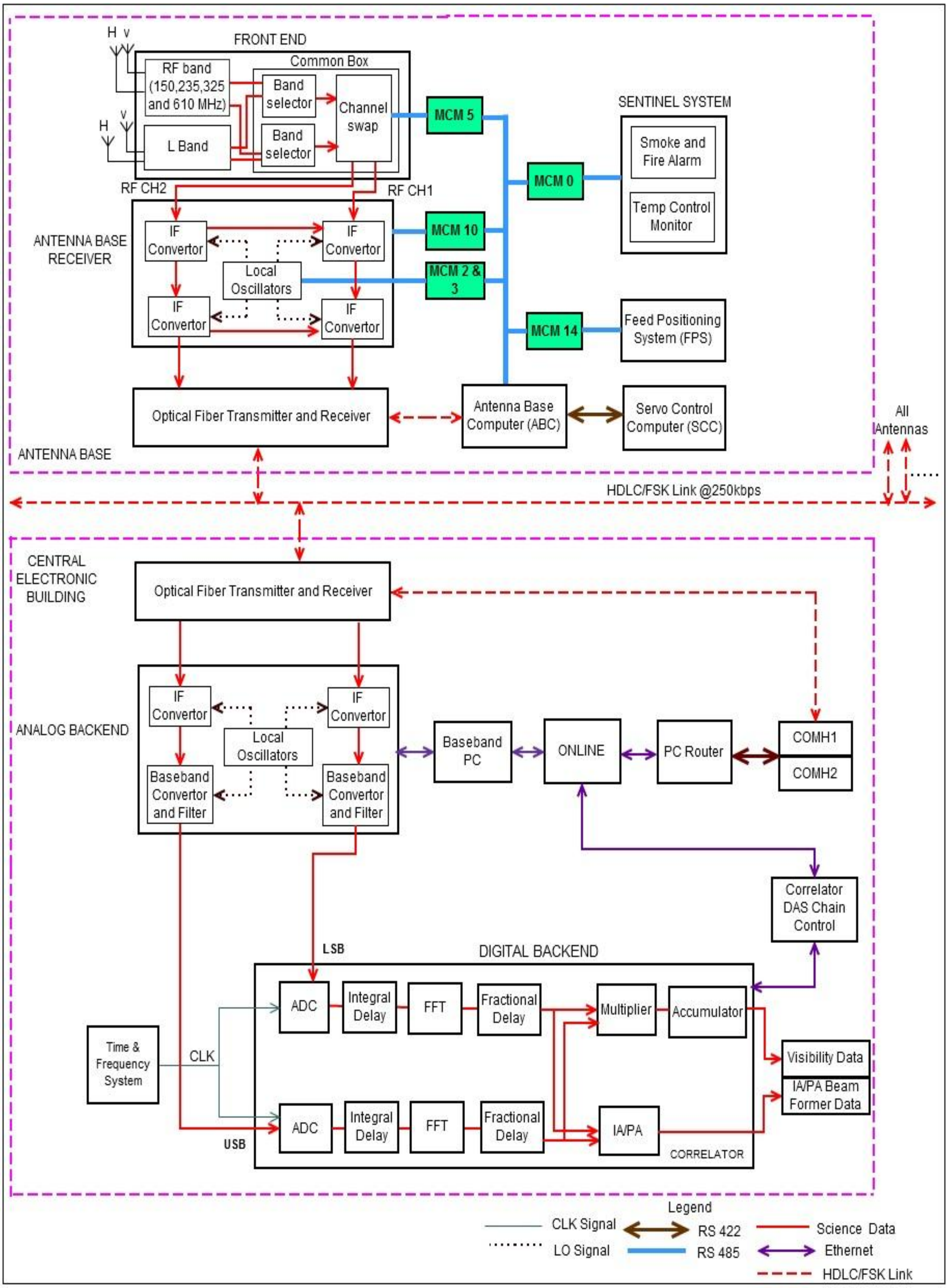

Figure 2: Block diagram of existing receiver chain of GMRT

1.5.3. Antenna Base Receiver

ABR is used to convert RF bands to Intermediate Frequency (IF) bands such that the CH1 frequency is converted to 130MHz and CH2 frequency to 175MHz. This conversion is necessary because directly dealing with RF signals increases the complexity of electronic processing circuit. This frequency transition also enables the transmission of both the polarised signals using Frequency Division Multiplexing (FDM) technique over the optical fiber to the CEB.

ABR is controlled using MCM 2, 3 and 10.

1.5.4. Optical Fiber Transmitter and Receiver

At every Antenna Base and at CEB, the Optical Fiber transmitters and receivers are used to convert the electrical signals to optical signals and vice-a-versa. These signals are transmitted over the optical fiber network between the antennas and CEB. Separate links are used for transmission of control commands and science data. The optical fiber transmission reduces the transmission losses over the long distance.

1.5.5. Servo System

Servo system is used to position the GMRT antenna at the correct position in two axes (Azimuth – horizontal axis and Elevation/Altitude – vertical axis) with a tracking accuracy of ~1 arc min. Each antenna has a Servo Control Computer (SCC) which is responsible for controlling the motion of the antenna. It uses RS-422 differential data link at 9.6 Kbps to communicate with ABC and this link is used to send/receive various commands/responses to the electro-mechanical systems of GMRT. The SCC accepts movement commands, position information and so on. From the ABC, checks that the command is valid, and if so obeys it. It also returns the antenna status information periodically through the same link. This information is passed on by the ABC to ONLINE for displaying to the user in CEB.

The main goal of the GMRT servo system is to support precision tracking of celestial source from a remote location, with minimum pointing errors, even under disturbing wind conditions. It is equally important to secure the safety of the antenna at all times. From a control system point of view, each axis control is made up of three control loops viz. Position, speed and current as briefed below:

Current loops: There are two current loops per axis. These loops are responsible for performing a closed loop control of motor currents.

Speed loops: There is one speed loop per axis. This loop performs a closed loop control of the average speeds of tow motor.

Position loop: There is one position loop per axis. This loop performs a closed loop control of the antenna axis position.

Current loops are the inner most loops; speed loop is outside the current loop and then position loop encloses the speed loop. Thus output of the position loop controller is fed as demand speed to the speed loop, whose output in turn becomes demand current to the two current loop controllers. Counter torque scheme is implemented so as to reduce gear back-lash error. This is achieved by biasing the motor currents by equal and opposite value.

1.5.6. Sentinel System

All the antenna shells are equipped with various intelligent subsystems and sensors for ensuring the safety of antenna systems from intrusion, fire, smoke and over temperature conditions. These parameters of the subsystems are continuously monitored and appropriate alarms / actions are initiated to take the corrective actions. The sentinel system includes the GMRT Antenna Temperature Control and Monitor, GMRT Intruder Alarm System, GMRT Smoke and Fire Alarm System, Electronic Door Closer. The sentinel system also has extended capabilities for Closed Circuit Television Network, Hot-line Telephony System, RF Shielding and Measurements and Video Conferencing. MCM 0 is used to control and monitor the operations of the Sentinel System.

1.5.7. Feed Positioning System

The GMRT antennas are equipped with four different feeds. Each feed is selective to a specific frequency (150, 325, 1420 and 235/610 MHz feeds as GMRT has co-axial feed), thus enables GMRT to operate in specific band of frequency. The feeds are mounted on a four faces of a rotating turret, supported by antenna quadrapoles. Rotation of this turret is controlled through a FPS (MCM 14) of GMRT.

1.5.8. Antenna Based Computer

There is ABC (also called an ANTCOM) located in each and every antenna shell. All communication between the ONLINE/COMH and sub-systems in the antenna is routed through the ABC at the antenna shell. The ABC receives various parameters (commands) sent by ONLINE/COMH, performs some computations if necessary, and passes on the commands to the appropriate subsystem of the antenna.

In detail, the ABC has three communication links as explained below:

- The main data link between COMH & ABC which operates at 125 Kbps
- An asynchronous 9.6 Kbps, RS 422 communication link between ABC and the Servo Station Computer (SSC)
- An asynchronous 9.6 Kbps, RS 485 communication link between ABC and MCMs.

ABC can communicate with 16 MCMs in a cycle time of 1 sec. FPS is also configured as one of the MCMs.

Following are the main functionalities of the ABC:

- Initialise ABC in application mode : Tallies the command & response counters of ABC to Unix,
- Set the time for ABC. Configure MCMs, set mask, and load antenna specific tracking parameter.
- Handle three communication links as explained above.
- Communicate with configured MCMs; enable/disable specific MCM monitoring.

- Receive time dependent, source specific parameters and antenna parameters from ONLINE/COMH.
- Communicate with servo system: generate periodic display command for ONLINE, control tracking operation locally for the specified maximum duration.
- Auto parking of antenna (Elevation: 90 degree, Azimuth: 0 degree).
- Form and send a response frame to COMH.
- Set various timing and communication parameters for ABC, COMH, MCMs and SERVO.

1.5.9. Monitor and Control Module (MCM)

MCMs are a general purpose microcontroller based card, which provides 16 TTL Control O/Ps and can monitor up to 64 analog signals. These MCMs are the interface to all settable GMRT subsystems such as the Front End, LOs, and attenuators and so on. It uses 9 bit asynchronous protocol at 9.6 Kbps for communication with ABC using RS-485. At each antenna, MCM5 is the interface to the front end system, while MCMs 2, 3, and 9 are the interface to the LO and IF systems.

1.5.10. Overview of Control and Monitoring System

The present monitoring and control activities of GMRT are carried out from CEB and Antenna Base. The block diagram of the existing monitoring and control system of GMRT is depicted in ***Figure 3.***

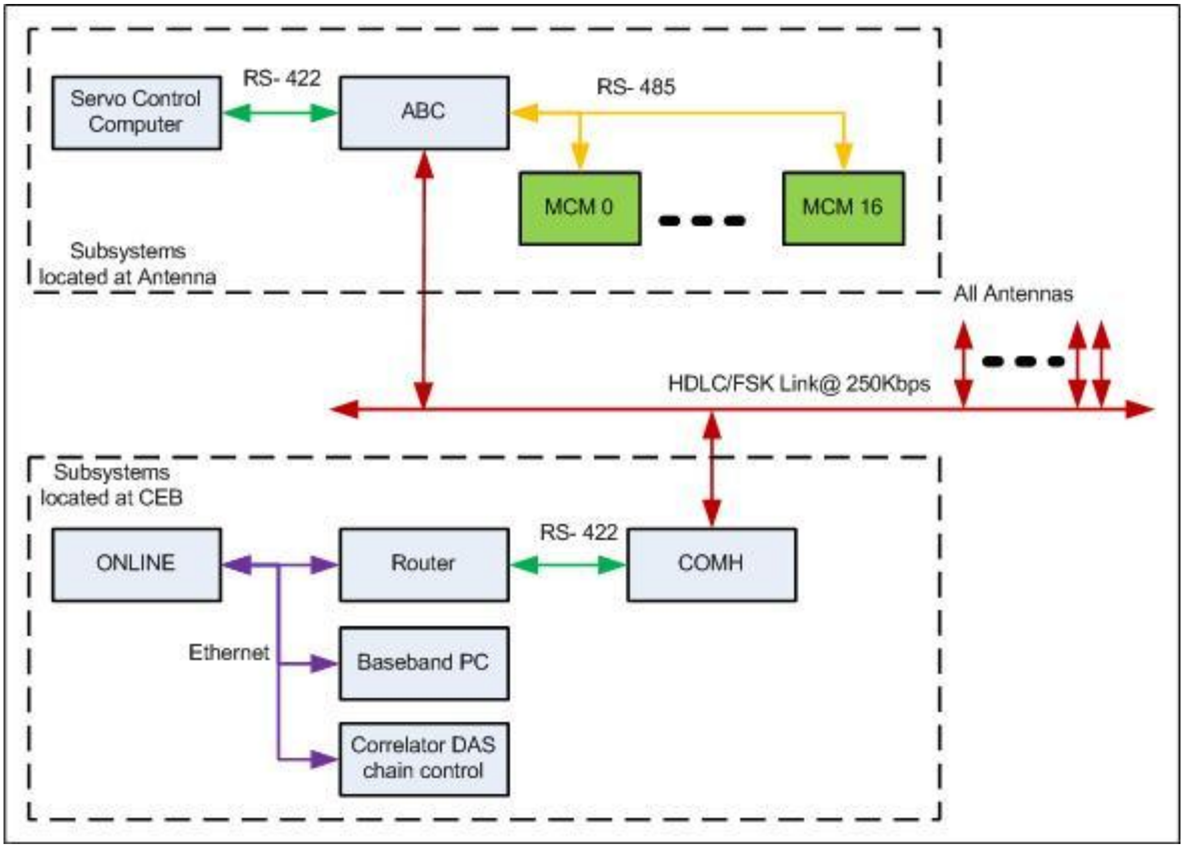

Figure 3: Block Diagram of Existing GMRT Monitoring and Control System

The existing system enables monitoring and control from Antenna Base as well as from the Central Electronic Building (CEB). The subsystems of present monitoring and control system located at CEB are described below:

1.5.11. ONLINE

The ONLINE is a central supervisory system that controls and monitors the other sub-systems of GMRT located at antenna base (servo, antenna receiver, sentinel systems, FPS and so on.) and CEB (baseband, software correlator configuration and data acquisition and so on.). The ONLINE software running on a UNIX workstation provides the user interface for the control and monitor system. ONLINE also logs the monitoring data related to various GMRT sub-systems. Upon detection of any critical subsystem failure, ONLINE raises an appropriate alarm so that remedial action can be taken. The ONLINE software consists of a number of independent communication programs which runs on UNIX workstation. These programs are developed in-house; mainly using FORTRAN and C. ONLINE can form a number of sub-arrays (group of antennas) which can perform multiple observations simultaneously by allowing multiple user-terminals for either executing the observing sessions or engineering test.

1.5.12. PC Router

The PC Router converts the commands/responses of TCP/IP Ethernet stream at 100 Mbps from/to ONLINE system to/from asynchronous 8 bit - RS422 serial communication link at 38.4 Kbps of COMH.

1.5.13. COMH

Communication Handler (COMH) handles all communication between ONLINE and ABCs. Error checking retry, timeout and so on mechanisms are built into the COMH. COMH communicates these status to ABC and ONLINE.

1.5.14. Baseband PC

The baseband PC fulfils the monitoring and control needs of the baseband system by facilitating setting up of LO Values. ONLINE client program communicates to the baseband PC using socket communication.

The baseband system process the incoming dual polarised IF system signals from all thirty antennas. Baseband can apply filters to provide IF signals to the GMRT software backend with bandwidth of 32, 16 and 6 MHz. For each band-width, respective baseband LOs can be selected for synthesizer 1 and 2. For example for 32 MHz LO values 149.0 to 156.0 MHz, for 16 MHz LO values are 138.0 and 167.0 and for 6 MHz LO values are 133.0 and 172.0 MHz. Thus, base-band provides the total 64 inputs to GMRT software backend where 4 inputs (two antennas with dual polarised signal, channel-1 and channel-2) provided to each ADC card. There are total 16 ADCs card on 16 data acquisition nodes of the GMRT software backend.

1.5.15. Correlator DAS Chain Control

The GMRT Software Back-end (GSB) is a full polar real-time software correlator with high time resolution incoherent and coherent array beam formation/processing back-end. The GSB takes two channels from 32 antennas. So total 64 input analog channels, with frequency of either 16 MHz (from existing Base-Band (BB) unit) or of 32 MHz (BB output from new IF-BB conversion unit) can be processed by GSB.

There are two main functional modes of the GSB - one is raw dump and other is real time mode. In raw dump mode, 32 MHz base-band signals are recorded on the disk array for off-line read-back and computation purposes. In real-time mode, GSB gives final visibilities near about 2sec integration time on gsbm1 Linux machine. This data is transferred to data host machine gsbm4 in a GMRT LTA (Long Term Acquisition) format for recording and monitoring purpose. Along with interferometric data, Incoherent array (IA) and Phased array (PA) beam formation can take place simultaneously on GSB pulsar host machine node33 and node34 respectively. The pulsar data is processed (data marker checks, GPS time stamping etc.) and transferred to data host machines node 37 or 49 and node 38 or 50 for recording and monitoring purposes.

The ONLINE takes commands from the user terminal for the configuration of GSB and astronomical data acquisition from the GSB. These commands are passed to the GSB via data-acquisition server which accepts the client connection from the GSB. The GSB configuration file from the ONLINE is send as the GSB initialization and configuration part, after the successful initialization, user can acquire the data using the simple start and stop data acquisition command along with the observing project information. Online provide the RA, DEC and frequency information of the target source so that the GSB can use this information for the delay tracking and fringe stop.

1.6. Upgraded GMRT System

GMRT is being upgraded in several aspects such as seamless frequency coverage from 150 MHz to 1500 MHz, large instantaneous bandwidth of observations (maximum of 400 MHz) revamped servo system, associated support systems along with the provision of modern and versatile M&C system. ***Figure 4*** depicts the schematic of GMRT's planned upgrades.

1.6.1. Receiver System

In Figure 4, the RF signal processing path from front end system to digital backend data processing system is depicted. All the components shown in yellow colour indicates the set-points/monitoring points for M&C system, green colour is used to show the micro-controller cards in receiver chain systems.

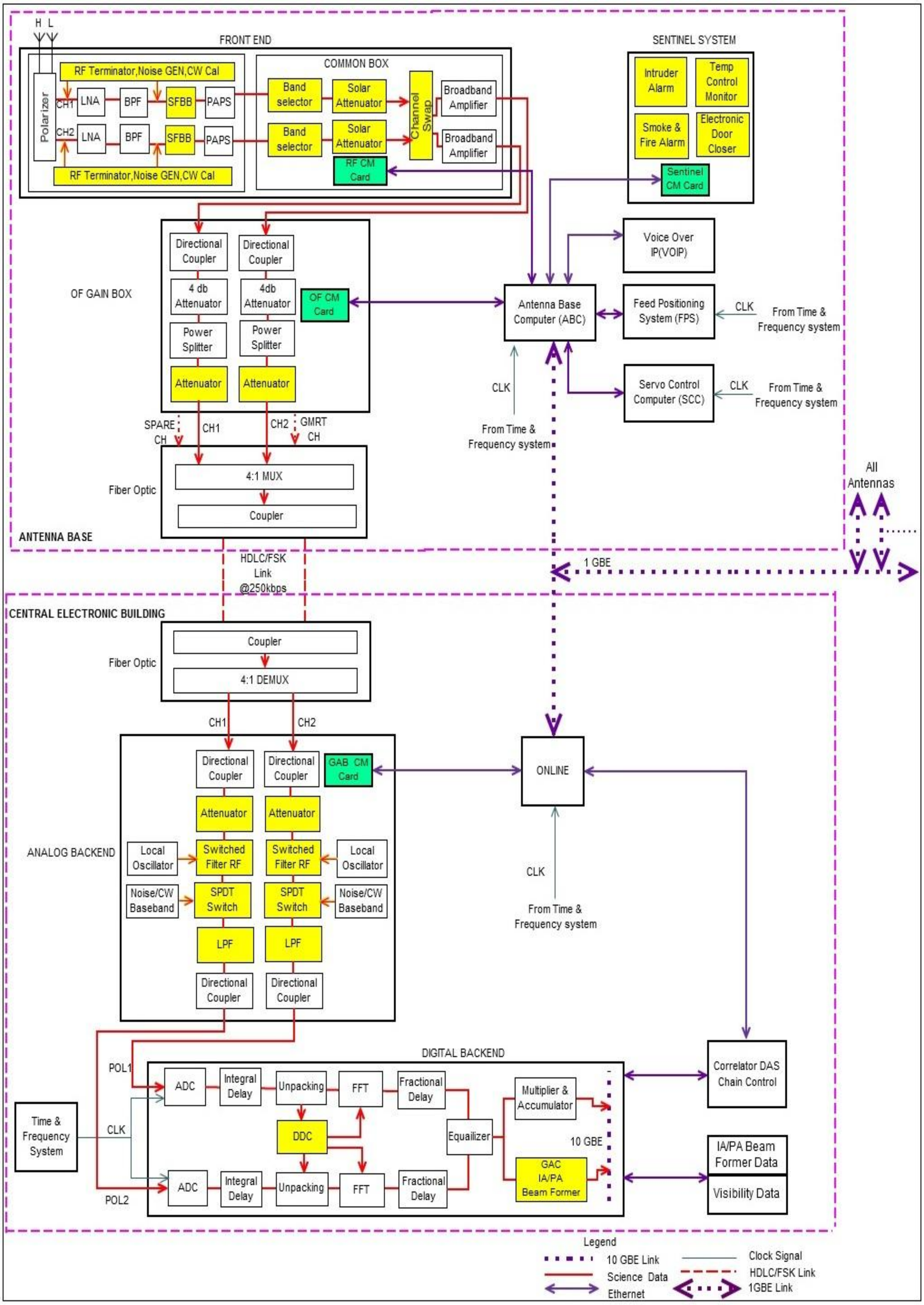

Figure 4: Block diagram of GMRT receiver (with planned upgrades) and associated subsystems

A brief description of planned upgraded GMRT subsystems is provided blow:

1.6.2. GMRT Feeds

In the upgrade plan of the GMRT system, the existing feeds are being replaced by wide-band feeds (maximum bandwidth is 400 MHz) to provide seamless frequency coverage from 50 MHz to 1500. The existing feeds and the new feeds under planned upgrades are given in ***Table 5***: **GMRT Feeds** along with the band-width coverage.

Table 5: GMRT Feeds

Sr No	New Feeds	Band [MHz]	Existing Feed	Band [MHz]
1.	Dual Ring Feed	130–260	Thick Folded Dipole	120–240
			Dual Co-axial Feed	225–245
2.	Cone Dipole Feed	200–500	Kildal Feed (Cross Dipole)	290–420
3.	Cone Dipole Feed / Wideband Horn Feed(CSRIO)	550–900	Dual Co-axial Feed	580–700
4.	Corrugated Horn Feed (L-Band)	1000–1450	Corrugated Horn Feed	1000–1450
5.	Thick Folded Dipole (RRI)	30–80	NA	NA

1.6.3. Front End

Following upgrades are planned for Front End (FE) box of FE system:

- Calibration Noise (Cal Noise) injection or Continuous Wave (CW) calibration signal for both channels – The receiver chain can be calibrated by injecting one of the four levels of calibrated noise named as Low Cal, Medium Cal, High Cal and Extra-High Cal. One of these calibration signals can be selected depending on the flux density of the sky-source being observed.

- RF ON/OFF – Any observing band in FE box can be switched ON/OFF conditionally in order to calibrate the receiver noise and to diagnose the Radio Frequency Interference (RFI) conditions for given antenna. The RF signal switching (ON/OFF) is possible for individual channels (Ch1 and Ch2)

- RF Termination – The incoming dual polarised RF-signals can be terminated individually.

- Switched Filter Bank and Bypass Mode – A wide-band RF can be split into three to four sub-bands using the Switched Filter Banks having four band-pass filters and also the provision of getting a complete wide-band (up to ~400Mhz) by using the direct path. At present, Front End box for the 550–900Mhz Cone Dipole feed provide three sub-bands each of 100Mhz band-width such as 550–670Mhz, 660–780Mhz, 770–890Mhz and

350Mhz band 590– 900Mhz (Bypass mode). Front End box for the L-band feed provides four sub-bands each of 120 MHz band-width centred at 1060 MHz, 1170 MHz, 1280 MHz and 1390 MHz L-band feed also has the capability to give a complete 900–1450 MHz band in bypass mode.

- To minimise the cross-coupling between CH-1 and CH-2, a phase switching using Walsh functionality has been provided in the post unit.

The following upgrades are planned to CB:

- Band Selector – Common box has flexible band selection scheme where dual polarisation channels for single frequency band or channels with single polarisation for different band can be selected using the band selector switch.
- Solar Attenuators – For observing strong radio sources such as sun, the RF signal strength must be attenuated at the optimal power range. The dual polarised RF signal can be attenuated individually using selectable attenuations of 14, 33 and 44 dB.
- RF Swap – To diagnose the receiver path or to check polarisation leakage, RF CH1 and CH2 signal path can be swapped using the RF Swap facility.

1.6.4. Fiber Optics (FO) System

The GMRT is being upgraded to the Coarse or Dense Wavelength Division Multiplexing (CWDM or DWDM) based broadband analog Fiber Optic (FO) system. This system uses optical multiplexing and bi-directional FO link on a single core of optical fiber cable. The FO configuration shown in ***Figure 4*** depicts two fibers per antenna running between CEB and antenna. The first is 1 GB Ethernet link for transmission of control commands; the other is used for science data. One spare link is also maintained between antennas and CEB (shown as SPARE CH in the diagram). The existing Optical Fiber link will also be maintained along with broadband links.

The OF Gain block in ***Figure 4*** shows the FO system at the Antenna Base where the incoming RF signal is monitored using the directional coupler. Power splitter is used to give one input to the existing IF system at the Antenna Base and another directly connected to the broadband analog FO link. Since the total power of incoming RF-signals varies with the selected frequency band, a suitable attenuation needs to be selected using the variable attenuators (0 dB to 31.5 dB in steps of 0.5 dB).

FO system uses rabbit micro-controller to set the attenuation bits, monitor the temperature of laser diode, Laser bias voltages, RF amplifier bias voltages, power supply and so on.

At the CEB, the power levels of broadband RF signals coming from all the 30 antennas (CH1 and CH2) are planned to be monitored using the directional couplers and Lab jack monitor and control card. The optimal power level of incoming broadband signals will be achieved by adjusting the attenuations in the OF gain systems at the Antenna Base.

1.6.5. GMRT Analog Backend (GAB) system

Analog backend system at the CEB, converts incoming dual polarised RF broadband signals from all the 30 antennas into the base-band frequencies in the range of 0 MHz to 400MHz. For this conversion, GAB uses individual signal LO signal for each antenna using the synthesizers in the frequency range of 600 MHz to 1600MHz. LO frequencies lower than 600 MHz plan to set from the common oscillator system. A 10 MHz reference signal from the GMRT Time and Frequency System (FTS) is distributed to each antenna backend system to generate the final LO frequency using the synthesizer unit. At present, the same local oscillator frequency is given for both the polarisations of the antenna. The GAB system block for individual antenna is shown in ***Figure 4***, the main features and set-points are as follows:

- The GAB has individual synthesizer unit for each antenna to generate the local oscillator frequency in the range of 600 MHz to 1600 MHz in steps of 500 KHz. The same local oscillator signal is used for both.
- Polarisation channels from one antenna.
- RF signal power monitoring port is provided at the input of each GAB units.
- Instead of incoming RF-signals from the antenna, a noise or continuous wave signal can be injected using the SPDT (single pole double throw) switch to calibrate the GAB system.
- The incoming RF-signal power level can be adjusted using the variable attenuation (from 0 dB to 31.5 dB in steps of 0.5 dB) to keep the power at optimum level.
- Filter RF (FilRF): A filter-bank has total eight filters, which can be selected using the SP8T (single pole 8 through switch) depending on the RF-band selection in the Front End Box/Common system. These filters allow a maximum of 400 MHz wide-band RF-signal for further processing.
- An incoming RF signal below 400 MHz can be directly brought to digital processing, and the signal above 400 MHz is converted to the base-band signal using LO. The signal flow can be set using the SPDT switches.
- At the final stage of GAB system, a four-way switch is used to select the low pass filters of band-width 100 MHz, 200 MHz and 400 MHz or direct path the can be chosen to get the complete RF-band.

Each GAB unit for individual antenna has control and monitoring Rabbit RCB 4300 card, which provides the TCP/IP based Ethernet communication and hence allows remote setting of the local oscillators for both the polarisation signals, filter selections and so on. There will be total 30 Rabbit cards, which are connected to the GAB server PC through a network switch. The GAB server PC will allow to control and monitor all the 30 antenna GAB systems. In each rack of the GAB system (around four antennas per rack), there will be a temperature monitoring points, noise generator and signal generator units to control.

1.6.6. Digital Backend System

The new upgraded GMRT digital backend system will facilitate the wide-band data processing up to 400 MHz for various types of astronomical observations with a high dynamic range. The digital backend system can be configured to conduct various types of astronomical observations such as continuum observations for the imaging, pulsar observation and spectral line observation in either total intensity or full-stokes mode. The digital backend process the dual polarised RF signals of 30 antennas coming from the GMRT analog backend systems GAB. In the interferometry mode of digital backend system, the mutual coherence function of the electric field due to a given source brightness distribution in the sky is measured by cross-correlating the voltages from each antenna pair. The measured cross-correlating function is also called visibilities. The array combiner of digital backend system gives the IA and PA beam former output for the pulsar observations. ***Figure 4*** shows the GMRT digital backend system with hybrid technological approach using the Field Programmable Gate Array (FPGA), Graphic Processing Units (GPUs) and CPUs along with 10 GB Ethernet link for data transport between the computational blocks. The description of digital backend systems is given below.

1.6.6.1. Correlator

Analog-to-Digital Converter (ADC) block digitises the dual polarised RF signals of 400 MHz band-width coming from the GAB systems of all the 30 antennas at the Nyquist sampling rate of 800 MHz (ADC - 4/8 bit for quantisation). The cosmic signal received by antennas suffers from different propagation and instrumental delays due to the relative locations of the antennas and different optical fiber lengths between the antennas and correlator (called the geometric delay and fixed delay respectively). The FPGA Roach board is used to compensate the course delay correction (integral multiple of sampling frequency) using a dual-port memory. The signal after being converted into digital form is processed through the cluster of GPUs and CPUs nodes. The Fast Fourier Transform (FFT) unit takes two integral delay compensated data streams by multiplying the data weighting function knows as standard window function and gives signals in spectral/frequency domain. Even after compensating the integral delays, the output of the correlator may have two types of residual phase errors; one is due to the delay compensation done at the base-band frequency rather than the RF frequency where the geometric delay suffers (known as fringe stop), and other is due to the compensated delay (course delay) is not equal to the required geometric delay (known as fine delay or fractional sampling time correction - FSTC). The fine delay/fringe Stop block compensate these two types of delays and after proper scaling the input is provided to the Multiplier and Accumulator (MAC) block. The MAC computes the 30 X (30+1)/2 = 465 self and cross products from the 30 antennas for each polarisation and integrate the data for specified accumulation period to give visibility output i.e. Cross amplitude and phase in real and imaginary (complex) format.

1.6.6.2. Array Combiner

The GMRT array combiner operates in two modes for pulsar observations; one is the Incoherent (IA) mode in which addition of total power coming from the individual antennas after proper scaling of the FFT output by equalizer block and other is Phased Array (PA) mode, where Phase Array synthesises the coherent resultant beam by adding the voltages from different antennas in phase to compute the Stokes parameter from which full-stokes information can be constructed. Phased Array output has a higher sensitivity by N times, where N is number of antenna used for voltage addition of signals. Both IA and PA modes can have independent set of antennas and data rate.

1.6.6.3. Digital down Conversion

Spectral Line observation requires more spectral resolution. The Digital Down Conversion (DDC) block down-converts the 400 MHz bandwidth signal to the desired frequency band of interest using the Local oscillator. This also allows the frequency band of interest to shift down to base-band frequency so that the sample rate and data rate can be reduced. The limited FFT (number of frequency channels) size over narrow band utilised to get more spectral resolution. The GPU unit decreases the time of various operations to implement the DDC block. Hence, the DDC design is done in GPU.

The M&C system talk to digital backend system control host PC and data hosts PC over the TCP/IP based Ethernet communication. The control host allows the user interface to control and monitor Correlator sub-blocks viz. Pulsar backend, DDC, FFT/Scaling block and so on.

1.6.7. Servo System

The following upgrades are planned for servo system:

- Dedicated PC-104 will be used to control the operations of servo system; this will replace the existing SCC.
- Servo system is planned to communicate with M&C over Ethernet interface.
- Brushless DC motor will be used to rotate the antennas.
- Temperature of the Motor Windings to be monitored.

1.6.8. Feed Positioning System

The following upgrades are planned for FPS system:

- Dedicated PC-104 will be used to control the operations of FPS.
- FPS is planned to communicate with M&C over Ethernet interface.
- Brushless DC motor will be used to rotate the feeds.
- Temperature of the Motor Windings to be monitored.

1.6.9. Scope/ External Interfaces

The block diagram in ***Figure 5*** depicts various subsystems of GMRT and their interface with M&C. The diagram also outlines the scope of M&C. The subsystems perform specific task in overall operation of telescope.

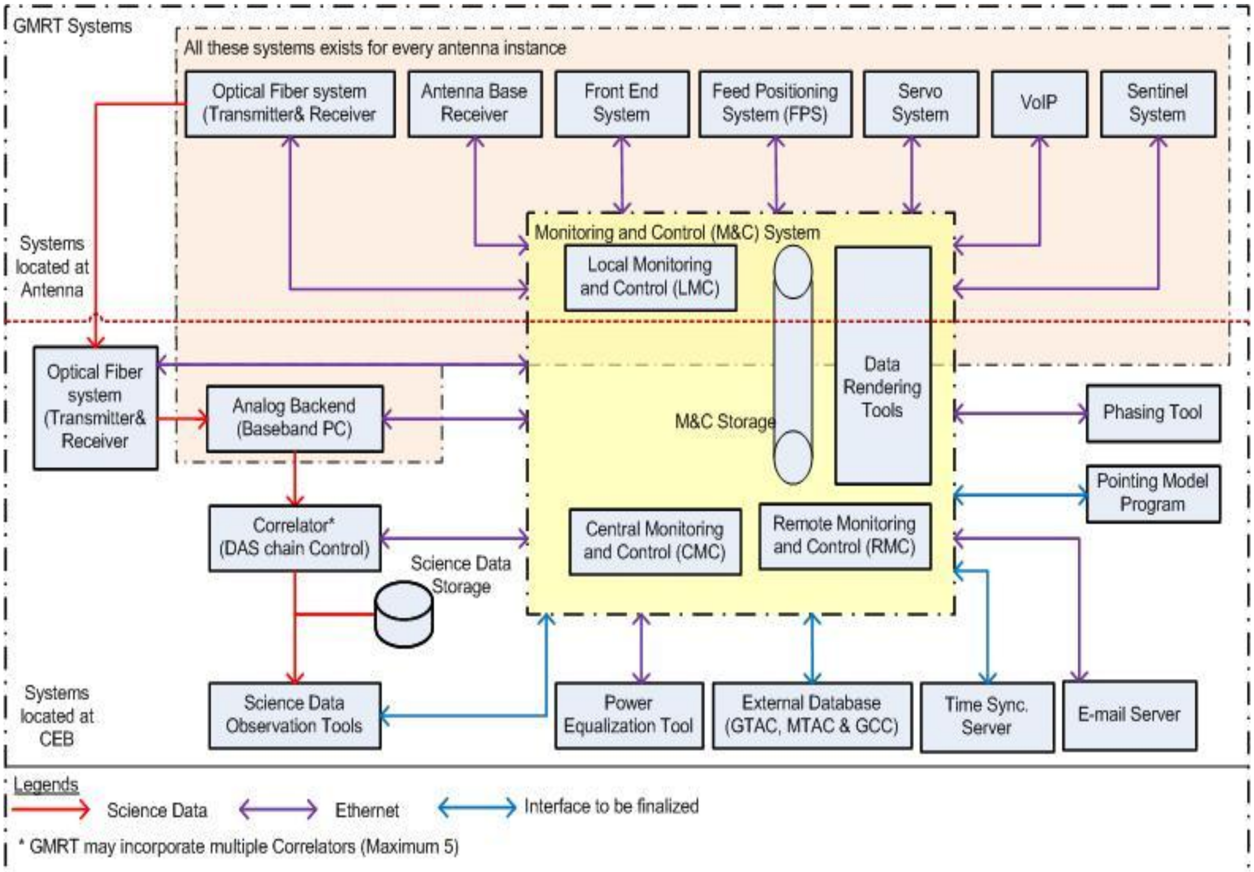

Figure 5: External Interfaces of M&C[2]

M&C shall comprise Central Monitoring and Control (CMC), Remote Monitoring and Control (RMC), Local Monitoring Control (LMC), data rendering tools and data storage. CMC is the main component of M&C accessible from the Central Electronics Building (CEB). The RMC is typically used by other stakeholders such as engineers or the Operations group for testing, maintenance and administration purposes within the GMRT network. The Local Monitoring and Control is at each Antenna Base, which helps in local control and monitoring activities. In addition, there is a possibility of extending RMC to a remote network (Internet) for astronomers to enable remote observations; this is not shown in the ***Figure 5***. The details of all interfacing subsystems, type of interface, purpose and data being exchanged between these subsystems and M&C are provided in ***Table 6.***

1. [2] *The FPS and Servo systems are the part of control systems of GMRT, but for the clear understanding of the scope of proposed M&C they are shown as external systems to M&C.*

2. *The network landscape, depicting how these systems are connected needs to be finalised before design phase.*

Table 6: Data Exchanged between M&C and External Subsystems

Sr No	Subsystem	Type of Interface		Purpose		Data being exchanged[3]		Remarks
		Existing System	Upgraded System	Existing System	Upgraded System	Existing System	Upgraded System	
1.	Optical Fiber Transmitter System (Transmitter and Receiver)	RS-485 (MCM0)	Ethernet	Optimising the power levels	• Optimising the power levels. • Monitor the LASER diode temperature	Value of attenuation	Values of: Attenuation Read LASER Diode Temperature	NA
2.	Front End System (FE)	RS-485	Ethernet	Select observation frequency and tune receiver	Select observation frequency and tune receiver	Values of: Attenuation, gain, Enable/Disable: Noise/ RF signals, Solar Attenuator Read RF detector count, power supply reference voltages	Values of: Attenuation, gain, Enable/Disable: Noise / RF signals, Solar Attenuator Read RF detector count, power supply reference voltages, temperature or FE and CB, Set RF filter banks.	NA
3.	Antenna Base Receiver	RS-485	NA	Converting the RF to IF	NA	Values of: LO frequencies, IF bandwidth and attenuation Read: VCO monitoring parameters	NA	NA
4.	Feed Positioning System (FPS)	RS-485	Ethernet	Positioning the desired feed for observation	Positioning the desired feed for observation	Commands for positioning the feed.	• Commands for positioning the feed. • Temperature of the motor winding	As a upgrade to GMRT, FPS is being implemented using PC-104
5.	Servo System	RS-422	Ethernet	For moving the antenna in Azimuth and/or Elevations	For moving the antenna in Azimuth and/or Elevations	Commands for rotating the antenna	Commands for rotating the antenna	As a upgrade to GMRT, servo system is being implemented using PC-104
6.	Analog Backend (Baseband PC)	RS-485	Ethernet	Convert IF signals to Baseband signals	Convert RF signals to Baseband signals	Set LO frequency and apply band pass filter	Set LO frequency and apply band pass filter	In Upgrade GMRT system, RF signals from Front End are directly transmitted to CEB. The interface with analog backend is through a baseband PC.
7.	Correlator (DAS chain control)	Ethernet	Ethernet	Setup Correlator, initialize user's project and start/stop data acquisition	• Setup Correlator, initialize user's project and start/stop data acquisition. • Read diagnostic information from Correlator	ADC Gain, convey the Correlator Setup mode (Continuum/ pulsar and so on.) commands for data acquisition start/stop,	ADC Gain, convey the Correlator Setup mode (Continuum/pulsar and so on.) commands for data acquisition start/stop, Monitor Correlator room temperature	There is possibility of interfacing with multiple Correlators. This is also called as digital backend. The interface with correlator is through a DAS chain control PC.
8.	Science Data Observation Tools	NA	To Be Determined (TBD)	NA	Flagging of the data, in case of failures/ alarms/ warnings and so on.	NA	TBD	NA
9.	Power Equalisation Tool	NA	Ethernet	To derive the appropriate attenuation, gain values for various subsystems, so as to achieve the	To derive the appropriate attenuation, gain values for various subsystems, so as to achieve the optimum	Values of Bandwidth, reference power level, observing frequency, number of antennas/sub arrays,	Values of Bandwidth, reference power level, observing frequency, number of antennas/sub	Presently the data is being exchanged using flat file.

[3].The detailed list of I/O parameters will be worked out in following phase of the project.

Sr No	Subsystem	Type of Interface		Purpose		Data being exchanged[3]		Remarks
		Existing System	Upgraded System	Existing System	Upgraded System	Existing System	Upgraded System	
				optimum output power levels at that subsystem.	output power levels at that subsystem.	number of iterations for performing power equalisation	arrays, number of iterations for performing power equalisation	
10.	External databases (GMRT Time Allocation Committee (GTAC)/ Maintenance Time Allocation Committee (MTAC)/GCC)	NA	TBD[4]	NA	Retrieve the details from database for triggering the automatic observations, logging the fault sheet details and so on.	NA	TBD	Presently the data is being exchanged using flat file.
11.	Sentinel System	RS-485	Ethernet	Monitor the temperature and smoke detector	Monitor the temperature ,smoke detector and Intruder alarm	Monitor the temperature, smoke detector and Intruder alarm; based on this parameter takes safety actions.	Monitor the temperature, smoke detector and Intruder alarm; based on this parameter takes safety actions.	NA
12.	VoIP	NA	Ethernet	NA	Monitor the status parameter of VoIP system	NA	Monitor the status parameter of VoIP system	NA
13.	E-mail Server	NA	Ethernet	NA	• For sending the e-mail alerts/ reminders/ status reports, observation reports and so on. • Administrator uses this to share the password/ user name with new users	NA	TBD	NA
14.	Time Sync. Server	Ethernet	TBD	To synchronise the timings of various GMRT subsystems, ONLINE and ABC	To synchronise the timings of various GMRT subsystems and M&C system.	Timestamp	Timestamp	NA
15.	Phasing Tool	Ethernet	Ethernet	To compensate the residual phase errors so that, signals from all the antennas can be added coherently in GMRT Array Combiner (GAC) during PA mode.	To compensate the residual phase errors so that, signals from all the antennas can be added coherently in GAC during PA mode.	Antennas selected for phasing, phasing iterations, subarray number and RF frequency	Antennas selected for phasing, phasing iterations, subarray number and RF frequency	NA
16.	Pointing Model Program	Manual	TBD	To correct the fine antenna offsets for Azimuth and Elevation axis during observation	To correct the fine antenna offsets for Azimuth and Elevation axis during observation	Pointing model program reads the coarse antenna offsets stored in database and observing source position to calculate the resultant antenna offsets. M&C reads the resultant antenna offsets for a	Pointing model program reads the coarse antenna offsets stored in database and observing source position to calculate the resultant antenna offsets. M&C reads the resultant	NA

[4] TDB: Details to be provided by NCRA

Sr No	Subsystem	Type of Interface		Purpose		Data being exchanged[3]		Remarks
		Existing System	Upgraded System	Existing System	Upgraded System	Existing System	Upgraded System	
						given antenna/ subarray	antenna offsets for a given antenna/ subarray	

1.7. GMRT Observation Modes

Different observation modes are supported by the GMRT. These modes help to study the specific radio astrophysical problem or science objective. The existing M&C aids in monitoring and control of the system operations in these usage modes and helps astronomers study the science objective. Based on science objectives, the GMRT usage modes or observation types can be broadly categorised as follows:

- Continuum observation: For imaging the radio sources such as galactic Supernova, extra galactic sources such as normal and giant radio galaxies, galaxy clusters and so on.
- Spectral-line observation: Detection of highly red-shifted Neutral atomic Hydrogen- HI line from Protoclusters or Protogalaxies, Deuterium lines, CO, OH lines from the molecular gas and so on.
- Pulsar Observation Mode: To search and study the pulsars. Pulsars are rapidly rotating neutron stars with extremely high densities.
- Sun/Planetary Observation Mode: For studying the solar and planetary emissions. This is a non-standard observation, because the target's coordinates are changing in the sky while the observation is in progress.
- Survey mode: Survey mode is used to search the new celestial sources.
- High-time Resolution Mode: To study the solar flare, extra solar planets, pulsar imaging (gating).
- Raw Voltage Mode: To acquire raw data voltages for offline processing of the data.

In all types of observations mentioned above, M&C system has to validate the observation-setup and observation execution plan as briefed below:

- Verify the GMRT specifications to choose the appropriate frequency, primary and synthesised beam sizes available for the given observing frequency.
- Verify the antenna availability to carry out particular type of observation. For example, in imaging observation, central square antennas as well as distant antennas in Y-arms are essential. In pulsar observation, Central Square and nearby antennas are useful.
- Select the desired observing frequency feed into focus.
- Determine rise and set timings for the target and calibrator sources under observing plan. Prepare the source catalogue in the M&C readable format.
- Select the observing frequency parameters, that is, tune the receiver of the GMRT antennas to get the desired RF-band of interest, mention the total band-width for the observation.
- Prepare and validate the observing plan. Observing the plan can be implemented using the batch kind of facility, where the astronomer/user mentions the catalogue name of the target and calibrator sources, source name, time intervals for acquiring the data on

source, start and stop data acquisition, number of iterations to repeat the observation process and so on.

- Trigger the observation and receiver setup.
- Configure the digital back-end and its required sub-units. The settings/configuration of digital backend mainly driven by the usage mode of the telescope.
- User start the observation and monitor the observation progress and may alter the observation plan depending on the various circumstances such as antenna availability and environmental conditions such as RFI, high wind, electrical power problem and so on .
- Load the basic antenna pointing offsets and antenna pointing corrections given by the pointing model before each observing data acquisition scan starts.
- At the end of observation, user collects the astronomical data and meta-information such as observation log, malfunctioning system logs to flag the bad data and so on.

The sub-sequent sections of this chapter brief about the usage/observation mode and addresses the specific requirements for each type of observation.

1.7.1. Continuum Observation

Continuum observation mode is mainly used for imaging purpose and an interferometer records the mutual coherence function also called the visibility of the signals from the sky. The visibility is the Fourier transform of the sky brightness distribution. As the radio spectrum of celestial sources for continuum observations do not vary over the time, the use of earth rotation is used to get a maximum number of Fourier components of the source brightness distribution over the required period to get a better sampling, so that an image of good quality can be produced by Fourier inversion of the visibilities. This is known as the earth rotation aperture synthesis. The image obtained by the Fourier inversion has the spatial resolution, which varies inversely with the maximum baseline length for the measured visibility. Using the arc-second resolution from the long arms baseline and adequate sensitivity to diffuse emission received in broader-beams by the closely spaced central square antennas baselines can construct a radio image of targeted celestial source.

To measure and remove the effects of the ionosphere gain fluctuations, which vary slowly over the time scales of hours to short scale rapid variations of a few minutes, and to make the corrections for the slowly varying instrumental gains during the observing time, periodic observation on strong unresolved calibrator source (known as phase calibrator) is required. The correction determined on the phase calibrator is applied to the target source. Also, the frequency-dependent antenna based on complex gains vary over the pass band mainly due to the filter shapes and residual fixed delay errors. These variations change with time, but much more slowly than the temporal gain-phase changes due to the atmosphere/ionosphere. Therefore, it is necessary to correct these variations before averaging the visibilities from individual channels to form a continuum database. Generally, a strong point source having a flat continuum spectrum is used to determine the band pass response function, known as a band pass calibrator. To scale the flux-densities measured on the target source, a known flux-density calibrator is used as a reference source during the beginning or at the end of observation.

Hence, the Continuum observation comprises the following important parameters and procedure:

- The image sensitivity (Signal to Noise ratio) increases with the total observing band-width, total time on target source and number of baselines, that is, arm and central square antennas with larger observing band-width is essential.
- The usual observation procedure is as follows:
  - Observe flux-calibrator/band-pass calibrator.
  - Observe phase calibrator for certain duration (typically ~10 minutes).
  - Observe the target source for longer duration (~30 minutes to 40 minutes) or for the duration specified by the user.
  - Continuously loop the observation of phase calibrator and the target source.
  - Observe flux-calibrator and band pass calibrator at the end.

Note: In continuum observation, as per the science goals like imaging wide field, studying astronomical signal variability, sun imaging M&C requires procedural changes like observing multiple fields in cycle or configuring digital backend in high resolution mode.

1.7.2. Spectral-line observation

Spectral-line observation is used in various circumstances such as observing the neutral hydrogen (HI) line in emission or absorption to detect hydrogen gas in our galaxy and in external galaxies, to know the streaming motions of the nearby galaxies. Also, to detect Deuterium, CO and OH lines from the molecular gas and the study of the hydrogen recombination lines in the interstellar medium. One of the prime goals of GMRT is to detect the highly redshirted spectral line of neutral hydrogen expected from Protoclusters or Protogalaxies before they condensed to form galaxies in the early phase of the universe.

If the rest frequency of target source line is known, the apparent frequency (observing frequency) can be calculated which depends upon the relative velocity between the observer and source. The red-shift for far Universe source is used to know the observing frequency.

In the spectral-line, temporal gain/amplitude and the phase calibration is similar to that of the continuum observation. However, it is essential that for the band-pass calibrator, the calibrator should not have any spectral features in the observing band of interest. There are two methods of band-pass calibration:

- Position Switching - The observation of band shape calibrator and the target source at the same frequency and bandwidth is done in iteration. Depending on the accuracy to which the corrected band shape is required, the band-pass calibrator is observed for every few minutes up to few hours after observing the target source all iterations.
- Frequency Switching - Frequency switching calibration method is required in two cases:
  - When the position switching is not desirable as the band-pass calibrator is far from the target source.

- The band of interest covers the Galactic HI. In this situation, all calibrators will also have some spectral feature within this band due to the ubiquitous presence of Galactic HI, that is, no calibrator is suitable for band shape calibration. In both the cases, a nearby band-pass calibrator is observed by slightly shifting the observing frequency to get the line-free region in the RF band.

For spectral-line observations, following parameters are considered:

- The desired observing band-width is narrow enough to get at least two-three spectral channels across observing/expected line width.
- The accuracy of apparent/observing line frequency is essential. Hence, the selection of local oscillator and down-conversion LOs used to get the final band at the digital back-end shall not miss the spectral-line, which is expected at the certain frequency.

Observing procedure is much similar to that of the standard continuum observation procedure. In frequency switching calibration, LO settings are often changed.

1.7.3. Pulsar observation

Pulsar is a very highly magnetised rotating neutron star, which emits pulses with a very high precision period. Since the radio emission from the pulsar is weak, a beam forming technique is used to improve the signal to noise ratio. In incoherent (IA) beam former, the total power of individual antennas is combined to give a single incoherent beam. As the total power is combined, phase information is lost. The IA beam improves the sensitivity by sqrt (N), where N is the number of antenna and beam-width is equivalent to a single antenna. In Coherent/Phased Array (PA) beam former, voltage signals from the N antennas are combined to give the single coherent beam where sensitivity improves by N times and the resultant beam is narrower than the single antenna. The resultant beam-width is inversely proportional to the largest spacing between antennas in array. In phased array, a full-stokes information can be constructed. IA beam is applicable during the pulsar surveys and PA beam is used to study the known pulsars by acquiring the full polarisation information on it.

For estimating the pulsar flux, either calibrated noise sources are injected in the signal path or known calibration source is observed.

During the pulsar observations, the following parameters are important:

- Higher time resolution for the data acquisition is required as pulsar period is very small (few second to msec).
- Higher spectral channel resolution is preferred to avoid the smearing of the pulses due to the differential dispersion delay of frequencies across the band as the pulse signal propagate through the interstellar medium.
- For estimating the spectral index, a multiple group of antennas are used to observe pulsar at different observing bands simultaneously, whereas in case of pulsar search multiple group of antennas can be used at the same observing frequency.
- The GMRT Array combiner is used to select the individual antennas polarisation (single or both) for power and/or voltage addition.

- Pulsar IA or PA backend configuration is set for:
  - Input data and output data acquisition band-width
  - A number of spectral channels, number of channels for averaging and sampler window
  - Pre (basic) and post integration
  - Bit packing and so on

Observation procedure: In pulsar observation, automatic gain controllers are switched off. Apart from this, pulsar mode has following special requirements:

- Power of all antennas should be equalised to optimal range.
- In case of Phase array, the entire antenna grouped under one sub-array will be phased. This requires the digital backend interferometry mode must be on and running (that is, delay and fringe corrections are happening with respect to the target pulsar).
- Pulsars data is acquired after the power equalising and phasing (if necessary in case of PA).
- Scale of the flux of pulsar Noise calibrator on-off and known-flux calibrator is observed.
- IA and PA bin should be configurable independently, with common or different antennas.

1.7.4. The SUN and Planetary Source Observations

The SUN and planetary observation aimed for imaging is the same as that of the continuum observation mode. However, the telescope tracking in case of the SUN and planetary observation differs because unlike the other celestial sources, the Right Ascension (RA) and Declination (DEC) for SUN and planetary sources vary over the time of a given day. The factor for changes in RA-DEC and the rate of change of RA-DEC has to be taken into account while providing the track command for the GMRT antennas. Sometimes, to study astronomical signal variability like the Jupiter pulsations rate study, it is desirable to use IA/PA beam former backend.

The main aspects for the SUN and Planetary observations are:

- The SUN/planetary source's Right Ascension (RA) and Declination (DEC) must be updated after specific interval (For example, 15 minutes to 30 minutes).
- The rate of change of RA and DEC has to be taken into account while issuing the track command to the GMRT antennas. (User will only provide the rate of change of RA and DEC as inputs.)
- Whenever the telescope goes on to the SUN, a required solar-attenuator (14 dB or 30 dB) in the Common Box has to be set to avoid the saturation of the radio-telescope. While going to the calibrator source, the solar-attenuation has to be removed.

1.7.5. Survey Mode

Survey observations are driven by different kinds of science objectives. For example continuum all sky survey (TIFR-GMRT Sky Survey) to detect the new sources and observe the existing sources at lower frequencies which is still un-explored, the surveys to detect new pulsars, surveys of galactic plane or particular patch of the sky to detect the ionised hydrogen associated with the new stars, non-thermal emissions from supernovae, supernovae search in external galaxies, the HI survey of various nearby galaxies (metal poor galaxies and spiral galaxies) and the surveys of halos in edge-on galaxies and cluster galaxies.

All kind of survey observation includes the basic modes of observation being facilitated in the GMRT; however, the survey observation needs to be catered by following aspects:

- Largely survey observations are executed in auto mode. This require book keeping of number of catalogue, sources information and observing plans.
- While observing in survey mode, special requirement may arise such as grouping of antennas under different sub-array at the same or different observing frequency. Antennas may see different directions hence special commands like slewing across the sky may need to be implemented using the procedure/batch kind of methods.
- Since the number of sources to be observed during the allotted time is large, while accepting the observing plan sources which may not be available (source set below the horizon) during the observing time shall be omitted by giving warning message to the user. The auto start of the data acquisition by waiting for some sources which is about to rise above the horizon in a one or two minute.
- In survey observation, the antennas are positioned at a specific location of the sky and astronomical data is acquired while the sky is drifting. This is required, in case of transit observation, where the digital back end updates the fringe rate for the given hour angle with respect to specific location/ target.
- Dynamic scheduling of the auto-execution is required as some times it is need to skip a few sources during the observing run.
- Meta information such as RFI status, malfunctioning of the telescope systems plays important role in discarding the bad data in the survey observation.
- Similarly, observation logs associated with the survey observation plays important role while analysing the survey data.

1.7.6. High Time Resolution Mode

High time resolution mode of the observation is used to carry out specific observations such as observing the solar flares, supernova explosions, extra solar planets and the pulsar imaging. High time resolution mode has the following important requirements:

- The high-time resolution mode acquires the interferometric data with the higher data acquisition rates (~ a few milliseconds to hundreds of millisecond). Hence, such observation demands large data sizes; one can opt to reduce the data size by recording a few spectral channels from the digital backend.

- The start data acquisition or stop data acquisition commands need to be aligned with the time precisely.
- High time resolution mode need to be supported by enabling the special modes in the digital back-end which demands the control of multiple data acquisition system chain.

1.7.7. Raw Voltage Mode

Sometimes, it is desirable to record the raw voltage signals received by all antennas. The raw dumps voltages are acquired by the ADCs are sent directly to the recording nodes and processed offline at later stage. Raw voltage mode required meta-information keeping such as source and observing frequency information, which can be used while offline processing of the raw data.

Raw voltage mode requirements are:

- The digital backend needs to be configured in raw voltage mode for deciding the data acquisition band-width, time-sampling and number spectral channels.
- The data acquisition flow needs to be control by the M&C system.
- For each raw record, Meta information such as target observing source information and the observing frequency and LOs used for down-conversion and time-stamp for data acquisition is required.

1.8. User Categories

The different categories of user that are envisaged to use the M&C system are listed in ***Table 7.***

Table 7: User Categories of M&C

Sr No	User Category	General Characteristics	Effect/ Impact on the System/ Solution
1.	Telescope Operator	• Exhibits fair technical skills • Works in Shift	Most of the Telescope operations are executed by the Telescope Operators. Hence, they are the major end users of M&C system.
2.	Engineers	• Highly technical • Responsible for troubleshooting/ Maintenance/ testing/ enhancement of the various subsystems of GMRT	Uses M&C for testing / maintaining / troubleshooting the various subsystems of GMRT
3.	Operations/ Administrator	• Highly technical • In-house OEMs for GMRT	They are the administrators of the M&C system.
4.	GMRT Co-ordination Committee	• Exhibits the managerial skills • Co-ordinates between various	Uses the system for monitoring the overall status of the GMRT and governs the GMRT usage

Sr No	User Category	General Characteristics	Effect/ Impact on the System/ Solution
	(GCC)	departments of GMRT	policies.
5.	Astronomer	• End users of the GMRT • Scientific research is the prime focus • Least interested in performing the low level control activities	The high usage of the GMRT facility is dependent on the availability of the M&C system. This in turn determines the score card of the GMRT at international level.

1.9. Objectives of the Stakeholders

The stakeholders and their objectives in implementing the M&C system are listed in the following table:

Table 8: Objectives of the Stakeholders

Sr No	Stakeholder	Objective
1.	Senior Management	• Reduce the operational cost of the GMRT. • Leverage the cutting edge technology solutions to create the GMRT as a unique and best in class, highly stable facility of international reputation. • To gain maximum know-how from this implementation and use it to benefit in SKA design and implementation.
2.	Astronomer	• Improve the quality of the science data being collected during observations. • Achieve accurate analysis and results from the science data. • Reduce the dependency on control room operators. • Reduce the human errors which may arise due to communication/ interpretation of the information and so on.
3.	GMRT Co-ordination Committee (GCC)	• Ensure the highest availability of the GMRT facility for observations. • Reduce the downtime of the observatory, by using M&C to determine the point of failure
4.	Operations/ Administrator	• To make the system operations safe. • Cater for scalability needs of the GMRT facility. • Reduce the downtime of the system, with advanced diagnostic facilities. • Reduce chance of errors due to human error.

Sr No	Stakeholder	Objective
5.	Engineer	• Reduce the downtime of the system/ subsystem with improved maintenance support functionalities in M&C.
6.	Operators	• Increase the productivity. • Automate the manual tasks.

1.10. Assumptions and Dependencies

This section provides the broad assumptions and dependencies of the M&C requirements. Refer section ***2.3*** for the dependencies and assumptions of individual requirements in the embedded spreadsheet.

TCS has assumed the following points while laying down the requirements of M&C system:

- The requirements in this document supersede the requirements shared by NCRA with TCS through documents/MoM/discussions and so on before the creation of this document.
- NCRA shall provide further necessary inputs pertaining to the areas of domain, technical and business and so on, so as to develop the detailed Software and Hardware Requirements of M&C system-based on the requirements mentioned in this document.
- All the external interfacing systems of M&C shall be made available by NCRA during the entire implementation period of M&C. Should any modification is required to interface external subsystems with M&C, NCRA will own it.
- The SRS and HRS document shall be derived from the contents of the URS contents (all chapters including Background to Appendix. Also includes the all fields of Use cases such as summary, pre-conditions, post conditions, process rules, data validation rule and so on.), the functional and non functional system requirements mentioned in embedded system requirements spreadsheet under section ***2.3*** of this document.

Following dependencies are identified, while laying down the requirements of the M&C system:

- The software of M&C system shall be implemented to help to comply with the reliability, availability and performance requirements of M&C system; however the overall performance, reliability, accuracy and availability requirements of the M&C system are dependent on the external interfacing tools and systems (subsystems of GMRT).

2. Requirements

The requirements of the M&C system for GMRT are documented in this section. The user-level functional requirements of the system are documented using the use case and activity diagrams. Few are identified by documenting the problems with the existing system and special scenarios that system needs to handle while in operation, maintenance and enhancement/configuration. The system-level functional and non functional requirements are captured under ***System Requirements*** section.

2.1. Use Cases

The functional requirements M&C from the perspective of various stakeholders of GMRT are depicted using the separate use case diagrams in this section, followed by the detailed description of each of the use cases.

Note: Activities coloured in yellow have associated use cases written for it.

The use case diagram for Operator is depicted in ***Figure 6.***

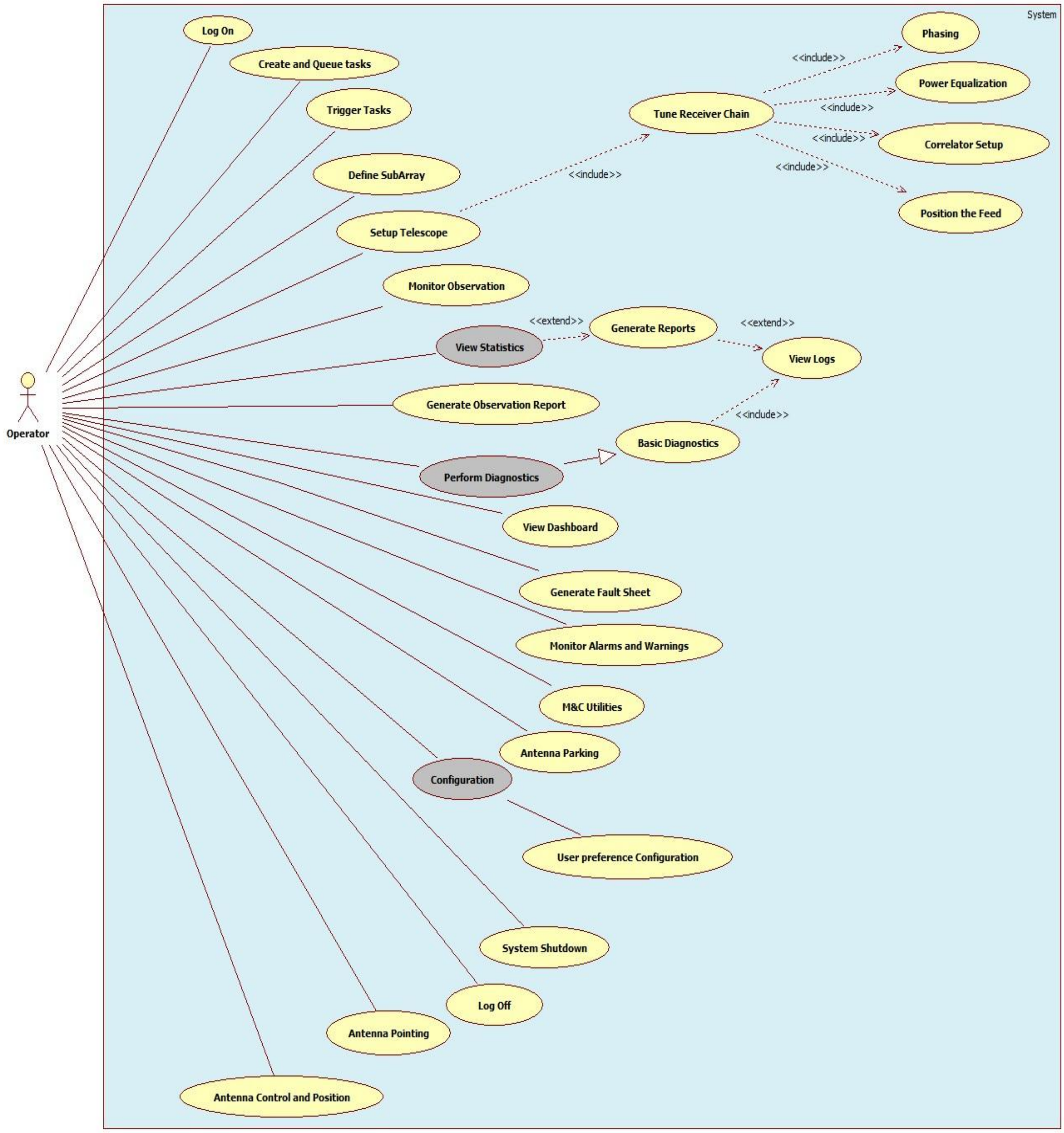

Figure 6: Use Case Diagram for Operator

The use case diagram for Engineer is depicted in

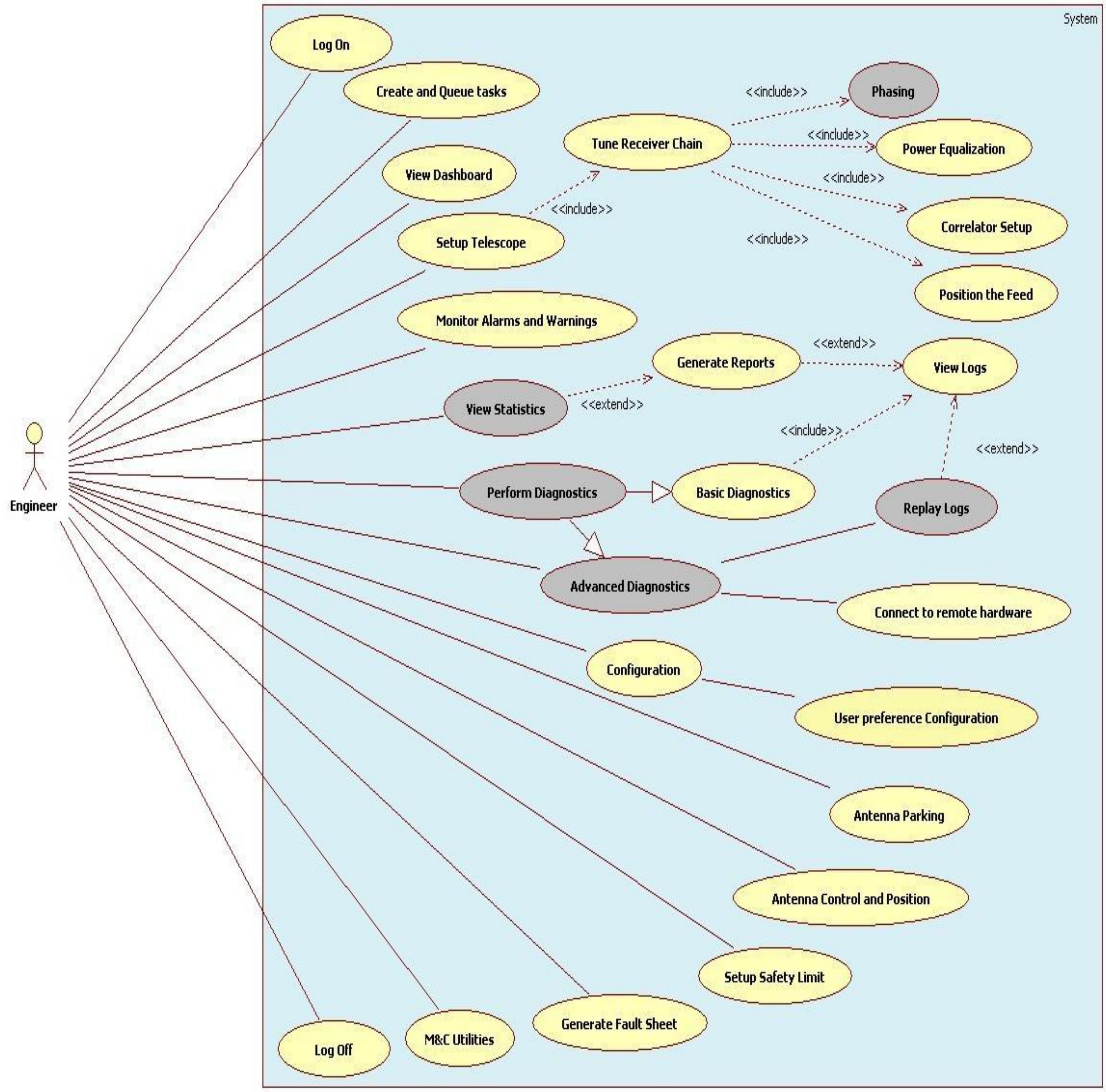

Figure 7: Use Case Diagram for Engineer

.

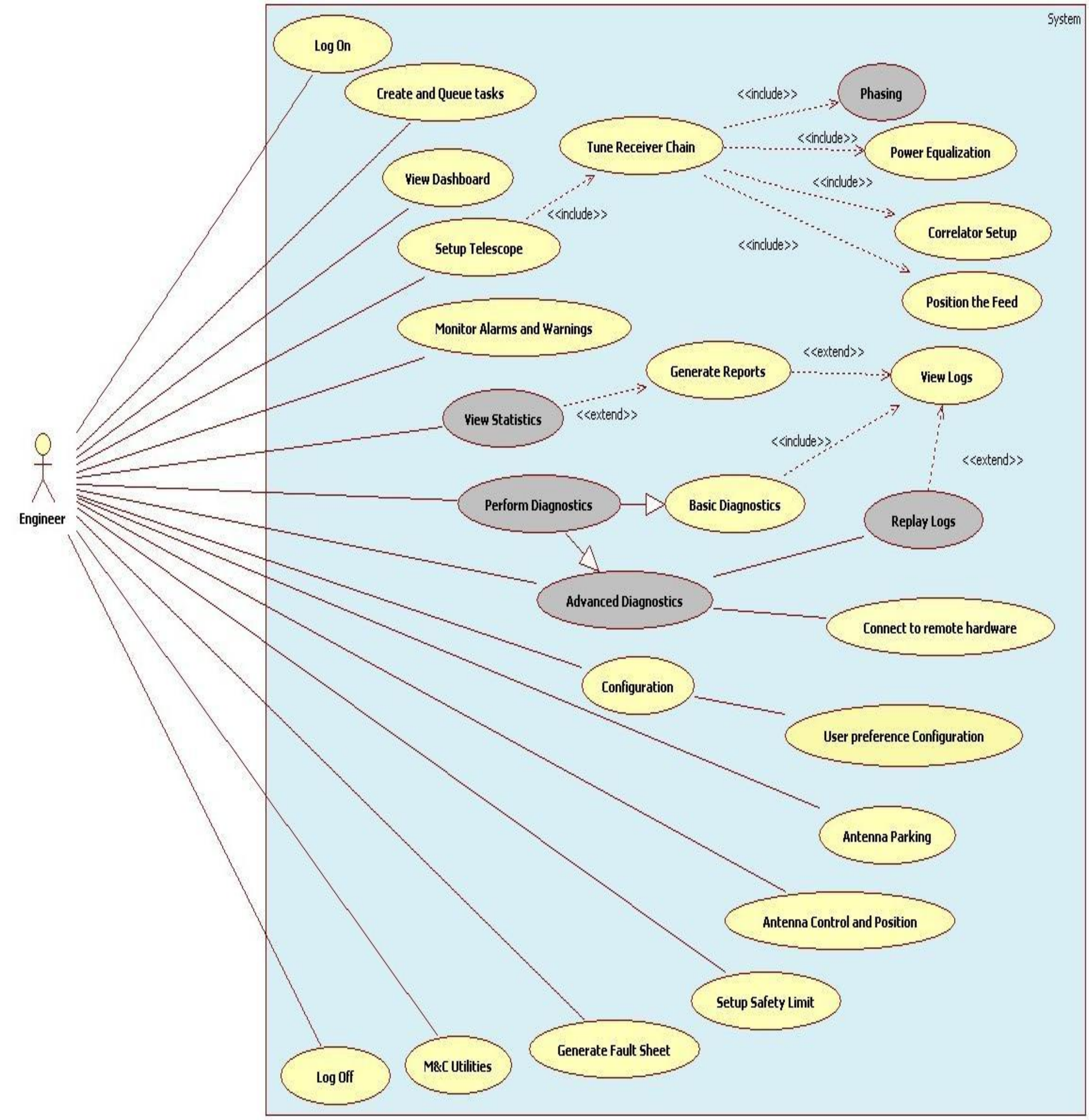

Figure 7: Use Case Diagram for Engineer

The use case diagram for Operations group/ Administrator is depicted in ***Figure 8 .***

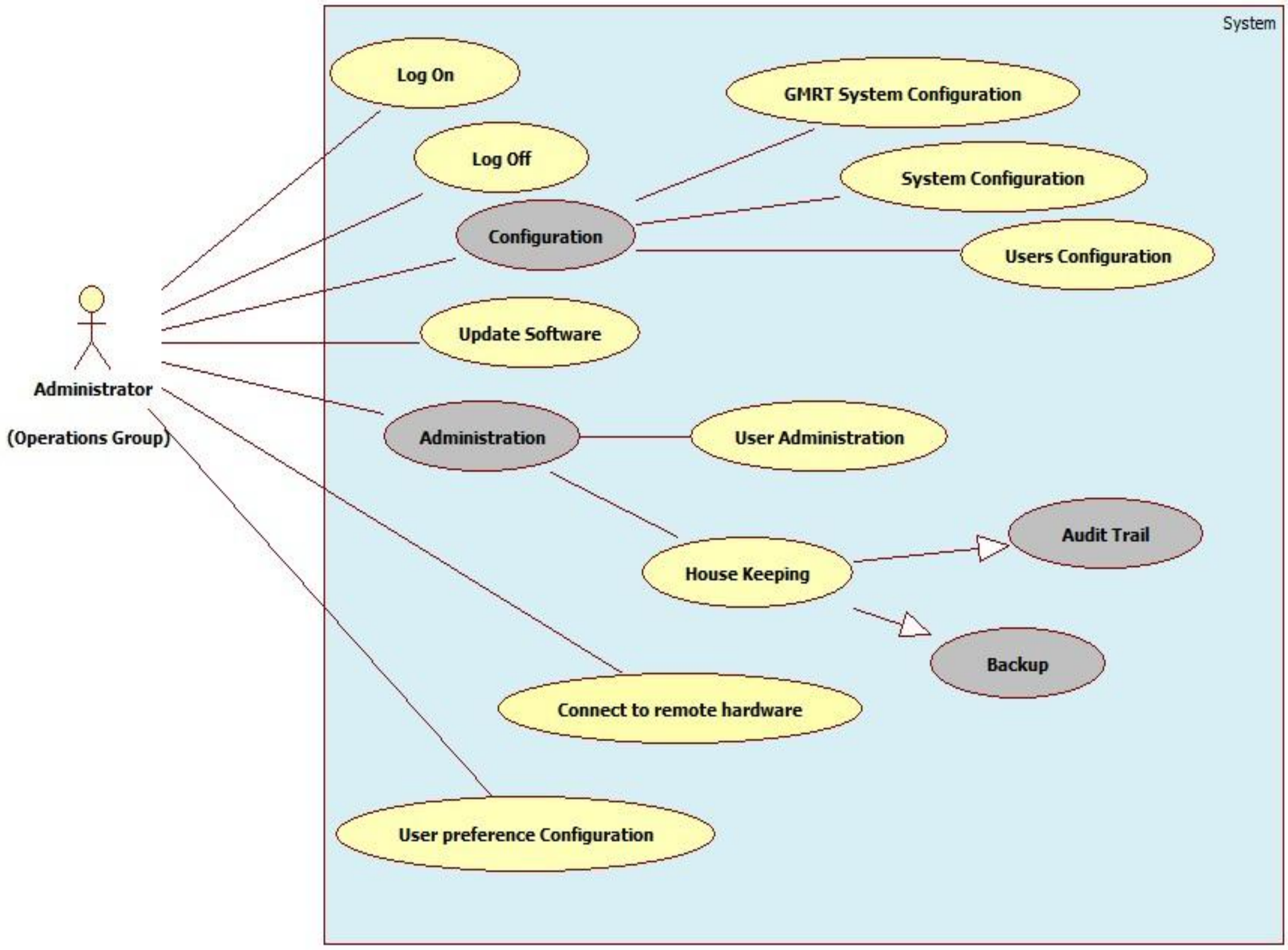

Figure 8: Use Case Diagram for Operations/ Administrator

The use case diagram for GCC is depicted in ***Figure 9***.

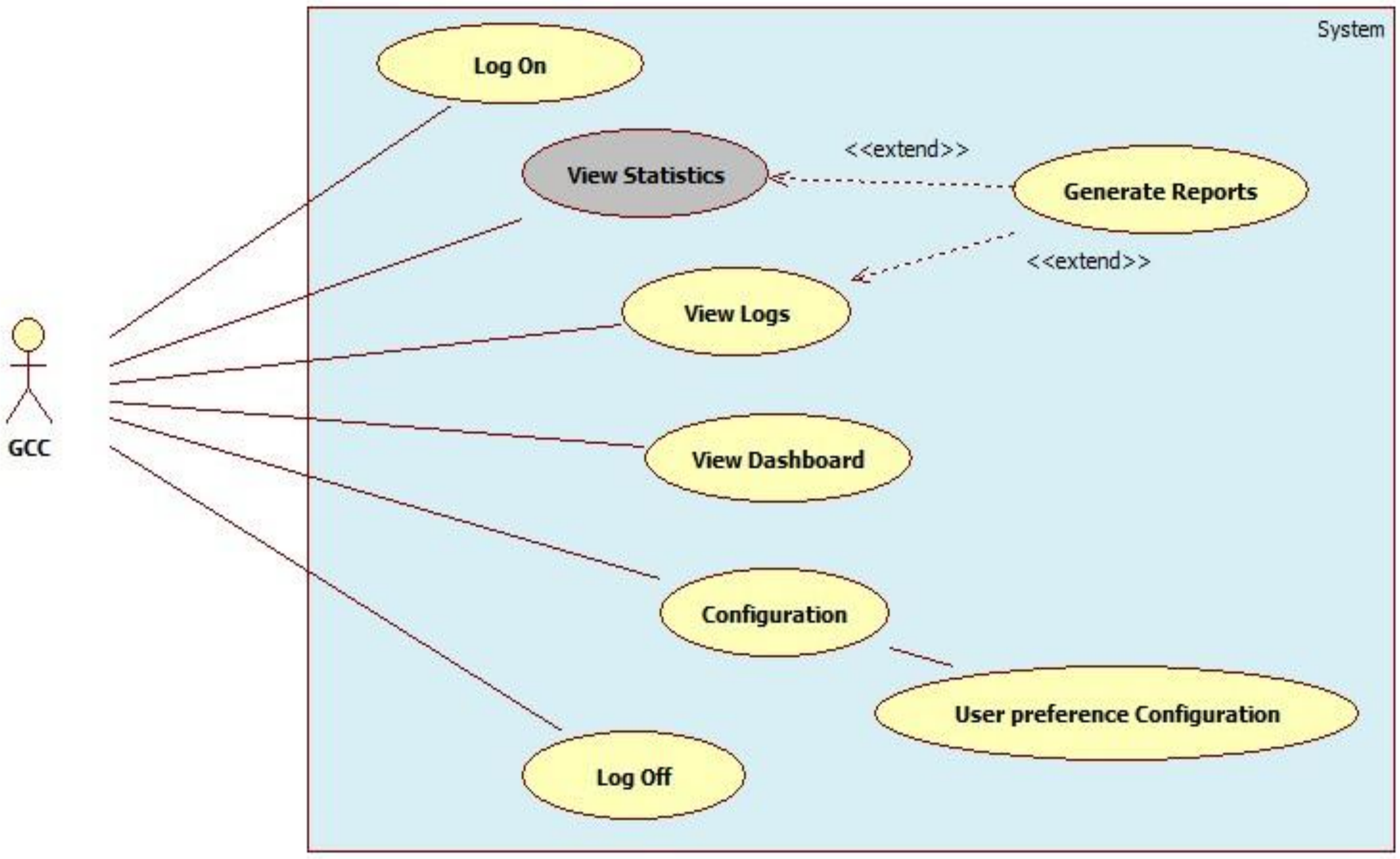

Figure 9: Use Case Diagram for GCC

The use case diagram for Astronomer is depicted in ***Figure 10*** .

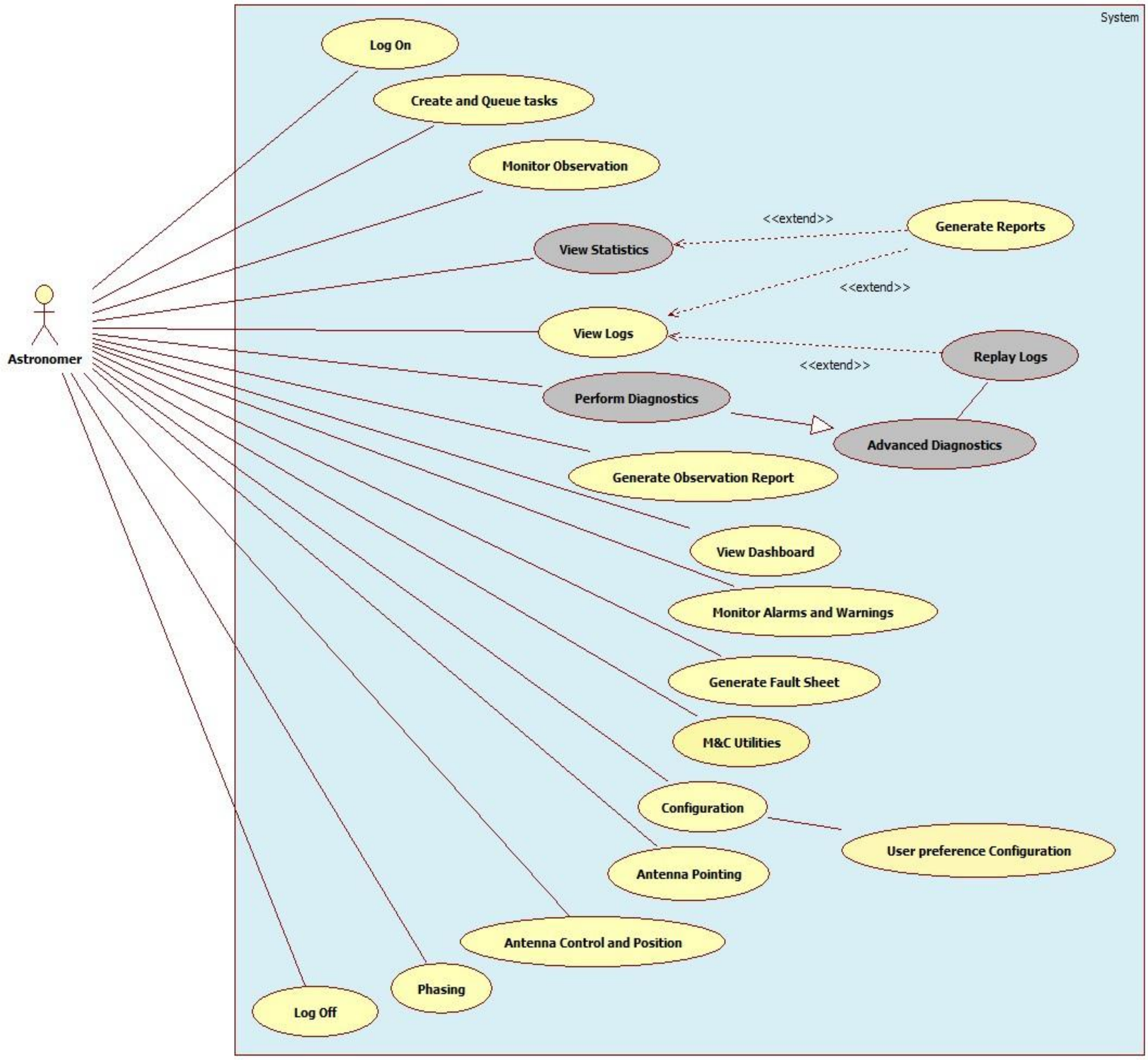

Figure 10: Use Case Diagram for Astronomer

Additionally, the activities that are automatically performed by the system are identified with M&C system itself as an actor and depicted in ***Figure 11***.

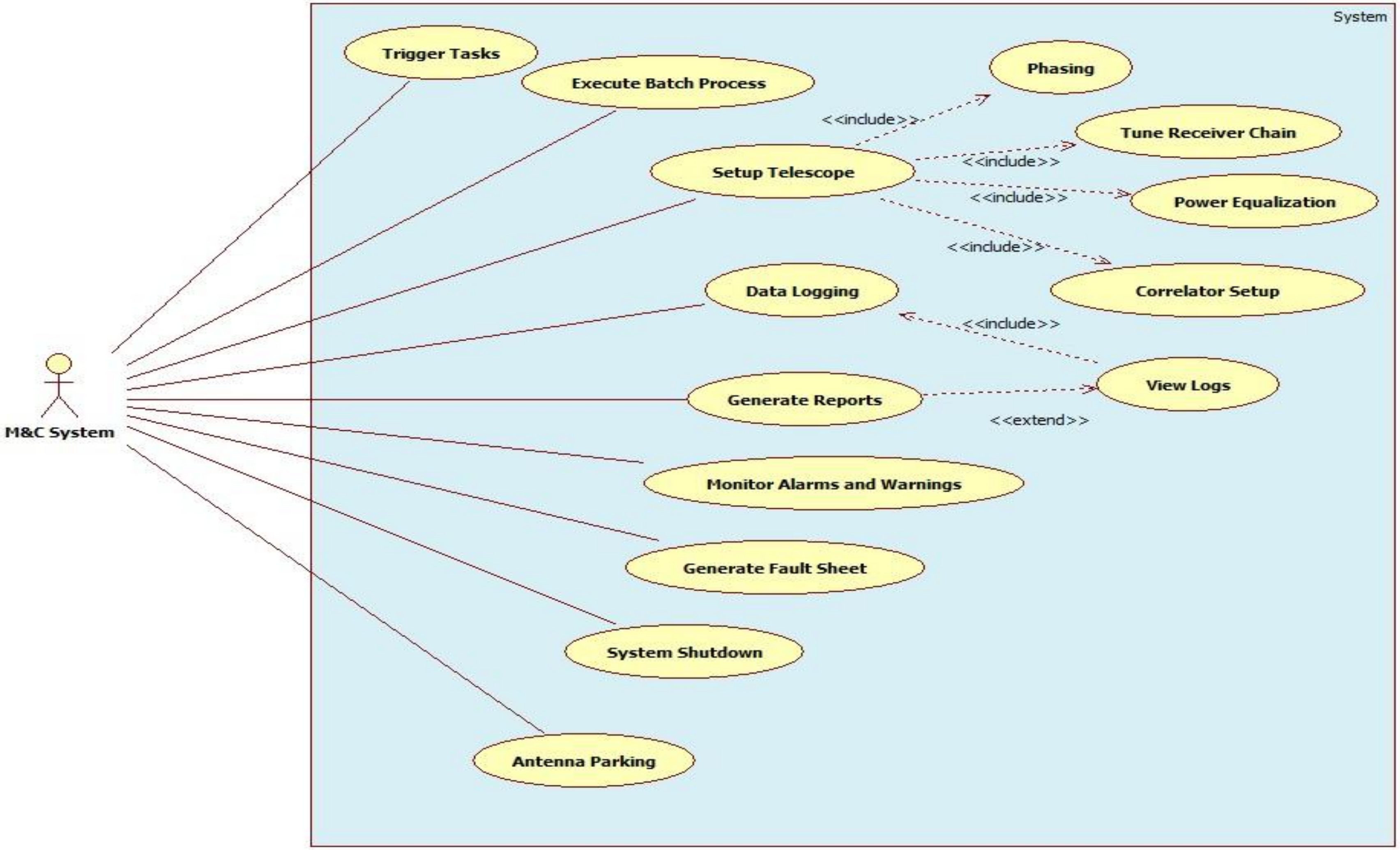

Figure 11: Use Case Diagram for M&C system

The use cases are described in the subsequent sections.

Note: It is highly recommended that the user refers section ***A.6*** of **Appendix,** to get acquainted with the use case fields and conventions used in the use case tables.

2.1.1. Log on

Table 9: Use Case for Log on

Use Case: Log on		
Use Case ID		M&C_UC_001
Goal		To log on to the GMRT M&C system.
Summary		All user interactions with the GMRT system requires user authentication. This is to ensure safety, accountability and relevance of M&C operations to the users. This use case begins when user desires to login to GMRT M&C system or its components. Users provide their login credentials to the system, which validates and authenticates the users. Authentication of users is governed by a configurable authentication policy for the M&C system which defines how users are authenticated, protocol to be used, database for users, encryption methods and rules for authentication fields (username, password).
Actors		All users
Priority		1
Status		Accepted
Preconditions		• M&C is up and running. • User is not authenticated. • Authentication User Interface is selected.
Trigger		On Demand
Assumptions		NA
Use Case Flows		
Basic Flow		Successful Authentication.
1.	User	User enters authentication credentials.
2.	M&C	Reads these inputs and validates them against its database in configuration.
3.	M&C	Loads the user interface on successful validation.
		Exit use case.

Use Case: Log on		
Alternate Flow 1		Failed Authentication without User Lockout.
2	M&C	Reads these inputs and validates them against its database in configuration.
2_1	M&C	Identifies that validation failed and notifies user.
2_2	M&C	Verifies User lockout condition as per defined authentication policy.
		Continue to Step***1***.
Alternate Flow 2		Failed Authentication with User Lockout.
2_2	M&C	Verifies User lockout condition as per defined authentication policy.
2_2_1	M&C	Identifies that User Lockout condition has been reached.
2_2_2	M&C	Notifies User.
		Exit use case.
Stakeholders		
Stakeholder		All Users of the GMRT M&C System.
Interest		Log on to GMRT M&C System.
Post Conditions		
On Success		Users can successfully log on to GMRT M&C System.
On Failure		Users will be unable to authenticate and not use M&C functionalities.
Process Rules		
Sr No	Process Rule	

Use Case: Log on		
1.	Authentication needs to be governed by system authentication policy which shall define the following: • Authentication type (For example- BASIC, LDAP). • Authentication protocol (For example- MD5, CRYPT). • Authentication database or server information. • Policy for Authentication fields (For example- Username policy, Password Policy, PIN policy). • User Lockout policy. • Change password policy (For example Frequency of change, forgot password). • Single Sign On – Single Sign OFF (SSO) rules. • Single Session/Multiple Session rules. • LOGIN/LOGOUT Conditions (For example Astronomer User cannot login while in Maintenance). • Breach policy. • Session handling rules. • Settings for Proceed Action (For example- Proceed Action defines what actions to perform, and what is the destination user interface on authentication).	
2.	User Interface for authentication should be compliant authentication policy as governed by UI Design.	
3.	Authenticated user (Administrator) may configure Authentication policy.	
4.	User needs to be notified of successful or failed authentication. Notifications methods are governed by UI design.	
5.	Whenever data is not available or authentication is not possible (due to connectivity problems), user must be notified.	
6.	System shall maintain authentication logs for audit trail.	
Additional Data Validation Rules		
Sr No	Validation Rule	
1.	NA	
Working Details		
Sr No	Issues for Resolution	Status

Use Case: Log on		
1.	Authentication policy as described above needs to be finalized.	Open

2.1.2. Create and Queue Tasks

Table 10: Use Case for Create and Queue Tasks

Use Case: Create and Queue Tasks	
Use Case ID	M&C_UC_002
Goal	Facilitate the automation of the existing manual triggering process for observation/Engineering experiment/ test.
Summary	Presently the user of GMRT instructs the Operator over phone/ e-mail to setup and start a given task (Observation/ Engineering experiment/ test). Operator asks for the additional information (if required) through the similar channels to the user. Sometimes this leads to wrong configuration of the telescope due to the misinterpretation of information, oral communication gaps and so on. To minimize such instances, M&C provides a feature to capture all the details pertaining to a given task directly from the users, well ahead of time. M&C also validates these user inputs by interfacing with the GTAC/ MTAC database and its internal database. These captured details are stored as the task requests in the queue of M&C.
Actors	Astronomer, Engineer, Operator
Priority	2
Status	Accepted
Preconditions	M&C is up and running
Trigger	On Demand
Assumptions	The changes in GTAC/ MTAC database may lead to changes in related interface of M&C.
Use Case Flows: This is explained with the help of activity diagram in ***Figure 12.***	
Stakeholders	
Stakeholder	Operator, Engineer and Astronomer.
Interest	To enable the automatic triggering of the observing sessions.
Post Conditions	

Use Case: Create and Queue Tasks	
On Success	M&C queues the Observation request.
On Failure	M&C cannot queue the Observation request.

Process Rules

Sr. No	Process Rule
1.	The tasks in queue can be modified, deleted/cancelled, before they are triggered.
2.	Task will be carried out if GTAC/MTAC ID is valid.
3.	The changes in GTAC/MTAC database need not to reflect automatically in the queued tasks of M&C system.

Additional Data Validation Rules

Sr No	Validation Rule
1.	NA

Working Details

Sr. No	Issues for Resolution	Status
1.	Is it required to extend this M&C functionality over internet/intranet for enabling the remote users to specify the observation details?	Open
2.	Need the details of task that needs to be provided by the user to M&C	Open (Can be finalized in SRS)
3.	How many observation requests should M&C keep in a Queue?	Open
4.	How many days in advance should M&C allow to create/ edit the tasks?	Open
5.	Who else can modify/ cancel the observations in the queue, apart from the user who has created it?	Open
6.	Who needs to view the information of all the queued tasks in M&C? / Is this a part of their dash-board?	Open
7.	Share the sample GTAC/ MTAC ID	Open
8.	Can Operator change all the details of the task, specified while submitting the GTAC/ MTAC details? Which of them cannot be modified? Need list.	Open

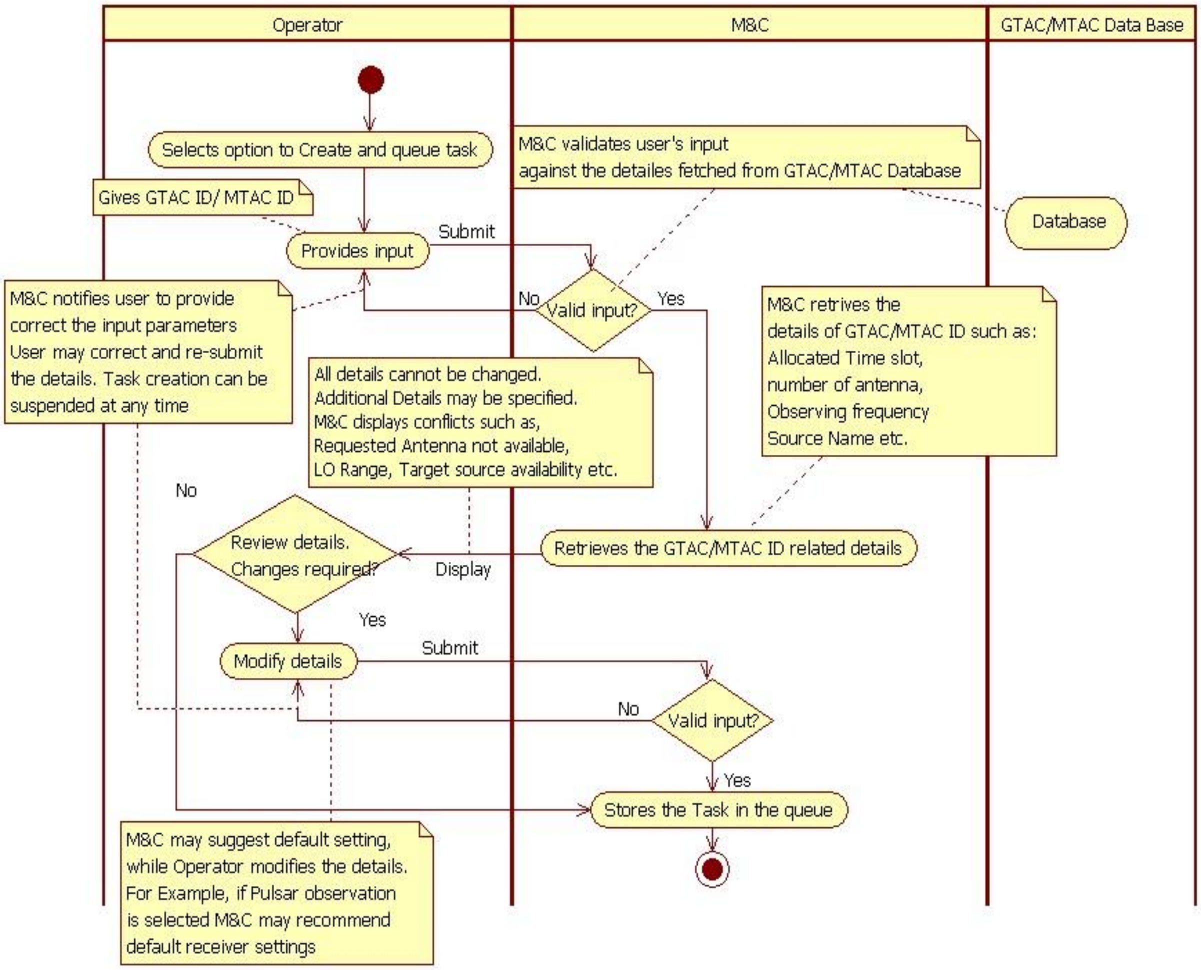

Figure 12: Activity Diagram for Create and Queue Task

2.1.3. Trigger Tasks

Table 11: Use Case for Trigger Tasks

Use Case: Trigger Tasks	
Use Case ID	M&C_UC_003
Goal	Automate the existing manual triggering process for observation/Engineering experiment/ test.
Summary	Presently, the Operator refers the GTAC/MTAC schedule/ E-mail and determines which tasks are due to start at a given time (During the shift in which Operator is working). The proposed M&C monitors the queued tasks and pro-actively informs Operator about the task that is due to be started. M&C reads the tasks queue and determines which task needs to be started at that

Use Case: Trigger Tasks	
	point of time. Retrieves all the details pertaining to the task and displays it to the Operator. M&C also checks for the conflicts for execution of a particular task and notifies to the Operator while displaying the task details.
Actors	M&C
Priority	2
Status	Accepted
Preconditions	• M&C is up and running. • M&C is running in Automatic Mode (The Modes of M&C will be detailed out in a Software Requirements Specifications (SRS) document).
Trigger	Continuous
Assumptions	Whenever system needs to validate the user inputs, the required data for validation/ validation rules are preconfigured in the system.
Use Case Flows: This is explained with the help of activity diagram in ***Figure 13***.	
Stakeholders	
Stakeholder	Operator, Astronomer, Engineers
Interest	To enable the automatic triggering of the tasks in queue.
Post Conditions	
On Success	• M&C displays all the details of the task to be performed to the Operator. • Operator may wish to proceed with the displayed Task, or ignore it.
On Failure	Operator needs to refer to the MTAC/ GTAC schedule for knowing the tasks to be performed/ executed.
Process Rules	

Sr No	Process Rule
1.	The task to be triggered needs to be displayed to Operator, before of its scheduled execution. The time before which operator has been notified should be configurable.
2.	If Operator doesn’t take any decision on the presented task details and the scheduled time of execution of the task is lapsed, system should log this as an event. The task being displayed should also disappear.
3.	Reminders to all relevant users can be given before the task begins as given the task configuration.

Use Case: Trigger Tasks		
4.	At a given time, there can be multiple tasks (observation/engineering) which needs to be triggered.	
5.	If operator mistakenly, discards the notifications and time is available, tasks should be capable of re-triggering.	
6.	If the tasks details are presented to the Operator and Operator does not act on it then system raises alarm. Also in this case system will not trigger observation automatically.	
Additional Data Validation Rules		
Sr No	Validation Rule	
1.	NA	
Working Details		
Sr No	Issues for Resolution	Status
1.	If more than one Operator is present in the Control room, which Operator needs to be informed about the task to be triggered?	Open
2.	The list of entities for which M&C could be able to check the conflicts needs to be evolved	Open

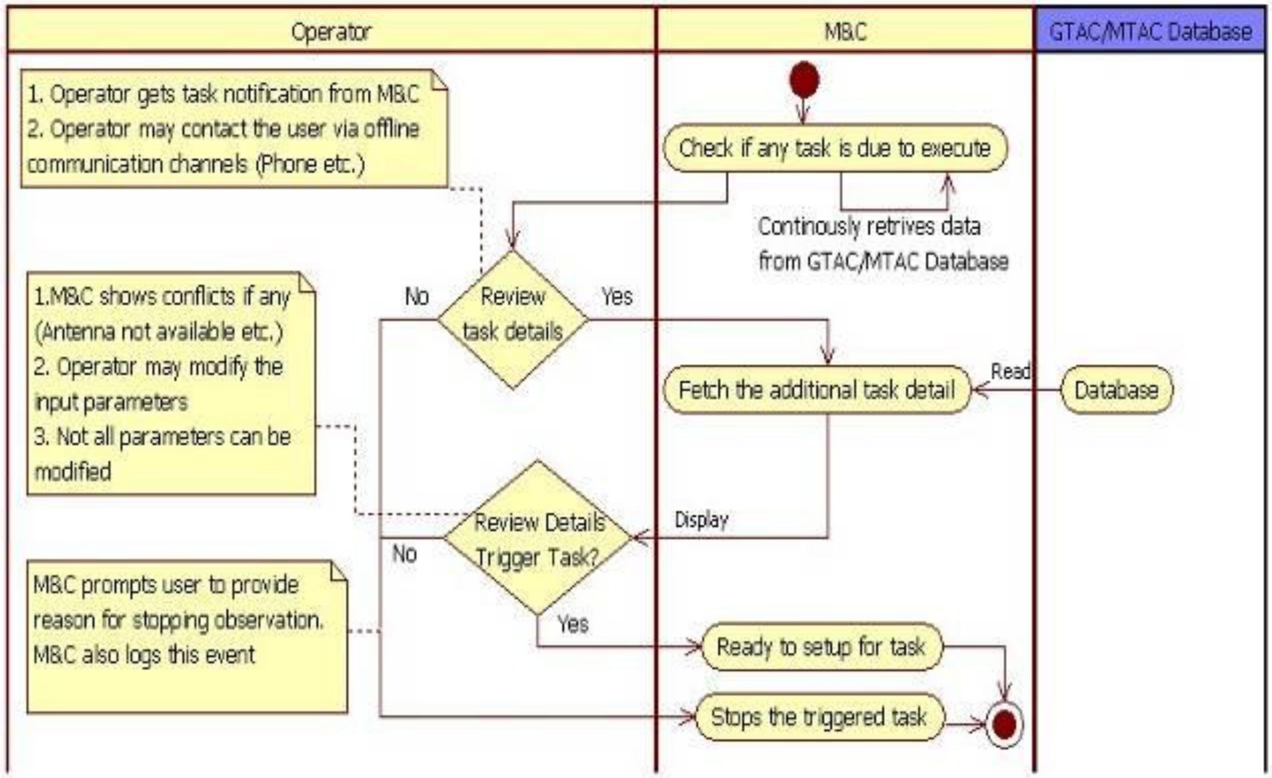

Figure 13: Activity Diagram for Trigger Tasks

2.1.4. Setup Telescope

Table 12: Use Case for Setup Telescope

Use Case: Setup Telescope	
Use Case ID	M&C_UC_004
Goal	Conduct the Observation/ Engineering Experiment/ test as per the requirements provided by user.
Summary	The success of the task being executed using GMRT is dependent on correct configuration of its subsystems. M&C ensures the correctness with help of some of the features such as suggesting the default settings for a chosen task and capturing the configuration information from the direct end users. While the telescope is operating in Automatic Mode, it can be setup against the task which is due for its execution. While it's operating in Manual Mode, it can be setup against the task which was scheduled in past. Also, in Manual Mode, the individual components of the telescope can be configured by Operator. This activity is independent of the task to be performed using telescope. The setup of telescope involves following activities:

Use Case: Setup Telescope	
	• Array Phasing • Tune receiver Chain • Correlator Setup • Power Equalisation • M&C Utilities
Actors	Operator, Engineer
Priority	1
Status	Accepted
Preconditions	M&C is communicating with the relevant subsystems of GMRT.
Trigger	On Demand
Assumptions	M&C is preconfigured to be able to validate the telescope subsystem settings.
Use Case Flows: This is explained with the help of activity diagram in ***Figure 14***.	
Stakeholders	
Stakeholder	Operator, Engineer and Astronomer.
Interest	To ensure that the telescope is correctly configured.
Post Conditions	
On Success	The scheduled/ unscheduled task can be started.
On Failure	• Telescope subsystems are not configured. • The accuracy/ usefulness of the tasks (Observation/ Engineering Experiment/ Test) if conducted cannot be guaranteed.

Process Rules	
Sr. No	Process Rule
1.	User may change the setup/ configuration of subsystems, even during the experiment.
2.	User should be able to setup observation at any time quickly using previous configuration.
Additional Data Validation Rules	
Sr. No	Validation Rule

Use Case: Setup Telescope		
1.	NA	
Working Details		
Sr. No	Issues for Resolution	Status
1.	Configuring telescope against the task which was executed in the past needs to maintain the history of the tasks in M&C. How many past task records should the system store?	Open
2.	Please spell out the exceptions to process rule ***1*** (If any)	Open

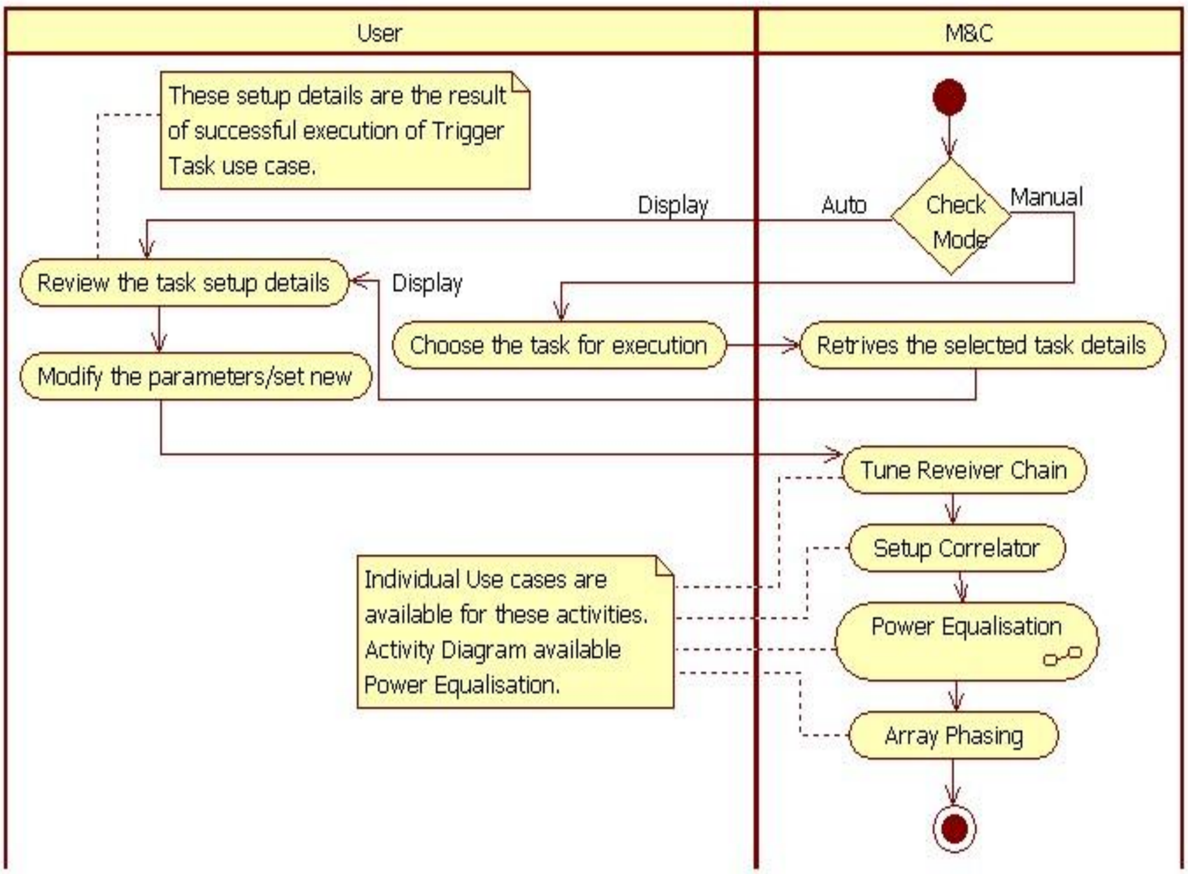

Figure 14: Activity Diagram for Setup Telescope

2.1.5. Monitoring Observation

Table 13: Use Case for Monitoring Observation

Use Case: Monitor Observation

Use Case ID		M&C_UC_005
Goal		To monitor observation progress and system status during observation.
Summary		While an observing session is in progress, the observing astronomer and the Operator can view the overall status of observation and the high level logical status of the subsystems on the user's dashboard. The high level status may include observation progress indicator, current executing activity and antenna pointing and source position details. In addition, other users of the system can also monitor observation as per the privileges given to the user. Monitoring of an observation is governed by monitoring privileges assigned to the user. Each observation may be monitored by specific group of users as configured in the system. For list of parameters available for monitoring, list of alarms, refer to ***GMRT Parameter List.*** Dashboard parameters for all users will be detailed during the subsequent phases of the project.
Actors		Operator, Astronomer and Engineer
Priority		1*
Status		Accepted
Preconditions		• M&C is up and running. • User is authenticated.
Trigger		On Demand
Assumptions		Observing session(s) is in progress.
Use Case Flows		
Basic Flow		User monitors observation progress.
1.	User	User selects to monitor observation.
2.	M&C	Validates user type and observation monitoring privileges.
3.	M&C	Loads relevant high level observation progress monitoring parameters on the dashboard as per the configuration for monitoring observation.
		Exit use case
Alternate Flow 1		User does not have observation monitoring privilege.
2	M&C	Validates user type and observation monitoring privileges.
2_1	M&C	In case user does not have observation monitoring privileges, user is notified.

Use Case: Monitor Observation		
2_2	M&C	Loads default dashboard monitoring parameters as per the configuration for the user.
		Exit use case
Stakeholders		
Stakeholder		Operator, Engineer, Astronomer
Interest		To monitor all important operational, health and sentinel parameters during an observing session to monitor overall observation activities and status of systems that are relevant to the stakeholder. This aids fault isolation and identification of problems and helps in early detection of faults during observation.
Post Conditions		
On Success		All relevant observation parameters that are to be monitored by the stakeholder are available for monitoring.
On Failure		User will be unable to monitor the observation progress.
Process Rules		
Sr. No	Process Rule	
1.	There can be multiple observing sessions in progress simultaneously. Astronomer can view all observations (as per privileges), but only one observation at a time.	
2.	Operator can view overall status of all observations at any time.	
3.	Observing session monitoring privileges are defined during scheduling of observation.	
4.	Only privileged users can monitor observation and high level progress parameters.	
5.	User can optionally perform drill down monitoring as described in ***View Dashboard*** use case.	
6.	User may exit observation monitoring any time.	
7.	User may monitor sky plots, polar plots of antenna position and source position. This may be done with the help of external tools.	
8.	An authenticated user with privileges may terminate the observing session in progress.	
9.	User can upload source catalogue and use this data for sky plots and antenna position tracking with respect to source	
10.	During observation, all occurrences of failures and faults are logged by the M&C as flag data.	
11.	User may view the digital back-end astronomical data acquisition, digital back-end configuration (including project title, code, observer name, das status, frequency parameters for fringe	

	stopping and so on.)	
Additional Data Validation Rules		
Sr. No	Validation Rule	
1.	NA	
Working Details		
Sr. No	Issues for Resolution	Status
1.	List of parameters for monitoring during observation for various users is required.	Open
2.	List of interfacing tools for monitoring and the data to be exchanged are to be identified.	Open
3.	Process for Remote Observation and its constraints needs to be identified.	Open

2.1.6. Define Sub Array

Table 14: Use Case for Define Sub Array

Use Case: Define Sub-array	
Use Case ID	M&C_UC_006
Goal	Facilitate simultaneous observations by allocating specific group of antenna to specific user.
Summary	GMRT consists of 30 antennas. Given observation may not need all 30 antennas to be used for capturing the science data. Further, multiple users may wish to conduct the observation/testing and so on during a given time slot. To facilitate this, groups of antennas are formed and allocated to different users (astronomer/Engineer/Telescope Operators). Each of these groups is then identified as Sub-array. M&C allows defining the sub-arrays and assigning them to individual users for control and monitoring purpose. Maximum of eight sub-arrays can be defined in the system. Forming sub-array enables following functionalities in the system: • Single instruction can be broadcasted to a group of antennas for achieving certain task (For Example- An instruction to park all the antennas in a given sub-array, tracking a given source, collecting science data for a given observation session, and so on). • Handing over the complete responsibility of control and monitoring to a specific user. • Within a sub-array, user can regroup the antennas under a sub-array control (that is, sub sub-arrays). Note: Master M&C is itself treated as a Sub-array. To have stand-by, Sub Array-1 is duplicated to Array-0 having Master authorisation. This helps in keeping Master M&C intact

Use Case: Define Sub-array	
	during regular operations.
Actors	Operator
Priority	1
Status	Accepted
Preconditions	• M&C is up and running and required antennas are configured in M&C system. • User has privileges to define the Sub-arrays.
Trigger	On-Demand.
Assumptions	NA
Use Case Flows: This is explained with the help of activity diagram in ***Figure 15***.	
Stakeholders	
Stakeholder	Astronomer, Engineer and Telescope Operator.
Interest	Ensure the optimal use of observatory resources.
Post Conditions	
On Success	User can proceed for the science observation or Engineering experiment or tests.
On Failure	Relevant error message is provided to the user and antenna control is reserved with Super Operator[5] only.
Process Rules	

Sr. No	Process Rule
1.	Sub-Array control can be changed dynamically by the Super Operator.
2.	Antenna group after terminating/aborting of sub-array(s) need to give back to M&C system.
3.	Each sub-array will have independent interface for Monitoring and control and specific dash-board display for the antenna(s) grouped/defined under Sub-array created.
4.	Antenna allocated in one sub-array is not allowed to be used in other sub-array simultaneously.

[5] Super Operator will have the more privileges than the other Operators (For example defining the sub arrays, assigning the sub arrays to the other Operator/ Engineers and so on. The user privileges will be defined in detail during the SRS phase.

Use Case: Define Sub-array		
5.	Group of antennas can track only one source or in some cases local tracking of individual antennas are allowed.	
6.	Grouping of antenna, that is, forming/initialisation of the sub-array and halting of sub-array shall be possible at any time by the Master M&C system.	
7.	Single user can be allocated with multiple sub-arrays.	
8.	Minimum and maximum antennas to be assigned to a given sub-array should be configurable.	
Additional Data Validation Rules		
Sr No	Validation Rule	
1.	User must be authorised by using token/password facility for the given Sub-array.	
Working Details		
Sr No	Issues for Resolution	Status
1.	Need to identify list of scenarios and constraints in forming sub array	open

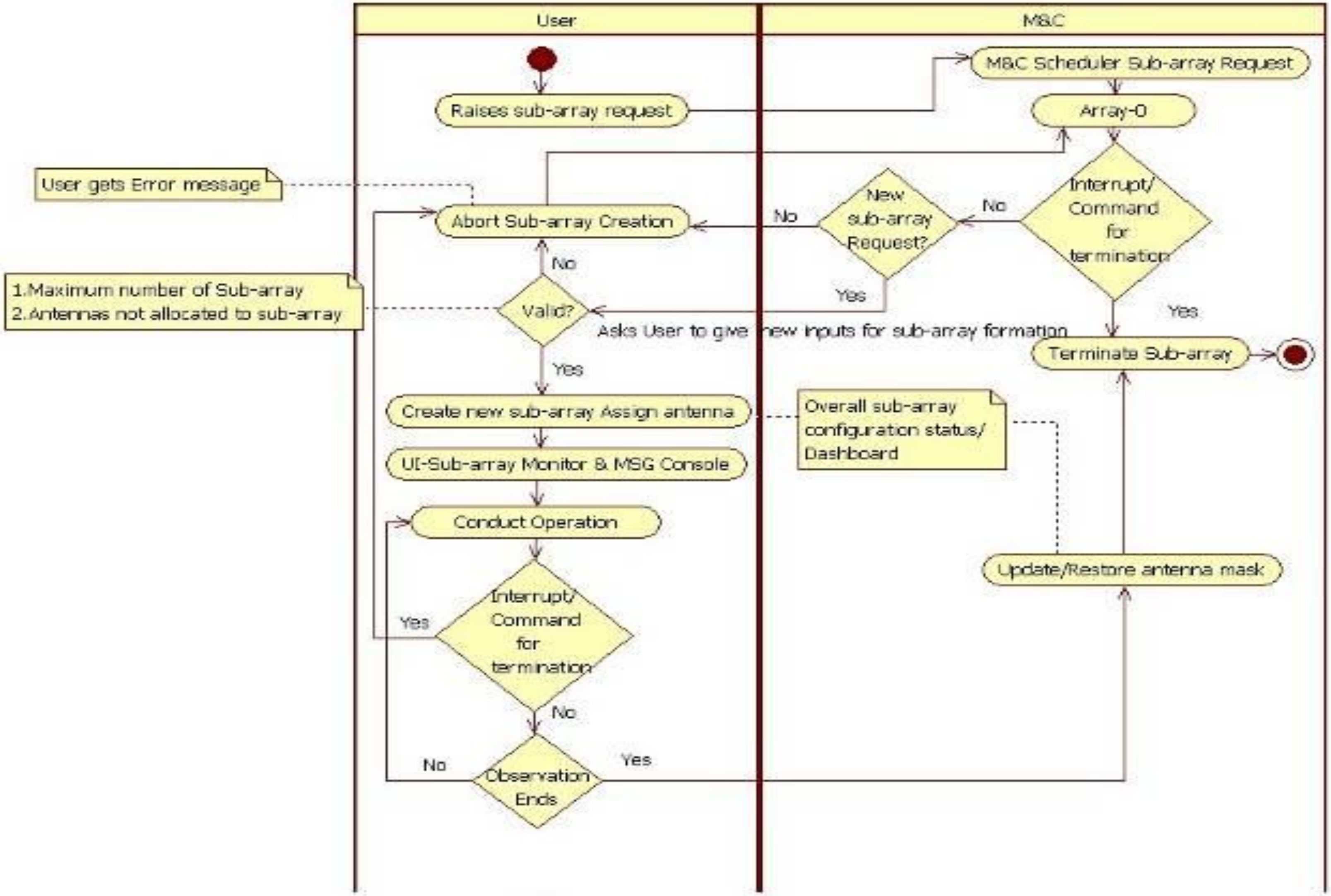

Figure 15: Activity Diagram for Forming Sub-Arrays

2.1.7. Position the Feed

Table 15: Use Case for Positioning the Feed

Use Case: Position the Feed		
Use Case ID		M&C_UC_007
Goal		Position the feed of the antenna at the desired observation frequency.
Summary		The GMRT antennas are equipped with four different feeds. Each feed is selective to a specific frequency (150, 325, 1420 and 235/610 MHz feeds. Mentioned at last is a co-axial feed), thus it enables GMRT to operate in specific band of frequency. The feeds are mounted on a four faces of a rotating turret, supported by antenna Quadra poles. Rotation of this turret is controlled through a Feed Positioning System (FPS) of GMRT. M&C communicates with FPS[6] for positioning the appropriate feed for a given observation session. MCM-14 of the present GMRT system interfaced with ABC over RS-485, acts as FPS. As a part of GMRT upgrades, FPS will be implemented using a PC-104 system. M&C needs to interact with the new FPS over Ethernet. Also, during upgrades the number of feeds and their frequencies at which they operate are likely to change.
Actors		Operator, FPS Engineer
Priority		1
Status		Accepted
Preconditions		• M&C is up and running. • FPS is calibrated and calibration information is available with M&C. • M&C is correctly configured to communicate with old/ new FPS.
Trigger		On Demand/ Automatic during the observation.
Assumptions		The high level commands to be exchanged with existing MCM based FPS and PC_104 based FPS will be same.
Use Case Flows		
Basic Flow		Positions the desired feed.
1.	User	Selects an option to rotate the feed.
2.	User	Specifies the antenna number and feed to be positioned / focused.
3.	M&C	Validates the user inputs, and requests FPS to position the feed as specified by the

[6] *On the similar grounds, M&C communicates with FPS to facilitate the calibration of feeds, also exchanges the configuration parameters and reads the health parameters.*

Use Case: Position the Feed		
		user.
4.	FPS	Processes the M&C request and responds to M&C.
5.	M&C	Interprets the response from FPS and acts on it.
6.	M&C	Interprets that the feed is being rotated/ rotated completely to the desired position.
7.	M&C	Display the relevant message to user and store the current feed position for future use.
		Exit use case.
Alternate Flow 1		Failure in positioning the selected feed.
5	M&C	Interprets the response from FPS and acts on it.
6_1	M&C	Interprets that the FPS is unable to rotate the feed.
6_2	M&C	Generates the alarm, logs the failure to rotate feed attempt and displays the relevant message to user.
6_3	M&C	Exit use case.
Stakeholders		
Stakeholder		Astronomers, GCC, FPS Engineer and Operator.
Interest		To ensure that the FPS is in operational state and is functioning as per the needs.
Post Conditions		
On Success		Feed is rotated at desired position.
On Failure		• Feed is not rotated at desired position. • Current feed position may not be known to M&C (In this case FPS needs to be restarted). • Generate and log the Alarm.
Process Rules		
Sr. No	Process Rule	
1.	User may select multiple antennas or a sub-array or multiple sub arrays for positioning the feed.	
2.	Users can broad-cast single FPS command to all antennas which shall be interpretable at the FPS control-card level or ABC level (For example Move FPS).	

Use Case: Position the Feed		
Additional Data Validation Rules		
Sr. No	Validation Rule	
1.	NA	
Working Details		
Sr No	Issues for Resolution	Status
1.	The communication protocol between M&C and FPS needs to be finalised.	Open

2.1.8. Tune Receiver Chain

Table 16: Use Case for Tune Receiver Chain

Use Case: Tune Receiver Chain	
Use Case ID	M&C_UC_009
Goal	Configure receiver chain of GMRT.

Summary	GMRT conducts the observations with varying frequency over a wide band of frequency range. Also, it allows conducting observations in different modes (Refer ***GMRT Observation Modes***). All this is achieved by configuring subsystems and receiver chain of GMRT- often referred as tuning receiver chain.
	
	The receiver chain tuning involves:
	
	• Selecting the appropriate observing band and sub-bands in FE-CB box using the band-selector switch and Filter-banks.
	• Selecting the respective RF-filters in the GAB system to get the band, down-convert it to base-band signal using the LO and further limit the wide-band signals using the Low pass filters.
	• In case of spectral observation, select the narrow band signal (for example-1 MHz to 10 MHz) of interest using the DDC LO signal.
	• Calibration of the incoming RF astronomical signal and Receiver electronics system chain by performing following operations on the front end electronics of the receiver chain :
	    o Injecting the noise-calibrator or continuous signal.
	    o Terminating RF, Noise Generator or Continuous Wave (CW) signal.
	    o Walsh function signal input.
	    o Swapping of RF-channels.
	    o Setting up correct gain and attenuation values for obtaining an optimum power.

Actors	Operator

<table>
<tr><th colspan="3">Use Case: Tune Receiver Chain</th></tr>
<tr><td colspan="2">Priority</td><td>1</td></tr>
<tr><td colspan="2">Status</td><td>Accepted</td></tr>
<tr><td colspan="2">Preconditions</td><td>M&C is up and running.
GMRT Frequency and Time standard system locked to the GPS and 10 MHz reference signal is stable.
M&C and relevant subsystems are communicating (GAB, Digital backend, FE, OF and so on.).</td></tr>
<tr><td colspan="2">Trigger</td><td>On Demand/ Automatic during observation.</td></tr>
<tr><td colspan="2">Assumptions</td><td>This use case is written for the new upgraded receiver chain system of the GMRT. There may be minor changes in the receiving chain systems in functionality wise.
The existing RF receiving signal path supports the major functionality as that of the upgraded system.
In case of RF signal attenuation in the optimal power range, refer to the Use case Power Equalisation.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Use Case Flows</td></tr>
<tr><td colspan="2">Basic Flow</td><td>Configure receiver chain</td></tr>
<tr><td>1.</td><td>User</td><td>Provides following details:
Band name.
Preferred Calibration method (Walsh function, Noise-calibrator or Continuous Wave calibrator).
LO to be used (Higher or Lower than RF frequency, LO value is not expected)
Total observing band-width.</td></tr>
<tr><td>2.</td><td>M&C</td><td>Based on the user inputs in the previous step, configures the following parameters of FE/CB:
Switch to a desired feed using band selector.
Determines values for RF Filter (Selects from Filter banks- 1, 2, 3, 4 or direct path).
FE termination or Noise calibrator or Continuous wave signal.
RF (ON/OFF) and solar attenuator.
RF channel Swap, (Swap/ Un-swap).</td></tr>
<tr><td>3.</td><td>M&C</td><td>M&C configures the GMRT Analog Backend (GAB System), depending upon the combination of Band selector switch in the common-box and RF filter-bank selection for the given feed in the Front-end system, the GMRT GAB system selects the same FilRF switch in the GAB system such that desired RF signal channelled down the line</td></tr>
</table>

Use Case: Tune Receiver Chain		
		for further signal conditioning in the GAB system. OR In case of calibration, the GAB can inject Noise-generator or Continuous Wave signal to calibrate the GAB system.
4.	M&C	The GAB Local oscillator value for both the pole of individual antennas are set to the edge of the RF band / sub-band from the Front-End system to avoid aliasing i.e. LO Frequency value is equal to the value at the edge (lower/higher) of RF band/ sub-band. The RF band selected below 600 MHz does not need down-conversion, hence RF signal can be channelled directly via direct path i.e. No need of Local oscillator signal. OR In case of calibration, the GAB can inject Noise-generator or Continuous Wave signal to calibrate the Digital Back-End system
5.	M&C	Depending on the total band-width for the observation GAB sets Low Pass Filter from the LPF Filter-bank (0, 100, and 200, 400 MHz or direct path)
6.	M&C	M&C system sets the DDC block of the GMRT Correlator (Digital back-end system) in case of spectral-line observation requirement only. In the spectral mode of observation, the DDC LO shall be selected such that the desired observing band-centre is processed in the digital back-end system. DDC LO value is equal to the edge (Lower/Higher) of Observing band of interest given by the user i.e. Total band-width value given for the observation and the band-centre frequency can be used to calculate the edge of observing band.
7.	M&C	M&C system validates the above inputs mentioned in step 2 to 4 and presents to user for confirmation.
8.	User	User checks the resultant inputs and Confirm to proceed. OR Re-adjusts the inputs mentioned in step 1 to 4 and repeat step ***5***.
9.	M&C	M&C sends these parameters to respective subsystems of selected antenna or group of antennas.
10.	Sub-systems of GMRT	Sub-systems of antenna process the requests from the M&C and send responses to the M&C system.
11.	M&C	M&C waits and interprets response from the subsystems.
12.	M&C	Interprets that the receiver chain is configured successfully for all the antennas.
		Exit use case.
Alternate Flow 1		User modifies the receiver chain parameters.
8	User	User checks the resultant inputs and Confirm to proceed.

Use Case: Tune Receiver Chain		
8_1	User	User modifies input parameters (Includes by inline validation from M&C) and submits the details.
		Continue to step ***8.***
Alternate Flow 2		Resend set-up commands for the failed set points.
9	M&C	M&C waits and interprets response from the subsystems.
9_1	M&C	Gets failed response from one or many sub-systems of selected antennas.
9_2	M&C	Displays the failure message to user and logs the failure event.
9_3	M&C	Resends the command after user confirmation.
		Exit use case.
Stakeholders		
Stakeholder		Astronomer, Engineers (Analog, digital back-end systems and OF system), Telescope Operator.
Interest		Tune the receiver of the GMRT antennas to get the desired band of interest for the astronomical observation or the engineering tests/experiment.
Post Conditions		
On Success		• User (Astronomer/Engineer) is ensured to get the correct desired observing band data for the science observation or Engineering experiment. • Tune-receiver settings shall be saved in a default place/database so that M&C can re-tune the receiver system after the observation/experiment interrupts.
On Failure		• The receiver chain is not configured properly. • The accuracy of science results/ observations may not be guaranteed. System provides such warnings to the user.
Process Rules		

Sr No	Process Rule
1.	M&C suggests the default values of tune-receiver chain for the particular band of frequency. These values can be changed and saved for the future use.
2.	Authorised user can set the individual set points of the GMRT receiver chain system by sending a separate command to the particular sub-system of the selected antenna.

Use Case: Tune Receiver Chain		
3.	In case of tune-receiver chain setting commands being executed in back-ground process (For example- batch script or procedure), number of default re-try to issue command for the tune-receiver set-point should be configurable.	
4.	There can be two different RF bands selected for two polarisation channels for the single antenna using the band-selector switch of the common-box system.	
5.	The Local Oscillator signal has to be set to the edge of the RF band / sub-band from the Front-End system to avoid aliasing.	
6.	Both polarisation channels (Channel-1 and Channel-2) from the single antenna need to operate at same Local Oscillator (LO) frequency i.e. No two Local Oscillators are allowed in the first stage. Note: The upgraded GAB allows setting different LOs.	
7.	The scheme allows setting of different LO signal for each antenna using the individual synthesisers in the frequency range 600 to 1600MHz. LO frequencies lower than 600MHz (with observation bandwidths less than 400 MHz) can be set from the common oscillator.	
8.	While selecting a particular filter, if the observing frequency falls in edge and neighbouring filter is better, a warning should be generated.	
9.	User should be able to select bands of feed not on focus for specific tests.	
Additional Data Validation Rules		
Sr No	Validation Rule	
1.	The GAB LO frequencies can be changed from 600 to 1600 MHz in the steps of 500 KHz only (LPF 0, 100, 200, 400 MHz or Direct path). Following are the attenuation values at each sub-sequent stages of the receiver chain: • CB Solar attenuations: 0 or 14 or 30 or 44 dB. • Optical Fiber system attenuations: 0 to 31.5 dB in steps of 0.5 dB. • GAB attenuations: 0 to 31.5 dB in steps of 0.5 dB. Digital-back end gains (Intrinsic to the Correlator not decided yet).	
Working Details		
Sr No	Issues for Resolution	Status
1.	Minor changes in the functional or data validation rules in the receiver chain system.	Open

2.1.9. Power Equalisation

Table 17: Use Case for Power Equalisation

Use Case: Power Equalisation	
Use Case ID	M&C_UC_010
Goal	To optimise the power levels at various receiver subsystems and Correlator.
Summary	The sensitivity of the GMRT is highly dependent on optimum power levels at its various subsystems such as, analog and the digital backend systems. The process of optimizing the power levels at various subsystems (power level monitoring points) of GMRT is referred as power equalisation. Power equalisation is specific to a target source, observing frequency and bandwidth and is done only when Automatic Gain Controller (AGC) is OFF. In power equalisation process, the gains and/or attenuations at Optical Fiber (OF) system, SIGCON system (Signal Conditioning) and the Correlator (CRR) are adjusted (using M&C) such that the output power levels at these subsystems is optimum. Hence this is an iterative process. ***Figure 16*** shows the diagrammatic representation of interface between M&C and PET for achieving the power equalisation. Presently, the power equalisation is achieved with the help of an external PET. As this tool is independent of the M&C, the present power equalisation process involves manual operations. NCRA wishes to automate this process by developing a suitable interface between, M&C and PET(s).
Actors	Operator
Priority	1
Status	Accepted
Preconditions	• M&C is up and running (In present situation, this means, ABC is communicating with ONLINE, All other subsystem such as servo, FPS, MCM are working properly). • Antenna is pointed to a desired source. • There are no critical alarms in active mode. • User is authenticated. • The required Power Equalisation Tool (PET), is up and running and has a working interface with M&C. • If Power Equalisation is intended on the existing GMRT receiver chain subsystem then AGC should be turned OFF.
Trigger	On Demand, During PMQC or during science observing session.
Assumptions	If required, external tool(s) for power equalisation will be developed by NCRA.

Use Case: Power Equalisation		
Use Case flow is explained with the help of Activity diagram shown in ***Figure 17***.		
Stakeholders		
Stakeholder	Astronomers, Operator, Analog Engineer, Digital Engineer, Engineer.	
Interest	To set the gain and attenuation for the receiver chain for the selected antennas.	
Post Conditions		
On Success	• The gain and attenuation of the power equalisation set points is adjusted. • Power equalisation at monitoring points converges to desired power level. • Input configuration parameters of PET along with Gain and attenuation are stored as reference parameters for the power equalisation set points.	
On Failure	Power output of few / all the selected antennas will be different.	
Process Rules		
Sr No	Process Rule	
1.	User may abort the process of power equalisation at any time.	
2.	Power equalisation cycles will continue till the power is equalised for all the power monitoring points or if the maximum iterations are reached.	
3.	Power equalisation process can be done by user with appropriate privileges defined in the system configuration.	
Additional Data Validation Rules		
Sr No	Validation Rule	
1.	NA	
Working Details		
Sr No	Issues for Resolution	Status
1.	Required to define the list of critical alarms that cause to initiate the system shut-down/ antenna parking process.	Open
2.	NCRA to take decision, whether or not to implement the external power equalisation tools for OF and Correlator.	Open

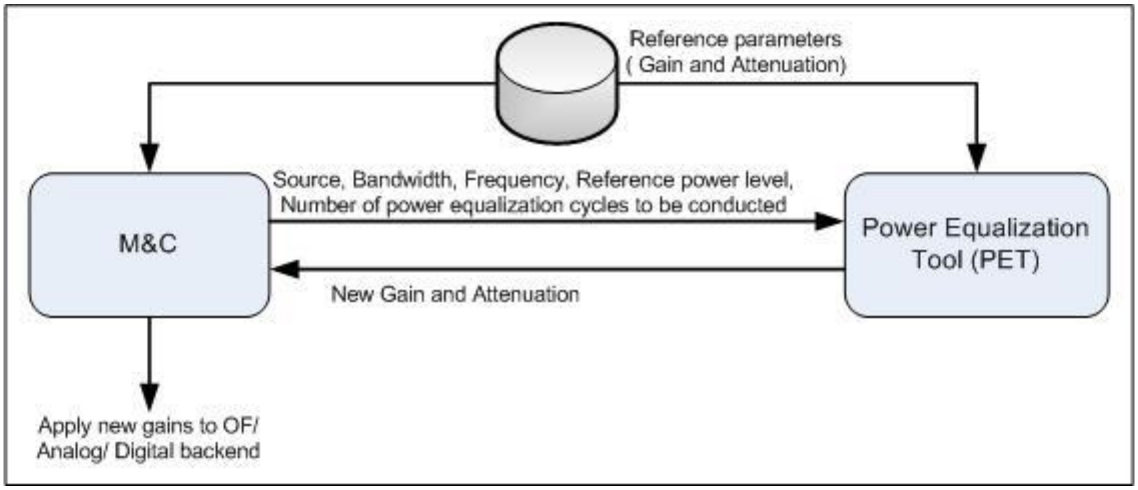

Figure 16: Interface between M&C and PET for Achieving Power Equalisation

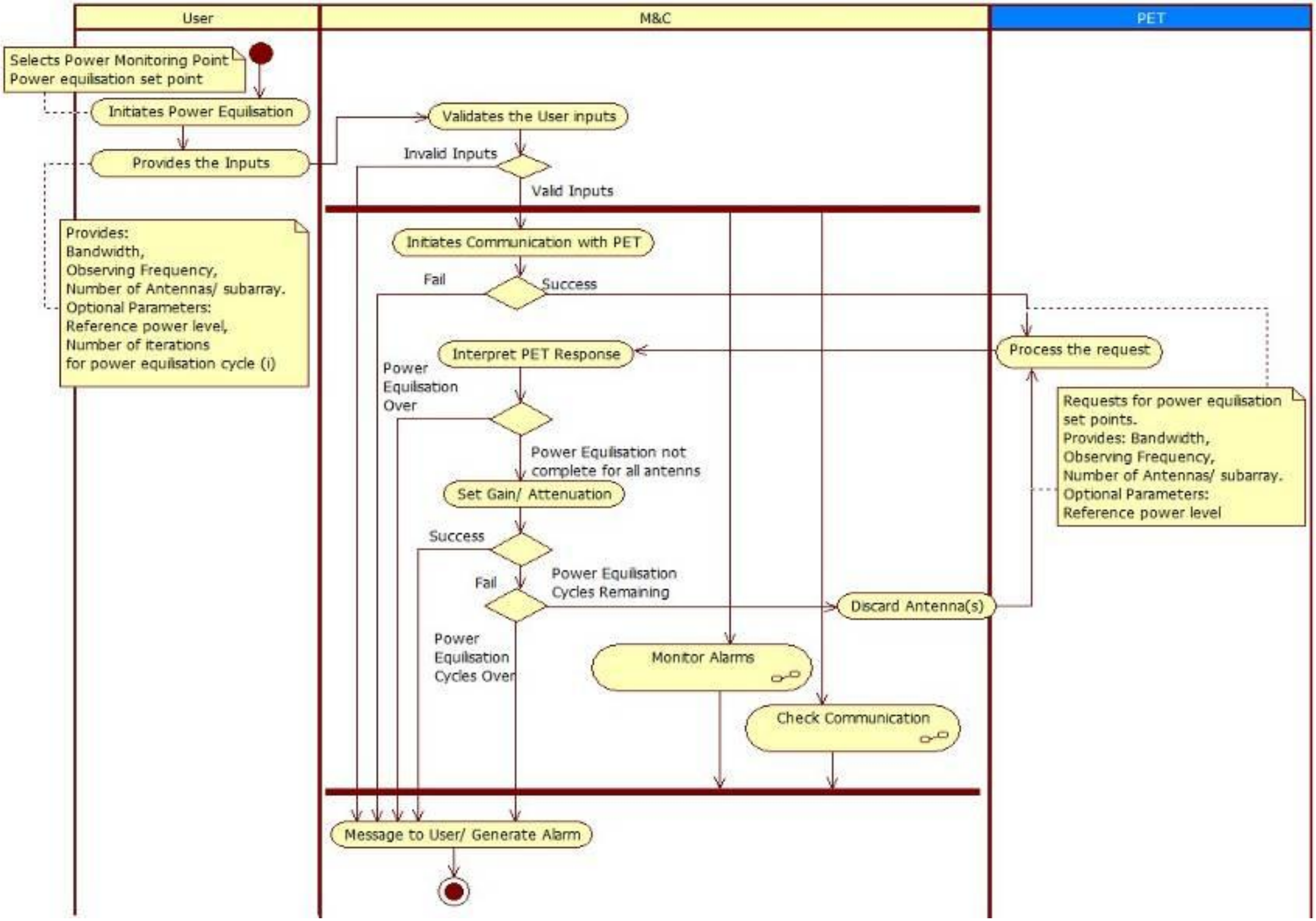

Figure 17: Activity Diagram for Power Equalisation Process

2.1.10. Correlator Setup

Table 18: Use Case for Correlator Setup

Use Case: Correlator Setup	
Use Case ID	M&C_UC_011
Goal	Configure and setup the digital back-end in possible operating mode, give the data processing inputs during the digital back-end operation and control the data acquisition flow from the digital back-end.
Summary	The digital back-end system can be setup to conduct various types of astronomical observations (viz. continuum observations for the imaging, spectral observation to detect atomic or molecular lines and the pulsar observation). The digital back-end processes the dual polarised RF signals of thirty antennas coming from the GMRT GAB. In the interferometry (or Correlator) mode of digital back-end system, the mutual coherence function of the electric field due to a given source brightness distribution in the sky is measured by cross-correlating the voltages from each antenna pair. Correlator gives self and cross products from all 30 antennas for each polarization and integrates the data for specified accumulation period to give visibility output i.e. Cross amplitude and phase in real and imaginary (complex) format. In the interferometry mode, spectral line observation requires more spectral resolution which is achieved by down-converting the wide band-width signal to the desired band of interest using the DDC (Digital Down convert) Local Oscillator or by De-sampling the input band-width signal. The GAC operates in two modes for pulsar observation, one is Incoherent Array (IA) mode in which total power coming from the individual antenna is added and other is PA mode where PA forms coherent beam by adding the voltages of different antennas in phase. Note - As the antenna has dual polarised signal (Left circular polarisation and Right circular polarisation or Linear Vertical and Horizontal polarisation), one can process both the polarisation signal either in IA and PA mode or one polarisation signal in IA mode and other polarisation signal in PA mode. Thus, GAC can provide total four outputs in principle for each polarisation IA and PA or for both polarisation IA or PA. M&C System gives User Interface for the digital back-ends to carry out following functionality : • Choose the desired scientific observation mode by providing configuration data to configure/set the digital back-end. • Initialise the multiple projects to conduct the observations or engineering tests. • Start and stop the data acquisition for individual project. • Stop the user projects. • Halt the digital back-end.

Use Case: Correlator Setup		
		• Show the status of digital back-end. • For the initialised project, generate project specific system malfunctioning report so that the bad data can be flagged. • Configure the GMRT array-combiner and select the number of antennas for power or voltage addition.
Actors		Operator
Priority		1
Requirement Status		Accepted
Preconditions		• User is authenticated • M&C interface (Either Engineering console or main M&C and Sub-array) is up and communicating to the digital back-end clients. • GPS and 1 PPS/CLK reference signal at the input of ADCs is provided.
Trigger		For the astronomical observation or engineering experiments (On demand)
Assumptions		• M&C system interface is compatible with the digital back-end interface. • User means manual command entered by the user or auto execution through batch/procedure kind of execution facility (applicable where user intervention is not required).
Use Case Flows- The use case flows are also explained using the activity diagrams in ***Figure 18*** and ***Figure 19***		
Basic Flow		Digital back-end data acquisition is in progress.
1.	User	• User selects the desired observing mode (continuum observation, spectral observation, pulsar observation, high resolution mode OR raw voltage mode). • User selects the digital back-end to be used.
2.	M&C	M&C system loads the default choice to configure the digital back-end for the given observing mode selected. The configuration parameters can be : • Data acquisition Band-width at the input and output. • Number of spectral channels. • Data integration/time resolution. • Scaling factor. • Selection and configuration of the digital back- Polarisation mode (total intensity or full-stokes).

Use Case: Correlator Setup		
		• Digital Backend sub-blocks (DDC, Array-combiner, and RFI excision block.).
3.	User	User re-adjusts the parameters as per preference submits the digital back-end initialisation request to the respective digital back-end.
4.	M&C	M&C system validates the user request and accepts the command for the digital back-end initialisation. Go to Next Step. OR M&C system invalidates and gives the error message in the digital back-end selection and repeat step 1 to 4.
5.	M&C	M&C system sends the initialisation (INIT) digital back-end command to the selected digital back-end and waits for the response.
6.	Digital back-end	Digital back-end system accepts the M&C command and processes it. After processing, sends the response to the M&C system.
7.	M&C	M&C system interprets the INIT response from the digital back-end system.
8.	M&C	M&C interprets that the digital back-end initialisation succeeds.
9.	User	User gives inputs for initialising project for the science observation or engineering experiment by providing following information. (Though this information can be obtained from the proposal management system, however for the Target of Opportunity kind of observations, this information needs to be provided by the user) (i) Antenna masks (Interpretable to actual antenna addresses). (ii) Project-code (Maximum 8 characters) (iii) User name (iv) Project title (v) Sub-array number being used to execute the observation/engineering test.
10.	M&C	M&C checks that antennas defined under the given project are not assigned to any other initialised project; also check other input-fields. If validation successful go to Next step OR If project input invalid, give error message to user and go to Step 9 to readjust the parameters.
11.	M&C	M&C sends command to initialise the project to selected digital back-end.
12.	Digital backend	Digital back-end system accepts the M&C command and processes it. After processing, sends the response to the M&C system.
13.	M&C	M&C system interprets the INIT-PROJECT response from the digital back-end system

Use Case: Correlator Setup		
14.	M&C	M&C interprets that the project initialisation succeed • M&C start the Project based log to store the observation related information (Digital back-end configuration, project information, data acquisition start/stop time along with relevant information like observation source, frequency and so on.) and the malfunctioning system information so that the bad data can be flagged.
15.	User	User issues start data acquisition command to the digital back-end along with the requisite information : • Source information (Source Name, Right Ascension, Declination and Epoch). • Frequency information (First channel Frequency and incremented or decremented band). • Number of antennas to be used for updating the integral delay and fractional delay correction.
16.	M&C	M&C validates the input (I) antenna mask given for the fringe-stop is valid i.e. given antennas are assigned to the project assigned to sub-array under control (ii) Frequency information to be used by the digital-back end is correct. If validation successful go to Next Step. OR Go to step 15 to correct the input parameters.
17.	M&C	M&C sends start data acquisition command to selected digital back-end.
18.	Digital backend	Digital back-end system accepts the M&C command and processes it. After processing, sends the response to the M&C system.
19.	M&C	M&C system interprets the start data acquisition response from the digital back-end system.
20.	M&C	M&C interprets the start data acquisition is successful.
21.	Digital-backed	• Digital back-end starts data processing which can be monitored or recorded by the digital back-end programs. • Digital back-end diagnostic program reports the digital back-end problems on occurrence to the M&C system.
22.	M&C	If the GMRT Array-Combiner (GAC) IA/PA beam is enabled during the digital back-end initialisation. Go to Parallel Flow 1.
23.	M&C	Waits for the data acquisition stop command.
24.	User	Gives stop data acquisition command.
25.	M&C	M&C sends stop data acquisition command to digital-back-end.

Use Case: Correlator Setup		
26.	User	User executes the Start Data Acquisition command again, continues to ***15***.
27.	User	User gives stop project command.
28.	M&C	Sends stop project command to the selected digital back-end system.
29.	Digital back-end	Digital back-end system accepts the M&C command and process it. After processing, sends the response to the M&C system.
30.	M&C	M&C system interprets the Stop Project command response from the digital back-end system.
31.	M&C	M&C interprets the stop project is successful.
32.	M&C	• M&C update and restore the status of antennas so that it can re-assign antennas when the next project initialise trigger. • M&C closes the project based log.
33.	User	User executes the next project initialisation again, Go to Step ***9***. OR Go to next step.
34.	User	Halts the digital back-end system.
35.	M&C	M&C system sends Halt command to back-end system.
36.	Digital Backend	Digital back-end accept the halt command and processes it by: • Closing all the running processes. • Halting the GMRT Array-combiner. Digital back-end sends the halt command response to M&C system.
37.	M&C	Interprets the halt response received from the digital back-end.
38.	M&C	Digital back-end halted successfully.
		Exit the use case.
Alternate Flow 1		Digital backend initialisation failed.
7	M&C system	M&C system interprets the INIT response from the digital backend system.
7_1	M&C	M&C interprets that the digital back-end initialisation Failed.
7_2	M&C	M&C system displays the failed message and the reason for failure to user.
		Exit the use case.

Use Case: Correlator Setup		
Alternate Flow 2		Project initialisation failed.
13	M&C	M&C system interprets the INIT-PROJECT response from the digital back-end system.
13_1	M&C	M&C interprets that the digital back-end Project initialisation failed.
13_2	M&C	M&C displays the error message to user.
13_3	User - M&C	User intervenes to debug the problem and Repeat the step 9 to 13. OR Go to Next Step.
		Exit the use case.
Alternate Flow 3		Start data acquisition failed.
19	M&C	M&C system interprets the start data acquisition response from the digital back-end system.
19_1	M&C	M&C displays the start data acquisition failure message to user.
19_2	User	User intervenes to debug the problem and Repeat the step 15 to 19. OR Go to Next-Step.
19_3	User	Go to Step ***27***: Stop Project.
Alternate Flow 4		Stop project command failed.
30	M&C	M&C system interprets the Stop Project command response from the digital back-end system.
30_1	M&C	• Displays the error message to user. • Closes the project based log.
30_2	User	Go to Step ***34***: Halt the Digital back-end system.
Alternate Flow 5		Halt back-end system failed.
37	M&C	Interprets the halt response received from the digital back-end.
37_1	M&C	M&C displays the Error message.
		Exit the use case.
Parallel Flow 1		Acquire the pulsar observation/Engineering experimental data through the In-coherent (IA) or Coherent (PA- Phased Array) beam.
22	M&C	If the GMRT Array-Combiner (GAC) IA/PA beam is enabled during the digital back-end initialisation.

Use Case: Correlator Setup		
22_1	User	User can select the GMRT array-combiner in various modes : IA – IA, PA-PA, IA-PA, IA-OFF, PA-OFF, OFF-Voltage mode. User selects the detailed configuration parameters such as : • Input data and output data acquisition band-width. • Number of spectral channels, number of channels for averaging, Sampler window. • Pre (basic) and post integration. • Bit packing. • 50 Hz Filter parameters – FFT (Fast Fourier Transform) length, Number of bands and so on. Note: Next steps are applicable to both the IA or PA blocks (Hence referred as the GMRT Array Combiner - GAC).
22_2	M&C	M&C system validates the user request and accepts the configuration for the GMRT Array combiner. Go to Next Step. OR M&C system invalidates and gives the error message. Go to step 22_1.
22_3	M&C	M&C system sends the initialisation (INIT) command for the selected IA or PA.
22_4	IA/PA	The GAC accepts the M&C command and process it. After processing, sends the response to the M&C system.
22_5	M&C	M&C system interprets the INIT response from the GAC.
22_6	M&C	M&C interprets that the GAC initialisation succeeds.
22_7	User	User selects the antennas for addition of total power or voltages from the individual antenna.
22_8	M&C	M&C system sends the antennas selection information to the GAC for adding the total power in case of the IA or phased voltage signals in case of PA.
22_9	User	User issues start data acquisition command for IA or PA.
22_10	M&C	M&C sends the start data acquisition command to the GAC along with the following additional information : • Astronomical source information for which the digital back-end updating the delays (this source is called phase centre). • The information about the project which is in progress by the digital-backend. • RF frequency. • In case of pulsar as a celestial source, sends the requisite information such as

Use Case: Correlator Setup		
		Dispersion measure (DM), pulsar period, start, stop and reference spectral channel and so on.
22_11	IA/PA	The GAC accepts the start data acquisition command from the M&C system and processes it. After processing, sends the response to the M&C system.
22_12	M&C	M&C system interprets the start data acquisition command response from the GAC.
22_13	M&C	Starts data acquisition command successful. (User ensures the data correctness using the pulsar monitoring tools)
22_14	M&C	M&C waits until the data acquisition command is received from the user.
22_15	User	User issues stop data acquisition command for the GAC.
22_16	M&C	M&C sends the stop data acquisition command for the GAC.
22_17	IA/PA	The GAC accepts the stop data acquisition command from the M&C system and processes it. After processing, sends the response to the M&C system.
22_18	M&C	M&C system interprets the stop data acquisition command response from the GAC.
22_19	M&C	M&C interprets the command succeeded.
22_20	User	User issues start data acquisition command for the GAC then performs Step 22_6. OR User issues HALT command for the GAC (IA/PA) go to next step.
22_21	M&C	M&C sends the HALT command to the GAC (IA/PA).
22_22	IA/PA	The GAC accepts the HALT command from the M&C system and processes it. After processing, sends the response to the M&C system.
22_23	M&C	M&C system interprets the HALT command response from the GAC.
22_24	M&C	M&C interprets that HALT command succeeded.
		Exit the use case.
Alternate Flow 1		The GAC initialisation failed.
22_5	M&C	M&C system interprets the INIT response from the GAC.
22_5_1	M&C	M&C interprets that the GAC initialisation Failed.
22_5_2	M&C	M&C system displays the failed message and the reason for failure to user.
		Exit the use case.
Alternate Flow 2		The GAC start data acquisition failed.
22_12	M&C	M&C system interprets the start data acquisition command response from the GAC.

Use Case: Correlator Setup		
22_12_1	M&C	M&C displays the start data acquisition failure message to user.
22_12_2	User - M&C	User intervenes to debug the problem and repeats the step from 22_9. OR Go to Next-Step.
22_12_3	User	Go to Step 22_20: HALT the GAC.
Alternate Flow 3		The GAC Halt command failed.
22_23	M&C	M&C system interprets the HALT command response from the GAC.
22_23_1	M&C	M&C displays the Error message.
		Exit the use case.

Stakeholders	
Stakeholder	Astronomer and Engineer
Interest	Carry out astronomical observations or Engineering Diagnostic tests (Debugging/Calibration).

Post Conditions	
On Success	• Observational/Engineering test data acquired from the digital back-end is ensured to be correct. • User receives project-based flag-file from the M&C system, which can be used to flag the bad-data.
On Failure	• Correctness of the science observation or engineering test is not ensured. • M&C generates the fault log report.

Process Rules	
Sr No	Process Rule
1.	After successful initialisation (Configuration set-up done successfully), multiple projects shall be allowed to run independently or in a synchronous manner.
2.	One project per sub-array is allowed. There can be 6 sub-arrays. (Refer to Use Case: ***Define Sub Array***).
3.	The digital back-end interferometry mode and Array combiner mode (Incoherent Array, Phase Array or Two Phased Array) run in parallel. To run the Array combiner, it is mandatory that interferometry mode is running.
4.	The GMRT array combiner can change the antenna selection for adding the antenna power (IA) or antenna voltages in phase (PA) during the observing run.

Use Case: Correlator Setup	
5.	Assuming the digital back-end is up acquiring the data, IA or PA can be independently initialised or halted.
6.	IA and PA can share the antennas for addition of total power or voltages from the individual antenna.
7.	Dual polarised antenna signals' gain can be changed during the run time if such facility is available in the new (GPU-CPU) digital back-end.
8.	If the source under the observation is set, then the data acquisition should be automatically stopped.
9.	If multiple beams get added in future, this could be supported by M&C system since M&C has noted the requirement of supporting multiple correlators.
Additional Data Validation Rules	
Sr No	Validation Rule
1.	M&C shall able to display and update the input-fields, which are interdependent, at the UI. Also, validate only the allowed following digital back-end configuration: • Desired input acquisition band and output band-width limit. • Default scaling factor. • Number of spectral channels allowed for the selected band-width. For example- 32 MHz and 256 channels or 16 MHz and 512 channels, 200 MHz and 2048 channels and 400 MHz and 1024 channels. • Two PA beam or one IA and one PA beam. • Time resolution or data acquisition rate allowed for the selected band. • Input band-width dependent decimation factor (Final band-width allowed at the output) in spectral observation mode. Note: Above rules for the digital back-end selection and validation can be captured during the SRS phase.

Working Details		
Sr No	Issues for Resolution	Status
1.	While digital back-end processing the data, diagnostic parameters such as CLK/PPS at the ADC input, data block number, standard deviation at the ADC, EOR switch status has to be provided to M&C system by independent process.	Open

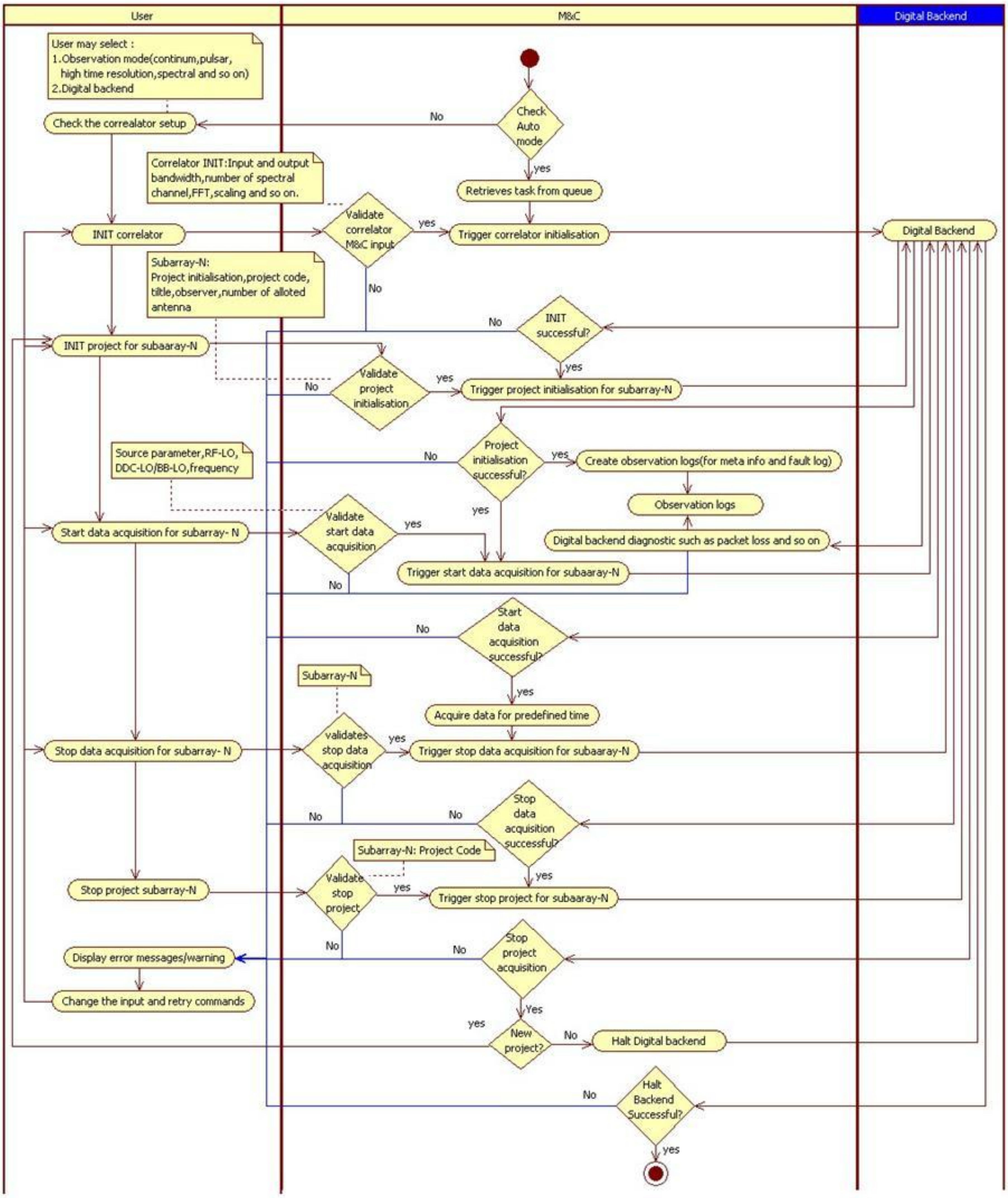

Figure 18: Activity diagram for Correlator Setup

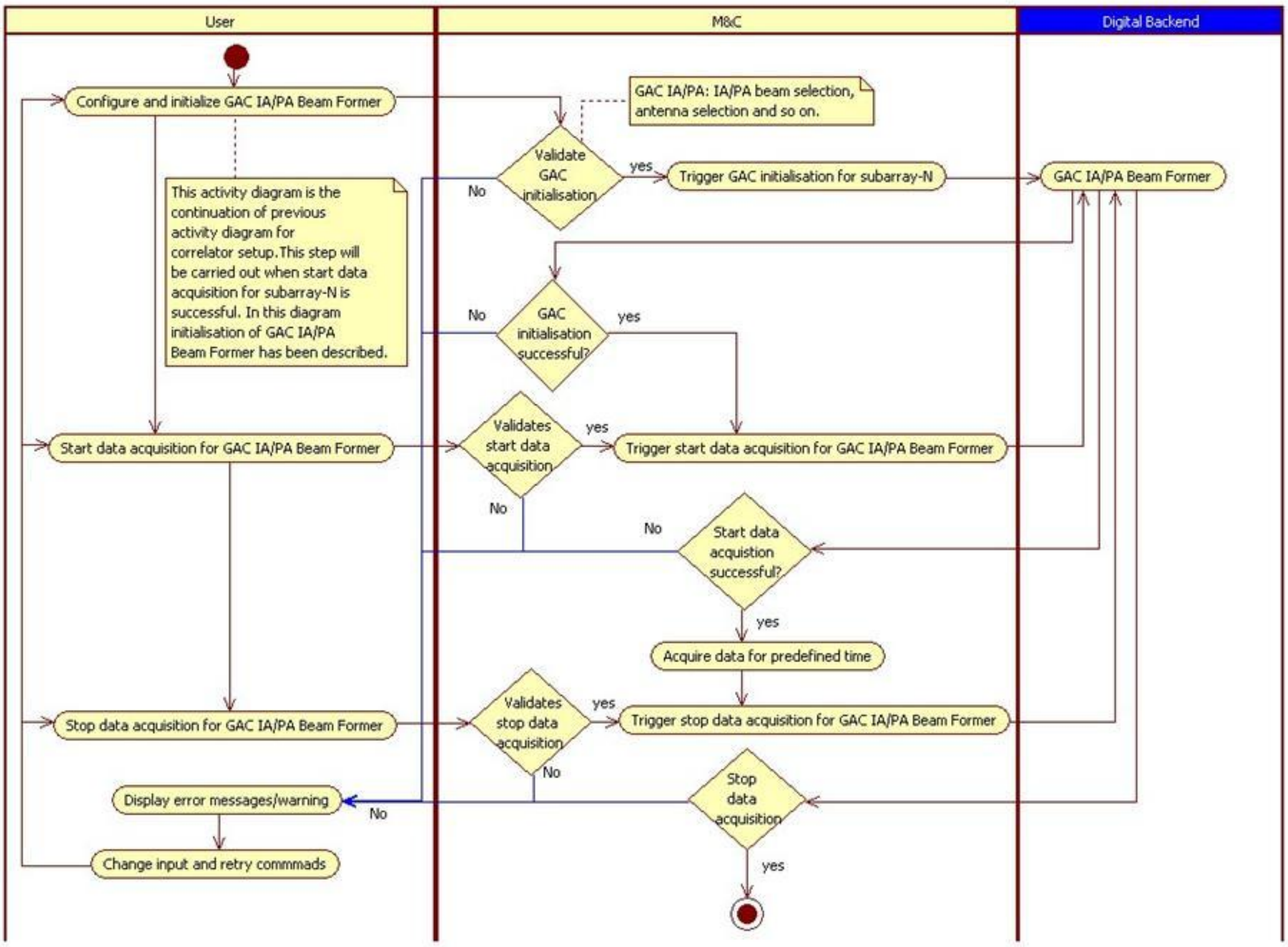

Figure 19: Activity diagram for Correlator Setup- Initialization of GAC and IA/PA Beam Former

2.1.11. Generate Observation Report

Table 19: Use Case for Generate Observation Report

Use Case: Generate Observation Report	
Use Case ID	M&C_UC_012
Goal	To view and generate observation reports for given observing session(s).
Summary	All observing session data is logged by the M&C. This can include all engineering data from all the subsystems, user – system transactions, alarm and warning occurrences and so on. User can generate observation session logs by specifying the desired observation(s) sessions in the past. Generating observation sessions reports are governed by user privileges configuration. Observation reports includes all the engineering data relevant to the observation, flagged data available to the M&C through its interface with external data quality monitoring tools and observation meta information such as Astronomer, frequency of observation, no. of antennae used. User may optionally export observation reports in formats pre-defined in configuration. Observation reports mainly contains the following : • M&C malfunctioning system/sub-system data: This includes information such as alarm raised for antennas not tracking the target source, sub-systems not communicating (timeout) and so on. This data is referred as the flag-file. The flag-file generated by M&C system can be used to flag the science/astronomical data (acquired using the digital back-end systems). • Observation log: This includes the meta-information fields such as observing-code, date, time, project title, project user, frequency band used, GTAC cycle number, observing log number and so on. Telescope operator writes information manually for the problem occurred or sequence of task executed in case of changed observing plan or problems such as electrical power failure, malfunctioning of the correlator and so on. • User Notes: User can append the notes, additional logs (for example-observing experience summary) to the observing log.
Actors	Operator, Astronomer
Priority	3
Status	Accepted
Preconditions	• M&C is up and running. • User is authenticated.
Trigger	On Demand
Assumptions	NA

Use Case: Generate Observation Report		
Use Case Flows		
Basic Flow		User views desired reports.
1.	User	User selects option to view reports.
2.	User	User selects Observation(s) to generate observation reports.
3.	M&C	Validates if Observation reports are available.
4.	M&C	Displays all available data logs and reports for the desired observation(s) to the user.
		Exit use case.
Alternate Flow 1		Unable to generate observation reports due to invalid request or data not available.
3	User	Validates if Observation reports are available.
4-1	User	Identifies that user request is invalid or desired data is not available.
4-2	M&C	Notify to user.
		Exit use case.
Stakeholders		
Stakeholder		Operator, Astronomer, Engineer.
Interest		To view and generate observing session reports such as engineering information from logs, observation meta information, flag data information from interfacing tools.
Post Conditions		
On Success		Observation reports can be retrieved.
On Failure		Observation reports cannot be retrieved and hence cannot be used for Science Analysis.
Process Rules		
Sr No	Process Rule	
1.	User must have appropriate permissions to view or generate reports relating to a given observation.	
2.	User may also provide additional logs as part of observation report generation. These logs may be from interfacing tools (For example- data quality monitoring).	

Use Case: Generate Observation Report	
3.	User can export generated reports in pre-defined file formats and send them over e-mail
4.	User can select to view observation reports for multiple observations.
5.	User is notified of all errors while retrieving observation data and generating reports.
6.	User input to generate observation reports for given observations are governed by UI Design (For example- Dropdowns, Text).
7.	User may also query for observations and view summary information of all observations (that the user has view privileges) and then view or generate reports.
8.	User may custom generate observation report package by choosing the list of logs to be part of the observation report. (For example- User may choose not to include flag data as observation reports).
9.	In addition to logs, the reports may include comments recorded by operator or astronomer. This can be written while observing session is progress or while generating reports.
10.	The observation reports can be automatically sent to the astronomers and co-investigators via email.
11.	The observation reports can be exported to the external USB data storage device.
12.	User can upload custom files to the observation reports package. (For example- file containing a User's feedback to management about the observing experience)
13.	The observation logs only pertaining to the observations conducted using new M&C system could be retrieved.

Additional Data Validation Rules

Sr No	Validation Rule
1.	NA

Working Details

Sr No	Issues for Resolution	Status
1.	Need to identify all reports to be combined as observation report package.	Open
2.	Template of the reports and GUI designs for the reports page will bring the clarity to this requirement. Need to finalise it as soon as possible.	Open

2.1.12. Data Logging

Table 20: Use Case for Data Logging

Use Case: Data Logging	
Use Case ID	M&C_UC_013

Use Case: Data Logging		
Goal		To log the data of M&C
Summary		The M&C continuously monitors data received from various monitoring points. In addition to this , the M&C logs various types of data such as user transactions with the system, commands and responses, occurrence of failures, monitoring parameters, messages coming from various subsystems to M&C. The logged data helps in data analysis, fault and failure diagnosis and audit rail of logged data. System configuration defines the data to be logged, the logging formats, log signatures, rates at which specific data is to be logged. Although data logging is a continuous activity, M&C also logs event based data such as user transactions, alarm and warning occurrences.
Actors		M&C System
Priority		1
Status		Accepted
Precondition		M&C is up and running.
Trigger		Continuous
Assumptions		System configuration for Data logging is valid.
Use Case Flows		
Basic Flow		Logs the data.
1.	M&C	Monitors all M&C data and events.
2.	M&C	Loads data logging configuration for all monitoring parameters.
3.	M&C	M&C logs all data as described in the configuration.
		Exit Use case.
Alternate Flow 1		Data logging is unsuccessful due to corrupt logs or no disk space.
3	M&C	M&C logs all data as described in the configuration.
3_1	M&C	Identifies that data logging is unsuccessful due to corrupt logs or no disk space.
3_2	M&C	Notifies the user and raise appropriate alarm condition.
		Exit use case.
Stakeholders		
Stakeholder		Operator, Astronomer, Engineer
Interest		To log all operational and system data for analysis and audit trail.

Use Case: Data Logging		
Post Conditions		
On Success	All monitored data is logged correctly for analysis.	
On Failure	All data related to the M&C will not be logged and data may be lost.	
Process Rules		
Sr No	Process Rule	
1.	System allows configuration of log data formats.	
2.	System allows definitions of custom data logs using user interface of M&C.	
3.	All the logged data should be retrievable.	
4.	User may view and replay logs on demand.	
Additional Data Validation Rules		
Sr No	Validation Rule	
1.	NA	
Working Details		
Sr No	Issues for Resolution	Status
1.	What kinds of events are allowed to be logged?	Open
2.	What happens if data gets corrupted or data is unavailable?	Open
3.	Data logging constraints (read write restrictions, minimum time after which data can be retrieved for replay logs) needs to be finalised	Open

2.1.13. View Logs

Table 21: Use Case for View Logs

Use Case: View Logs	
Use Case ID	M&C_UC_014
Goal	To view the logs
Summary	M&C of GMRT records and saves various types of data from all monitoring points and operation performed in the form of data logs. M&C records all monitoring and event data in predefined log formats This may be used for fault identification, diagnosis and for audit trail purposes. Audit trail helps in viewing user and system activities over time such as user log-on and log-off, messages sent and received by the system and other user-system transactions.

Use Case: View Logs		
		Replay logs are mainly used for the diagnostic purpose. On replaying logs user can identify failure points and can flag events during diagnosis. M&C displays the logs as raw text data, tables, graphs and charts as configured. The process of viewing logs is depicted in activity diagram in ***Figure 20***.
Actors		Engineer, Operator, Astronomer.
Priority		2
Status		Accepted
Precondition		M&C is up and running.
Trigger		On Demand
Assumptions		NA
Use Case Flows		
Basic Flow		View the logs.
1.	User	Requests M&C to display log.
2.	M&C	Validates user's request as per UI design.
3.	M&C	Retrieves logs based on user’s query.
4.	M&C	Displays the logs.
		Exit use case.
Alternate Flow 1		View logs are not successful due to invalid user query or logs not available.
2	M&C	Validates user's request as per UI design.
3_1	M&C	Identifies user’s request as invalid or data logs are not viewable.
3_2	M&C	Notifies user.
		Exit use case.
Stakeholders		
Stakeholder		Operator, Engineer and Astronomer.
Interest		To view and replay logs for troubleshooting, to get details of the performed task, and to figure out various events as well as errors occurred during the execution of task.
Post Conditions		

Use Case: View Logs	
On Success	• User views and replays logs to diagnose the failure if any. • User may perform an audit trail.
On Failure	• User can not view and replay logs. • User may not be able to diagnose the faults.

Process Rules

Sr No	Process Rule
1.	Viewing logs is possible only for historical data log.
2.	Viewing logs is governed by user privileges configuration.
3.	User has an option to select the rate of replaying logs.
4.	User can export logs in predefined export formats.
5.	M&C displays the logs over the same time span as it has executed during task.
6.	User can query for logs over a specified duration of time and can view logs as graphs, tables, charts as governed by UI design.
7.	M&C notifies user if logs are not viewable.
8.	System shall perform archival of logs as defined in the configuration during housekeeping.
9.	If data for the logs is not available with the central M&C system, then data could be retrieved from LMC data base.
10.	System should provide the facility to search event from a list of events.

Additional Data Validation Rules

Sr No	Validation Rule
1.	NA

Working Details

Sr No	Issues for Resolution	Status
•	NA	NA

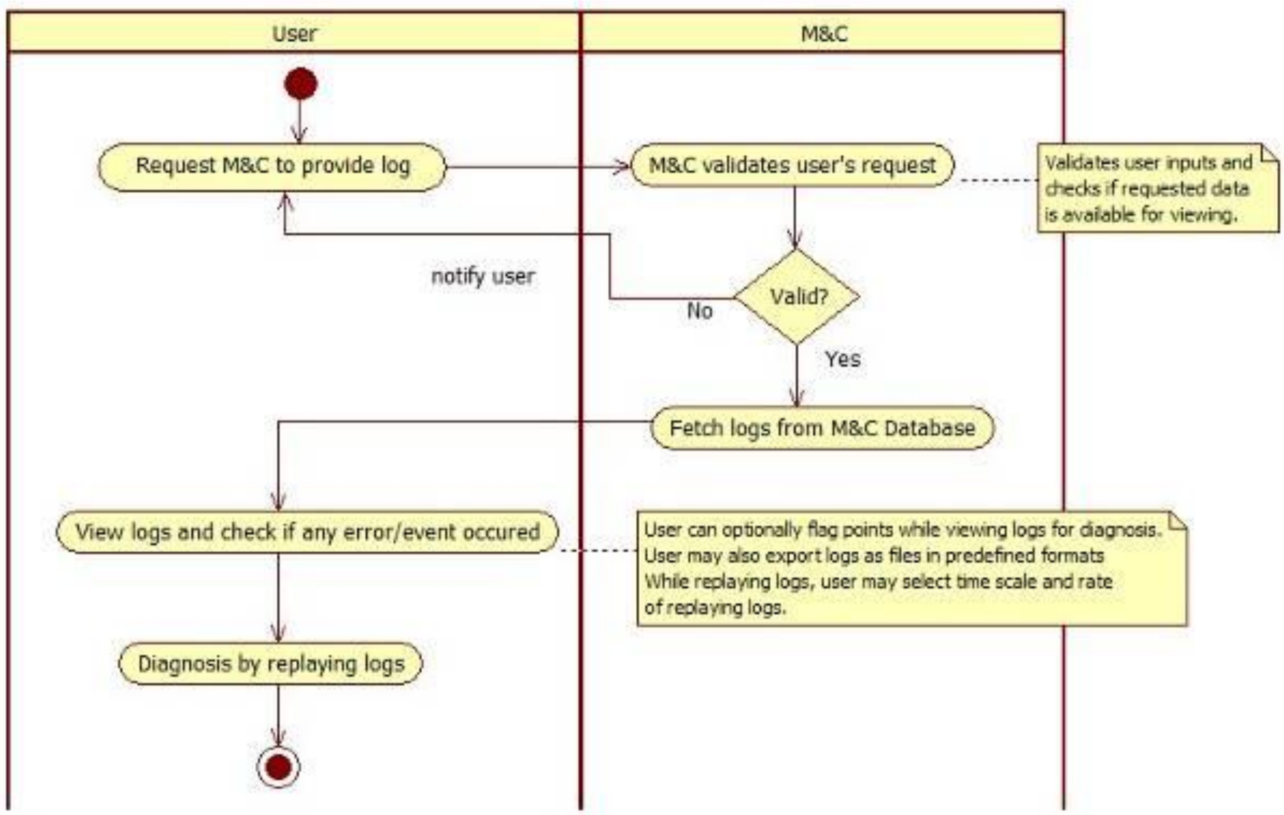

Figure 20: Activity diagram for View Logs

2.1.14. Basic Diagnostics

Table 22: Use Case for Basic Diagnostics

Use Case: Basic Diagnostics	
Use Case ID	M&C_UC_015
Goal	To perform basic diagnostics by sending control commands to GMRT subsystems
Summary	User performs basic diagnostics operations by sending control commands to various subsystems. This helps during maintenance and diagnostic purposes as well as testing and calibration activities. An authenticated user optionally issues commands which can override normal operating limits for testing purposes. User can set an antenna/ subsystem to be under test to perform diagnostics. Diagnostic activities can be done by the Engineer or an Operator on a given antenna, group of antennae or any subsystem in the receiving chain. Some examples when user may perform basic diagnostics by sending control commands include: Calibrate hardware or verify for errors, after maintenance activities are carried out

Use Case: Basic Diagnostics		
		on antenna or subsystems To carry out testing activities (For example- finding optimum power level at various monitoring points For fault identification and isolation. To set/reset subsystem parameter limits for operations and maintenance activities (For example- Servo safety limits for azimuth and elevation).
Actors		Operator, Engineer
Priority		1
Status		Accepted
Preconditions		• M&C is up and running. • User is authenticated.
Trigger		On Demand
Assumptions		System configuration is valid
Use Case Flows		
Basic Flow		Performs diagnostics successfully.
1.	User	Selects subsystem or antenna to perform diagnostics.
2.	M&C	Performs safe mode/state transition procedure as defined in configuration after checking user privileges before allowing the user to perform diagnostics.
3.	M&C	Loads Maintenance user interface as governed by UI configuration for the user.
4.	User	Authenticated user or any other privileged user performs diagnostics by providing input of subsystem, antenna, control command to be sent, command's arguments and values.
5.	M&C	Validates inputs and notifies user.
6.	M&C	Interprets that the user inputs are valid.
7.	M&C	Sends control command based on the inputs given by the user.
8.	User	Monitors diagnostics activities on dashboard.
		Exit use case.
Alternate Flow 1		Diagnostics cannot be performed due to state transition failure, insufficient user privileges.
2	M&C	Performs safe mode/state transition procedure as defined in configuration after checking user privileges before allowing the user to perform diagnostics.

Use Case: Basic Diagnostics		
3_1	M&C	Interprets diagnostics cannot be performed due to state transition failure, insufficient user privileges.
3_2	M&C	Notifies the user.
		Exit use case.
Alternate Flow 2		Basic diagnostics failed due to invalid inputs for control commands.
5	M&C	Validates inputs and notifies user.
6_1	M&C	Interprets that diagnostics cannot be performed due to invalid user inputs for subsystem, antenna or control commands, arguments, values or messages.
6_2	M&C	Notifies the user.
		Exit use case.
Stakeholders		
Stakeholder		Engineer and Operator
Interest		To perform basic diagnostics by sending control commands to the GMRT subsystems for fault analysis, diagnosis, testing, and maintenance activities.
Post Conditions		
On Success		Use can perform diagnostics on desired systems / antenna.
On Failure		User is unable to perform diagnostics and hence fault identification, isolation and recovery is not possible and can hinder operational safety, system availability and reliability.
Process Rules		
Sr No	Process Rule	
1.	User may optionally choose to trigger fault sheet after diagnostics.	
2.	System shall ensure command integrity and operational safety when performing diagnostics.	
3.	Only privileged users can perform diagnostics as defined in the configuration.	
4.	User is notified of all errors occurrences while performing diagnostics.	
5.	Command selections, Destination system selection, arguments for the command are predefined in the configuration. UI Design governs how the input is given to the system and how the monitoring parameters are viewed.	

Use Case: Basic Diagnostics		
6.	Alarms and warnings management rules for diagnostics are predefined in the configuration.	
7.	System shall maintain all activity logs during diagnostics for audit trail purposes.	
8.	System shall handle mode changes between normal operation and diagnostics for a subsystem or any antenna while an operation is in progress. This shall ensure operational integrity, safe state transitions and fault isolation.	
9.	User may also connect to remote hardware and can perform diagnostics using low level commands to the hardware from CMC, RMC and LMC.	
10.	User who set system to diagnostic mode may be different from user who performs diagnostics. For example- an Operator may set an antenna in maintenance or diagnostic mode while and engineer with privileges may send control commands to the antenna under diagnostics.	
11.	Changing of system mode from diagnostic or normal should be taken offline.	
Additional Data Validation Rules		
Sr No	Validation Rule	
1.	NA	
Working Details		
Sr No	Issues for Resolution	Status
1.	List of constraints for performing diagnostics on one or more antenna or subsystems, during and post observations, is required.	Open
2.	Mode transitions and related processes need to be finalised	Open

2.1.15. View Dashboard

Table 23: Use Case for View Dashboard

Use Case: View Dashboard	
Use Case ID	M&C_UC_016
Goal	To monitor the high level state of overall GMRT system.
Summary	The dashboard provides the overall high level logical state of the GMRT systems/ subsystems. Users of the GMRT system have varied interests to monitor different information related to GMRT systems. This information is monitored using the user's dashboard. Dashboard shall help user to view the high level real-time status, analysis results, tracking the information with the help of plots/chart, proactive-alerting and drill-down monitoring for the detail diagnosis relevant to the system. Contents of the dashboard that is the parameters that the user monitors, varies from one user to another as defined in the configuration. M&C provides the dashboard to all categories of the users with the default

Use Case: View Dashboard	
	monitoring parameters for user category. System also allows configures their dashboard parameters. User may also choose how the parameters need to be displayed on the dashboard. (Example using graphs or tabular data or a dial). Some users can use the dashboard to view intermediate high level data to be monitored in addition to monitoring parameters. M&C also provides the facility of drill-down monitoring which is used to view detailed information about selected high level parameter depicted on a dashboard. The indicative list of the default monitoring parameters for various subsystems is listed under ***GMRT Parameter List.*** Dashboard monitoring parameters for various users of the system including drill monitoring shall be detailed during subsequent phases of the project.
Actors	Operator, Engineer, Astronomer, GCC
Priority	1*
Status	Accepted
Preconditions	• M&C is up and running. • User is authenticated.
Trigger	On Demand
Assumptions	NA
Use Case Flows: This is explained with the help of Activity diagram in ***Figure 21***	
Stakeholders	
Stakeholder	Operator, Analog Engineer, Digital Engineer, Astronomer.
Interest	To monitor all important operational, health and sentinel parameters relevant to the stakeholder to aid fault isolation and identification of problems, testing and to ensure operational safety.
Post Conditions	
On Success	All relevant parameters that are to be monitored by the stakeholder are available for monitoring.
On Failure	User will be unable to monitor critical system operations, health and status parameters.
Process Rules	
Sr No	Process Rule

Use Case: View Dashboard		
1.	User may navigate in a drill down approach to view detailed information when available.	
2.	User may navigate or exit to view higher level dashboard view while in drilled down monitoring level (view detailed information on a parameter).	
3.	User should be able to configure their dashboard to define the list of parameters to monitor.	
4.	In addition of monitoring parameters, user should be able to navigate to other M&C functionalities (such as View statistics, Generate Reports, View configuration) as governed by the UI design.	
5.	User should be able to perform relevant control functions for some functionality of the M&C from the dashboard (UI) as configured in the configuration.	
6.	Whenever data is unavailable, user must be notified.	
Additional Data Validation Rules		
Sr No	Validation Rule	
1.	NA	
Working Details		
Sr No	Issues for Resolution	Status
1.	Dashboard details for all users including list of monitoring parameters and mode of display will be required.	Open

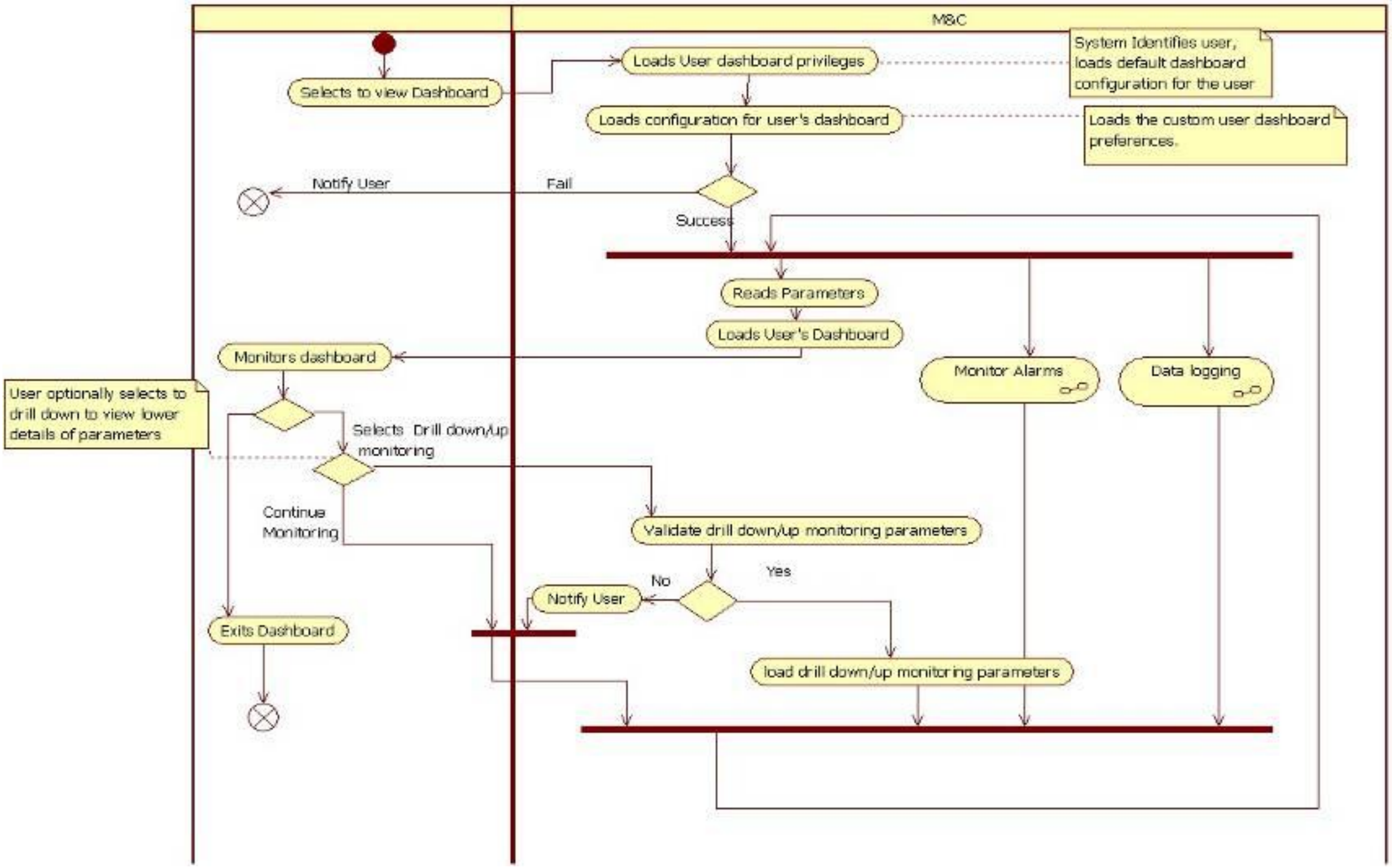

Figure 21: Activity Diagram for View Dashboard

2.1.16. Monitor Alarms and Warnings

Table 24: Use Case for Monitor Alarms and Warnings

<table>
<tr><th colspan="3">Use Case: Monitor Alarms and Warnings</th></tr>
<tr><td colspan="2">Use Case ID</td><td>M&C_UC_017</td></tr>
<tr><td colspan="2">Goal</td><td>To monitor alarms and warnings occurrences in the system.</td></tr>
<tr><td colspan="2">Summary</td><td>The monitoring and control system, continuously acquires the data from various subsystems. M&C monitors the values of the acquired parameters and raises alarms/warnings when the values exceed the preconfigured limits or error conditions are reached. The criticality of the alarms (Warning/ Medium/ High/ Emergency) will be preconfigured in the system to aid early corrective actions on occurrence of alarms. The alarm conditions, mode of notifications, the list of users to be notified on occurrence alarm are preconfigured in the system. M&C generates alarms and warnings on the following occurrences:
Alarm signal is received by the M&C.
Monitoring parameter(s) has reached alarm conditions or limits as defined in the configuration.
When an alarm or a warning condition is raised, all relevant stakeholders are notified of the alarm. An authenticated user with privileges may perform corrective action in order to douse the alarm condition. Some alarm/warning conditions may have auto-corrective actions defined in system, which then system executes to douse the alarm conditions. User can also generate a fault sheet for the alarms, which is used for offline diagnostics and maintenance of the system.

The indicative list of the default alarms and warning parameters for various subsystems is listed under GMRT Parameter List.</td></tr>
<tr><td colspan="2">Actors</td><td>M&C, Astronomer, Operator, Engineer</td></tr>
<tr><td colspan="2">Priority</td><td>1</td></tr>
<tr><td colspan="2">Status</td><td>Accepted</td></tr>
<tr><td colspan="2">Preconditions</td><td>M&C is up and running
User is Authenticated</td></tr>
<tr><td colspan="2">Trigger</td><td>Continuous</td></tr>
<tr><td colspan="2">Assumptions</td><td>All relevant system configurations (alarms and warnings) are valid.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Use Case Flows</td></tr>
<tr><td colspan="2">Basic Flow</td><td>Alarm/ Warning condition is triggered and user is notified.</td></tr>
<tr><td>1.</td><td>M&C</td><td>Continuously monitors meta data of all subsystems and finds that operational limits or error conditions are reached for one or more monitoring parameters.</td></tr>
</table>

Use Case: Monitor Alarms and Warnings		
2.	M&C	Identifies the alarm or warning configuration (notifications types, criticalities, relevant stakeholders to notify, associated actions to perform, if any, from its configurations).
3.	M&C	Raises alarm/warning and notifies to the relevant user(s).
4.	M&C	Identifies associated actions for all and notifies user.
		Exit use case
Alternate Flow 1		Non-conflicting auto dousing actions are defined.
4	M&C	Identifies associated actions and notifies user.
4_1	M&C	Performs associated dousing actions as defined for the given alarm/warning conditions.
4_2	M&C	Notifies updated alarm conditions status to user.
		Exit use case
Alternate Flow 2		Conflicting or no auto dousing actions are defined.
4	M&C	Identifies associated actions and notifies user.
4_1	M&C	Identifies that auto dousing actions for the active alarm is not defined or conflicting.
4_2	M&C	Notifies user that auto dousing cannot be performed.
4_3	User	Performs dousing action as per available privileges. These may include performing corrective control actions, shutdown, snoozing alarms or initiating maintenance activities to identify problems and douse alarm.
		Exit use case.
Stakeholders		
Stakeholder		M&C system, Engineer, Operator, Astronomer
Interest		To monitor all critical system parameters relevant to stakeholders and receive notified on error or alarm conditions to aid speedy fault isolation and recovery.
Post Conditions		
On Success		• Alarm and warnings are notified to the relevant users. • Logs the Alarm/warning occurrence event into the system. (Following details are logged: Timestamp, Description, and Alarm Acknowledgement time). • Take pre-defined auto-corrective action if any, in the M&C system.

Use Case: Monitor Alarms and Warnings	
On Failure	• User will be unable to monitor occurrences of critical system alarms or warning conditions and will be unable to diagnose problems. • System safety and availability will be adversely affected.

Process Rules	
Sr No	Process Rule
1.	User may set custom preferences for alarm notifications and choose not to get notified on specific alarm conditions.
2.	User optionally selects parameters to view detailed information on any alarm (drill down monitoring dashboard).
3.	Some alarm and warning conditions may have an alarm generation hierarchy, in which alarm in one or more low level monitoring parameters can result in one high level alarm conditions.
4.	Alarms Management methods and processes should be compliant with industry standards.
5.	User can choose to acknowledge and ignore alarms and warnings, unless it requires mandatory dousing action by at least one user.
6.	Once acknowledged, alarms are passively monitored on the user's dashboard for a specified duration of time. After this time, if alarm persists, alarm notification is re-initiated.
7.	System should handle alarm flooding situations and resolve alarms conflicts wherever necessary and possible.
8.	User optionally triggers fault sheet generation process for pre-defined alarms using M&C.
9.	Critical alarm should be differentiated from active alarms.

Additional Data Validation Rules	
Sr No	Validation Rule
1.	NA

Working Details		
Sr No	Issues for Resolution	Status
1.	List of parameters, alarms and warning conditions to be monitored, notification methods, dousing actions are required.	Open
2.	User privileges for monitoring alarms, warning conditions need to be finalised.	Open
3.	What if the commands are issued simultaneously from different systems/users together?	Open

2.1.17. Antenna Parking

Table 25: Use Case for Antenna Parking

Use Case: Antenna Parking		
Use Case ID		M&C_UC_018
Goal		Perform safety operation to avoid the structural damage to the GMRT antenna.
Summary		The Parking position is the safest state for the GMRT antennas from the structural safety points of view. In Parking position, antenna is brought to a Stow Position (Presently, this is defined as, an elevation angle of 90° with an accuracy of ±1° followed by application of the brakes to servo system motors and stow locking). Parking of the GMRT antenna is a safety requirement of M&C. M&C communicates with Servo system at regular interval. Servo system reads the Wind speed continuously and communicates to M&C. If the wind speed reaches beyond the preconfigured limits, servo system initiates the antenna parking and communicates to M&C about initiation of the parking process. Based on this information M&C initiates the parking of all other antennas. This process is also explained using activity diagram in ***Figure 22***.
Actors		Operator, M&C, Engineer
Priority		1
Status		Accepted
Preconditions		M&C system is communicating to the servo sub-system at the GMRT antenna base. Servo system is in the normal state.
Trigger		On Demand/ System Shutdown
Assumptions		Stow position of the antenna is known to M&C and/or Servo system.
Use Case Flows		
Basic Flow		Park Antenna.
1.	M&C	Detects the need of antenna parking (User issues a command to either park antenna or to shut down M&C or Servo system raises an alarm of high wind speed).
2.	M&C	Requests to all antenna servo systems to park the antenna.
3.	Servo System	Acts on the antenna parking request (Stows the antenna) and responds to M&C.
4.	M&C	Interprets the response from Servo system.
5.	M&C	Interprets that the antenna parking was successful.

Use Case: Antenna Parking		
		Exit use case.
Alternate Flow 1		Apply Only Breaks.
4	M&C	Interprets the response from Servo system.
5_1	M&C	Interprets that the antenna parking was not successful.
5_2	M&C	Requests servo system to apply the break Elevation and Azimuth axis.
		Exit use case.
Stakeholders		
Stakeholder		Operator, GCC, Servo System, Senior Management.
Interest		To ensure the system safety.
Post Conditions		
On Success		The antenna(s) are parked successfully.
On Failure		• Antennas are not parked, structural safety is compromised. • Astronomical data acquisition is stopped.
Process Rules		
Sr No	Process Rule	
1.	Astronomical data acquisition needs to be stopped before user issues antenna parking command.	
2.	Antenna tracking needs to be stopped (if in progress), before parking the antenna.	
3.	If any antenna on any arm faces problem such as high wind then all antenna will be parked.	
Additional Data Validation Rules		
Sr No	Validation Rule	
1.	NA	
Working Details		
Sr No	Issues for Resolution	Status
1.	NA	NA

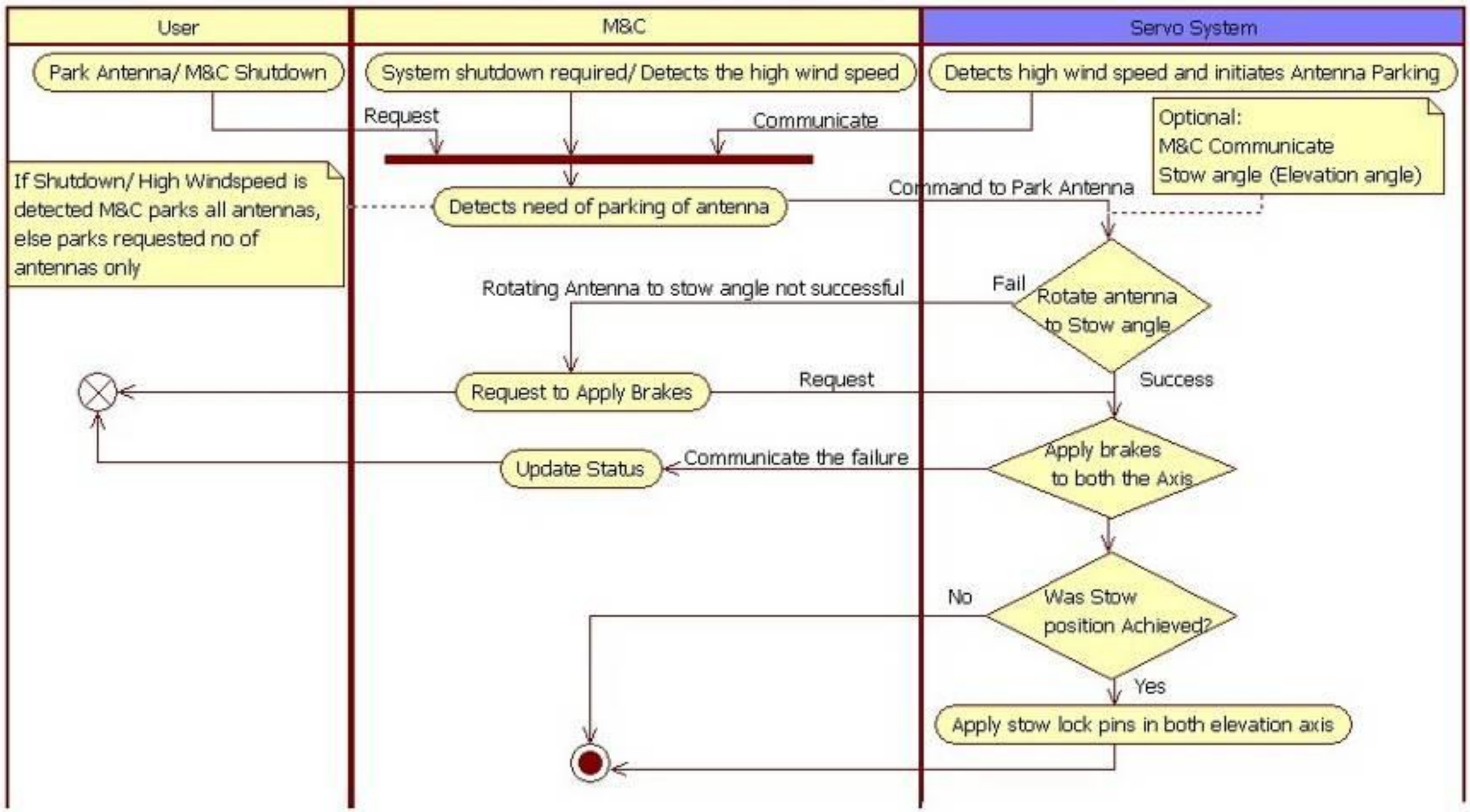

Figure 22: Activity Diagram for Antenna Parking

2.1.18. Generate Fault-sheet

Table 26: Use Case for Generate Fault-Sheet

Use Case: Generate Fault-sheet		
Use Case ID		M&C_UC_019
Goal		To automate the process of generating the fault-sheets.
Summary		In case any of the GMRT subsystem is observed to be not functioning as per the norms, then Operator generates the fault sheet and hands it over to the GCC department. With the present system, Operator fills the fault-sheet details by hand. There is a scope to turn around the existing process into an automated paperless operation. M&C monitors all the alarms of GMRT operations. The specific alarm, against which fault-sheet needs to be generated, is pre-configured in the system. Also, a facility to turn-off the automatic fault-sheet generation is provided to facilitate the maintenance activities.
Actors		Operator, Astronomer, Engineer
Priority		3
Status		Accepted
Preconditions		M&C is up and running
Trigger		On occurrence of Alarm/ fault
Assumptions		NA
Use Case Flows		
Basic Flow		Generate and log the fault-sheet
1.	M&C	Detects the alarm/ fault situation for which a fault-sheet needs to be generated.
2.	M&C	Retrieves the relevant details from the system pertaining to the alarm/fault and automatically generates the fault-sheet and displays it on user interface. (The details in the fault-sheet includes: Antenna Number, present settings of Local Oscillator (LO), Radio Frequency (RF), Intermediate Frequency (IF), servo and feed position, description of the fault, timestamp of the occurrence of the fault and so on.).
3.	User	Takes appropriate action
4.	User	Reviews the fault-sheet details, corrects/edits the information if required and chooses an option to log the fault-sheet.
5.	M&C	Generates and assigns the unique identifier (ID) to the fault-sheet.
6.	M&C	Logs the fault-sheet details.

Use Case: Generate Fault-sheet		
		Exit use case
Alternate Flow 1		Ignore the fault-sheet.
3	User	Takes appropriate action
4_1	User	Reviews the fault-sheet details then accordingly decides to discard it, with the reason for ignoring it.
4_2	M&C	Records the fault-sheet rejection event along with the reason.
		Exit use case.
Stakeholders		
Stakeholder		GCC
Interest		To ensure highest availability of the GMRT facility.
Post Conditions		
On Success		• Fault-sheet details are logged. • GCC views/assigns the fault-sheet to respective subsystem-owner/ department.
On Failure		Fault-sheet details are not recorded in system.
Process Rules		
Sr No	Process Rule	
1.	NA	
Additional Data Validation Rules		
Sr No	Validation Rule	
1.	NA	
Working Details		
Sr No	Issues for Resolution	Status
1.	Get the complete list of the parameters/entities to be logged for the fault-sheet mentioned under step ***2.***	Open

Use Case: Generate Fault-sheet		
2.	Finalise the scheme for generation of the fault-sheet ID mentioned under step ***5.***	Open

2.1.19. Generate Reports

Table 27: Use Case for Generate Reports

Use Case: Generate Reports		
Use Case ID		M&C_UC_020
Goal		To generate reports and view statistics on GMRT system operations.
Summary		Users of the GMRT system often generate reports pertaining to system operations, subsystem failure reports, system availability, critical alarms and warning occurrences, system usage, usage data of various devices in the GMRT system, ambient conditions and introspection reports. These reports are generated using the historical data logged by the M&C. System usage statistics can be used for analysis and predictive maintenance of subsystem hardware. These data may include usage data of motors in servo system and other hardware devices which help the user (engineer) to pre-empt problems due to hardware wear and tear before reaching usage limits. User may generate reports by querying for various data fields and criteria and share them with stakeholders. User may also configure scheduled generation of reports and notifications (daily, weekly, monthly, and annually). Indicative list of high level reports and statistics that can be monitored by various users shall be detailed in subsequent phases of the project.
Actors		Operator, Astronomer, Engineer, Operations Group, GCC.
Priority		2
Status		Accepted
Preconditions		• M&C is up and running. • User is authenticated to view the reports.
Trigger		On Demand.
Assumptions		NA
Use Case Flows		
Basic Flow		User views desired reports.
1.	User	User selects option to view reports.
2.	M&C	Provides default summary of statistics and reports as per the user category and configuration.
		Exit use case.

Use Case: Generate Reports	
Stakeholders	
Stakeholder	Operator, Astronomer, Engineer, Operations Group, GCC.
Interest	To generate reports and view statistical information of various parameters. Some statistical information aids preventive maintenance by providing usage statistics of hardware device to pre-empt wear and tear and failure.
Post Conditions	
On Success	All relevant statistics, metrics, and reports are available for user for monitoring.
On Failure	User will be unable to view or generate reports on various system operations and behaviour.

Process Rules	
Sr No	Process Rule
1.	User can optionally provide inputs to query or filter for M&C data to generate reports in graphical or textual form.
2.	User can export generated reports or statistics dashboard to various pre-defined file formats.
3.	User can define custom reports to be generated based on a criterion that the user provides. Each report may have multiple queries for report generation.
4.	M&C administrator can define predictive maintenance data from which statistics can be computed.
5.	Statistics relating to Predictive maintenance may be available to M&C through interface to external applications.
6.	User can configure auto notification of generated reports over a specified frequency, notification method and format.
7.	The operations group can configure the templates for various types of reports.

Additional Data Validation Rules	
Sr No	Validation Rule
1.	NA

Working Details		
Sr No	Issues for Resolution	Status

Use Case: Generate Reports		
1.	List of high level introspection parameters, metrics, reports viewable by various users need to be provided.	Open
2.	Template of the reports and GUI designs for the reports page will bring the clarity to this requirement. Need to finalise it as soon as possible.	Open
3.	Need to identify how predictive maintenance is done using M&C and how is the data available to M&C.	Open

2.1.20. Antenna Control and Position

Table 28: Use Case for Antenna Control and Position

Use Case: Antenna Control and Position	
Use Case ID	M&C_UC_021
Goal	To control and position the antenna during observation, tracking the moving celestial source with offset.
Summary	Servo system of GMRT is responsible for Antenna control and positioning operations. Servo system performs following four main functions related to antenna control: • Source Tracking • Antenna Positioning • Scanning • Source Tracking with Offset In source tracking, AZ and EL for positions of the antenna are adjusted such that it continuously follows the given source trajectory. This is achieved by calculating the new AZ and EL positions based on the present IST and RA, DEC, Epoch of a given source. For a given source, values of RA and DEC remains constant[7], however it's hour angle (LST - RA) changes. Based on the changes in LST, the new AZ and EL positions are calculated by M&C and communicated to servo at predefined interval (30 sec. presently). The source tracking can be started if the entire selected antenna (sub array) is pointed towards a desired source. The antennas in a given sub array may exist in different AZ and EL positions and may needs varying amount of time to point towards a source of interest. M&C waits for a time, called as tracking delay to facilitate this scenario. The time interval to position the antenna to the target source before starting of the actual tracking starts is called tracking delay. Position involves the movement of antenna to a specified AZ and/or EL positions. This operation is not a time dependant operation. During Scan operation, the antenna is moved faster than the speed at which source moves in the sky, so that the antenna quickly scans the source. (This operation is similar to the operation of RADAR, which scans the object in the sky at regular interval). To achieve this, M&C provides the information of AZ and EL

[7] For the planetary source the value of RA changes. While setting up the observation/ test user provides this information appropriately.

Use Case: Antenna Control and Position	

	or RA and DEC, tracking rate and target time to the servo system.
	Source tracking with offset is a similar to source tracking, however, a known offset is applied either to RA and DEC or to AZ and EL before sending the track command to servo system.
	
	Apart from above mentioned functions, servo system also controls the other antenna operations such as antenna parking, etc.
	To fulfil the above mentioned functionalities of servo system, M&C system performs following functions:
	• Initialize the servo system
	• Send basic operational, display and set commands to servo without any conversion.
	• Execute higher level tasks such as:
	  o Get Real time status of servo system per second.
	  o Send basic track command per 30 seconds to follow the source trajectory.
	  o Read servo events and take safety major actions.
	  o Keep antenna within servo safety limits.
	• Send higher level commands to group of antennas for the tracking or positioning.
	• Receive the asynchronous messages from servo system and act on it
	Majority of the operations mentioned above are performed by the LMC component of M&C system.

Actors	Operator, Astronomer, Engineer
Priority	1
Status	Accepted
Preconditions	• Source is up in the sky • Observation is scheduled • M&C is up and running • Servo system is initialised and communicating properly • Desired source shall be available in the user/ GMRT source catalog • No critical alarm is enabled • Antennas are configured under sub-array in case of array-tracking.
Trigger	On Demand
Assumptions	Before tracking and scanning the source M&C has information about source coordinates.
Basic Flow	Source tracking

Use Case: Antenna Control and Position		
1.	M&C	Ensures communication with servo system is initialised. Refer Figure 23
2.	User	Chooses any of the following tasks: • Source Tracking • Antenna Position • Scanning
3.	User	Selects source tracking and provides the tracking inputs which includes: • Source name • Tracking duration (hour or minutes or second).
4.	M&C	Accepts user inputs and searches the source in user/GMRT source catalog.
5.	M&C	Waits for tracking delay (if any)
6.	M&C	Converts source equatorial coordinates RA-DEC, epoch into horizontal coordinates Azimuth and Altitude (Elevation) and send 'track' command to given antenna after AZ and EL antenna offsets corrections.
7.	Servo System	Accepts command and acts on it, also sends monitoring parameters to M&C.
8.	M&C	Interprets servo system's response.
9.	M&C	Interprets that the command was executed successfully.
10.	M&C	Repeats steps 6 to 8 per pre-defined time till tracking time is over or user aborts operation or source is set or any alarm is raised reached or higher/lower limit of Elevation or Inner-Outer Limit of Azimuth is reached.
		Exit use case
Alternate Flow 1		Scanning
2	User	User may select any of the task: • Antenna Tracking • Antenna Position • Scanning
2_1	User	User selects option for scanning and provides following input: • AZ and EL OR RA and DEC • Tracking rate • Expected Target time for the exact on source.
2_2	M&C	Accepts user inputs and sends scan command to servo system.
2_3	Servo System	Accepts command and acts on it, also sends monitoring parameters to M&C.
2_4	M&C	Interprets servo system's response.
2_5	M&C	Interprets the success response of command.
2_6	M&C	Repeats basic flow step 6 to 8 for pre-defined time interval till scan operation is Over or user aborts operation or source is set or any alarm is raised or

Use Case: Antenna Control and Position		
		higher/lower limit of Elevation or Inner-Outer Limit of Azimuth is reached.
Alternate Flow 2		Antenna position
2	User	Selects may select any of the task: • Antenna Tracking • Antenna Position • Scanning
2_1	User	User selects option for antenna position and provides following input: • AZ or EL or both axis • Position values for the AZ or EL or both axis in Deg:Arc-min:Arc-sec
2_2	M&C	Accepts user inputs and sends scan command to servo system.
2_3	Servo System	Accepts command and acts on it, also sends monitoring parameters to M&C.
2_4	M&C	Interprets servo system's response.
2_5	M&C	Interprets the success response of command.
		Exit use case
Alternate Flow 3		Source not found in User/GMRT catalog.
4	M&C	Accepts user inputs and searches the source in user/GMRT source catalog.
4_1	M&C	Cannot find the source, either in User or GMRT catalog.
4_2	M&C	Raises the alarm, logs the failure and displays the relevant message to user.
		Exit use case
Alternate Flow 4		Failure in receiving/executing a command by servo system.
8	M&C	Interprets servo system's response.
8_1	M&C	Interprets that servo system is unable to receive/ execute the command.
8_2	M&C	Raises the alarm, logs the failure and displays the relevant message to user.
		Exit use case
Stakeholders		
Stakeholder		Administrator, Operator and Engineer.
Interest		To observe the particular source during observation
Post Conditions		

Use Case: Antenna Control and Position	
On Success	A given source can be tracked with for a desired period of time. Source can be scanned; antenna can be moved to desired AZ and EL positions.
On Failure	During the observation/test, Flag file is updated so that bad data can be flagged.

Process Rules

Sr. No	Process Rule
1.	Elevation or/and azimuth can be commanded to move along a desired trajectory with minimum pointing errors.
2.	After the antenna is reached near the target position, M&C system converts the source coordinates to AZ, EL for the next target time (IST format HH:MM:SS) and convey the new positions to servo system. The advance target antenna positions at predefined time send to servo system per 30 second (i.e. track command so that antenna can follow the source trajectory in real-time.
3.	While using the servo system, user may or may not send the basic servo commands but sends much higher level commands which are finally converted to basic servo commands by M&C system.
4.	High level tracking commands includes: • Track antenna under normal circumstances which includes the celestial sources which are not in the solar systems that is RA–DEC conversion to AZ–EL conversion is in normal way. • Track antenna with some offsets either in RA/ DEC or AZ/ EL. • Track antenna for the planetary systems with given RA and DEC rate of changes. • Scan the target source either in AZ–EL or RA–DEC by giving the tracking rate and target time.
5.	User provides the source coordinate information to servo system for track and position antenna.
6.	Antenna tracking time is predefined (generally 30 sec) and not recommended to change but still user can configure tracking time.
7.	Tracking and positioning continues till the source is up in the sky or the time provided by the user.
8.	To know real time of the servo status, M&C sends the display command per second and acquired servo status.
9.	System reads asynchronous events and alarms from the servo system, and takes predefined actions through batch/procedure facility.
10.	The operations to be performed (Track, scan or position) for antenna has to be specified by the user.
11.	M&C should search source information in both user catalog as well as in GMRT source catalog.
12.	Offset tracking can be done for either the offset specified in AZ/EL OR RA/DEC.
13.	System can enable or disable servo communication link.
14.	M&C checks the difference between target source and actual antenna position while tracking the source and raises the alarm if the difference is greater than the threshold value.

Use Case: Antenna Control and Position		
15	M&C System shall able to put the servo tracking in inner or outer tracking operation mode for the servo.	
16	For sub-array tracking, system shall able to calculate tracking delay while positioning the antenna towards target source i.e. When tracking command issued, antenna moves/position first towards target source with maximum predefined speed of Azimuth (~30d/min) and elevation (~20d/1min). After positioned to the desired target position, actual antenna tracking start with issuing of tracking commands per 30 sec in quasi-continuous way to track the target source trajectory in real-time.	
Additional Data Validation Rules		
Sr. No	Validation Rule	
1.	Target positions (Elevation or Azimuth) shall not exceed the software limits for elevation axis (Lower-Upper) and azimuth axis (Inner-Outer).	
Working Details		
Sr. No.	Issues for Resolution	Status
1.	NA	NA

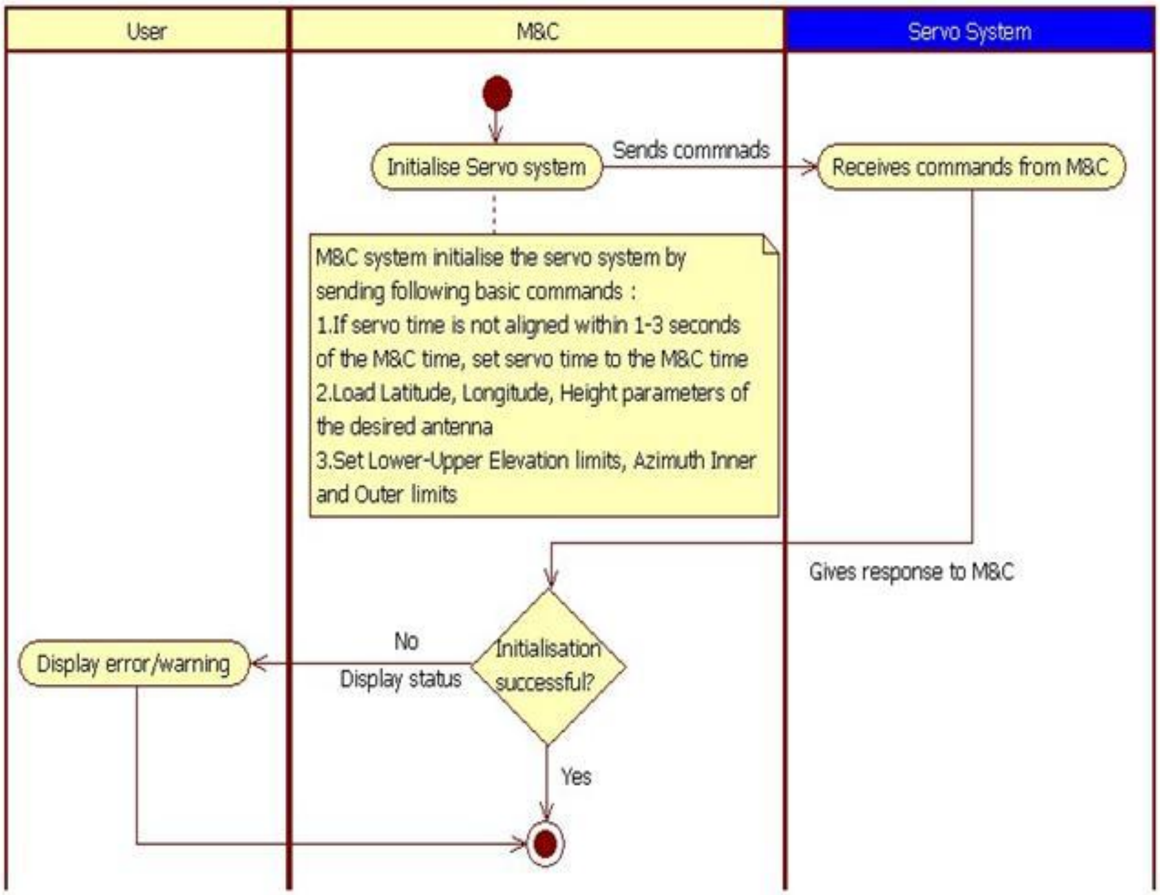

Figure 23: Activity diagram for Servo initialisation

2.1.21. Log off

Table 29: Use Case for Log Off

Use Case: Log off	
Use Case ID	M&C_UC_022
Goal	To log off GMRT M&C system

Use Case: Log off		
Summary		This use case begins when user desires to log out of GMRT M&C system. When user selects option logout, the system handles this request and ensures operational safety while logging off the user. To ensure operational safety, system notifies the user in case log out may affect system operations in progress. For example, while an observing session is in progress, if an astronomer selects log out, astronomer is notified and required to confirm logout. On confirmation, M&C performs actions configured in system (logout procedure) so that user can be safely logout. (For example- parking antenna, shutdown antenna power supply, release sub arrays, close observation and so on.). User log on and log out functionality is governed by system Authentication Policy.
Actors		All users
Priority		1
Status		Accepted
Preconditions		• M&C is up and running. • User is authenticated.
Trigger		On Demand
Assumptions		NA
Use Case Flows		
Basic Flow		Successful Log Off.
1.	User	User selects Log Off.
2.	M&C	Validates if log off is possible.
3.	M&C	Identifies that log off is possible.
4.	M&C	Loads the user interface on successful logout as defined in configuration.
		Exit use case.
Alternate Flow 1		Safe logout is not possible due to operation in progress.
2	M&C	Validates if log off is possible.
3_1	M&C	Identifies that user logout can affect system operations in progress or queue.
3_2	M&C	Notifies User and asks for confirmation for logout.
3_3	User	User Confirms logout.
3_4	M&C	M&C performs safe logout procedure for the user logout as defined in configuration.

Use Case: Log off		
3_5	M&C	Returns to ***Step 2***.
Alternate Flow 2		User Cancels Logout request.
3_2	M&C	Notifies User and asks for confirmation for logout.
3_3_1	M&C	User Cancels logout.
3_3_2	M&C	Returns to operating state.
		Exit use case.
Stakeholders		
Stakeholder		All Users of the GMRT M&C System.
Interest		To logout of GMRT M&C System.
Post Conditions		
On Success		Users can successfully logout of GMRT M&C System.
On Failure		User's session continues.
Process Rules		
Sir No	Process Rule	

<table>
<tr><th colspan="3">Use Case: Log off</th></tr>
<tr><td>1.</td><td colspan="2">Authentication needs to be governed by system authentication policy which shall define the following:
Authentication type (For example- BASIC, LDAP).
Authentication protocol (For example- MD5, CRYPT).
Authentication database or server information.
Policy for Authentication fields (For example- Username policy, Password Policy, PIN policy).
User Lockout policy.
Change password policy (For example Frequency of change, forgot password, password expiry).
Single Sign On – Single Sign OFF (SSO) rules.
Single Session/Multiple Session rules.
LOGIN/LOGOUT Conditions (For example Astronomer User cannot login while in Maintenance, Last Remaining Operator cannot log out while operation is in progress).
Breach policy.
Session handling rules.
Settings for Proceed Action (For example- Proceed Action defines what actions to perform, and what is the destination user interface on authentication).</td></tr>
<tr><td>2.</td><td colspan="2">User may be prompted for initial confirmation for log off on selecting logout as per GUI design.</td></tr>
<tr><td>3.</td><td colspan="2">Authenticated user (Administrator) may configure Authentication policy.</td></tr>
<tr><td>4.</td><td colspan="2">User needs to be notified of successful or failed log out. Notifications methods are governed by UI design.</td></tr>
<tr><td>5.</td><td colspan="2">Whenever data is not available or authentication is not possible (due to connectivity problems), user must be notified.</td></tr>
<tr><td>6.</td><td colspan="2">System shall maintain authentication logs (log-on and log-off) for audit trail.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Additional Data Validation Rules</td></tr>
<tr><td>Sr No</td><td colspan="2">Validation Rule</td></tr>
<tr><td>1.</td><td colspan="2">NA</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Working Details</td></tr>
<tr><td>Sr No</td><td>Issues for Resolution</td><td>Status</td></tr>
</table>

Use Case: Log off		
1.	Authentication policy as described above needs to be finalised.	Open

2.1.22. M&C Utilities

Table 30: Use Case for M&C Utilities

Use Case: M&C Utilities	
Use Case ID	M&C_UC_023
Goal	To achieve the following functionalities: • Calculate and display the India Standard Time (IST), Local Sidereal Time (LST), Universal Time (UT), and JULIAN date • Add a new source to the existing source catalog • Check the availability of the source for observation (check the rise and set time of the celestial source) • Prepare to track the antennas on a desired celestial source

<table>
<tr><th colspan="2">Use Case: M&C Utilities</th></tr>
<tr><td>Summary</td><td>
The various functionalities mentioned earlier needs to be executed by M&C while preparing for the observation or even during the observation. For example, to check whether the source is up during the observation time, calculation of RA/ DEC precession for the desired epoch, to know the observing frequency from the rest frequency of target source for spectral line observation and so on.
These utilities also helps to determine the IST, Local Sidereal Time (LST), UT, Julian date, Equatorial to Horizontal coordinate system conversion for the celestial source (RA–DEC, associated epoch or AZ–EL), rise and set time and so on.
Few concepts associated with these functionalities are briefed as follows:
A source position in the sky is generally referred by two types of coordinate system. They are as follows:

Horizontal Coordinate System: This system uses observer's local horizon as the fundamental plane and zenith axis centred on the observer. Source is located using the altitude or elevation and azimuth angle. Elevation is the angle between the object and observer's local horizon (that is between 0 to 90 degrees) and azimuth is the angle of the object around the horizon with reference to the north. The horizontal coordinate system is fixed to the Earth, hence the source's altitude and azimuth changes with time.
Equatorial Coordinate System: This is an Earth centric coordinate system where the Earth's equatorial plane is projected onto the celestial sphere forming the celestial equator. Declination (δ or DEC) measures the angular distance of the celestial source perpendicular to the celestial equator, positive to the north (that is north celestial pole has $\delta = +90$ degree and south celestial pole has $\delta = -90$ degree). Right ascension (α or RA) measures the angular distance of source eastward along the celestial equator from the vernal equinox. The vernal equinox ($\alpha = 0$ h) is the point where ecliptic plane intersect the equatorial plane.

Spectral line observation requires some care for setting the observing frequency because, due to Doppler tracking effect, actual spectral-line frequency (Rest frequency) shift to other value. Hence observing or sky frequency of the telescope needs to set to the changed value. Spectral line observation measures spectral-line intensity and the line-of-sight component of velocity. For planning spectral-line observations there are a few basic inputs need to be considered, total velocity coverage, optical velocity resolution and the correct sky frequency for the observation.
</td></tr>
<tr><td>Actors</td><td>Telescope operator, Astronomer, M&C system</td></tr>
<tr><td>Priority</td><td>1</td></tr>
<tr><td>Status</td><td>Accepted</td></tr>
<tr><td>Preconditions</td><td>Valid source catalog must be accessible into the M&C utility
Desired source shall be available in the source catalog
Latitude, longitude and height of the location/ antenna are known</td></tr>
<tr><td>Trigger</td><td>On Demand</td></tr>
<tr><td>Assumptions</td><td>M&C Functionality or utility components described in this use-case shall be usable even if the M&C is down that is in case user only wants to check or prepare the target source observing plan.</td></tr>
<tr><td colspan="2"></td></tr>
</table>

Use Case: M&C Utilities		
Use Case Flows		
Basic Flow		Target source of interest selected from the source catalog is validated for the GMRT antenna tracking before or during the observing run. The validation can be achieved by using the following M&C functionality.
1.	M&C	M&C system display and use the required current time format: • IST • LST • UT • Julian Date: A continuous count of days and fractions since noon Universal Time on January 1, 4713 BCE): (for further information see http://aa.usno.navy.mil/data/docs/JulianDate.php) Time conversion: Time conversion from one time format to other format shall be possible for example, IST to UT, Julian Day, LST.
2.	User	User adds the source catalog into the M&C system.
3.	M&C	Validate the source catalog as per the proposed format of source catalog.
4.	M&C	Source catalog addition is successful. Go to next step. OR M&C system displays the error message about invalid syntax of source catalog format and goes to Exit Use Case.
5.	User	Provides input for the source of interest either by giving source name or RA–DEC and Epoch fields for the source.
6.	M&C	M&C system search for the target source of interest.
7.	M&C	M&C system found the source of interest. M&C displays the source catalog name and source information. Go to next step. OR M&C system displays the error message that source is not available in the M&C source catalog or in the source catalog submitted by user. Go to Step ***5.***
8.	User	User can choose one of the following menus • LST, source rise-set and transit time, source RA, DEC precession and so on, go to next step • For spectral line observation, calculate sky or observing frequency from the rest frequency, go to Alternate Flow 1.

Use Case: M&C Utilities		
9.	M&C	M&C read Right Ascension, Declination and Epoch from the catalog. To convert the equatorial to horizontal coordinate system and to display the rise and set-time. M&C can execute the following steps: • Calculate LST with respect to current time. • Process Right Ascension and Declination of the target source to the current Epoch (Calculate apparent RA–DEC). • Calculate Hour Angle from the LST and RA (HA = LST – RA). • AZ and ELEV can be calculated using the standard formulae from the above parameters that are RA, DEC, Latitude (LAT) and Hour Angle (HA). • sin(ELEV) = sin(DEC)×sin(LAT)+cos(DEC)×cos(LAT)×cos(HA) • cos(AZ) = (sin(DEC) – sin(ELEV) × sin (LAT)) / (cos(ELEV) × cos (LAT)) • Calculate rise-set time of the source and the transit time (the time at which source is at celestial meridian of the observer).
10.	M&C	M&C validate the target source for the tracking with the help of following parameters which are displayed to the users: • M&C displays the RA mean and apparent for the targeted epoch (for example, current date/ observing date). • M&C displays the source rise, set and transit time.
11.	User	User or M&C (In case of through batch kind of facility) issue the track command to antenna by sending the RA, DEC, equinox (Reference epoch) values along with other parameters such as tracking duration, tracking offsets in RA–DEC or AZ–EL and so on.
		Exit Use Case
Alternate Flow 1		Calculate observing frequency from the rest frequency for the spectral-line observation.
8	User	For spectral line observation, calculate sky or observing frequency from the Rest frequency go to Alternate Flow 1.
8_1	User	User provides inputs for the following parameters: • Spectral Line Rest Frequency (MHz) • Velocity of source (km/s) • Velocity Definition : Radio or Optical • Reference System : LSR or Heliocentric • Date and Time for the observation
8_2	M&C	Uses external tools to calculate sky or observing frequency.
8_3	M&C	M&C system displays the sky or observing frequency in MHz.
		Exit use case
Stakeholders		
Stakeholder		Telescope operator, Astronomer, and M&C system.

Use Case: M&C Utilities		
Interest	Validate and execute the target source of interest for the antenna tracking while executing the observing session.	
Post Conditions		
On Success	Execution of observing plan or the tracking of the celestial source of interest is possible.	
On Failure	Target source of interest is invalid and cannot be observed in the planned observing session.	
Process Rules		
Sr. No	Process Rule	
1.	In the M&C system addition of multiple source catalogs shall be allowed.	
2.	In case of the target source of interest given by user is duplicated, latest entry (based on date-time) shall be taken for the coordinate calculation.	
3.	M&C system shall allow deleting single or multiple entries of the source catalog.	
4.	Addition or deletion of source catalog, selection of the source of interest, execution of M&C functionality shall be allowed using the batch kind of facility.	
Additional Data Validation Rules		
Sr. No	Validation Rule	
1.	Proposed format of the source catalog to be used in the M&C system shall be used for validation. Proposed GMRT format for the source catalog is given in the Appendix of this Use Case.	
Working Details		
Sr. No.	Issues for Resolution	Status
1.	NA	NA

2.1.23. Setup Safety Limit

Table 31: Use case for Setup Safety Limits

Use Case: Setup Safety Limits	
Use Case ID	M&C_UC_024
Goal	To define safety limits for various operations to ensure operational safety of the system

Use Case: Setup Safety Limits		
Summary		In order to keep antenna safe during the observation engineer configures the safety limit of system operation. Safety limits are configured for following reasons: • To set limits for normal operations of various systems/ antenna • To set limits for maintenance and testing activities for various systems/ antenna • To set limits for operations during various system modes • Safety limits may also be set at local monitoring and control hardware/ software
Actors		Engineer
Priority		1*
Status		Accepted
Preconditions		• M&C is up and running • Desired antenna/ sub-system must be under maintenance
Trigger		On Demand
Assumptions		Engineer and operator are accountable for setting safety limits
Use Case Flows		
Basic Flow		Configure safety limits of desired parameters of a given antenna/ sub-system.
1.	User	Selects option to configure safety parameter of a given antenna/subsystem(such as servo system, sentinel system, OF, FPS and so on)
2.	M&C	Validates the system state for configuration of safety limits.
3.	M&C	Identifies the user input as setting parameter and prompts user to give safety limits.
4.	User	Provides inputs for setting safety limits for parameters.
5.	M&C	Validates the user's safety limit inputs for the given parameters.
6.	M&C	Identifies the user input is valid.
7.	M&C	Set values.
8.	M&C	Notifies user on the result of the operation.
		Exit use case.
Alternate Flow 1		Checks if the system allows setting the safety parameters.

Use Case: Setup Safety Limits		
2	M&C	Validates the system state for configuration of safety limits.
2_1	M&C	Checks the current state of antenna/ sub-system that is whether antenna/ sub-system is in maintenance or any other operation is in progress.
2_2	M&C	Notifies user that safety limits cannot be set.
		Exit use case.
Alternate Flow 2		Unable to set safety limits due to invalid user inputs.
5	M&C	Validates the user's safety limit inputs for the given parameters.
5_1	M&C	Identifies that the user inputs are invalid and cannot set the safety limit for the desired parameter.
5_2	M&C	Notifies user that safety limits cannot be set.
5_3	User	Continues to step ***4***.
Stakeholders		
Stakeholder		Engineer, Operator, M&C
Interest		To configure the antenna/ sub-system safety limits to ensure operational safety during normal operations as well as maintenance
Post Conditions		
On Success		Setup of safety limits ensures safe system observation in whichever mode the system is.
On Failure		Antenna can be damaged if safety limits are not configured properly.
Process Rules		
Sr. No	Process Rule	
1.	User can set safety limits only in maintenance mode.	
2.	There should be no other operations in progress at the desired antenna/ sub-system for setting safety limits.	
3.	System should validate if current state of the system allows setting of safety limits for the antenna/ sub-system.	
4.	Safety Limits can be common for all antennas for particular sub-system or individual sub-system of each antenna can have separate safety limits.	

Use Case: Setup Safety Limits		
5.	Safety Limits stored in configuration files or in database remain intact during the M&C shutdown and restarting of the M&C system.	
Additional Data Validation Rules		
Sr. No	Validation Rule	
1.	NA	
Working Details		
Sr. No.	Issues for Resolution	Status
1.	List of parameters for which safety limits has to be defined.	Open
2.	Operational constraints for setting safety limit needs to be defined.	Open

2.1.24. User Administration

Table 32: Use Case for User Administration

Use Case: User Administration	
Use Case ID	M&C_UC_025
Goal	To perform M&C user administration task
Summary	The Administrator or the Operations Group (OG) is responsible for configuration of all M&C details. In addition, the administrator is also responsible for administration of all the stakeholders, resources and housekeeping of the M&C system. User administration of the M&C system may include the following tasks: • User account administration ○ Add, Modify, Delete User data. ○ Prune user accounts ▪ Enable, Disable user accounts • User privilege administration ○ Assigning roles to users ○ Assigning privileges to users
Actors	Administrator
Priority	2
Status	Accepted
Preconditions	Administrator is logged in
Trigger	On Demand
Assumptions	M&C is preconfigured to be able to validate the telescope sub-system settings.

Use Case: User Administration		
Basic Flow		Administrator successfully performs desired administration operation.
1.	User	Selects a user administration task (Add User, Modify User, Delete User data, set user role or privilege) and provides required inputs for the administrative task.
2.	M&C	Validates the user inputs and actions to be performed
3.	M&C	Identifies that user inputs are valid
4.	M&C	Performs the request operation for the given inputs
5.	M&C	Notifies the user of the result of the operation
		Exit use case
Alternate Flow 1		Administrative task failed due to invalid inputs or operation not possible.
2	M&C	Validates the user inputs and actions to be performed
2_1	M&C	Identifies that user inputs are invalid
2_2	M&C	Identifies that the requested action is not possible or not permitted
2_3	M&C	Notifies the User
		Exit use case
Stakeholders		
Stakeholder		Administrator
Interest		To perform administrative tasks like manage user accounts
Post Conditions		
On Success		Administrator may be able to perform the desired administrative operation using the M&C.
On Failure		M&C system administration is not possible and hence can lead to unsafe operations and affects availability, maintainability and reliability of the system.
Process Rules		
Sr. No	Process Rule	
1.	All administrative tasks can be carried out independently of each other as permitted by the system configuration.	
2.	Some administrative operations may be dependent on system modes, operation in progress or system states. These constraints are identified in the system configuration.	

Use Case: User Administration		
Additional Data Validation Rules		
Sr. No	Validation Rule	
1.	NA	
Working Details		
Sr. No.	Issues for Resolution	Status
1.	Need to identify all process constraints and dependencies on system states for all administrative tasks.	Open
2.	Need to define how many administrators are allowed for the system and how to manage them.	Open
3.	Need to define what privileges to be provided. (For example Change configuration settings, operational privileges).	Open
4.	Need to identify important administration keys for various users (User identification key, operations identification keys, privilege definitions).	Open
5.	Need to identify user role and privilege constraints (Multiple roles, privilege constraints on two or more operations).	Open

2.1.25. User Preference Configuration

Table 33: Use Case for User Preference Configuration

Use Case: User Preference Configuration	
Use Case ID	M&C_UC_026
Goal	To set custom user preferences by an authenticated user

Summary	User of M&C system can set custom preferences so that the user may modify relevant configuration that may be of interest to the user. The default system configuration as defined by the administrator is applicable for all the user roles. User preferences are configuration options that apply to a single user. This may include preferences for user's dashboard, user account settings, reports and statistics preferences, notifications and so on. User defines custom preferences are available as per user privileges so that the M&C can be personalised to user's specific needs of monitoring, control, report generation and other activities.
	Administrator of the M&C defines the list of user configurable parameters for the users and various roles. User preference configuration is governed by the system configuration.
	The broad classification of the user preferences configuration are given as follows:
	• Alarm and Warning notification configuration
	    o Preferred notification methods
	    o Enable or disable alarm notifications for the user
	• Reports and Statistical Configuration

Use Case: User Preference Configuration		
		○ Choice of reports and statistics ○ Notification methods ○ Frequency of notification • Dashboard Configuration ○ Monitoring parameters configuration ○ UI configuration • Utilities ○ Location, Date, Calendar and Time configuration The list of all configurable parameters, modes and system operations shall be detailed during subsequent phases of the project.
Stakeholders		All Users
Priority		2
Status		Accepted
Preconditions		NA
Trigger		On Demand
Assumptions		The default configurations for a given user role is defined in the system by the Administrator.
Basic Flow		User sets desired custom preferences.
1.	User	Selects an option to set the user preferences.
2.	M&C	Presents the default preferences/ previously modified preferences by the user.
3.	User	Changes the preferences of desired categories (as mentioned in the summary of this use case)
4.	M&C	Validates user inputs
5.	M&C	Identifies user inputs are valid
6.	M&C	Sets the desired user preference configuration to the given input values
7.	M&C	Notifies the user about the result of the operation
		Exit use case
Alternate Flow 1		Unable to set user preferences due to invalid configuration, user privileges or user inputs.
4	M&C	Validates user inputs
4_1	M&C	Identifies that user preferences cannot be set due to invalid configuration, user privileges or user inputs
4_2	M&C	Notifies the user about the result of the operation

Use Case: User Preference Configuration		
		Exit use case
Stakeholders		
Stakeholder	All users	
Interest	To set custom user preferences so that system is personalised and more relevant to the user.	
Post Conditions		
On Success	User may be able to set custom preferences.	
On Failure	User may not be able to set custom user preferences. Default preferences will be available to user.	
Process Rules		
Sr. No	Process Rule	
1.	The default configuration for a given role shall be defined by the administrator in the system.	
2.	User may revert to the default configuration at any time.	
3.	Administrator is accountable for data integrity and sanctity of system configuration.	
Additional Data Validation Rules		
Sr. No	Validation Rule	
1.	User preferences are validated against system configuration.	
Working Details		
Sr. No.	Issues for Resolution	Status
1.	Need to be identify list of all user configurable parameters, process constraints and dependencies on system states for all configuration tasks and user preference configuration	Open
2.	Need to define how user preferences configuration is done.	Open
3.	Need to know how to handle user preference data conflicts (For example all users choose alarms notifications OFF, system configurations changes after user changed preferences)	Open

2.1.26. Update Software

Table 34: Use Case for Update Software

Use Case: Update software

Use Case: Update software	
Use Case ID	M&C_UC_027
Goal	To update software
Summary	The components of M&C such as LMC, CMC, RMC, Rabbit Control Board (RCB) or PC104 kind of control board may be needed to update with the latest software versions, as a consequence of bug fixing or new feature release and so on. At LMC, CMC and RMC updating software refer to either updates to application software or configuration or both. Whereas for RCB it refers to firmware update. The software updates to CMC, LMC and RMC can be handled by M&C by integrating or using the external Commercial off the shelf (COTS) tools or a built-in facility can be provided for updating the software in M&C (The decision to use the COTS tool for updating the software of CMC, LMC and RMC will be taken during the design phase of M&C system). However, for updating the firmware M&C needs to integrate with the external tool. M&C provides the facility to interact with these external tools for updating the software.
Actors	Administrator
Priority	2*
Status	Accepted
Preconditions	RCB is communicating with M&C
Trigger	On Demand
Assumptions	• M&C can access the repository of application softwares and RCB firmware. • All RCB uses the same version of firmware. • The underlying technology of the M&C (such as operating system) should be able to integrate with the firmware update tool if required. • The first time installation and configuration of the hardware is out of scope of M&C system.
Use Case Flows: This is explained with the help of activity diagram in ***Figure 24***: Activity Diagram for Update Software	
Stakeholders	
Stakeholder	Administrator
Interest	To update the software so as to add new functionalities.
Post Conditions	
On Success	Software updates will be installed on the desired components of M&C system and/ or RCB.

Use Case: Update software		
On Failure	Software updates will not be installed on the desired components of M&C system and/ or RCB.	
Process Rules		
Sr. No	Process Rule	
1.	If the system fails to update the software version, then it should restore the previous version of the software.	
Additional Data Validation Rules		
Sr. No	Validation Rule	
1.	NA	
Working Details		
Sr. No.	Issues for Resolution	Status
1.	NA	NA

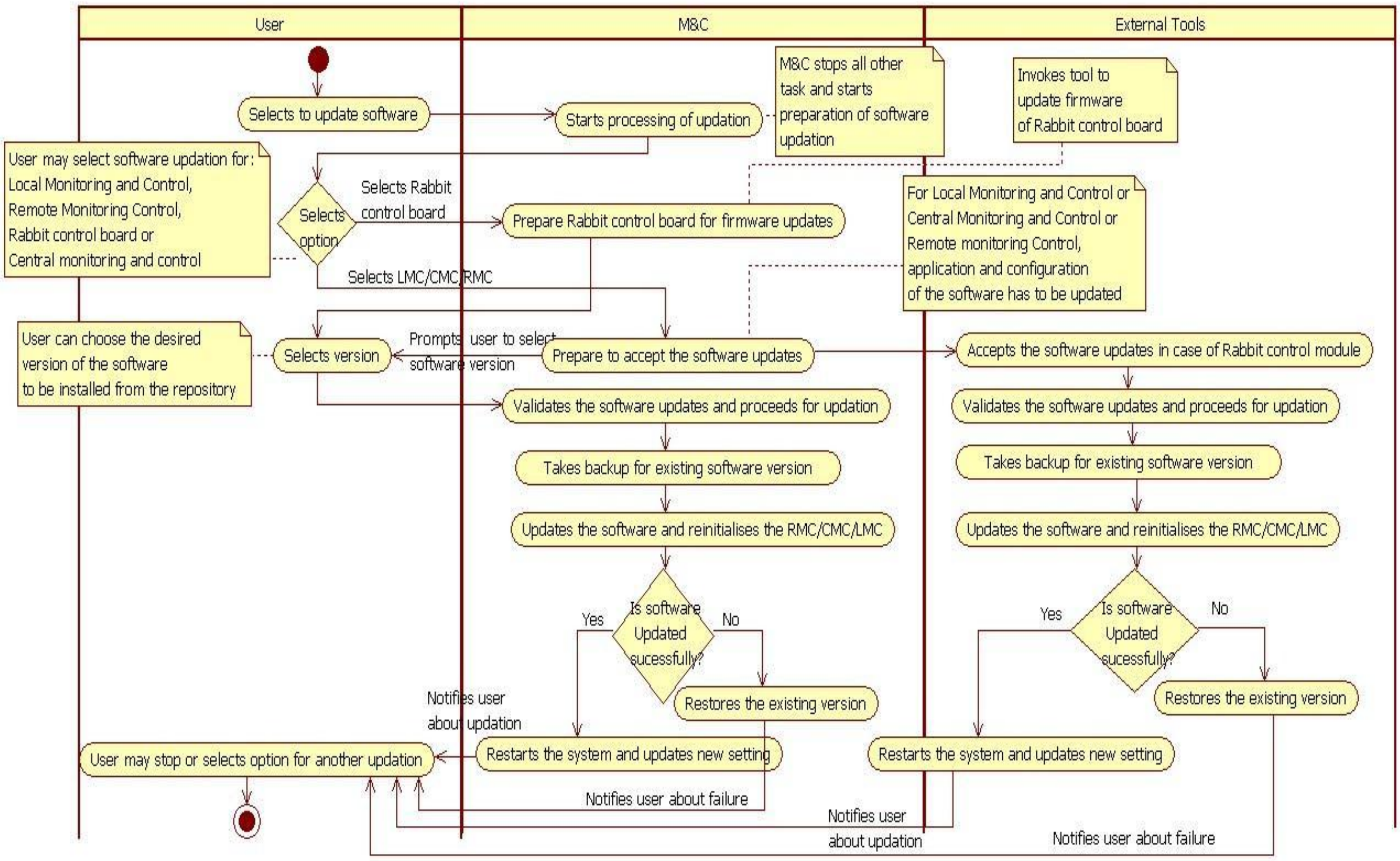

Figure 24: Activity Diagram for Update Software

2.1.27. Connect to Remote Hardware

Table 35: Use Case for Connect to Remote Hardware

Use Case: Connect to Remote Hardware		
Use Case ID		M&C_UC_028
Goal		To connect to remote hardware (RCB and LMC) directly and perform diagnostics
Summary		Administrator or engineer may need to establish a direct communication with rabbit control module and LMC for diagnosing certain faults. When connection to remote hardware is completed, the normal command and response hierarchy of the receiving chain is bypassed (The normal control hierarchy is, CMC issues command to LMC and then LMC passes it to rabbit control module). This is useful when the user need to issue low level control commands to the sub-systems in the receiving chain. The response to the certain low level commands issued in this mode, needs to be verified manually.
Stakeholders		Engineer, Administrator
Priority		3
Status		Accepted
Preconditions		NA
Trigger		On Demand
Assumptions		• The control cards like PC-104, Rabbit card and Lab jack kind of module supports the remote connectivity feature. • Not only the predefined commands but the new commands also could be issued to the PC-104 or Lab jack or rabbit control kind of module and LMC.
Basic Flow		User connects to remote hardware and issues commands
1.	User	Selects an option to connect to desired remote sub-system hardware.
2.	M&C	Validates current state of the system if connection is possible to the desired set point.
3.	M&C	Identifies that the remote connection is possible to the desired set point, puts the PC-104/Lab jack/LMC/rabbit control kind of module in the respective state and bypasses it from the normal hierarchy.
4.	M&C	Presents the set of low level commands that can be issued to given PC-104/Lab jack/LMC/rabbit control kind of module.
5.	User	Selects the low level commands available or specifies the custom command to be issued to the rabbit control module/ LMC.
6.	M&C	Validates user inputs (checks for command, arguments, values, connectivity and so on).
7.	M&C	Identifies that user inputs are valid and issues command.
8.	M&C	Notifies user

Use Case: Connect to Remote Hardware		
		Exit use case
Alternate Flow 1		Unable to connect to remote hardware
2	M&C	Validates current state of the system if connection is possible to the desired set point.
2_1	M&C	Identifies that direct connection to the desired remote set point is not possible. (This may be due to system state and mode transition privileges, user privileges, system configuration and so on).
2_2	M&C	Notifies the user
		Exit use case
Alternate Flow 2		Unable to issue commands to the desired remote set point
6	M&C	Validates user inputs (checks for valid command, arguments, values, connectivity and so on).
6_1	M&C	Identifies that the user inputs are invalid
6_2	M&C	Notifies the user
6_3	User	Continues to step ***5.***
Stakeholders		
Stakeholder		Engineer, Administrator
Interest		To connect directly to remote hardware and issue low level control commands
Post Conditions		
On Success		User may be able to connect to remote hardware directly and issue low level commands.
On Failure		User may not able to issue commands directly to the desired sub-system hardware and relies entirely on the M&C commands and intelligence.
Process Rules		
Sr. No	Process Rule	
1.	All set points, and related low level commands and related parameters are to be validated against those defined in the configuration.	
2.	User may issue commands which are unknown to the M&C system.	
3.	Only an authenticated user with appropriate privileges may connect to remote hardware and issue commands.	
4.	User may choose to ignore the M&C validation.	
5.	All messages and errors are notified to the user.	

Use Case: Connect to Remote Hardware		
6.	When user is connected to remote sub-system hardware directly, other control operations may not be permitted (and the state of the sub-system is maintained by M&C).	
Additional Data Validation Rules		
Sr. No	Validation Rule	
1.	System should verify if commands can be issued to the desired set point depending on the current state of the system and if there are any operations in progress.	
2.	Before issuing any command, the M&C may validate the command for syntax and data.	
Working Details		
Sr. No.	Issues for Resolution	Status
1.	Need to define all the set points and the relevant commands, arguments in the receiving chain.	Open
2.	Need to define the process constraints (which operations are allowed and disallowed on connection with remote hardware).	Open
3.	Need to know whether M&C validate the commands to be sent, Also need to know whether M&C detect possible invalid sub-system states or conditions after the user sends control commands.	Open

2.1.28. Phasing

Table 36: Use Case for Phasing

Use Case: Phasing	
Use Case ID	M&C_UC_030
Goal	Dual polarized signals at the input of GMRT array combiner shall be in coherent form that is all cross correlation phases should be zero after correcting the antenna based residual phases.
Summary	Phased array mode is used in pulsar observation to improve the signal to noise ratio and to the get full-stokes information. In the GMRT array combiner, coherent beam is constructed by addition of phased voltage signals received from the individual antennas. Residual phase errors due to the ionosphere and instrumental delays are corrected in the digital back-end in the frequency domain where channel dependent antenna base phase solution applied in the fractional delay block of the digital back-end. Phasing is an iterative calibration process, the steps in phasing are: (i) Acquire the visibility data (cross amplitude and phases) from all the base-lines (antenna pairs) on standard phase-calibrator source using the digital back-end. (ii) Provide this data to Rantsol program which process the base-lines based phases to get the channel-dependent antenna based phase

<table>
<tr><th colspan="3">Use Case: Phasing</th></tr>
<tr><td colspan="2"></td><td>solution.
(iii) These phase-solutions are applied in the fractional delay block of the digital back-end.
(iv) Cross-phases again re-observed on the phase-calibrator sources.
(v) If residual phase errors are compensated, all the base-lines show zero cross-phases otherwise phasing process repeats again.
NCRA wishes to automate this process by developing a suitable interface with M&C.</td></tr>
<tr><td colspan="2">Actors</td><td>Astronomers, Digital Engineers, Operators</td></tr>
<tr><td colspan="2">Priority</td><td>1</td></tr>
<tr><td colspan="2">Status</td><td>Accepted</td></tr>
<tr><td colspan="2">Preconditions</td><td>• M&C is up and running (In present situation, this means, data acquisition system in the digital back-end and ABC is communicating with ONLINE. All other sub-systems such as servo, FPS, MCM are working properly).
• Antenna is pointed to a desired phase calibrator source.
• The digital backend is running in the interferometric mode with the GMRT Array-combiner PA (Phased array block) enabled.
• Antennas selected for phasing are grouped under sub-array controller.
• There are no critical alarms in active mode.
• User is authenticated.
• The required phasing tool (PT), is up and running and has a working interface with M&C.</td></tr>
<tr><td colspan="2">Trigger</td><td>On Demand, During test or during science observing session.</td></tr>
<tr><td colspan="2">Assumptions</td><td>If required, external tool(s) for Phasing will be developed by NCRA.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Use Case Flows</td></tr>
<tr><td colspan="2">Basic Flow</td><td>Phasing is complete at the phase monitoring point.</td></tr>
<tr><td>1.</td><td>User</td><td>User selects an option to initiate phasing process at the phases monitoring points and at desired set points in the receiver chain as depicted in following table:
<table><tr><th>Phase Monitoring Point</th><th>Phase Set Point</th></tr><tr><td>Back-end Interferometric data output in the GMRT LTA format.</td><td>Backend input point (phase table/ file area on back-end control machine)</td></tr></table></td></tr>
<tr><td>2.</td><td>M&C</td><td>Initiates the communication with external PT(s).</td></tr>
<tr><td>3.</td><td>User</td><td>Provides phasing configuration parameters such as bandwidth, observing frequency, number of antennas (or group of antenna), record time and so on. User may optionally provide the phasing threshold (for example +/–5 degree or +/– 10 degree) and maximum number of iterations parameters for conducting the phasing cycles and the phasing iteration number (0 during the beginning/ resetting the phasing procedure).</td></tr>
<tr><td>4.</td><td>M&C</td><td>Validates above inputs, sends to PT and requests to generate the appropriate</td></tr>
</table>

Use Case: Phasing		
		phase table.
5.	PT	Processes the request and responds to M&C.
6.	M&C	Interprets the response from PT and acts on it.
7.	M&C	Interprets that, phasing is completed for requested antennas within threshold level for phasing.
8.	M&C	Display the relevant message to user and store this status for future use.
		Exit use case
Alternate Flow 1		Phasing is not up to the mark.
6	M&C	Interprets the response from PT and acts on it.
6_1	M&C	Interprets that the, phasing of some of the antennas is complete and incomplete for some of the remaining.
6_2	M&C	Display the message to user (Phasing is not done properly).
6_3	M&C	Redo the phasing.
6_4	M&C	Repeats steps 3 to 6.
Alternate Flow 2		Discard the Antenna
6_3	M&C	Redo the phasing
6_3_1	M&C	Detects any of the following conditions: • Communication with Antenna is lost • Antenna is not fringing • Antenna is not tracking • RFI • Alarm condition persists for a given antenna
6_3_2	M&C	Discards the particular antenna/ antennas.
		Continue to basic flow step ***3.***
Alternate Flow 3		Phasing is not completed after maximum number of iterations
6_3_1	M&C	Produces warning message to the user and keep a log.
		Exit use case
Stakeholders		
Stakeholder		Astronomers, Operator, Digital Engineer
Interest		To phase the array for pulsar observations
Post Conditions		

Use Case: Phasing		
On Success	1. The phases at monitoring points converge to desired level. 2. Phase solution table saved for the next iterations.	
On Failure	The Phases of the selected antennas will be different.	
Process Rules		
Sr. No	Process Rule	
1.	User may abort the process of phasing at any time.	
2.	Phasing cycles will continue till we get the desired results at the monitoring points or if the maximum iterations are reached.	
3.	Phasing for the multiple sub-arrays should be possible simultaneously.	
4.	Phasing shall be possible within the batch-execution kind of process.	
Additional Data Validation Rules		
Sr. No	Validation Rule	
1.	NA	
Sr. No	Validation Rule	
1.	Phase solutions depend on the various parameters like RFI, scintillation and so on.	
Working Details		
Sr. No	Issues for Resolution	Status
1.	At present phases are checked manually, there is no algorithm to check whether the phasing is done or not.	Open

2.1.29. Antenna Pointing

Table 37: Use Case for Antenna Pointing

Use Case: Antenna Pointing	
Use Case ID	M&C_UC_031
Goal	To find the antenna pointing offset.
Summary	Antenna pointing is used to find the antenna pointing offset. Antenna pointing offset can be defined as the correction to be applied to the calculated AZ, EL before sending to Servo system. This correction (antenna pointing offset) is expressed in degree: arc minute: arc Seconds, Pointing the antennas in the desired direction leads to better images. Incorrect pointing of an antenna leads to loss in sensitivity and positional errors. For this reason it is important to periodically estimate pointing errors for each antenna and

Use Case: Antenna Pointing	
	correct them. At GMRT, typical pointing errors of one arc minute for each of the elevation and azimuth axes are tolerated while correcting. Antenna offsets are of following two types: • Fixed offsets (Stored by servo system and LMC component of M&C) • Variable offsets (Changed with respect to time and theoretically calculated using a pointing model developed by NCRA. This offset is the function of AZ and EL). Various methods (pointing procedure) are developed to estimate the antenna pointing offsets: • Self Pointing: This method is used to find large antenna offset in any one axis while the other axis should have known offsets. This method is not useful when both axes have an unknown offsets. Strong source is required to get the proper results; very few strong sources are available for all the time in the sky. For regular use (smaller offsets) this method is not used due to less accuracy. It is less time consuming and can work for one or many antenna at a time. • Cross Pointing: This method is used to find large and small antenna offset in any one axis while the other axis should have known offsets. This method is not useful when both axes have an unknown offsets. Point source calibrator is required to get the proper results; many point sources calibrators are available for all the time in the sky. For regular use (smaller offsets) this method can be used due to its high accuracy. It is less time consuming and can work for one or many antenna at a time. It cannot be used in multi-frequency mode. If the reference antenna fails during the test, then test has no meaning. • Grid with Self/ Cross Pointing: This method is used to find large antenna offset when both axis offsets are unknown. One can use this in self mode or cross mode. Instead of scanning the antenna in one axis a grid of offsets in both the axis is made and loaded to the antenna in a specific sequence. It has lees accuracy but less time consuming. It finds the unknown offsets in both axes simultaneously. • Grid Pointing, Regular Use: This method is used to find large or small antenna offset in any one axis at a time. This method is not useful when both axes have an unknown offsets. Point source calibrator is required to get the proper results; many point sources calibrators are available for all the time in the sky. For regular use (smaller offsets) this method can be used due to its high accuracy. It can work for two or more than two antenna at a time. It cannot be used in multi-frequency mode. Total time can be minimized by reducing the number of grid points. This method is regularly used every after feed rotation or weekly.
Actors	Operator, Astronomer
Priority	1
Status	Accepted
Preconditions	• M&C is up and running. • Desired frequency is set for antenna pointing • Group of antenna(s)/ sub-array is configured • No critical alarm is in active state • Desired feed is focused • Digital backend is communicating properly

Use Case: Antenna Pointing		
Trigger	On Demand	
Assumptions	NA	
Use Case flow is explained with the help of activity diagram shown in ***Figure 25***. The method of loading the pointing model during the observation is depicted in ***Figure 26.***		
Stakeholders		
Stakeholder	Operator, Astronomer, Engineer	
Interest	To track the moving celestial source accurately without any error.	
Post Conditions		
On Success	Antenna can be pointed towards a correct source and antenna offset can be determined.	
On Failure	Antenna offset cannot be determined accurately. Sensitivity of the telescope decreases and tracking errors increases.	

Process Rules	
Sr. No	Process Rule
1.	The antenna offset varies with time.
2.	Default offset can be previous configured offset or zero pointing offset.

Additional Data Validation Rules	
Sr. No	Validation Rule
1.	NA

Working Details		
Sr. No	Issues for Resolution	Status
1.	M&C will provide interface to execute pointing model. Need to understand pointing model input and output.	Open

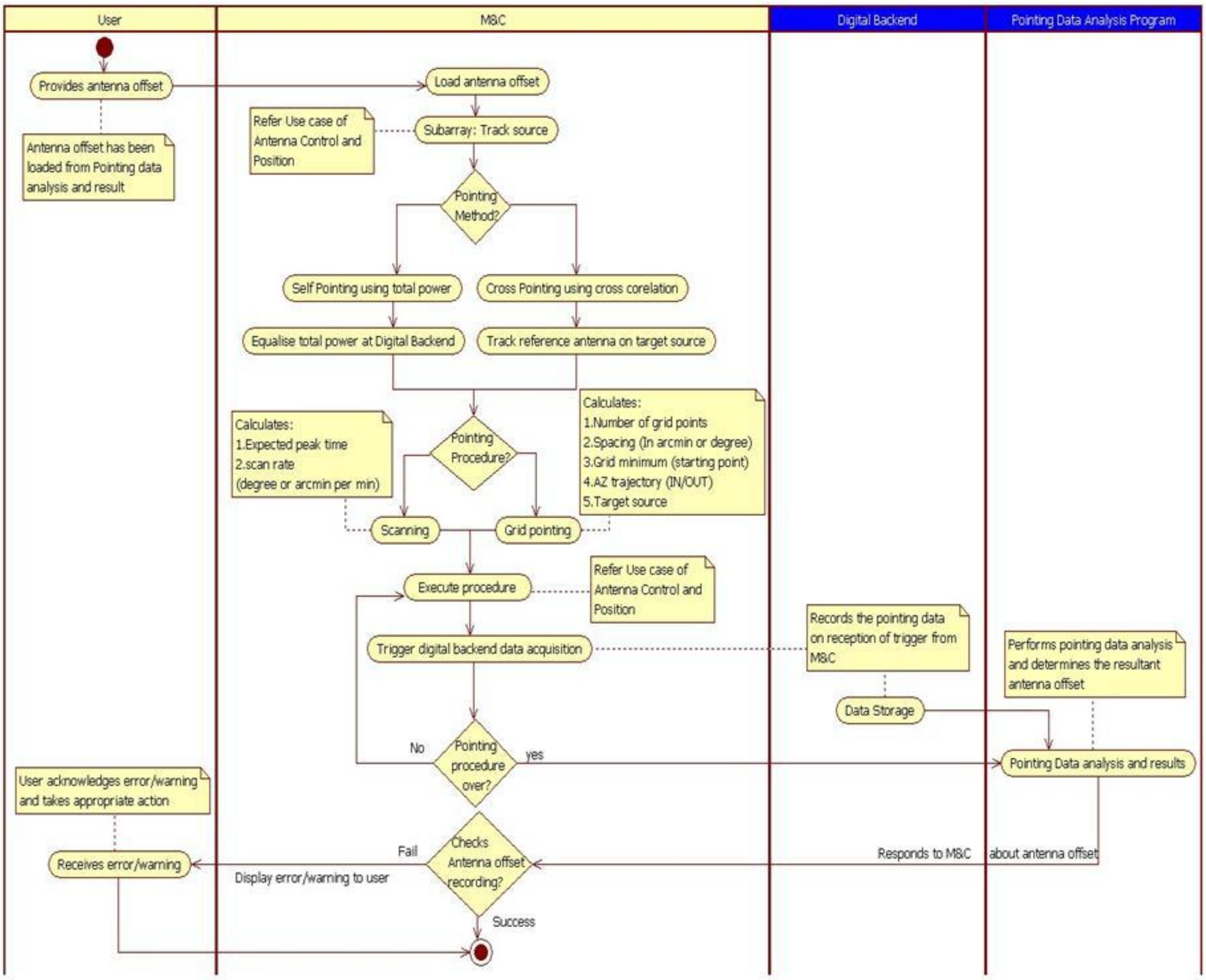

Figure 25: Activity Diagram for Antenna Pointing

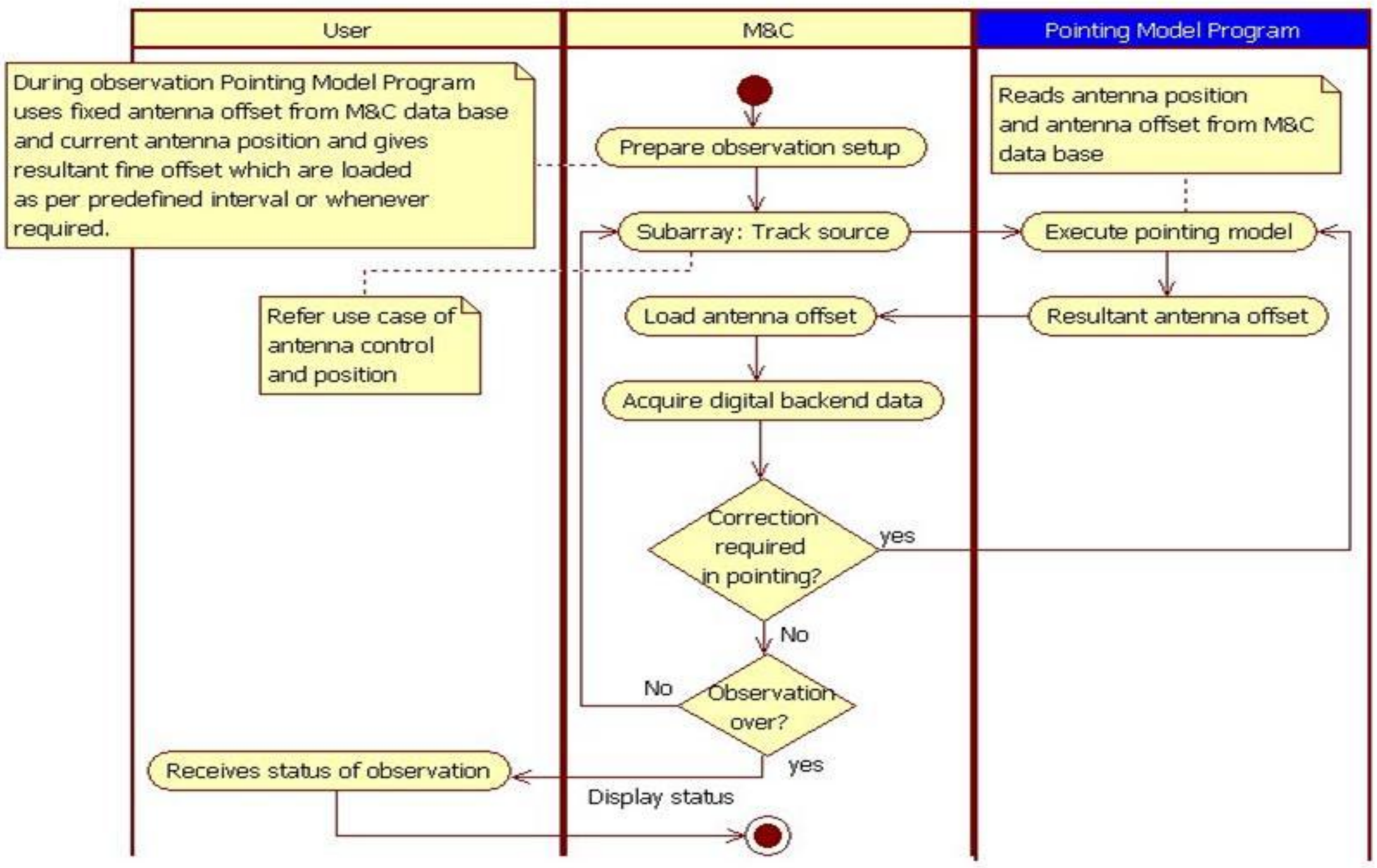

Figure 26: Activity diagram for incorporating the Pointing Model

2.1.30. Remote Observation

Table 38: Use Case for Remote Observation

Use Case: Remote Observation		
Use Case ID		M&C_UC_032
Goal		To monitor observation from remote location
Summary		The GMRT provides facility for astronomers to monitor observation from a remote location outside the GMRT network. Other remote users may also monitor the system as per the user's privileges. Remote monitoring capability helps astronomers located anywhere in the world to have access to GMRT facility for science experiments. The remote monitoring is done using the interface exposed by the M&C on the internet for this purpose. The list of monitoring and control capabilities is defined in the system configuration. The design principle of remote monitoring shall be detailed in subsequent phases of the project.
Actors		Remote User
Priority		3
Status		Accepted
Preconditions		• Remote monitoring facility should be allowed in the system configuration. • Remote User is logged on to the system.
Trigger		On Demand
Assumptions		NA
Basic Flow		User successfully monitors dashboard from remote location
1.	Remote User	Views dashboard as per user privileges for remote monitoring
2.	M&C	Continuously updates the dashboard with relevant monitoring information through the exposed interface for remote monitoring.
3.	M&C	Notifies the user about the result of the operation
		Exit use case
Stakeholders		
Stakeholder		Remote User
Interest		To monitor GMRT operations remotely

Use Case: Remote Observation		
Post Conditions		
On Success	Remote user may be able to monitor GMRT operations from outside GMRT network.	
On Failure	Remote monitoring facility may not be available.	
Process Rules		
Sr. No	Process Rule	
1.	The system needs to ensure sufficient security measures are in place, wherever applicable, for safe access of the interface across the network.	
2.	Monitoring and control privileges are defined in the system configuration.	
3.	Features and the contents of the remote monitoring dashboard are governed by UI design principle.	
4.	Authentication of remote user is governed by authentication policy.	
5.	In case of errors in remote monitoring, remote user is notified.	
6.	M&C system maintains logs of remote activity wherever applicable.	
7.	Observing session monitoring privileges are defined during scheduling of observation.	
8.	Only privileged users can monitor observation and high level progress parameters.	
9.	User can optionally do drill down monitoring as described in ***View Dashboard*** use case.	
10.	User may exit observation monitoring any time.	
11.	User may monitor sky plots, polar plots of antenna position and source position. This may be done with the help of external tools.	
12.	An authenticated user with privileges may terminate the observing session in progress.	
13.	User can upload source catalog and use this data for sky plots and antenna position tracking with respect to source	
14.	During observation, all occurrences of failures and faults are logged by the M&C as flag data.	
15.	User can submit the observing session plan through batch-script kind of facility.	
Additional Data Validation Rules		
Sr. No	Validation Rule	
1.	NA	
Working Details		
Sr. No.	Issues for Resolution	Status
1.	Need to identify operational constraints on remote monitoring (Control facility, hierarchy of operations)	Open

Use Case: Remote Observation		
2.	Need to identify network landscape for remote monitoring	Open
3.	Need to identify specific requirements for thin or thick client	Open

2.1.31. System Shut Down

Table 39: Use Case for System Shut Down

Use Case: System Shut Down		
Use Case ID		M&C_UC_033
Goal		M&C system executes shut down process sequentially in order to put all sub-systems under control in the desired state before exiting the M&C system.
Summary		M&C system shut down step triggers the sequential processes such as logging out users, put the sub-systems under desire state by executing the requisite scripts, store the old states, update the states in case of problematic conditions occurred during the shutdown process, disconnect all the M&C dependent processes and finally exit the M&C system process by shut down.
Stakeholders		Operator
Priority		1
Status		Accepted
Preconditions		User should be authorized
Trigger		On Demand
Assumptions		NA
Basic Flow		M&C System successfully shut down.
1.	User	M&C shut down process triggered using the menu available on the central M&C's UI terminal.
2.	M&C	M&C system checks user authorization. If user is authorized, go to next step. OR If authorization is invalid, reject the shut down process by displaying the message to user. Also, log the same message for further references. Go to Exit use case step.
3.	M&C	M&C system asks user confirmation again to proceed to shut down step.
4.	User	User confirmed about the shut down process. Go to next step OR User cancel the shut down process, shut down process aborted. Go to Exist use case step
5.	M&C	M&C system logs out all the users by displaying message on individual users' terminal.

Use Case: System Shut Down		
6.	M&C	M&C system execute the configured commands/ batch-file/ scripts in order to execute tasks such as: • Halt the correlator data acquisition process and close the connection. • Stop the local tracking of antennas (in case antennas are tracking). Move the antenna's elevation to 90 degree and park the antennas.
7.	M&C	M&C system checks all the requisite status to proceed to the shut down process.
8.	M&C	M&C interprets the states of sub-systems/ third-party tools/ applications under control.
9.	M&C	M&C system interprets that all the states and status are valid to proceed to the shut down process.
10.	M&C	M&C system closes all connections to M&C dependent sub-systems and applications/ third-party tools.
11.	M&C	M&C system closes all the intrinsic M&C components and clears associated memories or ports. M&C system displays all the shut down process messages and logs the same.
		Exit use case.
Alternate Flow 1		M&C system checks that all requisite status to proceed to the shut down process is not completed yet.
8	M&C	M&C interprets the states of sub-systems/ third-party tools/ applications under control.
8_1	M&C	M&C suspend the shut down process.
8_2	M&C	M&C system displays relevant messages, rise and logs the alarms about desired state to proceed to the shut down process is not completed.
8_3	User	User intervenes and takes manual actions necessary to put the sub-systems/ application under control to desired states.
8_4	User	User triggers shut down process again. Go to step ***1***.
Alternate Flow 2		User checks that all requisite status to proceed to the shut down process cannot be completed.
8	M&C	M&C interprets the states of sub-systems/ third-party tools/ applications under control.
8_1	User	User selects the option for forceful M&C shut down process.
8_3	M&C	M&C update the logs and alarms for sub-systems/ application under control not closed successfully.
		Go to step ***10***.
Stakeholders		
Stakeholder		Telescope operator

Use Case: System Shut Down		
Interest	Take the telescope shut-down operation in fail-safe mode so that M&C system re-initialization will not have any problem.	
Post Conditions		
On Success	• M&C system generate information fault log for the shut down. • M&C system can be re-initialized successfully as and when required.	
On Failure	• Manual intervention is needed to remove stale processes and associated memories and ports. • Manual intervention is needed, for example, in case of M&C system's disk full; create a disk-space by taking the back-up of relevant database and files. • M&C system generate information fault log for the shut down.	
Process Rules		
Sr. No	Process Rule	
1.	M&C system shall take sequential shut down steps from the predefined configurations.	
2.	M&C system may have shutdown modes such as: • Emergency shutdown: In this mode, minimal intrinsic components to M&C system will be closed. • Normal shut down: All M&C dependent sub-systems will be taken to the desired predefined state and then disconnect the sub-systems. After successful execution of sequential shut down process, M&C will execute the closing of intrinsic components of the M&C system.	
3.	In case of the M&C system's component or dependent sub-system is mal-functioning; M&C system shall allow shut down that particular malfunctioning component instead of a complete M&C shut down.	
Additional Data Validation Rules		
Sr. No	Validation Rule	
1.	M&C system shutdown validation shall be configurable for number of required sub-systems/ antennas, sub-systems in the CEB.	
Working Details		
Sr. No.	Issues for Resolution	Status
1.	NA	NA

2.1.32. GMRT Configuration

Table 40: Use Case for GMRT Configuration

<table>
<tr><th colspan="3">Use Case: GMRT Configuration</th></tr>
<tr><td colspan="2">Use Case ID</td><td>M&C_UC_034</td></tr>
<tr><td colspan="2">Goal</td><td>To define configuration for the GMRT System</td></tr>
<tr><td colspan="2">Summary</td><td>The administrator provides configuration of the GMRT system that defines the configurations that are specific to GMRT setup.

The broad classifications of the configurable aspects of the GMRT system are given as follows:

• GMRT setup configuration
    o Number of Antenna
    o Number of sub-systems
    o Sub-systems in each antenna
    o Sub-system interfaces
• Utilities Configuration
    o Interfaced applications configuration
    o Help and training configuration
    o Reports and statistics configuration
    o Location, Date, Calendar and Time configuration
    o Language configuration
    o Usability configuration

The list of all configurable parameters, modes and system operations shall be detailed during Software Requirements Specifications phase.</td></tr>
<tr><td colspan="2">Actors</td><td>Administrator</td></tr>
<tr><td colspan="2">Priority</td><td>1*</td></tr>
<tr><td colspan="2">Status</td><td>Accepted</td></tr>
<tr><td colspan="2">Preconditions</td><td>Administrator is logged in</td></tr>
<tr><td colspan="2">Trigger</td><td>On Demand</td></tr>
<tr><td colspan="2">Assumptions</td><td>NA</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="2">Basic Flow</td><td>Administrator performs desired GMRT configuration task</td></tr>
<tr><td>1.</td><td>User</td><td>Selects desired GMRT configuration task as per UI design and provides</td></tr>
</table>

Use Case: GMRT Configuration		
		configuration values as inputs.
2.	M&C	Sets the desired configuration parameter to the given input values.
3.	M&C	Notifies the user about the result of the operation.
		Exit use case
Stakeholders		
Stakeholder		Administrator
Interest		To tune system configuration parameters to desired values
Post Conditions		
On Success		Administrator may be able to define the GMRT specific system configuration.
On Failure		System cannot perform normal operations as GMRT configuration is prerequisite for normal system operation.
Process Rules		
Sr. No	Process Rule	
1.	Some basic parameters are pre-configured in the system configuration.	
2.	Mechanism of loading configurations needs to ensure failure free system operation.	
3.	Configuration interface may be as per UI design which can have a configuration viewer and editor to view and edit existing configuration.	
4.	Administrator is accountable for data integrity and sanctity of system configuration.	
5.	The list of basic configurable parameters cannot be modified.	
Additional Data Validation Rules		
Sr. No	Validation Rule	
1.	NA	
Working Details		
Sr. No.	Issues for Resolution	Status
1.	Need to identify all process constraints and dependencies on system states for all configuration tasks	Open
2.	Need to define how configuration is done	Open
3.	Need to know how the configuration is handled by the M&C in case of remote and local access to the M&C	Open

2.1.33. M&C System Configuration

Table 41: Use Case for M&C System Configuration

Use Case: Configuration - M&C System Configuration		
Use Case ID		M&C_UC_035
Goal		To specify configuration of the M&C system.
Summary		M&C system is configured by the administrator, who defines configuration parameters and values for the M&C system. The broad classifications of the configurable aspects of the M&C system are given as follows: • System meta information configuration (name, version) • System deployment configuration (databases, paths) • System modes configuration • States and State transition configuration; and action to be taken during the state transition (via pre defined scripts or procedures) for CMC and LMC. • System interface and protocol configuration • System time-server and synchronization configuration (Time server and synchronization time interval for the time alignment). • System email-server, user notifying method configurations The list of all configurable parameters, modes and system operations shall be detailed during Software Requirements Specifications phase.
Actors		Administrator
Priority		1*
Status		Accepted
Preconditions		Administrator is logged in
Trigger		On Demand
Assumptions		NA
Basic Flow		Administrator defines the desired M&C system configuration
1.	User	Selects configuration task as per UI design and provides configuration values as inputs.
2.	M&C	Sets the desired configuration parameter to the given input values.
3.	M&C	Notifies the user about the result of the operation.
		Exit use case
Stakeholders		
Stakeholder		Administrator
Interest		To set M&C system configuration parameters to desired values

Use Case: Configuration - M&C System Configuration		
Post Conditions		
On Success	Administrator may be able to configure the M&C system.	
On Failure	M&C cannot be configured, hence loses robustness, adaptability and is prone to failures.	
Process Rules		
Sr. No	Process Rule	
1.	Some basic parameters are pre-configured in the system configuration.	
2.	Mechanism of loading configurations needs to ensure failure free system operation.	
3.	Configuration interface may be as per UI design which can have a configuration viewer and editor to view and edit existing configuration.	
4.	Administrator is accountable for data integrity and sanctity of system configuration.	
Additional Data Validation Rules		
Sr. No	Validation Rule	
1.	NA	
Working Details		
Sr. No.	Issues for Resolution	Status
1.	Need to identify all process constraints and dependencies on system states for all configuration tasks.	Open
2.	Need to define how configuration is done	Open
3.	Need to know how the configuration is handled by the M&C in case of remote and local access to the M&C	Open

2.1.34. Operational Configuration

Table 42: Use Case for Operational Configuration

Use Case: Operational Configuration	
Use Case ID	M&C_UC_036
Goal	To define the operational configuration of the system
Summary	The administrator provides operational configuration of the GMRT system that defines the operational behavior and functionalities of the M&C system. The broad classifications of the operational configuration of the system are given as follows:

Use Case: Operational Configuration		
		• Commands and Response configuration • Alarms and Warnings configuration • Messages and Events configuration • Operational limits configuration • Operational constraints and Interlocks configuration • User interface configuration • Batch process configuration • Data logging configurations • M&C System global variables definitions and configuration. • Exception handling configuration in the events such as exceeding of the threshold values specified for monitoring parameters, logical alarm raised by the M&C system or state machine, alarm rise by the telescope sub-systems. • Configuration of LMC and its connectivity with sub-systems (devices) at antenna • M&C System and telescope sub-systems (GMRT analog back-end, digital back-ends, third-party tools applications and so on) connectivity configuration. The list of all configurable parameters, modes and system operations shall be detailed during Software Requirements Specifications phase.
Actors		Administrator
Priority		1*
Status		Accepted
Preconditions		Administrator is logged in
Trigger		On Demand
Assumptions		NA
Basic Flow		Administrator performs desired operational configuration task
1.	User	Selects desired operational configuration task as per UI design and provides configuration values as inputs.
2.	M&C	Sets the desired configuration parameter to the given input values.
3.	M&C	Notifies the user about the result of the operation.
		Exit use case
Stakeholders		
Stakeholder		Administrator
Interest		To tune system operational configuration parameters to desired values

Use Case: Operational Configuration		
Post Conditions		
On Success	Administrator may be able to define operational configuration of the system.	
On Failure	System cannot perform its operations as configuration for operations cannot be defined.	
Process Rules		
Sr. No	Process Rule	
1.	Some basic parameters are pre-configured in the system configuration.	
2.	Mechanism of loading configurations needs to ensure failure free system operation.	
3.	Configuration interface may be as per UI design which can have a configuration viewer and editor to view and edit existing configuration.	
4.	Administrator is accountable for data integrity and sanctity of system configuration.	
5.	The list of basic configurable parameters cannot be modified.	
Additional Data Validation Rules		
Sr. No	Validation Rule	
1.	NA	
Working Details		
Sr. No.	Issues for Resolution	Status
1.	Need to identify all process constraints and dependencies on system states for all configuration tasks.	Open
2.	Need to define how configuration is done.	Open
3.	Need to know how the configuration is handled by the M&C in case of remote and local access to the M&C.	Open

2.1.35. Housekeeping

Table 43: Use case for Housekeeping

Use Case: Housekeeping	
Use Case ID	M&C_UC_037
Goal	To perform M&C system housekeeping functionalities
Summary	Administrator also performs housekeeping activities as a part of M&C system maintenance. These activities may include taking backup of logs, clearing logs, reloading configuration from history, software version backup.

Use Case: Housekeeping		

		Housekeeping of the M&C system may include the following tasks:
		• Backup of M&C data as described in Backup and restoration scenario ***M&C_SC_008***.
		  ○ Backup of logs, reports, configuration, software
		  ○ Loading of configuration from backup
		• Clearing data
		• Perform audits using ***View Logs*** for audit trail

Actors		Administrator
Priority		3
Status		Accepted
Preconditions		Administrator is logged in
Trigger		On Demand
Assumptions		NA
Basic Flow		Administrator successfully performs desired housekeeping administration operation.
1.	User	Selects an administrative task (Backup, clear logs and so on) and provides required inputs for the administrative task.
2.	M&C	Validates the user inputs and actions to be performed.
3.	M&C	Identifies that user inputs are valid.
4.	M&C	Performs the request operation for the given inputs.
5.	M&C	Notifies the user of the result of the operation.
		Exit use case.
Alternate Flow 1		Housekeeping administrative task failed due to invalid inputs or operation not possible.
2	M&C	Validates the user inputs and actions to be performed.
3_1	M&C	Identifies that user inputs are invalid or the requested action is not possible or not permitted.
3_2	M&C	Notifies the User.
		Exit use case
Stakeholders		
Stakeholder		Administrator

Use Case: Housekeeping	
Interest	To perform housekeeping administrative tasks like backup of system logs and clear logs.
Post Conditions	
On Success	Administrator may be able to perform the desired housekeeping administrative operation using the M&C.
On Failure	M&C system administration is not possible and hence can lead to unsafe operations and affects availability, maintainability and reliability of the system.

Process Rules	
Sr. No	Process Rule
1.	All Administrative tasks can be carried out independently of each other as permitted by the system configuration.
2.	Some administrative operations may be dependent on system modes, operation in progress or system states. These constraints are identified in the system configuration.

Additional Data Validation Rules	
Sr. No	Validation Rule
1.	NA

Working Details		
Sr. No.	Issues for Resolution	Status
1.	List of all process constraints and dependencies on system states for all administrative tasks need to be identified.	Open
2.	Need to identify the backup procedure and scope of the backup functionality	Open
3.	Need to define how many administrators are allowed for the system and how to manage them.	Open
4.	Need to indentify the scope and process for archival of historical data using and clearing logs.	Open

2.2. Scenarios

The specific events, which do not occur very frequently during the observation, however M&C needs to take some actions for them are documented as scenarios in the ***Table 44.***

Table 44: List of Scenarios

Scenario ID	Scenario	Description
M&C_SC_001	Electrical power on for the sub-system	This scenario describes the events and actions being executed in the M&C system after the electrical power supply switched on at individual device/sub-systems: • Sub-system goes in RESET mode. RESET mode describes that sub-system is not in application but communicating with the central-electronics building via antenna base computer. • Sub-system gets initialised by the M&C system by loading/enabling the particular application software on that sub-system. • System loads threshold/limits parameters for the powered-on sub-system. • Restore the default or current settings to the sub-system (current settings are retrieved from the Central M&C or from the antenna base computer.
M&C_SC_002	Electrical power on for the antenna base computer	This scenario describes the events and actions being executed in the M&C system after the electrical power supply switched on at antenna base: • ABC boots up and loads the application software. • ABC communicates to all sub-systems which are up and also communicates to the central M&C system. • Antenna goes to RESET mode and sends its updated status to the central M&C continuously. • Central M&C initialises the ABC by loading the default threshold or limit parameters, configuring the communication to only the desired sub-systems (in case some known sub-systems continuously flooding the error messages to central M&C system). • ABC aligns time to the current TIME received either from the central M&C system or Date-time information from the network time server via NTP protocols. ABC sets the time to all configured child-sub-systems. • ABC configures and updates all sub-systems to the present configuration of telescope. • ABC continuously send monitoring/alarming and communication up messages to the Central M&C system.

Scenario ID	Scenario	Description
M&C_SC_003	Electrical power on at the central Electronics building	This scenario describes the events and actions being executed in the M&C system after the electrical power supply switched on at the central electronics building: • M&C invoke M&C components /processes and associated tasks. • M&C Component and process execution start. • M&C system invokes all other M&C dependent processes (Power equalisation tool, M&C system logger server, data quality server, Frequency and Time standard system and M&C Monitoring/Dash-board server) and connects/communicate with them. • Connects and configures all selected antennas. • Connects to GMRT analog backend system. • Connects to configure Digital backend systems. • M&C corrects the date and time of all configured antennas, sub-systems at the antenna base and in the central electronics time. • M&C system display the successful boots up message or report failure messages while booting up. • M&C system goes in Stand-by mode (where all live status of the telescope is being displayed to relevant users) to take further inputs from the control-room user that is telescope operator.

M&C_SC_004	Log out Scenario	This scenario describes the various conditions to handle while user attempts to logout of M&C System.
		• When user chooses to log out of the M&C system, the system handles the request and performs some checks so that user can be safely logout. This logout procedure includes the following checks:
		  ○ User type and user privileges.
		  ○ System state and operations in progress.
		  ○ System state transition scheme on logout.
		• System performs these checks to handle the following situations:

Scenario ID	Scenario	Description
		○ If user is an astronomer and has at least one operation (observation) currently associated with the user, then user can either terminate the observation or hand over session to operator. On termination, system initiates observation termination process. On session hand over, the system notifies the operator in charge who can then take control of the observation. ○ If the user is an engineer, and there is maintenance activity in progress associated with the user, system initiates shutdown of operations in progress. ○ If the user is the last remaining (currently logged in) operator in the M&C system, the system checks if there are any operations in progress (both maintenance and normal operation).Upon confirmation of logout from the user, system shutdown process is initiated (shutdown of operations, parking antenna and so on). In addition to the above, mode transitions are also handled by the system as per the state transition scheme.
M&C_SC_005	High Wind	Winds over 40 Km/hr speeds have been proven to be non-safe for operations from the structural safety point of view of the antennas of GMRT. Hence M&C needs to ensure the structural safety of Antennas by raising appropriate alarms on high wind occurrences. M&C needs to monitor for a high wind situation for all antennas (Wind sensors are interfaces with the servo system, which communicates the value of wind speed to M&C). If the high wind situation is detected from any of the antenna, then all antenna needs to be parked. (Refer ***Antenna Parking*** use case for details). Stop all the observing sessions that are in progress by stopping the science data acquisition (Send request to Correlator). M&C keeps monitoring the wind speed, if the speed is observed to be below threshold limit (This limit is predefined in system) for a predefined duration of time (presently it is 15 min.), then M&C starts all the observing sessions. This involves, rotating the antennas back to the tracking position and starting the data acquisition automatically. The occurrences of high wind, observation start and stop and other events need to be logged as events.
M&C_SC_006	False Alarm	A false alarm, also called a nuisance alarm, is the fake report of an emergency which can lead to unnecessary costs in operation and time. Such alarms are most probable in sentinel systems where there could be false fire, intrusion or smoke alarms. In addition to these, high wind alarms may also be false or irrelevant (over time). Such instances of false alarms known as false positive alarms can lead to mismanagement of alarms and reduce system availability. System should be capable of handling false alarms wherever possible and should provide all necessary information

Scenario ID	Scenario	Description
		to the operator to take informed decisions on alarm occurrences after offline verification.
M&C_SC_007	Execute Batch Process/ scripts	The existing GMRT monitoring and control system facilitates execution of commands in the form of programs and scripts. This enables a skilled operator to run background procedures including automatic execution of observation. This can also be used for testing activities and activities where operations are done iteratively. Execution of batch processes also helps in defining custom procedures with process validations which can speed up operations as compared to when done manually. Batch processes are defined by administrator by default. However, a skilled operator may also define custom batch procedures. In addition, user privileges for defining and execution batch processes can be defined in system configuration. User may define custom batch procedures (as per UI design), which allows the user to optionally run the process as a background process. User may also schedule a batch process to execute at a later time. The list of batch procedures, constraints and capabilities shall be detailed in subsequent phases of the project.
M&C_SC_008	Backup and Restoration Scenario	Administration of the M&C System includes several housekeeping tasks such as backup of data, logs, configuration settings as well as clearing old and unnecessary data. Backup of data from M&C is useful because the GMRT M&C system maintains important operational and audit information over possible large periods of time. Some of this data may become obsolete over time and may be rarely required. This may increase data access times and response delays. To avoid data loss and to prune obsolete data, the administrator periodically may perform backup of the M&C system. The data backup is done as desired from the user interface of the M&C system. Administrator may also clear obsolete data or custom logs that may be temporarily stored in the system. Since removal or deletion of data from the M&C system is a critical activity, only privileged administrator may manually perform this operation. Backup of data involves the following high level tasks: • Selection of data / entities to backup • Providing additional information for backup (time period, backup format , backup location) • Scheduling or executing backup Restoration of data is a manual activity that the administrator may perform offline or using external tools. This may involve importing data into M&C database, restoration of configuration and custom settings files, restoration of log data in M&C understandable format. Since restoration is a manual task, the administrator is accountable for ensuring data integrity and sanctity during restoration. M&C system shall have fault tolerance and exception handling to handle invalid data access exceptions.

Scenario ID	Scenario	Description
M&C_SC_009	Time Synchronisation	It is important to synchronise the timings of all the GMRT subsystems and M&C system, in order to establish an accurate data relationship between the science data and meta data. A reference time is obtained from the Frequency and Time Server (FTS). M&C system, should communicate with FTS to synchronise the following systems and subsystems with an accuracy of ±1 second. • CMC • LMC • Servo System • RCB • FPS The other subsystem of GMRT such as correlator gets synchronised by communicating with FTS directly. Time synchronization frequency and mechanism needs to be determined in the following phases of the project.

2.3. System Requirements

System requirements of M&C system for GMRT are documented in the embedded sheet *M&C_System_Requirements.xls*

M&C_System_Requir
ements.xls

3. Information Technology Plan

The preferred software technology platform for realization of M&C implementation is an open source platform.

The selected open source technology platform should enable to develop a robust and configurable M&C which can be scaled to implementation of TM for SKA telescope.

As far as possible, COTS hardware is preferred choice for hosting the M&C system.

The software and hardware technology platforms will be finalized in the subsequent phases of the project.

A. Appendix

A.1 User Interface Requirements

Following are the User interface requirements of M&C:

- The M&C system should provide easy to use and intuitive GUI for all the control, monitoring and diagnostics activities to be carried out from system.
- System should not enter into the non-responsive state and should keep the user updated about the system status, health, errors, warnings and alarms.
- Critical information on alarms, system health and warnings should be made available to user on priority and presented with due consideration to user interface ergonomics.
- System should adapt to the user's operational skill level. Experienced users should be able to adapt the interface to suit their particular ability level and preferences.
- GUI should provide the help options though the tool tips and context sensitive help.
- GUI should also facilitate basic troubleshooting in using the system.
- Users should be able to configure their own user interface. The configuration of interface will be covered in design phase.

A.2 Training Requirements

Following training requirements are identified for the M&C:

- All the stakeholders identified from the system user point of view, needs to be trained to operate M&C system independently.
- Training/ user's manual for M&C must be created.

A.3 Localization/Globalization Requirements

Following Localization/ Globalization requirements are identified for M&C system

- M&C system needs to provide support for English language only.

A.4 Rollout/ Deployment Requirements

Following rollout/deployment requirements are identified for M&C system:

- The components of the M&C system, being deployed at antenna base location, need to be deployed one after the other antenna sequentially.
- The GMRT facility may remain un-available for scientific experiments and observations while the M&C commissioning is in progress. However the commissioning schedule needs to be prepared in consultation with NCRA.

- The MCM of existing control and monitoring system and RCB of proposed M&C may co-exist for a given antenna. Hence proposed M&C must be able to communicate with both the hardware to perform the control activities.

A.5 GMRT Parameter List

The indicative list of GMRT parameter list for monitoring including alarm and warning conditions for various parameters is given in the embedded spreadsheet. This list shall be used to derive master parameter list of all monitoring, control, alarm, dashboard, and I/O parameters.

This indicative list shall be evolved in the subsequent phases of the project.

GMRT_Parameter_List.xls

A.6 Explanation of Use Case Template Fields and Conventions

The Explanation of the use case template fields is provided in the **Table 45*:***

Table 45: Use Case Template Fields Explanation

Use Case: <<Name of the Use Case, as it appears in use case diagram above>>	
Use Case ID	Provides unique ID of the use. For example- M&C_UC_001
Goal	Specifies the goal of use case.
Summary	Brief description of the use is provided here.
Actors	The users who initiates the use case/ uses the scenario/feature.
Priority	Specifies the implementation priority of the use case. The field will have values 1 to 3, 1 being the highest priority and 3 being the lowest priority. Priority marked with * implies that the requirement can be partially implemented in its following phase. (Priority will decide the phases of implementation of M&C)
Requirement Status	Specifies the status of requirement. Possible status is: Proposed, Under discussion, Accepted and Rejected.
Preconditions	Specifies the necessary conditions for successful execution of the use case.
Trigger	Specifies, the point/situation which will initiates the use case.
Assumptions	Assumptions for the requirement for which the use case is developed are documented here.
Use Case Flows	
Basic Flow	Depicts the main success scenario. This may have multiple steps.

Use Case: <<Name of the Use Case, as it appears in use case diagram above>>		
Alternate Flow	Depicts the possible failure/ alternatives while executing the use case. Multiple alternate flows may exists for the given use case.	
Stakeholders		
Stakeholder	The stakeholders who have an interest in this use case are documented here.	
Interest	Interest of the stakeholders, behind putting up the requirement is documented here.	
Post Conditions		
On Success	The post conditions of the system after successful execution of the use case are documented here.	
On Failure	The post conditions of the system after failure to execute the use case are documented here.	
Process Rules		
The data processing rules, interlocks and so on. Are documented here.		
Additional Data Validation Rules		
Sr No	Validation Rule	
1.	The data validation rules are specified here.	
Working Details		
Sr No	Issues for Resolution	Status
1.	Issues under discussion are documented here.	Open/Close

Following conventions are used in use case template

- Rows Highlighted in Yellow colour indicates that the activity is performed outside the boundary of M&C.
- Rows Highlighted in Blue colour indicates the branching of alternate flow.