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Gemini 8-M Telescopes Project

Controls Group

Software Concept Specification

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Credits

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1INTRODUCTION

1.1 Purpose

The purpose of this document is to define, in broad, nonspecific terms. the software for the Gemini Telescope. It constitutes the conclusion of the Concept Phase of the Gemini Software Project in which the user needs and the project objectives are broadly defined. It also serves as an overview of the conceptual framework for the Gemini Control Software.

It should be emphasized that not all of the parts described here will be part of the final Gemini system. The decision as to the implementation phasing and deletions will be a project decision taken at a later date when budgets and schedules have been decided.

1.2 Scope

This document starts the standard software lifecycle (as defined in IEEE Standard l012-1986, Section 1.1) for the Gemini software project.

The goal of this document is to focus on the general objectives and requirement for Gemini. It is. therefore, consciously kept at a general level, but in such a way that all other requirements can be traced back to it.

The intended audience ranges from users to software developers, who should have in this document the first common baseline.

This document is NOT meant to cover the Gemini software requirements at a level of detail on which design and implementation of the various packages could be based. This level of detail is given in the Gemini Software Requirements Specification (SRS), which follows this specification both conceptually and chronologically.

1.3 Applicable Documents

The following documents are official Gemini documents, referred to in the text, even if not all of them exist yet. These documents will be provided to all developers of Gemini software both to provide useful background and to provide the environment under which Gemini software will be generated.

1.3.1 References

1. [GSR] Gemini Scientific Requirements
2. [EDS] Gemini Electronic Design Specification
3. [SRS] Gemini Software Requirements Specification
4. [SMP] Gemini Software Management Plan
5. [SCP] Gemini Software Configuration Plan

6. [STP] Gemini Software Test Plan
7. [SPS] Gemini Software Programming Standards
8. [ARC] Gemini Archive Data Interface Requirements
9. [EMS] Gemini Enclosure Monitoring System
10. [SDD] Gemini Software Design Description

Some of these documents were not yet ready at the time this specification was written. They belong, however, to the currently planned set of documents for Gemini

1.3.2 Background Information

The following documents are given as references to provide background information.

1. Software Verification and Validation Plans IEEE Standard 1012-986
2. Guide to Software Requirements Specifications IEEE Standard 830-984
3. The STARTS Guide - A Guide to Methods and Software Tools for the Construction of Large Real-time Systems. 1987.
4. Specification Practices. Military Standard 490A
5. Engineering Management. Military Standard 499A
6. Technical Reviews and Audits for Systems, Equipments, and Computer Software. Military Standard 1521B, Notice 1

1.4 Abbreviations And Acronyms

The following abbreviations and acronyms are used in this document:

CCS Central Control Software

DBMS Data Base Management System

HOS High Level Operating Software

HW Hardware

ICS Instrument Control Software

IEEE Institute of Electrical and Electronics Engineers

ISO International Standardization Organization

OSI Open Systems Interconnection

LAN Local Area Network

LCU Local Control Unit

ROS Remote Observing Software

TBD To Be Defined

TBR To Be Resolved

TCS Telescope Control Software

UIF User Interface

WAN Wide Area Network.

1.5 Overview

The GEMINI software is defined as the software which will control the Gemini 8-m Telescope (G8MT) including its instrumentation in all the planned modes and configurations.

Many of the planned features are new and the G8MT will be one of the more complex ground-based telescope systems built so far. The individual subsystems themselves will be built in parallel by a diverse international community. This increase in system and interfacing complexity demands a more formalized approach to all aspects of software development than has been common practice in the past.

It is the intent of the Gemini Project that the majority of the GEMINI software will be adopted, adapted, or reworked from existing software; from either commercial or community packages. The project is willing to adapt to existing packages if doing so will meet a majority of its critical objectives and, at the same time, give either budget or schedule advantages.

Certain packages (defined later in Section 3.3.3) are considered as external software with respect to the G8MT software, even if used online during G8MT operation.

Interfaces to such packages (mostly commercial packages or used on other projects as well) are considered part of the G8MT software.

Any modification to such packages which will be required by the G8MT software must also be considered as an integral part of it.

Following this introductory section:

Section 2 describes the requirements for the G8MT software as perceived from the users' viewpoint.

Section 3 describes the general requirements and constraints both inherent in the control of a telescope system and/or specific to the G8MT.

Section 4 outlines, in very broad terms, a control system design concept which is capable of adequately fulfilling the requirements. It also provides an overview of the functional layout of the control system

2USER REQUIREMENTS

2.1 Locations Of Users Of The System

Users of the system will be located at one or more facilities. These are referred to in general as G8MT operations facilities. The G8MT enclosure and G8MT control facility are referred to collectively as the G8MT site.

2.1.1 G8Mt Enclosure

This is the enclosure housing the telescope. In general such use would be limited to maintenance and engineering.

2.1.2 G8Mt Control Facility

This is the facility collocated with the enclosure, either attached or detached. It is from here that nightly operations would take place.

2.1.3 G8Mt Site Support Facility

This is the facility where off duty personnel reside while stationed on the summit. This would be the Hale Pohaku facility on Mauna Kea and Cerro Tololo in Chile (assuming no support facility is constructed on Cerro Pachon).

2.1.4 G8Mt Base Facility

This is the facility where offices, shops, etc. are located. On Hawaii this would be with the JACH in Hilo and in Chile it would be either the La Serena or Cerro Tololo facilities.

2.1.5 G8Mt Remote Operations Facility

These are super sites, in general located in partner countries, which have direct links to the telescopes via communications lines. They may or may not be collocated with any administrative organization associated with the Gemini telescopes. These sites have remote operations capability.

2.1.6 Satellite Site Facility

These are sites with high bandwidth connections to the super sites. They have remote operations capability but at a reduced level.

2.1.7 Institutional Site Facility

These are sites, generally located at existing observatories, universities, etc. that have some form of connectivity, perhaps via satellite sites and/or super sites, to the telescopes. Although they have remote operations capability the link capacity will determine at what level.

2.2 Users Of The System

The users of the system consist of:

- Observing astronomers
- Operations staff
- Software development and maintenance staff.

Unless the contrary is explicitly stated, all requirements and modes presented are intended to be available to all users of the system.

It should also be noted that what the system has to guarantee in terms of operations must fulfill all possible requirements, but it does not mean that all features will be made available to all users at all locations at all times.

The available capabilities will have to be adapted to the operational needs both locally and remotely and these decisions can only be taken later in the life of the project.

2.2.1 Observing Astronomers

- Definition

Observing astronomers are the end users of the system. They range greatly in experience from occasional users of the system to very experienced users such as staff astronomers at the G8MT site and service observers.

- Purpose of work

Whatever their level of experience, observing astronomers will wish to concentrate on the efficient acquisition of astronomical data and online assessment of data quality, rather than on the details of controlling the telescope and instruments.

To allow observing astronomers to achieve this objective, the system must offer to a user an interface which, while fulfilling the various operational requirements in the different modes and offering status information both automatically and on request at any required level, is still simple to learn and secure in its use.

- Privileges

Observing astronomers shall have no privileges as far as the direct control of the telescope is concerned. They shall not be able to send control commands directly but they must be able to enquire about the status of the telescope or any subsystem at any time. The intent is not to restrict the capabilities of the observing astronomer in any way but rather to establish a single point of control and responsibility. It will be established in [SRS] whether programs, as opposed to observers, will have the capability of direct control of the telescope. This would allow the

observer to create an observing program which requested a telescope control function but would not allow the observer to enter (for instance) a command to slew the mount.

- Operation mode

Traditional interactive operation shall normally be replaced by operation via an automatic sequencer. This is essential to support operational requirements such as service observing and flexible scheduling (as defined later in Section 2.3).

A certain degree of interaction shall be provided, meaning in this case that the user will interact with the scheduler program, rather than with the control programs directly.

Observing commands will normally be submitted via the User interface to a queue for later execution. It must also be possible to break and resequence this queue. e.g. as a result of the quality assessment of previous data.

In particular, Operations staff will be able to enable direct interactive operation, but this shall not be considered as the normal operation mode for the reasons explained in Section 2.3. It is evident that, for some functions (such as adjustment of spectrograph slit width for seeing conditions) it must be necessary to include interactive capability. However each instance of such a function should be examined as a candidate for automation - such as focussing.

The existence of the scheduling queue shall be transparent to the on-site observer during the initial phases of telescope operation. Only after experience has been gained with the system will the existence of the queue become evident to the on site observer.

2.2.2 Operations Staff

- Definition

Currently, operations staff includes 'night assistants' and staff of the 'operations group'. Depending on the operations implemented on the G8MT, they may become telescope operators, operations supervisors of the G8MT telescope, and instrument operators and have to overview the G8MT operation.

These users will be very experienced users of the system. They will be very familiar with the G8MT and/or its instruments.

- Purpose of work

Operations staff will control the G8MT indirectly via a scheduler program or directly via commands. They will supervise telescope operation and will be able to advise observing astronomers on what they have to do to use telescope and instruments efficiently. They shall also monitor general performance and system safety.

- Privileges

Operations staff shall have privileges to access all commands and maintenance procedures in case of problems. This includes direct control of physical units.

However, they shall not have access to subsystems while these are in normal operation. If they need to access other parts of the system appropriate reconfiguration procedures have to be run.

- Operation mode

Operations staff shall have access to operation tables in update mode, while observing astronomers will have access to them only in read mode (for example the list of filters mounted on an instrument). Again, the intent is not to restrict the capabilities of the observing astronomer in any way but rather to establish a single point of control and responsibility. At the present time it is not clear how to handle visitor instrument requirements in this area.

They shall be able to change the operational status of units according to the results of tests performed on such units (e.g. to see if a faulty unit can be declared as operational again and redefined as part of the environment in use).

2.2.3 Software Development And Maintenance Staff

- Definition

Software development and maintenance are staff:

- based either at the G8MT site or base facility, or
- based at the G8MT remote operations facility, or
- non Gemini staff from a contract company or from an associated Institute.

These users will have a deep understanding of the way the G8MT software works.

- Purpose of work;

Software development and maintenance staff intervene when there is a major problem to be solved or an upgrade to be installed. They also perform system generation and installation of new software packages or new releases, according to established test and validation procedures.

- Privileges

Software development and maintenance staff need the highest privilege in order to be able to modify everything in the system. Nevertheless strict configuration control guidelines must be followed to prevent interference with ongoing normal operation.

- Operation mode

Software development and maintenance staff usually work at the test level (see Section 3.2.1) for the part of the software under test. Other parts of the G8MT may also need to run in test mode to support integration tests. This means that a number of commands are available which allow the hardware concerned to be tested (test commands) and are not accessible to observing astronomers .

2.3 Operational Context

This section derives directly from G8MT program requirements and specifies the operational context, which is a direct consequence of the structure of the G8MT system.

The G8MT operation has to cope with a complex environment produced by:

- multi-telescope concept
- multi-instrument context
- visitor instrument context
- multi-user context.

2.3.1 Multi-Telescope Context

Although there are two telescopes as part of the Gemini system there are no plans to support concurrent use of them as if they were a single telescope. It is, however, a long term goal of the Gemini project to be capable of being used in conjunction with nearby, perhaps non-Gemini, telescopes on the same site (for instance for interferometry).

2.3.2 Multi-Instrument Context

Normally up to five instruments will be mounted all the time on the cassegrain focus of the telescope. The G8MT is characterized all the time in a multi-instrument context.

Parallel access to all the mounted instruments shall be provided, though only one instrument has access to the telescope beam (active instrument).

Instruments which feed two detectors by using beam splitters or field splitters will be considered as a single active instrument. Feeding two separate instruments via beam splitters or field splitters and providing separate control nodes is not currently a requirement.

The only possible exception to this is referred to as hitchhiker mode. In this mode a simple instrument observes the edge of the field serendipitously. In this case there would be two active instruments - whether such a mode is supported will be decided in [SRS] after consultation with [GSR]. It must be pointed out that the implicit requirement to support two or more active instruments from two or more control nodes will greatly complicate the control system - mostly from the need to synchronize telescope and A&G motions between the two control nodes.

Various situations are possible for the other (inactive) instruments:

- they shall be able to take calibration or flat field exposures in parallel
- they shall be able to prepare for an exposure to start as soon as the telescope beam is switched back to them (in this case, they are in a hot standby situation)
- they shall be able to work; at all foreseen operation levels (observing, maintenance, test) (see Section 3.2. 1).

Irregardless of the status of an inactive instrument, it shall not be possible for any of its permitted actions to adversely impact the active instrument.

2.3.3 Visitor Instrument Context

The requirement to provide for support, installation, and operation of outside instruments brought by the observer has several implications for the system. Due to the specialized nature of visitor instrumentation it is unlikely that complete integration into the Gemini environment is

either feasible or warranted. In this case a subset of the available functionality must be made available through a standardized interface.

It should be the goal of this interface that it be a subset of the existing instrumentation interface (rather than a separate system). At a minimum this interface should support:

- acquisition of status information of entire system
- capability to enter preprogrammed observing sequences
- capability to offset the telescope position and focus

It should be a goal, but not a requirement, that the interface provide support for

- coordinate transforms between visitor instrument and the Gemini system
- archiving (or archivibility) of visitor instrument data
- maintenance of operations tables (such as filter lists) which can become part of an observation's permanent record

Due to the nature of visitor instrumentation it is unlikely that more complicated functionality can be supported. In particular coordinated motions of the Gemini system components with those of the visitor instrument (other than simple raster scans) will not be supported.

This does not mean that more complicated functionality will not be possible for visitor instruments which require it. Such functionality will not be offered as a standard service but will require a joint effort on the part of Gemini and the visitor instrument team. As more complicated functionality will be supported via standardized interfaces for the Gemini instruments, such as coordinated motions, it should be possible to adapt visitor instruments to this standard. The difficulty with offering such services as an externally supported standard, as opposed to an internally supported standard, is that decisions to change internal standards do not impact external users.

The support of visitor instrumentation is made simpler if the visitor equipment adheres to the Gemini standards. However it must be recognized that:

- the Gemini standards may not prove cost effective for some visitor instruments
- the Gemini standards will evolve over time as requirements and technology change
- the evolution of Gemini standards might require existing visitor instruments to rewrite or rework large areas of their control system
- visitor instruments built later in time than the initial complement of Gemini instruments may want to take advantage of different and/or less expensive technology if it better suits the goals of their project

For these reasons it is probably not possible to establish a combined standard to which all instruments, both Gemini and visitor, adhere to completely. It is much better to establish a subset of Gemini facilities which will be made available to visitor instruments via long lived, stable interfaces. Visitor requirements outside of these would be handled on an as needed basis.

The support of both Gemini and visitor instruments would benefit by the provision of a Gemini observatory simulator. This simulator, appearing to the instrument as a standards set of hardware and software interfaces, would present a functional definition of the observatory.

2.3.4 Multi-User Context

The requirements to have instruments operated as single units imply that several user stations will be active at the same time on the G8MT. On these user stations, different kinds of users may be working at the same time with the G8MT software.

Independently of the location of users at the telescope site, they shall be able to access (according to their privileges) any part of the whole setup with a simple logon and configuration operation. In other words. any subsection of the whole G8MT system should be accessible and controllable from any single point (but of course with protection ensuring security and safety).

A particularly simple case of multi-use of the system is multi-point monitoring. By this it is meant that, while some (active) user is in control of the G8MT, someone else can follow what they are doing by monitoring all the relevant data from telescope and instruments. This will typically be needed by the operation supervisor. All other users wishing to monitor G8MT operations will have to go through the procedures set up by Operations and get permission to do so.

The multi-point monitoring mode might also be important when certain difficult or rare problems occur, when expert advice is needed and can only be obtained from colleagues situated remotely. Multi-point monitoring will allow them to follow directly the results of tests performed and investigate how the system is working (e.g. by selecting different display pages with the uptodate status information on different parts of the system).

Monitoring shall exist both in the form of automatic displays of status information at different locations, and in the form of explicit access to the required status information from any point.

Monitoring shall not affect the performance of ongoing observations.

2.4 Operational Requirements

This section groups together the so-called high-level operational requirements, namely service observing, flexible scheduling, remote operation, preprogrammed observing, and queue scheduling.

The priority for implementation of the various observing modes contemplated will be:

- classical observing
- service observing
- remote operations
- preprogrammed observing
- queue scheduling
- flexible scheduling

A simulator will be required to make effective use of the more automated forms of observing.

2.4.1 Classical Observing

Classical observing with time allocation for full nights is a first basic requirement of the G8MT. It is therefore an essential requirement that telescope operation is supported by the software in a smooth and very friendly way in this mode.

Interaction will normally be via an automatic sequencer (see Section 2.4.5). This is clearly a top priority requirement and one which will have to be realized before implementing any other mode. The initial implementation of the automatic sequencer will operate in a "pass thru" mode where all commands are accepted and transmitted with minimal checking and delay.

2.4.2 Service Observing

Observing, as such, is the purpose of the G8MT system. But classical (interactive) observing is perhaps, in some cases, not the most efficient way to achieve this, although it will be necessary for certain kinds of observations (such as adaptive optics) and in certain phases (such as commissioning and test periods).

Service observing, on the other hand, means that the observing program can be performed by someone other than the proposing astronomer. It will be done on his behalf at a convenient moment, which is not exactly predefined and may be intermixed with programs from other users.

Service observing requires switching during the night among telescope modes and instruments. This might typically be a few times (2) per night, when sky conditions change.

It requires also that the observing program is so well specified that it can be executed by someone else. In other words, it requires a computer executable observing program.

Service observing requires a suitable organization to support it, and first of all, considerable experience with a smooth running system. For these reasons it can only be applied to the G8MT once the Classical observing requirement has been fulfilled and been in operation for a while. Nevertheless the software and data structures to support classical observing which have to be present in a system which is only interactive at the start might require considerable redesign to be adapted later to the service observing requirement.

2.4.3 Remote Operations

The choice of the name remote operations is meant to suggest an entire category of operations, such as remote observing but also remote access for diagnostic support. In this sense it is more general than pure remote observing.

Despite the obvious limitations introduced by the link bandwidths available at the different locations, the system shall be totally transparent to local or remote use. It is only necessary that the functionality of the system be transparent, it is accepted that the speed of the link will determine the perceived transparency of the system. However the system design should minimize the impact of link bandwidth on transparency.

Security of operation shall be considered and might imply different operation levels and privileges at different sites.

It is required that the remote operations software is considered from the beginning in the G8MT software design, to avoid redesign later. This should reduce the amount of specific software needed for remote operations, as the common layers of software shall cope from the beginning with a distributed environment .

1. Remote Control

Remote control means that the function normally associated with a local Telescope Operator, that of entering telescope control commands, would be available from a remote site. In practice remote control will be restricted to the G8MT Enclosure and G8MT Control Facility. The philosophy behind this is that, for safety considerations, telescope control commands cannot be issued without a staff member (not necessarily the same person) having direct access to:

- a hard wired "stop" button
- real time video and audio
- control of the telescope

2. Remote Observing

Remote observing means that users shall be able to observe from a remote site such as Cerro Tololo, Hilo or even home Institutes. This possibility has to be provided on the G8MT.

The extent to which realistic observing conditions can be reproduced depends, of course, largely on the link bandwidth available. Experience with previous telescopes at other observatories shows, however, that, even with very limited bandwidths, remote observing can be implemented, provided the software is suitable for this .

Remote observing, as meant in this context, does not mean remote control. Remote users shall normally interact with the system via

- operators at the G8MT control facility
- operators at the G8MT site facility
- operators at the G8MT base facility
- operators at the G8MT remote operations facility
- via the scheduler program

and shall not control any part of the G8MT directly.

In the last case they will use a remote User interface to submit commands to the G8MT scheduler at the G8MT site.

3. Multipoint Monitoring

In this mode the monitor's screen appears as a duplicate of that seen by the observer. The monitor's keyboard would not have any effect on the observer's environment.

4. Remote Monitoring

Remote monitoring is the simplest level of remote observing. It is sometimes called 'eavesdropping'. It is a requirement for the G8MT operation and will complement service

observing, making it friendlier for users. Remote monitoring coincides to a large extent with multipoint monitoring, but allows the remote user to "pick and choose" the information that is displayed on the remote screen. There is no requirement that the remote screen be a duplicate of the local screen. The remote keyboard will have no effect on the local user's environment.

5. Remote Access

Quite apart from remote observing, remote access to the G8MT and its instruments is required for monitoring and diagnostic purposes. This might be necessary to back up local users expertise and to help in case of problems. Remote access, in this case, must be possible from the G8MT base facility.

Distributed access to the G8MT software, once implemented. also allows, without extra requirements, local access (at the G8MT site) or remote access (G8MT support, base, and remote operations facilities).

2.4.4 Preprogrammed Observing

To achieve efficient service observing, queue observing, and flexible scheduling, it should be possible to carry out observations automatically, in accordance with predefined sequences of exposures, as is commonly done in space observatories.

This corresponds to what is meant by preprogrammed observing, which still requires competent monitoring at the G8MT site or remotely.

At the same time, one does not want to lose the advantages and the extra flexibility of ground-based astronomy. So whichever scheme is adopted to perform automatic sequences, interaction shall be allowed at the desired level (for example, only on error conditions and any time the user shall be allowed to break a sequence, etc.).

2.4.5 Queue Scheduling

To maximize the use of the available observing time it must be possible to queue all of the observing that is possible with the currently available instruments. These would most lin the form of preprogrammed observing sequences. It should be possible to resort the queue so that the next observation to take place comes to the front of the queue. This sorting will be based on properties of the individual observing sequences, current site conditions, and other rules established by the observatory directorate.

While these rules have yet to be worked out one could imagine rules such as "no more than 15% of observing will be preempted" or "a 10% overhead to the prime observing project is acceptable in order to pick up observations in similar parts of the sky with identical filters".

Thus queue scheduling is a superset of preprogrammed observing, with similar requirements. As the costs implementing such a scheduler are currently difficult to estimate it may prove necessary to implement it in a future phase of the project. The system design, if it does not include a scheduler, should specifically allow for its future implementation.

2.4.6 Flexible Scheduling

Flexible scheduling means the possibility of reacting to changes in weather and other conditions by allocating the current use of the telescope to the optimal observing program for those conditions.

It will require the use of service and/or remote observing, as users cannot stay around indefinitely waiting for the conditions required by their program. This can be complemented by remote monitoring, if users can be on standby at a suitably equipped remote site.

Flexible scheduling requires the possibility to change telescope scheduling quickly, exchanging observing programs. This can be achieved only with the help of appropriate scheduling software, which must advise the operations team on the best choice to make which is compatible with the relative priorities of the various observing programs. It should be recognized that such "expert scheduling" software does not currently exist - it should be a requirement of such software that it have an operational mode which merely supports the decision making process by presenting appropriate information.

Flexible scheduling requires switching during the night among telescope modes and instruments (typically 2 times per night). Thus flexible scheduling is a superset of queue scheduling, with similar requirements.

2.5 Test And Checkout Requirements

The telescope and instrument software shall contain built-in test (BIT) facilities to verify G8MT system and G8MT software performances.

Every G8MT software module shall have corresponding test specifications to check normal operation of releases, to be used both for acceptance tests and as an on-line test procedure.

The G8MT control software shall also provide for execution of self-test sequences of the G8MT system and subsystems. These shall automatically exercise all subsystems present in a given operational configuration.

Regression tests should be a part of every G8MT software package.

2.6 Contingencies

2.6.1 Fault Notification

Subsystems must notify the user when faults occur. This notification must be specific as to origin and problem. The notification must also be capable of being electronically logged. It may also prove useful to have multiple levels of fault notification such as detailed, verbose, short, etc. to aid in tracking down problems.

2.6.2 Fault Tolerance

Should a subsystem fail (e.g. one detector, one instrument) predefined procedures must exist to redefine the environment in such a way that operation can restart with the remaining equipment.

In case of computer hardware failure concerning the user station equipment, it shall be possible to transfer control from one user station to another via a simple software reconfiguration procedure.

In the case of local control unit failure (see Section 4 later under Control system design), no transfer of control to another LCU will be possible, due to the local connections and interfaces to the control electronics. In this case there shall be a procedure to replace faulty cards and/or assemblies.

2.6.3 Redundancy

Full redundancy is not a requirement of the G8MT and it will be acceptable to have to replace units in case of failure.

There are subsystems which are relatively inexpensive to support as redundant systems, such as telescope control computers. For each area where redundancy is decided to be cost effective, procedures for switching to the backup system will be established. There is no requirement for automatic switching to the backup system.

All communication shall be based on the use of standard communication protocols, where retry procedures are applied (a form of software redundancy).

Certain network concepts may be preferable as they offer intrinsic redundancy (e.g. double loops) and re-routing possibilities in case of node failures (single point failure protection).

3GENERAL REQUIREMENTS

3.1 Data Specifications

The final purpose of the G8MT software is the acquisition of astronomical data in digital form in the most efficient way.

To achieve this, many other data concerning the telescope and instruments (parameters) and control commands will have to be exchanged between different processing units in order to setup and control telescope and instruments. Additionally, video and voice data are also necessary (for example, field monitors).

3.1.1 Control Information Flow

Control information must be transferred, typically in the form of commands and replies from users, to telescope and instruments. Replies might contain status information and, in general, data concerning instruments and telescopes, to be stored together with the astronomical data.

Control information on all controlled variables must be provided by all subsystems on request. No request for information shall produce a delay of control activities or locking, even if the corresponding equipment is not available or faulty.

Delay times for the exchange of control information must stay within precise time limits to be defined in [SRS]. One can afford to re-transmit commands in case of transmission error or collision, but the protocol has to be predictable in that commands cannot get lost and replies have to come back reliably.

In a number of cases, synchronization with the Time Reference System at the G8MT site is also necessary.

Access to control parameters, telescope and instrument information for monitoring or other use makes a significant contribution to the control flow.

It is explicitly required that all such information is available to the G8MT software and is capable of being available to all users of the G8MT , subject only to restrictions with respect to updating. It must also be possible to restrict user access to such information.

In particular also, the meteorological information coming from [EMS] (in Section 1.3), should be available centrally.

3.1.2 Astronomical Data Flow

- Data flow

Detector data must be acquired and stored in the most effective way technology will allow; effectiveness should be evaluated in terms of cost, space requirements, longevity, and speed. This shall lead to the definition of a G8MT standard, used on all instruments. In general, operational overheads must be kept as low as possible, to maximize actual observing times.

Intermediate storage of raw data in memory on different nodes and in different formats should be kept to a minimum. However, there must be at least two copies. one to secure data as acquired and one to do assessment of data quality online (this last copy preferably on removable media).

The link chosen to transfer data should represent as small a bottleneck as possible for data acquisition.

- Format of data acquisition

Normally, raw data will be acquired and stored as such for quick look evaluations. There might, however, be cases (for example, infrared detectors) where fast preprocessing is needed and where, therefore, raw data will not be stored as such, but in a preprocessed format.

- Transport data format

Astronomical data will have to be transported between GEMINI and the home institutes of visiting astronomers in a standard format.

3.1.3 Other Information Flow

TV data concerning site monitoring and voice need to be capable of being available at all operations facilities. It will be a question of interfacing and bandwidth costs whether such information is actually available at a specific location. It is not a requirement that point to point video be available between G8MT operations facilities. It is a requirement that voice connectivity, perhaps point to point, be available on a permanent connection.

Other astronomical information such as that coming from sky field monitors, autoguider cameras and sky monitoring devices such as cloud and seeing monitors shall also be capable of being available.

3.2 Operation

3.2.1 Operation Levels

Operation of telescope, instruments and subsystems can be carried out at three different levels. There will be parameters associated with each level of operation which define the status of the system and / or control the system. The specific access by different types of users to particular parameters of the different levels will be specified in [SRS].

1. Observing level

This is the normal operational mode. It allows a certain number of embedded tests, normally at a fairly high level. Monitoring is also done at this level.

It is anticipated that all user categories have access to this level.

2. Maintenance level

This allows maintenance tables (for example, with instrument parameters) to be updated.

It is anticipated that the majority of parameters at this level will be accessed by operations and development staff.

3. Test level

This allows the installation and testing of new packages or new releases. Any low level test can be performed in this mode.

It shall be possible to update all non-protected parameter values, i.e. those not used by operations at observing level.

Access to this level will be extremely limited.

3.2.2 Privilege And Protection Levels

Privileges and protections are also important parameters to define user operations.

- Privileges

A further subdivision within the levels can be achieved by implementing privileges associated with categories of users or with the location of the user station (local or remote). For example some users might only be allowed monitoring, as a subsystem is in use by someone else.

- Protections

Protections must also be enforced (see also Security in Section 3.5.3) among users and the operational software should indicate clearly to users the current operation level and check the compatibility between subsystems in different modes.

3.2.3 Capacity

The capacity of the system can be expressed in terms of nodes, which is defined as the number of workstations, or in terms of users, which is defined as the sum total of users at all the nodes. The capacity requirements will be expressed in terms of nodes.

Each node will have the capability to run at all operation levels. The ability to run at a specific operation level will be determined in [SRS].

When the G8MT telescope is used in its normal observing mode, there will be a single operator node for the telescope and two data acquisition and instrument control nodes.

Some tests might be run in parallel on instruments which do not have the light beam at that moment, so in principle three additional nodes might be working at the same time, as the telescope might be equipped with up to five instruments in total. The system will provide for one auxiliary data acquisition and instrument control nodes.

In addition, the system must support off-site observing modes. The system will provide for a single off-site data acquisition and instrument control node - to be located at either the G8MT Site Support or Base Facility.

One supervisor will monitor the system, and other users might need to monitor the running of observing programs, locally or remotely. The system will provide for a single local monitoring node and a single remote monitoring node.

As a conclusion, the G8MT control software shall allow simultaneous operation of up to six active control nodes and up to two more monitoring nodes (one local and one remote) without appreciable degradation of performance.

In practice the operation and facilities foreseen so far for the G8MT will limit this number to a maximum in the order of three active nodes, but the G8MT computers and software shall be capable of coping with the load of 10 active nodes, should the case arise.

3.2.4 Performance Criteria

This section is intentionally kept at the level of performance criteria rather than response times (to be defined in [SRS]). Every command must be acknowledged in a positive or negative way before the occurrence of the corresponding action within given response times.

3.2.5 Procedures

There must be automatic procedures to implement startup and shutdown of the telescope and instruments. These must allow startup and shutdown of instruments independently of the telescope and without affecting the telescope operation.

Reconfiguration procedures must exist, to change the observing environment.

The definition of the observing environments must be dynamic, i.e. feasible during operations without the need to restart everything. The same applies to the related light path.

Operations staff have privileges to change the environment, meaning selecting a suitable combination of instruments.

The operational software should know which subsystems are installed and operational at any given time.

3.3 External Interface Requirements

3.3.1 User Interfaces (UIF)

The user interface defines the way users see the G8MT system. Given the large number of instruments, there can be many different stations which are active at the same time. It is essential for operational and maintenance reasons that, in spite of the obvious differences of the setups and commands available, the same philosophy is applied throughout. This calls for a homogeneous user interface, which can be achieved only by applying the same user interface tools to the whole project, providing the G8MT user interface's 'look and feel'.

The user interface should not be seen as a package linked to a specific computer. Given the requirement to be able to access the G8MT from several points, the user interface should rather

be seen as a package to be callable from a large number of stations, depending on where a user is. It should also be network transparent so that it does not matter where it is being run.

The user interface tools shall be based on standards, to be defined in [SRS], which will be portable across different computer hardware platforms (Portable User Interface Toolkit). The intent of a portability requirement is to facilitate migrating existing and future Gemini systems to different hardware as the need arises. As will be defined in [SRS] it is the current intent to limit the selection of computer hardware platforms to as few as is practical.

3.3.2 Hardware Interfaces

Main processor computer hardware requirements will be defined in the Hardware constraints (see Section 3.4.2).

This section deals instead with external hardware interfaces, namely the ones from the microprocessors to the control electronics. The definition of these terms is as follows:

- main processors - these are the computers with which the user interacts
- control electronics - these are the computers controlling the instruments
- microprocessors - these are computers embedded in the instrument (for instance a DSP or transputer required for array control functions)

Standard interfaces to the control electronics shall be available, in the form of:

- a standard bus system
- a standard set of interface cards to be used on all the subsystems and instruments
- a standard software skeleton running on the control electronics

The existence of hardware standards is clearly essential for maintenance and repairs. It is also essential to avoid software duplication, and to simplify the G8MT software. Microprocessor software in particular tends to contain hardware specific software, though one should try to keep it as hardware independent as possible, isolating different software layers.

The standard software must be adequate for the real-time requirements (to be defined in [SRS]) and must offer drivers to the standard electronics to be used on all the G8MT software subsystems and instruments.

Links between electronics interfaces and main processors must meet the requirements imposed by the data specifications (see Section 3.1). The bandwidths and response times will be specified in [SRS].

3.3.3 Software Interfaces

The G8MT software covers all aspects of control and data acquisition related to the telescope, instruments, and auxiliary instrumentation.

It also covers all the operational aspects of the G8MT, including online scheduling and rescheduling.

There is also software which, although it will be interfaced to the G8MT. is referred to as external. The external software consists of:

1. commercial software integrated into the G8MT software (e.g. DBMS)
2. preexisting software used in the G8MT (e.g. image processing systems, star catalogues)
3. software associated with visitor instrumentation
4. embedded software dedicated to hardware control, but not communicating online with the other G8MT software (in general this would be microprocessor code)

The G8MT software must interface to the external software and clearly the interfaces are fully part of the G8MT software.

The interface software consists of:

1. On-line image processing interfaces

In order to make efficient use of the telescope, to support different observing modes, and to support the versatility requirements, some form of on-line image (or pixel) quick-look analysis is required. The following statements are proposed:

> *"It shall be possible to monitor the quality (image quality, spectral resolution, signal to noise, etc.) of the astronomical data as it comes in.*
>
> *Standard reduction procedures should be available for basic online calibrations of the observed data. Ultimately, one would like to have fully reduced and calibrated data at the end of the observations. Advanced pipeline procedures might make this feasible, at least for observations of a standard nature."*

The above statements define the goal of quick-look analysis for the G8MT.

Quick-look data processing should be provided on the G8MT, with procedures suitable for fast online data preprocessing. A prerequisite for this is that acquired data are moved as directly as possible into the pixel processing database in a common format, and that all additional data related to an exposure and logging information are made available on-line at the same time. The pixel processing database, to be defined in [SRS], is intended to include all data acquired with a detector; images, spectra, photometry, speckle, etc.

To simplify the interaction of visiting astronomers with the quick-look pixel processing software, a system and commands which is a subset of one of the pixel processing systems which will be used for off-line pixel processing should be available on line.

Quick-look should be usable within exposure sequences to provide results and feedback parameters to the control software in a pre-programmed way, without the need for manual intervention .

Off-line pixel processing for full data reduction should also exist at the G8MT site, but does not have any interface to the G8MT software. The Astronomical communities have made considerable investments in image processing software, and therefore, compatibility with and adaptations to these packages must be sought .

This document does not try to be specific about the requirements for online pixel processing.

It should also be noted that some G8MT subsystems, such as adaptive optics, may require their own special on-line pixel processing software, which will be better defined in the requirements for those subsystems. This is largely due to the difficulty of applying online, the same algorithms used for full off-line reductions - in general due to the time critical nature of the image processing needs.

The same situation might also occur with other instruments, where specific observer support software has to be foreseen for online use.

In all these cases the specific online (quick-look) software shall be seen as a subset of the off-line data reduction system, to avoid as far as possible duplication of development effort.

Just as the image processing software can be viewed as a server to the Gemini software client it must also be possible to view the Gemini software as a server for the image processing system client.

2. On-line access to catalogues and previous data

The output format of the G8MT data must be compatible with the GEMINI archive requirements (see [ARC] in Section 1.3).

As comparisons with previous data might be of great value and affect the actual observing program, online access to the data archiving system should exist, so that access to this database is possible for G8MT users.

The specific types of data available; flat fields, calibrations, science exposures, etc.; the amount of a specific exposure available; header only, averaged exposure, complete raw data set; and the time frame within which such data will be made available; same night, weekly, after proprietary period; will be established in [ARC].

Computer access to star catalogues is also required, so that an automatic selection of candidate guide and standard stars can be made.

3. Access to other packages

The G8MT software must be able to interface with all commercial software packages available on the G8MT and integrated into the G8MT operation.

A relevant example of such a package is a general database management system (DBMS), where operational information such as schedules, logs, problem reports and maintenance information related to various pieces of equipment should be kept.

3.3.4 Communication Interfaces

Being in itself a distributed telescope system and having a large number of instruments, the G8MT system has internal communication needs.

A Local Area Network (LAN) shall support the majority of the G8MT system internal communication needs. This LAN must be capable of dealing both with the data bandwidths required (at peak and on average) and with the required response times and synchronization needs. This LAN shall be supplemented with a Local Time Bus, for distribution of absolute and

relative time signals, and a TBR bus, for distribution of signals with requirements not satisfied by a LAN.

Independently of the physical layout of such a network, its functional requirements can be split into several categories:

1. Local coordination and synchronization needs within a subsystem (for example, coordination of active support system for primary mirror, bi-directional traffic of commands/replies). This layer could be considered as internal to a given subsystem or instrument, but as more than one subsystem might need it, one should aim for a unique solution at the hardware and software level.
2. Global synchronization needs, such as the universal time synchronization requirement. The required accuracy will be defined in [SRS] (unidirectional traffic).
3. Exchange of control information, in the form of commands and status information. (Bi-directional traffic) (see also Section 3.1.1).
4. Collection and transfer (for archiving or remote access) of raw astronomical data. The capacity will be defined in [SRS] (Unidirectional traffic) (see also Section 3.1.2).
5. Access from Wide Area Network (WAN) for remote diagnostics and monitoring from operations facilities (Bi-directional traffic).

No distinction is made here between WAN and point to point links as there shall be no difference in the software between the two cases. However the system architecture will be designed so as to minimize the communication load placed on peer and higher level networks.

Control data and astronomical data have already been defined in the Data specifications (see Section 3.1). The reason for repeating them here is to have a complete view of the required network functionality.

To eliminate conceptual access problems, while coping with different bandwidths, LAN and WAN interfaces shall be homogeneous and shall be based on standards which allow migration on different media, should they become required during the G8MT project life.

For maintenance reasons and hardware independence, a clear hierarchical model must be implemented, supporting separation of logical and physical layers, e.g. ISO/OSI model.

Network redundancy should also be considered in the design phase as a way to increase reliability and security, in particular for control information.

3.4 General Constraints

3.4.1 User Constraints

It is envisaged that observing astronomers who have travelled to the G8MT site will make use of the G8MT control room facilities. This will allow centralized support and coordination of their operations, providing both operations support for individual instruments and supervision for all of them.

However, even at the G8MT site there will be users (e.g. software development and maintenance staff) installing or enhancing other parts of the system, possibly working directly at the telescope.

Finally, in the case of remote operations, other users (e.g. support staff) might be on Cerro Tololo or in Hilo.

To allow coordination both locally at the G8MT site between the various users and with remote users, the software shall support access to the system from any user station. It will then be an operational decision, implying privileges and priorities for the various categories of users, and definition of what a given user can actually do.

Access from any user station will make user stations in principle identical and software configurable as the user station of this or that subsystem. This should greatly simplify the coordination problem posed by the large number of simultaneous users (as already described in the Capacity requirements, Section 3.2.2).

3.4.2 Hardware Constraints

There are a number of constraints for the G8MT computer hardware. Although some of these constraints may appear redundant the project recognizes that:

- during the next 5 to 10 years new hardware will be available with features and costs that could benefit the project
- the hardware chosen as the standard at this point of time may be no longer available at some point in the future
- the cost of maintaining an existing hardware standard, even if available, may exceed the costs of adopting a new hardware standard

These constraints recognize that the majority of the expense in changing hardware standards is the cost of the software. Particular constraints are:

- Computers used at the G8MT site, particularly in the test phase when they are outside the control room and near the subsystem under test, shall be checked against altitude and humidity specifications for the G8MT site (see also [EDS] in Section 1.3).
- Computer hardware must be able to run the G8MT software environment (operating systems, G8MT software) and provide compatibility in data format (identical internal data representation).
- Common development and implementation tools must be both available and supported
- Identical network access must be supported
- Local processing power must be such that telescope and instrument control does not represent a significant overhead in the whole process of executing an observing program (the overhead, if any, should be limited by the time it takes for physical devices to act)
- The choice of a scalable hardware architecture with computers at various performance levels should solve the problem of adequate online data assessment, as the amount of this activity is very variable and dependent upon the kind of detector and method used.
- Due to the limited bandwidths which may be available remotely, there will be constraints on the functionality of remote operations and access.

Depending on funding, it is probably reasonable here to make a minimum and a desirable specification. The minimum situation could also coincide with what is needed in the test period before coming to full remote operation.

In any case, remote operation must include remote monitoring from the G8MT base facilities, together with access tools for diagnostic and test use. It should be a goal to support remote observing from the G8MT base facilities.

3.4.3 Software Constraints

Some of the general requirements which have a direct effect on the software are here explicitly transformed into software constraints.

These are:

- Individual instruments must be able to run fully independently.
- Telescope software at the two telescopes must be maintained to be identical in the upper layers (even if hardware should differ).
- Additions of new instruments should aim, as a goal, at introducing no modification to already operational parts. Modifications should be confined to the operational procedures and should not affect the bulk of the existing software.
- Switching to different configurations must be possible at any time with appropriate procedures.
- There must be easy procedures to reconfigure the system when subsystems are modified or removed.
- The number of main packages of software must be kept to a minimum to facilitate maintenance, but compatibly with the need to have the right degree of modularity.
- Commercial and public domain packages should be used whenever possible.
- Existing software packages should be reused wherever possible.
- All software which does not directly control specific hardware must be written as machine independent, portable code. Even for microprocessor software, the software should be hardware independent, to allow a later choice of the target microprocessors.
- To allow for expansion and maintenance, G8MT standards must be defined for the online software and the development environment.
- On-line version control

  At boot time, the G8MT software shall check the consistency of versions of all the various software components.

- Table-driven software

  It will be defined in [SRS] whether the software is table driven, message driven, or a combination of both.

  A more complete specification for software issues will be found in [SPS]. Changing system constants, such as arcseconds/bit for an encoder, shall not require recompiling but will be updated as part of system startup, and, for some constants, will be modifiable during operation. System status parameters will be maintained to an extent that will allow restarting the system and regaining the previous state. The extent of duplication of the previous state will be dictated by safety and practical considerations.

  Strict checking should be applied on this to preserve maintainability and reconfiguration of the system.

3.5 Attributes

3.5.1 Expandability And Maintainability

The G8MT system will be installed in stages over a period of years (when one includes all instruments). Over this time, it will have to be expanded, therefore, with new parts and components. Afterwards, it will have to be maintained as long as necessary in operation.

During such a period of time, computer hardware will evolve considerably. It is essential that the system is designed to be open to new additions without modifications to the existing parts, as far as possible .

General industry standards shall be followed to allow expandability and maintainability.

3.5.2 Modularity

The software must be strictly modular, i.e. the functionality of a subsystem should correspond to what belongs to that subsystem and only to that, so that software for different subsystems can be installed and maintained independently of all the rest. This is needed in particular for multiinstrument operation, for example, as instruments share the same subsystems on the telescope.

At the same time, the possibility must exist to acquire information about other parts of the system (for example, telescope coordinates) (as mentioned in the control flow requirements in Section 3.1.1).

It also important that there are no undesired interactions between subsystems. This may be enforced either at the client/server interface or at the message system level. This will be specified in [SRS].

3.5.3 Security And Safety

Safety protection must be applied whenever there is the risk that the actions of the control software could endanger people or cause damage to any G8MT subsystem, for example, by driving beyond limits or by overexposing detectors. This protection, where implemented, must be independent of the software. In general this will require mechanical hard stops, electrical interlocks, electrical hard limit switches, soft limit switches, software limits, and watch dogs, .

The order in which these systems will work is as follows:

- software limits - the software will not allow unsafe actions; the command will be rejected
- soft limit switches - the software will detect unsafe areas and halt; the software will allow movement off of soft limits
- software watch dogs - the software will halt if its watch dog has not been reset
- hardware watch dogs - the system will halt if its watch dog has not been reset
- hard limit switches - these switches will remove power from actuator when beyond soft limits; the software/electrical systems will allow movement off of hard limits
- hardware interlocks - these will prevent both software and hardware from action - there will be no bypass of these systems
- hard stops - the mechanism cannot move beyond this point due to mechanical limit(s)

The G8MT software shall be able to bring the G8MT system quickly to a safe state upon detection of danger. Safety aspects shall be analyzed during the functional specification phase of the software.

Security must be provided in order to both prevent accidental mix-up of commands from different users on different parts of the system and to prevent intrusion from the wide area network into the G8MT. In particular, the astronomical database must be protected from intrusion, whether the purpose is to access private data or to be destructive. It is acceptable, and may well prove to be the best solution, to provide intrusion security by a well designed network gateway acting as a firewall.

3.5.4 Reliability And Availability

Reliability is defined as *"The duration or probability of failure-free performance under state conditions"* or *"The probability that an item can perform its intended function for a specified interval under stated conditions"*. The [GSR] sets as a requirement of 2% and a goal of 1% for total system (mechanical, electrical, and software) downtime due to failures - this translates to a maximum of 15 minutes per night or 1 night per month of downtime. This in turn sets quite stringent requirements on both MTBF and MTTR for the software and controls.

To guarantee maximum availability of the control system, retry procedures must be embodied in the software in case of error or failure (e.g. time-out, hardware failure) to achieve recovery online whenever possible.

Should recovery also fail, the error or failure has to be reported in a clear form (to identify the cause of the problem) and the system shall put itself into a safe state, whenever a safety aspect might be involved .

To increase software robustness, range checking and validity checking shall be supported before execution of any input command. This must be possible ahead of time, preparing observing sequences for automatic observations and simulating observations to estimate results.

On-line pre-checking of the operational status of equipment should be done prior to sending critical or time consuming commands. It must be possible to apply continuous monitoring to all subsystems on request, both when in operation and when idle, to check their operational status.

3.6 Life Cycle Aspects

The G8MT software has to be developed according to a structured and formally defined development model. The purpose of this is to:

- make the development process visible (for quality and maintenance reasons)
- avoid incomplete specifications
- discover errors early (via review and audit procedures)
- secure structured, maintainable software
- guarantee software quality
- improve and ease cooperation.

This has to be defined in [SMP] and [SCP] (see Applicable Documents, Section 1.3), which will cover:

- Development methods
- Formal approval, review and audit procedures
- Documentation
- Coding and debugging
- Simulation
- Component and integration-verification and testing
- Configuration and version management.

3.7 Development Environment

The development environment for the G8MT software consists of the computer hardware and system software (operating system, languages and tools) chosen optimally to support the development model presented in the previous section on lifecycle aspects.

The choice of such an environment has to be defined, together with the choice of all the G8MT standards, but excluding the target computer hardware, in [SRS].

The following criteria for later selection shall be kept in mind:

- Emphasis on development and productivity requirements, including cross support tools
- Portability of software (target hardware independence)
- Hardware and vendor independence
- Use of industrial and defacto standards.

3.8 Installation Aspects

Test procedure methods have to be defined in the Software Test Plan (STP), while test plans shall be written for all individual software packages and modules comprising the G8MT software.

Apart from the component and integration test procedures, a formal release system should exist at package and module level, which should be checkable online by the operational procedures for consistency.

The test operation level has already been discussed in Section 3.2.1.

The phasing of the various parts of the project will be defined in [SRS] and [SMP].

4CONTROL SYSTEM DESIGN

4.1 Functional Structure And Interrelationships

The G8MT system is intrinsically distributed and allows user access to any instrument. This leads naturally to a distributed operations structure. The implementation plan, with the two telescopes and the instrument complement going into operation at different times, demands a stepwise implementation of the control system.

When one takes into account the control needs of the various elements the telescope is itself a distributed system where control functionality and computing power has to be provided.

All the above leads to a design of a control system distributed both at the telescope level and again at a higher level, to cope with the distributed architecture of subsystems and instruments.

4.2 Control System Layout

Figure 1 gives a schematic view of a layout of the hardware for the G8MT control system that GEMINI has in mind. The telescope, subsystems and instruments are shown in the top part. The central part shows the computer and communications equipment located in the G8MT control room. The bottom part shows in a schematic form the remote access facility on Cerro Tololo or Hilo.

Similarly, Figure 2, 3, and 4 give varying schematic views of the software for the C8MT control system., as proposed by Gemini. In Figure2, the shading shows the responsibilities within the Gemini Project Office for the various software components. Figure 3 provides a mapping between each component and the anticipated source for that software. Finally, Figure 4 shows the mapping between the components and the various Gemini Software and Controls Work Packages.

In addition to the schematic layout of the control system, it is useful to understand the functional behavior of the control system during operation, as it might be viewed by the observer. Figure 5 shows this breakdown of the system into its logical subsystems during normal operation.

4.3 Control System Architecture

Referring again to Figure 1, one finds at the top (near the control electronics interfacing with telescope and instruments) the Local Control Units (LCUs) and then a network of coordinating processors (telescope and instrument processors and workstations) and central and remote workstations.

In this respect the hardware layout has a two layer structure, but the various subsystems are separated via bridges and gateways from the network backbone. This means that the network backbone will not receive the messages between LCUs and workstations on the telescope, except those which are explicitly sent to outside nodes.

A hierarchical structure with three layers can be implemented in the software, separating the local branches of the local area network from the central backbone, so that the central computers can be seen as the top layer. This offers advantages in modularity and security in the case of operations at the observing level (e.g. a command from a central workstation will go to the coordinating processor of the telescope and from there will be re-routed to the appropriate LCU).

At the same time at the test level, the normal operation hierarchy can be bypassed and any local controller can be addressed and tested directly from a central workstation (two layer hierarchy).

The exact level of access filtering between the top layer (local or remote access) and the bottom layer (LCUs) has to be defined in [SRS]. This means that the software shall implement the control hierarchy required for secure and reliable operation.

The system described:

- supports access from any workstation to all or parts of the G8MT,
- can be implemented in steps, and
- implements distributed control at the telescope level via the LCUs.

Different buses have been introduced to handle the different constraints imposed by the inter-subsystem communications. These buses are:

- video bus - used for transport of video data in a standard format
- network bus - used as a LAN
- time bus - used to distribute both absolute and incremental time information
- TBR bus - used for command and control between subsystems which cannot use the network bus

Different LANs have been introduced with the purpose of coping with the different requirements represented by synchronization needs, control data, astronomical data and remote access. The current set of LANs support:

- command and control
- data transfer
- summit backbone
- off site communications
- remote site network

This design achieves the required degree of modularity and expandability for the G8MT system and also allows:

- a reduction in the amount of cabling for hardware maintenance
- support for independent developments of the various telescope subsystems.

4.4 Functional Software Structure

The G8MT software can be divided into the following major functional blocks:

4.4.1 Remote Operations

- buildiing/site communications
- tv distribution system
- queue observing
- preprogrammed observing
- flexible scheduling
- access to external databases

4.4.2 Observatory Control

- reduction system interface
- graphical user interface
- client-server interface
- time service
- central computer services
- visualization tools

4.4.3 Enclosure Monitoring

- Enclosure audio-visual
- telescope environment monitoring
- enclosure environment monitoring
- exterior environment monitoring

4.4.4 Telescope Control

- mount
- primary
- secondary
- instrument rotator
- atmospheric dispersion compensator
- enclosure

4.4.5 Instrument Control

- instrument infrastructure
- scientific instruments
- acquisition & guiding
- adaptive optics

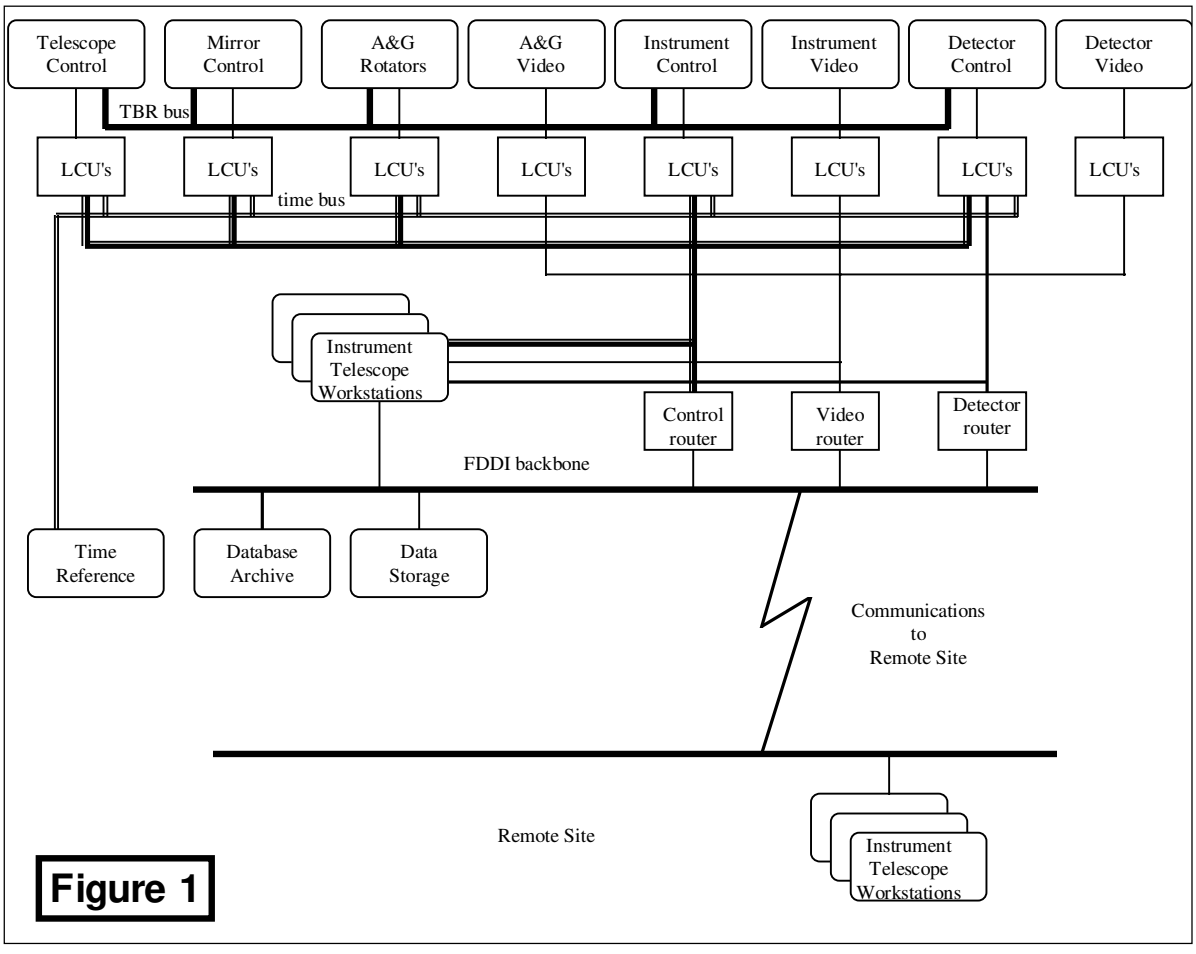


Figure 1

4.4.6 Data Control

- data storage
- data transport
- internal database
- gemini archive

It is worth pointing out that, due to the distances between the control facility and the telescope, all observing with the G8MT will effectively be remote. Given the prevalence of LANs, workstations, and X windows it is probable that there will be no difference between "local" and "remote" observing other than bandwidth - as far as workstation access is concerned. It is the other types of data flows, most notably video and audio, that will pose a problem in supporting remote operations.

It is recommended that a solution similar to workstation networking be explored where possible for video and audio "networking".

4.5 Implementation Strategy

The above functional blocks are divided into *work packages*, designed to simplify both the development efforts and the allocation of resources. These work packages are:

1. Remote Operations
2. Data handling and Archiving
3. Observatory Control Infrastructure
4. Telescope Control Software
5. Instrument Control Infrastructure
6. Mount Control System
7. Enclosure Control System
8. Primary Control System
9. Primary Thermal Control System
10. Secondary Control System
11. Enclosure Monitoring System

Details on these work packages can be found in [SMP]. However, for those work packages that map directly onto LCUs (those refered to as *System*s in the above list), the plan to develop the software relying heavily on the EPICS support software, with control communications between the LCU and the host (workstation) modules done using EPICS' *Channel Access* interface. Consequently, developers are expected to provide the following interfaces:

- An EPICS database, running on the LCU. This should permit simulation of the devices being controlled.
- An *Engineering User Interface* , as shown in Figure 6, for maintainance and testing of the subsystem in isolation from the rest of the system. This should include both a GUI-based operator's panel as well as support for progromatic testing and diagnostics.
- A OCS/EPICS Interface, as shown in Figure 7, implementing access to all subsystem features, suitable for use when connecting this subsystem into the rest of the control system.

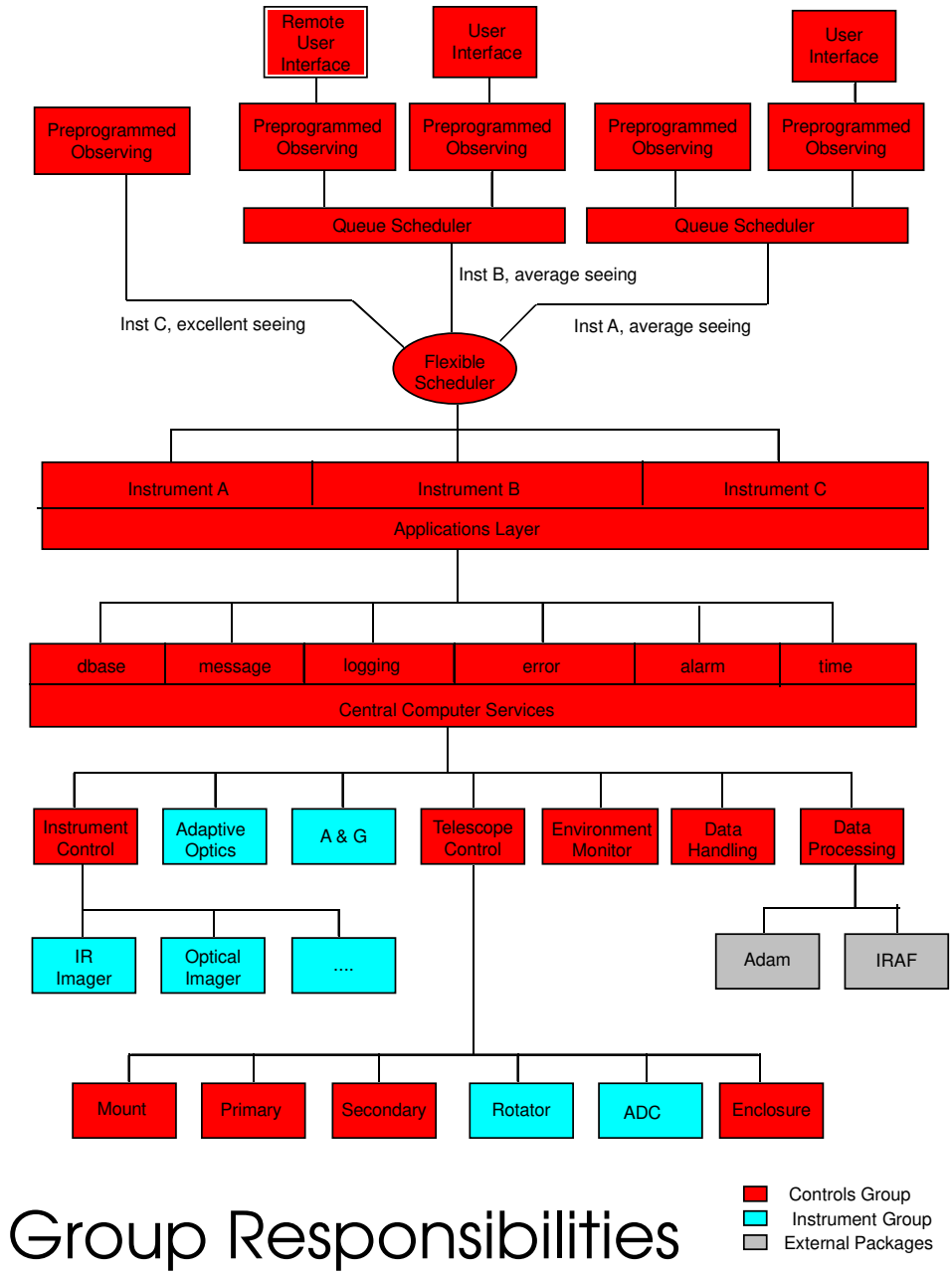
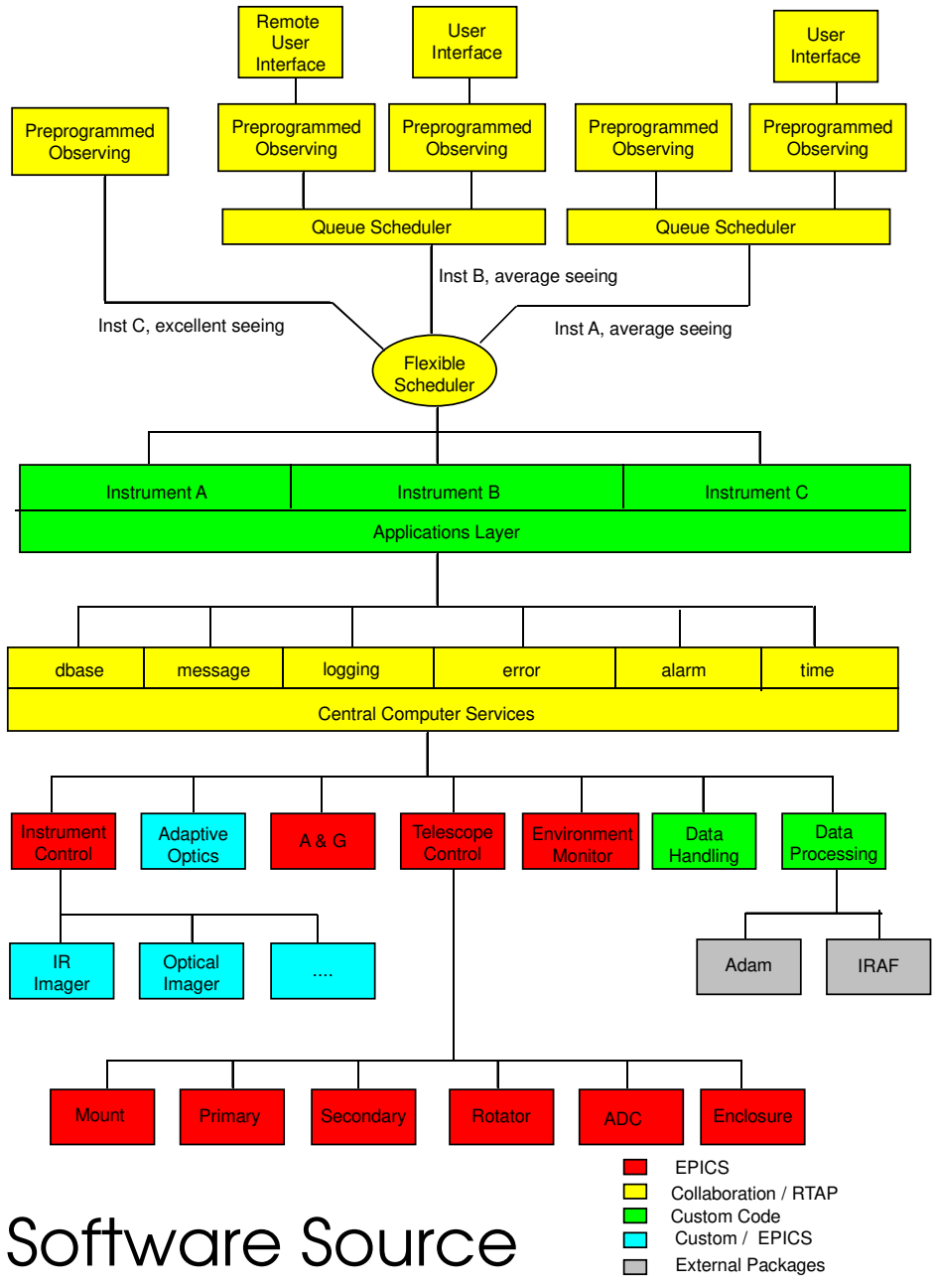

Remote User Interface
User Interface
User Interface
Preprogrammed Observing
Preprogrammed Observing
Preprogrammed Observing
Preprogrammed Observing
Preprogrammed Observing
Queue Scheduler
Queue Scheduler
Inst B, average seeing
Inst C, excellent seeing
Inst A, average seeing
Flexible Scheduler
Instrument A
Instrument B
Instrument C
Applications Layer
dbase
message
logging
error
alarm
time
Central Computer Services
Instrument Control
Adaptive Optics
A & G
Telescope Control
Environment Monitor
Data Handling
Data Processing
IR Imager
Optical Imager
....
Adam
IRAF
Mount
Primary
Secondary
Rotator
ADC
Enclosure
Group Responsibilities
Controls Group
Instrument Group
External Packages

Figure 2


Remote User Interface
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A & G
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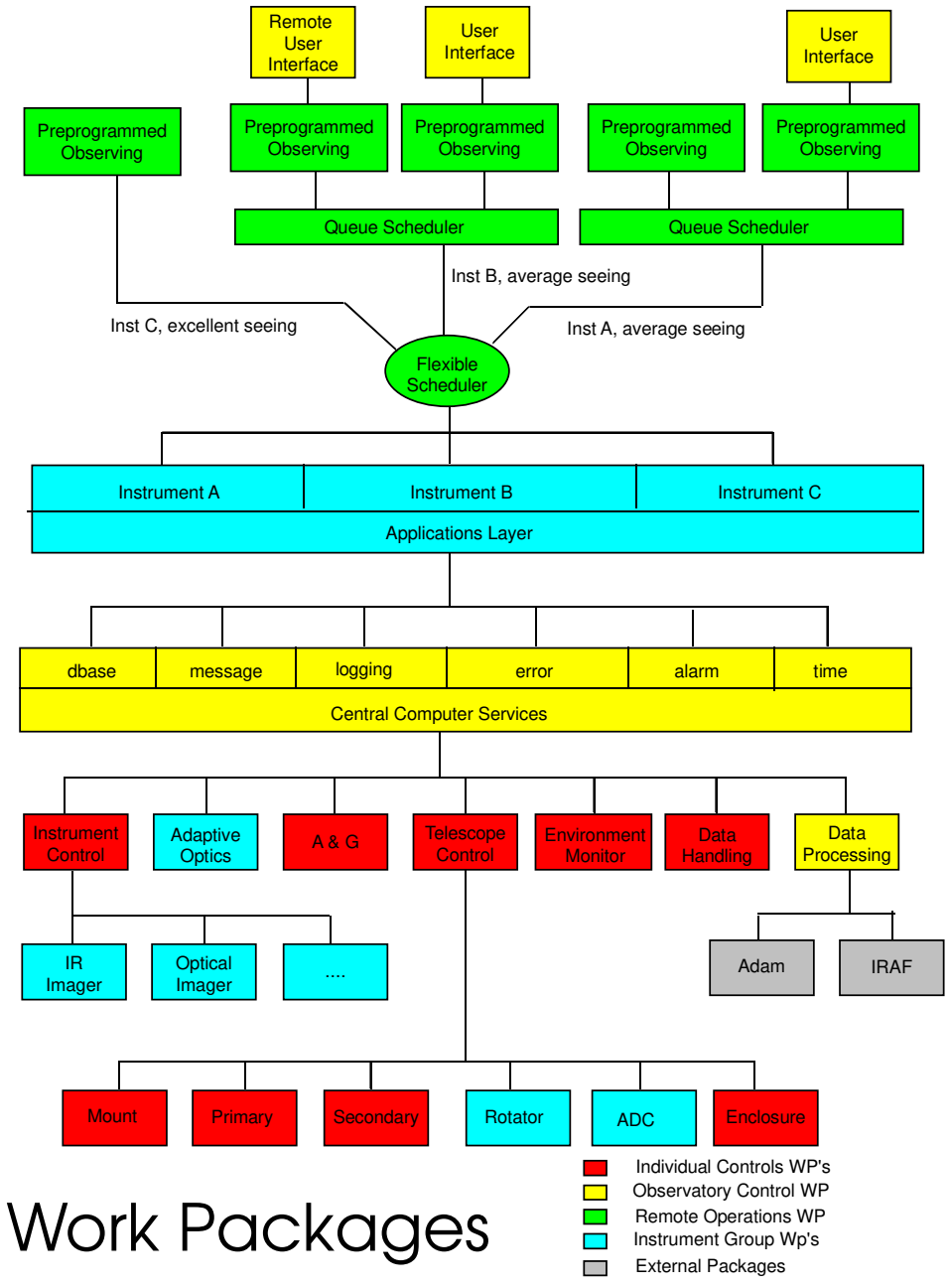
Environment Monitor
Data Handling
Data Processing
IR Imager
Optical Imager
....
Adam
IRAF
Mount
Primary
Secondary
Rotator
ADC
Enclosure
EPICS
Collaboration / RTAP
Custom Code
Custom / EPICS
External Packages
Software Source

Figure 3


Remote User Interface
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Telescope Control
Environment Monitor
Data Handling
Data Processing
IR Imager
Optical Imager
....
Adam
IRAF
Mount
Primary
Secondary
Rotator
ADC
Enclosure
Work Packages
Individual Controls WP's
Observatory Control WP
Remote Operations WP
Instrument Group Wp's
External Packages

Figure 4

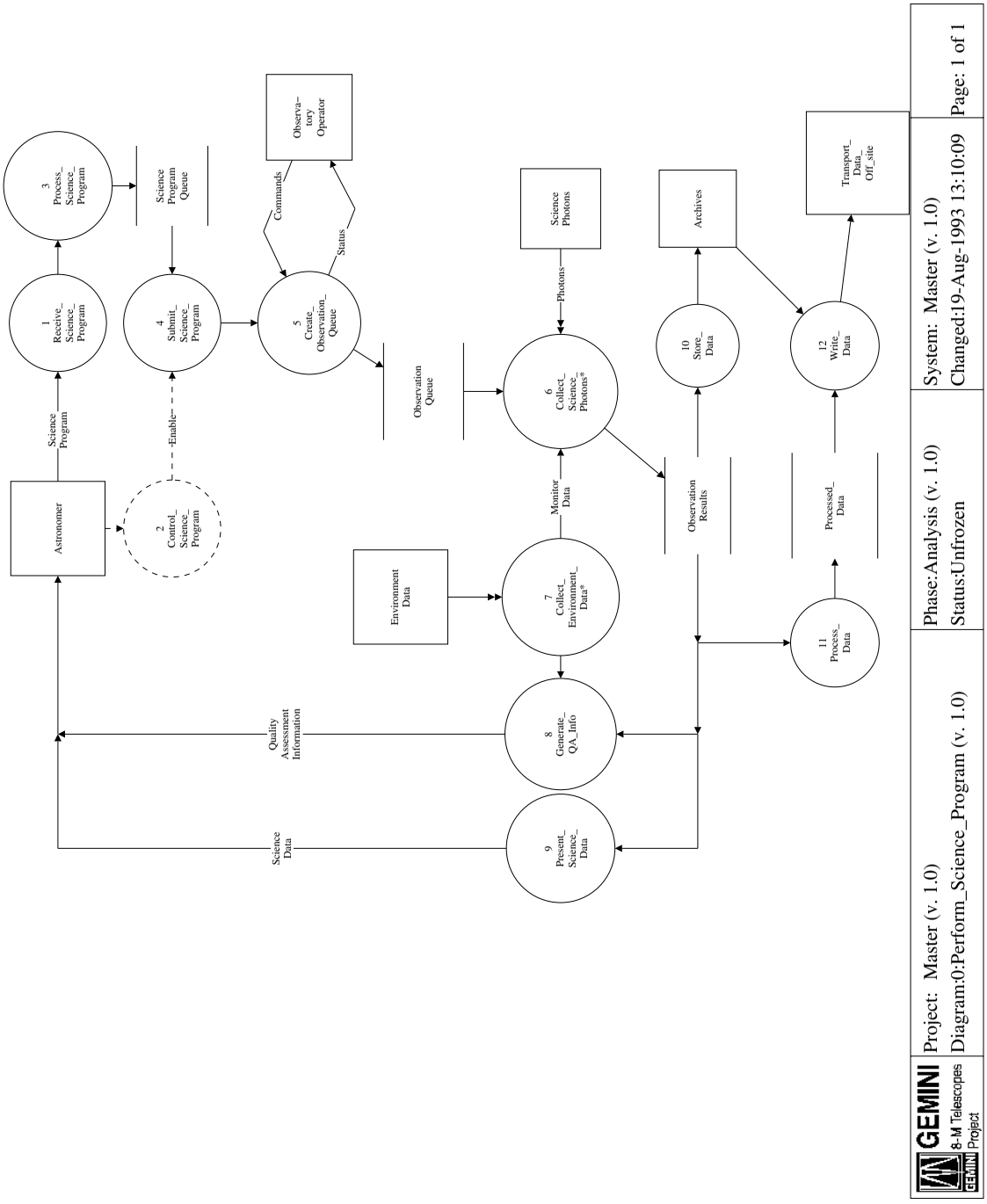
1 Receive_ Science_ Program
2 Control_ Science_ Program
3 Process_ Science_ Program
4 Submit_ Science_ Program
5 Create_ Observation_ Queue
6 Collect_ Science_ Photons*
7 Collect_ Environment_ Data*
8 Generate_ QA_Info
9 Present_ Science_ Data
10 Store_ Data
11 Process_ Data
12 Write_ Data
Astronomer
Observa– tory Operator
Science Program
Science Program Queue
Enable
Commands
Status
Observation Queue
Science Photons
Photons
Monitor Data
Environment Data
Archives
Observation Results
Processed_ Data
Transport_ Data_ Off_site
Quality Assessment Information
Science Data
GEMINI
8-M Telescopes Project
Project: Master (v. 1.0)
Diagram:0:Perform_Science_Program (v. 1.0)
Phase:Analysis (v. 1.0)
Status:Unfrozen
System: Master (v. 1.0)
Changed:19-Aug-1993 13:10:09
Page: 1 of 1

Figure 5

Gemini Generic Instrumentation Engineering Model

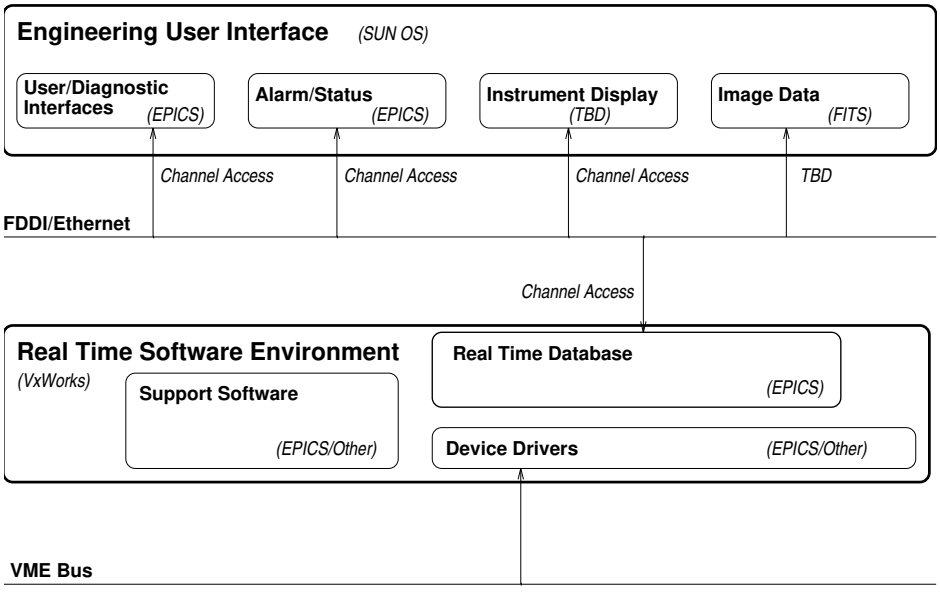

Figure 6

Gemini Generic Instrumentation Observing Model

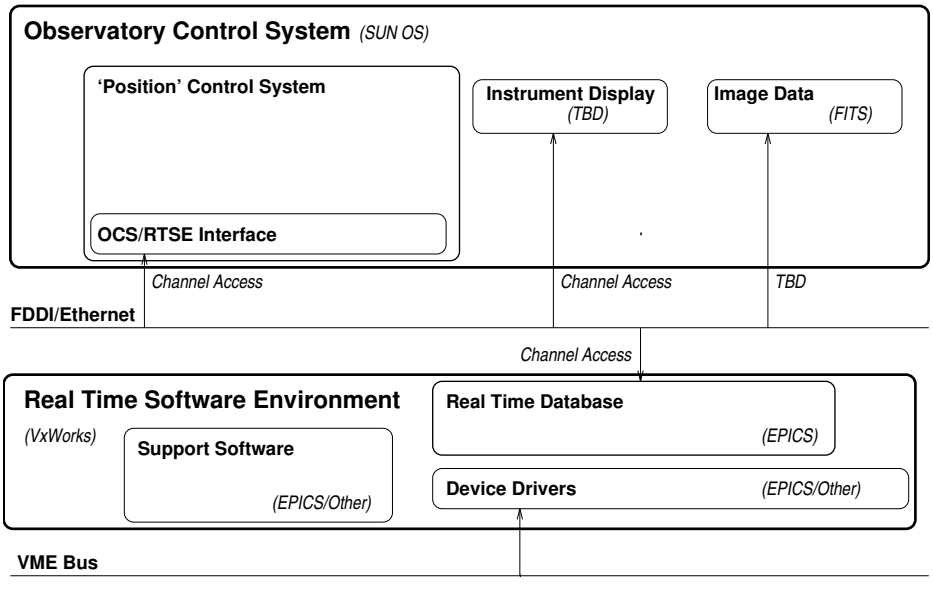

Figure 7