GEMINI

8-M Telescopes Project

Periscope Design Report

Gemini North and South LGS AO
Preliminary Design Review Material

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Version: Final

Revision Control

1/ 04-04-01 CELINE

Created document and outline

2/ 04-09-01 CELINE
Formatted write-up sent by Dick

3/ 04-20-01 AM CELINE
Incorporated modif to optical design (FoV must be +/-90mm, NOT +/-60mm)
Changed TCS for SCS
Wording modifs here and there in section 2
Add section 4.1.1 “preliminary comments”

4/ 04-20-01 PM CELINE
Changed the optical design prescription back to the one compatible with Jim’s drawings.

5/ 04-24-01 CELINE
Included modifs by Dick – optical design is now OK.

6/04-28-01 BRENT
Changed “telescope” to “secondary” in first sentence of section 3.3.5
Removed reference to “procurement” in section 3.4.1
Deleted section 4.2 (cost estimate)
Several minor changes to wording

1. Introduction

1.1. Acronyms and notations

The following acronyms will be used throughout the text.

AO	Adaptive Optics
CP	Cerro Pachón
FoV	Field of View
GNAO	Gemini North Adaptive Optics
GSAO	Gemini South Adaptive Optics
IR	Infrared
LGS	Laser Guide Star
LLT	Laser Launch Telescope
M2	Gemini Telescopes' Secondary Mirror Assembly
MK	Mauna Kea
OAP	Off-Axis Parabola
PM1	Periscope Mirror #1
PM2	Periscope Mirror #2
rpm	Rotations per Minute
SCS	Secondary Control System
SSS	Secondary Support Structure

1.2. General

During IR and near-IR observations, the Gemini Telescopes' science instruments 'look at' the secondary mirror of the telescope, and in some cases reimage the secondary mirror, which is the aperture stop of the Gemini telescope. If the secondary mirror is not perforated, the instruments would 'see' their own reflections, an effect known as 'narcissus'. Therefore, the secondary mirror has a 168 mm diameter hole through it, which if unobstructed would let the instruments look directly into space, producing a background similar to that of an entirely unobstructed telescope, but with marginally greater transmission and without focused light.

The Laser Launch Telescope (LLT) will be located directly above the secondary mirror, blocking the secondary mirror hole. To restore a view of space, two mirrors will be used to deflect light around the LLT and again allow the instrument package to see the sky. Owing to the limited space available to divert the light, simple flat mirrors will not work, so we have designed a quasi-Schwarzschild periscope to restrain the beam size within the SSS frame, and to minimize its profile as it runs along the outside of that structure.

Note that the periscope must NOT focus stars on the instrument focal plane, otherwise out-of-field objects will be confused with true telescope targets. Similarly, it is important that the periscope's field of regard be as small as possible, so that the exclusion angle for the moon is optimized.

The resulting design consists of two 'off axis' aspheric metal mirrors, made as thin as possible to reduce weight and take up minimum volume. These mirrors, PM1 and PM2, can be visualized in Figure 1 and Figure 2 of Section 4, which show the side and top views of the Parent mirror system from which the periscope optics are extracted.

The general location for placement of the periscope assembly is shown in drawing TELESCOPE1.DWG. The Periscope will be attached to the stationary portion of the M2 assembly, 35 mm below the SSS/M2 Interface. The Secondary Mirror itself is attached to the bottom of the M2 Module, allowing it to tip and decenter during the course of perfecting telescope performance, so it is necessary to design oversized Periscope optics to ensure the focal plane sees nothing but mirrors through the hole in the secondary mirror, regardless of its location.

There will be two periscope assemblies, one for the Gemini North telescope atop Mauna Kea, Hawaii, and one for the Gemini South telescope atop Cerro Pachón, Chile. Both systems will be identical and interchangeable.

The performance specifications are presented in Section 2, and miscellaneous functional specifications are given in Section 3. Section 4 gives an overview of the periscope opto-mechanical design as well as the prescription for the parent optical system.

The periscope will have interfaces with the following existing Gemini systems:

- Optical interface with IR instruments
- Mechanical interface with the M2 assembly
- Clearance interface with the SSS
- Software interface with SCS (for shutter remote control)

2. Periscope Performance Specifications

2.1. Optical specifications

2.1.1. Optical stop

The hole in the Secondary mirror of the telescope is the Aperture Stop of the Periscope, and is 168 mm in diameter. To allow for motion of secondary mirror relative to the Periscope, the design aperture was taken to be 180 mm. Packaging constraints result in the 168mm hole being reimaged as a distorted, star-side pupil 58 mm in diameter. This is the entrance pupil for calculating unwanted sky-side light pollution.

2.1.2. Field of view

The instrument field is **±1.5 arc minutes** of arc in object space, corresponding to ±55 mm at the focal plane. Additional coverage to ensure no vignetting of light with secondary mirror shifting results in a design field of **±90 mm**.

Packaging constraints dictate the size and shape of the beam path, from the instrument focal plane up to the end of the SSS. The beams over the whole field of view are contained within a straight circular cylinder that extends from the front of the SSS down to our own convex mirror, PM2, which has the least possible inclination to the side of the SSS. The overall beam envelop is not collimated; it diverges to form a cone of 3.7 degrees diameter, which is approximately half as large an angle as would occur if the optics were designed for collimated light in star space.

Calculation shows that stars focus about half way between the Secondary Mirror and the instrument Focal Plane, for a blur diameter about half the size of the 168 mm central perforation. This produces half the irradiance that would result without the obstructing Periscope, since the entrance pupil of the Periscope is just 58 mm.

2.1.3. Emissivity

If the two mirrors of the Periscope are recoated each time the main Telescope mirrors are re-silvered, then the emissivity of the 'hole' in the Secondary mirror of the telescope (except for the oblique view of the sides of the hole, and slight bevels) will inherently be the same as the image from the main part of the telescope itself. Calculations may reveal that less perfect coatings may suffice, so that the Periscope may not need to be recoated along with the main telescope mirrors.

Depending on the 'cosmetics' of the Periscope Mirrors and emission from mechanical components in the SSS, the precise determination of emissivity of the 'hole' may require more complicated modeling with ASAP software.

2.1.4. Image quality

2.1.4.1. Wavefront aberrations

The Periscope is intentionally NOT an image-forming optical system! The significance of 'image quality' has only to do with restricting the field of regard, so that out-of-field objects, notably the moon or clouds, will cause the least possible interference with observation.

If the parent system is made perfectly, the field of regard will be 3.7 degrees in diameter. The image of a star is defocused to a focal plane irradiance less than if the instrument were simply peering through a hole in the secondary mirror directly at the star itself, while extended objects, like the moon and clouds, affect the focal plane as though an f/98 camera lens were imaging an object within the 3.7 degree field onto the focal plane. If the optics were perfectly made, the exclusion angle would still be 3.7 degrees in diameter. The cost to produce substantially perfect optics is prohibitive, and for the purposes intended, unnecessary.

We experimented with parameter tolerances, and found that if the allowable exclusion angle were increased to 4.5 degrees, component fabrication and assembly tolerances corresponding to many hundreds of wavelengths of light are permissible. While optical methods may still be used to facilitate testing, ordinary mechanical tolerances are in fact sufficient.

2.1.4.2. *Optical alignment requirement*

The prime requirement is that no point on the instrument focal plane sees anything but space when it looks through the hole in the telescope secondary mirror. Important, but less vital, is that the angle of regard in star space be a minimum, which we have taken as a cone 4.5-degrees in diameter, and that the side of the SSS remains just barely out of the field of view.

Tolerances in terms of wavefront quality were shown to be very loose. The result of these loose tolerances is that 'boresight' of the Periscope becomes a primary mechanical concern when assembling the module by itself, and then installing it in the SSS. Pin registration of a precisely made module will ensure that the optics can be returned to the telescope after servicing, without need to align the optics ON the telescope. An alignment scheme to adjust the optics within the module will likely involve the use of an alignment telescope and both internal and external targets. Owing to the lax tolerances, measured in many minutes of arc, the periscope is not a precision mechanism and is virtually invulnerable to malfunction.

3. Periscope Functional Requirements

3.1. *Lifetime*

Assuming that the periscope optics are re-coated often enough for the periscope to meet its optical performance, the MK and CP periscopes shall meet their performance specifications and functional requirements for a period of **10 years** or longer.

3.2. *Environmental requirements*

The following requirements are based on the *Gemini Environmental requirements* ICD-G0013, Revision B, dated Oct. 8, 1996.

Two separate environmental conditions are specified. The first is involved with general site operations and the second with operating the periscope while mounted on the telescope. Due to very loose optical performance constraints, it will not be necessary to test the periscope under all of these conditions. This section is little more than a description of the conditions experienced by existing instruments in transit or operating at Mauna Kea and Cerro Pachón.

3.2.1. Handling Environment

The handling environment consists of those conditions experienced under normal telescope operations including:

- Storage at the base and mountain facilities
- Transportation and shipping to and from the base and mountain facilities
- Assembly/disassembly onto the telescope
- Storage and operation on the telescope.

The periscope is not expected to meet all of its performance requirements during those conditions that are harsher than the operating environment conditions described in the following section. However, after repeated cycles of the conditions listed below, the periscope must meet its operating performance requirements with no intervention from the operations staff other than routine tasks (handling, connecting services, etc.).

Transportation / Shipping / Handling / Survival Environment	
Condition	Requirement
Altitude	Sea level to13, 000 m
Ambient air temp	–25 °C to +71 °C
Ambient air temp step	±35 °C
Relative humidity [2]	0% to 100% with condensation
Wind speed	0 to 67 m/sec
Gravity orientation	All orientations
Vibration (minimum integrity) [1, 3]	PSD 0.015 g^2/Hz 10 to 40 Hz 0.00015 g^2/Hz @ 500Hz
Shock [0, 3]	Peak acceleration 15.0g, 0.015 second half-sine
Seismic acceleration [0, 3]	12 g X, Y and Z directions
Mechanical Interface	Handling cart or facility cranes, Shipping Crate
Cleanliness	Occasional wind blown dust, sand & insects

[0] Specification differs from ICD-G0013, Revision B
[1] IAW MIL-STD-810F, January `00, Section 514.5
[2] Frequent low humidity levels increase the risk of electrostatic discharge damage to sensitive electronic devices.
[3] It shall be demonstrated by analysis that the periscope meets those requirements (no vibration testing experiment required).

3.2.2. Operating Environment

The operating environment consists of the conditions experienced under normal telescope operations during adaptive optics observations. The periscope performance requirements must be met under these conditions. These conditions also include the testing of the periscope in the lab at the telescope and at the base facilities.

Operating environment	
Condition	Requirement
Altitude	Sea level to 4300m
Ambient air temp	-5°C to +20°C
Median air temp [4]	0°C Mauna Kea 9°C Cerro Pachón

Ambient air temp rate of change during the night	±0.2°C/hour Mauna Kea ±0.8°C/hour Cerro Pachón
Relative humidity [1]	0% to 90%
Wind speed [0]	0 to 11 m/sec
Gravity component limits [0, 2]	X axis 0g Y axis 0g to -1g Z axis -1g to 0g
Vibration [3]	PSD $1x10^{-5}$ g^2/Hz, 20-1000Hz, 6db/oct drop- off to 2000Hz
Cleanliness	Occasional wind blown dust, sand & insects

[0] Specification differs from ICD-G0013, Revision B
[1] Frequent low humidity levels increase the risk of electrostatic discharge damage to sensitive electronic devices.
[2] The coordinate system is the Optical Support Structure coordinate system (see drawing 90-GP-0001-0023, Rev. B).
[3] It shall be demonstrated by analysis that the periscope meets those requirements (no vibration testing experiment required).
[4] The Mauna Kea and Cerro Pachón median temperatures are significantly different. The design for the periscope, however, must be identical for both sites. If this temperature difference is significant in the design of the periscope, it must be accounted for in some form of adjustment or alignment internal to the periscope and not affect any of the space envelopes or interfaces defined in this document.

3.3. Mechanical requirements

3.3.1. Periscope location

As mentioned in Section 1.2, the Periscope will be attached to the stationary portion of the M2 Module, 35 mm below the SSS/M2 Module Interface as shown in drawing PERISCOPE12.DWG. Because the periscope is situated within the SSS and bounded by the LLT above and the M2 below, access to its components will be limited. All optical alignment adjustments must be performed on an optical bench prior to installation on the telescope. These alignments will be locked in place using a standard industrial bonding agent, such as a low temperature 2-part epoxy. This will reduce the maintenance on the periscope assembly to recoating the two mirrors. Any maintenance performed after installation of the periscope must be accessible through the SSS frame. This includes removing the primary and secondary mirrors for cleaning and coating. Due to the airborne debris in the environment and the need to close the periscope system during non-IR observations, the periscope will have a remotely-operated cover controlled through the SCS.

3.3.2. Space envelope

The location of the periscope assembly poses two problems, one geometric and one optical.

Due to the geometric constraints of the SSS, the periscope must be mounted when either the M2 Module or the LLT is removed from the telescope. This means that the periscope must fit within the SSS frame with sufficient clearance so that either approach to mounting is possible. The inside diameter of the SSS frame is 610mm. Due to welds on the inside of the SSS, a maximum diameter of **590 mm** will be used. Since the periscope's secondary mirror must be positioned outside this diameter, the periscope will be separated into two distinct components, the primary and secondary mirror brackets as shown in drawing PERISCOPE11.DWG. Location pins will be match-drilled and inserted into the primary/secondary bracket interface in order to remove and replace the secondary mirror bracket without realignment. Due to the cross bracing on the SSS, the secondary mirror bracket's vertical profile must allow it to fit through the SSS frame as shown in the elevation view of drawing PERISCOPE13.DWG.

Optically, the outgoing beams must not be vignetted by the SSS or any component mounted on it. This includes any mechanical components, electronic boxes (outlined in Section 3.4.2) and any cabling that may inadvertently cross the beam path.

3.3.3. Periscope/M2 interface

As mentioned earlier, the periscope assembly will be attached to the stationary portion of the M2 Module. Currently, the M2 Hole Cover Assembly is installed at this location and must be removed to install the periscope. The same interface hole pattern will be utilized with the periscope as for the existing M2 Hole Cover Assembly as shown in drawing PERISCOPE12.DWG.

3.3.4. Orientation

The periscope assembly will be situated within the SSS with the secondary bracket diverting the outgoing beam through the SSS cross bracing. In order to meet the optical performance specifications, the optical axis of the periscope must be collinear with the optical axis of the main Gemini telescope. Since the periscope will be mounted on the M2 assembly (setting the Z-height), the only freedom of movement remaining is the rotation about the optical axis. The orientation of the periscope assembly is limited by the vertical I-beams that provide structural support to the SSS. The eight SSS I-beams will physically allow the periscope to be oriented in eight different positions. The orientation of the periscope will therefore be defined as the direction of the secondary mirror with respect to the primary mirror.

Currently, the drawings show the periscope oriented along the –Y axis. However due to limited access to the SSS from its maintenance scaffolding, this may not be the optimum orientation. Since both the +X/-Y and –X/-Y orientations are downward facing during maintenance of the SSS, the installation of the secondary mirror bracket might be awkward. The +Y side of the SSS is difficult to reach due to its height above the scaffolding and most likely will be ruled out as well. The four remaining directions, +X, +X/+Y, -X/+Y and –X will be the most likely candidates for the periscope assembly's orientation.

3.3.5. Mass

The total allowable mass added to the secondary structure due to the AO system must not exceed **125±25 kg**. This mass has been divided amongst the LLT, BTOOB and periscope subassemblies in order to separate the design tasks. The mass allocation for the periscope assembly is **10 kg**. A breakdown of the periscope assembly mass is shown in Table 1. The periscope assembly will be replacing the M2 Hole Cover Assembly; therefore the mass of the existing cover assembly has been deducted from the total mass being added to the SSS. The total estimated change in mass is **3.9 kg**.

ITEM	INCLUDED ITEMS	VOLUME (mm^3)	DENSITY (g/mm^3)	MASS (kg)
Aluminum Brackets	Primary Mirror Bracket	1,710,187.5	0.00270	4.618
	Secondary Mirror Bracket	430,884.5	0.00270	1.163
	Bracket Hardware	7,212.1	0.00785	0.057
			Subtotal =	*5.838*
Primary Mirror	Aluminum Mirror	623,474.0	0.00270	1.683
	Mirror Hardware	11,233.1	0.00785	0.088
			Subtotal =	*1.772*
Secondary Mirror	Aluminum Mirror	65,958.1	0.00270	0.178
	Mirror Hardware	1,033.4	0.00785	0.008
			Subtotal =	*0.186*
Mirror Cover	Aluminum Cover	14,245.6	0.00270	0.038
	Aluminum Hinge	5,507.3	0.00270	0.015
	Hinge Hardware	698.9	0.00785	0.005
	Mirror Cover Motor	40,505.1	0.00270	0.109
	Mirror Cover Motor Bracket	27,438.9	0.00270	0.074
	Mirror Cover Motor Hardware	2,490.8	0.00785	0.020
	Mirror Cover Felt Strips	1,774.3	0.00040	0.001
			Subtotal =	*0.262*
Existing M2 Hole Cover Assembly	M2 Hole Cover Assembly	-1,532,595.5	0.00270	-4.138
			Subtotal =	*-4.138*
			Total Mass (kg):	**3.919**

Table 1 Periscope Mass

3.3.6. Mirror fabrication

The accuracy required for mirror fabrication resembles that found in the making of steel dies for automobile body parts. Therefore, numerically controlled machinery is suitable to the pre-polishing stage of mirror fabrication. The final surfaces will be polished with appropriate, possibly but not necessarily, optical machinery.

Because the space envelope for the periscope's primary mirror is limited, there will not be sufficient room for adequate mounting of a glass substrate mirror. Another deterrent to using a glass substrate is the restricted access to the primary mirror during maintenance. For these two reasons, a metal substrate will be used. Aluminum is a good choice due to its low density and versatility for mounting. The aluminum substrates will need to be electroless nickel-plated, stress-relieved, and measured to verify that component specifications have been met. Loose tolerances permit unusually thin metal sections on the mirrors. The current mirror thickness for the primary mirror is **~5 mm** at the thinnest section and **~7.5** mm for the secondary. The thickness of the two mirrors may be increased to insure accurate machining tolerances are met.

3.3.7. Mirror mounting

Both the primary and secondary mirrors will be mounted on their respective brackets using a three-point kinematic support. Since both mirrors are aspheric, they will be symmetric with respect to their central axis. This central axis is defined as the line passing through the lower mount that lies in the Y-Z plane (elevation view of drawing PERISCOPE12.DWG. The line of symmetry is shown in the 3D ASSEMBLED VIEW of drawing SUBSTRATE01.DWG.

The support for the secondary mirror uses smaller components with the same mounting concept as that of the primary mirror and so only the primary mirror will be discussed here. For consistency, the mirror mount will refer to all components necessary to mount the mirror on the M6 stud shown in the SECTIONAL VIEW SV1 of drawing SUBSTRATE01.DWG. The mirror tab will refer to the mirror portion of the mirror mount.

Two of the tabs on the mirror will be offset from the lower tab by 115 degrees. This will eliminate the possibility of orienting the mirror incorrectly (though it could be mounted upside down). Each mirror mount will be configured using a spherical mounting scheme. The mirror tab will be sandwiched between a spherical washer and spherical seat, both of which have coincident radii of curvature. This will allow the mirror to rotate between the two while keeping them both aligned with respect to the mounting stud. The central hole clearance on the seat and washer will allow them to move around the stud by 0.5 mm. This, in concert with the clearance hole in the mirror tab, will allow the mirror to rotate by up to 2 degrees. Shims will be used to optically align the mirror on the mirror bracket.

3.3.8. Mirror cover

Due to the airborne debris in the environment and the need to block light from passing through the SSS during non-IR observations, the periscope will have a remotely operated cover. A DC motor with a 2400:1 gear ratio will be mounted on the motor bracket, which will in turn be mounted on the secondary mirror bracket. The motor will be connected via a 2-bar linkage to the mirror cover panel. The motion of the motor will be remotely controlled through the SCS using limit switches to relay the location of the cover. The components of the mirror cover are shown in drawing PERISCOPE11.DWG.

3.3.9. Handling fixtures

No handling fixtures will be required to install the periscope assembly on the M2 module. However one or more fixtures might be required to support periodic recoating of both primary and secondary mirrors. The fixture will interface with the mirror mounting points and a coating vessel capable of handling mirrors this size.

3.4. Electrical / electronics / control requirements

3.4.1. Remote control for the periscope cover

Remote controls must be implemented through the Secondary Control System (SCS). The SCS controls various tasks using an EPICS interface. However, no software will need to be developed with the periscope. The electronics will receive power and control signals for motor driving. The power supply will also be turned on and off from the SCS. These signals will drive the mirror cover motor. It will send limit switch or encoder signals back to the SCS to indicate the mirror cover positions. The limit switch signals will also be used within the periscope electronics for internal protection. The periscope shall be designed with adequate testing capability to check that all remotely controlled functions are indeed working ('Self–test' features).

3.4.2. Electronics and cables

All necessary electronics should be mounted on the telescope, preferably not on the secondary frame, but possibly on the top-end ring and/or the telescope center section. The use of long cables should be foreseen, with a maximum length of about 50 m. Appropriate signal–transmission techniques must be employed over long cable–runs (for example, differential transmission and reception, shielding, use of current loop schemes, etc.) as required to ensure reliable operation with minimum interference with other adjacent systems. If absolutely necessary, some electronics boxes can be mounted on the secondary frame. The volume allocated to the boxes is **100x225x880 mm** as shown in drawing ICR03.DWG. Due to the tight thermal constraint applied to equipment mounted on the SSS, and the lack of coolant to this structure, the electronics mounted in this location must use a rigorous low–power design and, if practicable, have the ability to be either powered off entirely or placed in a low–dissipation state when not in use.

If periscope electronics are located on the telescope top-end ring or on the telescope center section, cables will be run along one of the secondary vanes so that the telescope primary mirror cannot see them. The vane is only **10 mm** wide and cables MUST be hidden behind the vane. Such cables shall have connectors at the top-end ring so that the top-end can be removed without dismounting the periscope first. This is a requirement for all systems mounted in this location.

The cabling used on the top–end ring is not subject to size restrictions, in contrast to that which passes across the vanes. In this case, the cabling must fit within the vane cable–tray space envelope of **7 mm X 30 mm**. Generally, this means a loose bunch of twisted–pair cables rather than a large single cable containing multiple pairs (as the latter is almost invariably of too great a diameter).

3.4.3. Gemini standards

This section provides as a list of guidelines in the event that the periscope design requires some of the following elements.

3.4.3.1. Standardization

The following standards shall be applied to ensure compatibility with existing telescope systems.

3.4.3.1.1. Connectors

Where possible (for example, when connecting power and data signals between units) an appropriate ITT-Cannon MIL-C-26482 Series 1 KPT or KPSE connector shall be employed. Use of keyed connectors to lower the risk of accidental connector swapping is strongly encouraged. Crimp connectors are preferred over solder types.

3.4.3.1.2. Cable and signal identification

All external cables shall be uniquely identified and labeled. The labeling and identification shall strictly adhere to the appropriate Gemini standard (Gemini Electronic Design Specification SPE-ASA-G0008 provided upon request) and shall be in a clearly visible and non-removable form. This identification scheme shall be identical to that used in the system documentation. Identification of cables by color-coding is appropriate and encouraged but not a substitute for clear labeling.

3.4.3.1.3. Electronic system documentation

All electronic circuit schematics and printed-circuit board (PCB) designs must be supplied in both printed and electronic form. The electronic form shall be OrCAD V9.0 native format or 100% compatible with it. The vendor must demonstrate, if non–OrCAD design files are supplied, that they are capable of being unambiguously and correctly imported into the current version of OrCAD. Gemini will then use the converted OrCAD file as the official design file document(s).

3.4.3.1.4. Environmental rating

All electrical and electronic components shall be rated for operation below zero degrees Celsius (rating to minus twenty degrees Celsius is sufficient). The ambient temperature in the telescope dome frequently falls below zero degrees Celsius for extended periods. The Vendor will ensure that electronic equipment supplied by third parties – for example, as part of a sensor package – meets this requirement. In particular, tolerances on electronic devices such as sensors, etc., must be such as to allow correct operation of the mechanism in which they are located over the entire temperature range without recalibration or adjustment. In other words, the component specifications must be such that the *system* meets the operating requirements over the full temperature range.

3.4.3.1.5. Electrical components

All commercially available electrical components have to be UL listed. Items that do not meet this requirement will have to be approved by Gemini prior to being incorporated into the system.

3.4.3.2. Signal Transmission

To minimize the risk of spurious operation of the periscope and other systems, adherence to the following guidelines are required. Low-level signals, for example those from analogue sensors that are routed outside of a screened enclosure, over extended distances, through or near areas of high electromagnetic interference, must be transmitted by an appropriate method. Examples of such methods include, but are not limited to, differential voltage transmission via shielded, twisted–pair cable, 4–20mA current–loop systems, etc. Appropriate design measures shall be taken to minimize the coupling, generation and radiation of interfering electromagnetic signals shall be taken wherever necessary. As indicated above, these measures shall include, but not be limited to, the provision of adequate grounding and shielding and the use of appropriate robust signal transmission techniques.

3.4.3.3. Fail-safe Systems

The following provisions shall be followed in regard to fail-safe systems in the periscope electronics.

3.4.3.3.1. Limit switches

Electromechanical or electronic limit switches, where used, shall be wired such that a break in the connecting cable to them shall cause a fault condition to exist. This precludes the use of switches wired such that the ‘normally open’ state indicates a ‘no fault’ condition. Limit switches used for safety interlocks should be equipped with positive opening safety contacts, as well as monitoring contacts.

3.4.3.3.2. Others

Fail-safe, self-checking circuits have to be incorporated in the design wherever control malfunctions or improper sequencing may create a hazard to personnel, cause personal injury or damage to equipment or parts. This circuitry should give a protection against:

- Failure of one or more devices to function properly
- Improper sequencing in manual or automatic operation

Control circuits incorporating position sensors, movement sensors, push buttons and similar devices should be designed in such a manner that a device must be released or otherwise returned to its reset state before it can be used to initiate a control action. The design should prevent continuous operation or cycling due to a device that has been tied down, jammed or otherwise defeated.

3.5. Heat dissipation

No more than **0.5 W** of heat must be dissipated into the air from all the periscope elements that are located behind the telescope secondary mirror (i.e. on the SSS). This requirement includes all heat dissipated by the electronics when used.

3.6. Optical cleaning and coating

The mirrors of the periscope may be serviced at the same interval as the main telescope mirrors, or they may be given less frequent cleaning and coating, depending of calculations concerning emissivity.

3.7. Optical alignment

3.7.1. Periscope internal alignment off telescope

The two mirrors within the periscope will be aligned within the periscope module by means of internal and external alignment targets, whose positions are measured with an alignment telescope. The mirrors will be secured in position and targets removed.

3.7.2. Periscope alignment with Gemini telescope

The tilt and centration of the periscope module may be adjusted with an alignment telescope located at the focal plane of the telescope, looking upward toward the hole in the secondary mirror, at a target affixed to the uppermost part of the SSS. The module will be secured and targets removed after alignment.

4. Opto-mechanical design

4.1. Periscope optical design

4.1.1. Preliminary comments

The following ZEMAX prescription is dated back on January 12, 2001. This is the prescription that was used to generate the AutoCAD drawings for the periscope mechanical design and interface with the SSS.

4.1.2. ZEMAX prescription

The following is the ZEMAX prescription used for the design of the periscope assembly. Figure 1 and Figure 2 show the side and top views of the periscope mirrors parent optics.

```
System/Prescription Data

File : K:\AO\MKlgs_(&CPlgs)\Laser Launch Telescope\optical\Celine\Celine
Periscope 01-12-01.ZMX
Title: Celine Periscope 01-12-01
Date : FRI JAN 12 2001

LENS NOTES:

       Identical to Modif of 011101e-mail_Modif of
catonePeriscopeFinal120300a (2).ZMX
       Corresponds to Jim's mechanical drawing in Periscope10.dwg as of
01-11-01 e-mail


GENERAL LENS DATA:

Surfaces                :                 7
Stop                    :                 1
System Aperture         : Object Space NA = 0.005443
Glass Catalogs          : Schott
Ray Aiming              : Off
Apodization             :Uniform, factor =   0.00000E+000
```

```
Effective Focal Length  :        2518.326 (in air)
Effective Focal Length  :        2518.326 (in image space)
Back Focal Length       :       -1233.966
Total Track             :        3053.443
Image Space F/#         :        13.98711
Paraxial Working F/#    :        28.67172
Working F/#             :        34.89352
Image Space NA          :      0.01743613
Object Space NA         :        0.005443
Stop Radius             :        90.02311
Paraxial Image Height   :        28.09125
Paraxial Magnification  :       -0.312125
Entrance Pupil Diameter :        180.0462
Entrance Pupil Position :               0
Exit Pupil Diameter     :        53.52761
Exit Pupil Position     :       -1982.662
Field Type              : Object height in Millimeters
Maximum Field           :              90
Primary Wave            :            0.55
Lens Units              :   Millimeters
Angular Magnification   :        3.363614

Fields: 5
Field Type: Object height in Millimeters

#       X-Value     Y-Value    Weight
1       0.000000    0.000000  1.000000
2       0.000000   90.000000  1.000000
3       0.000000  -90.000000  1.000000
4      90.000000    0.000000  1.000000
5     -90.000000    0.000000  1.000000

Wavelengths:      1
Units:            microns
#     Value       Weight
1     0.550000    1.000000
```

SURFACE DATA SUMMARY:

Surf	Type	Comment	Radius	Thickness	Glass	Diameter	Conic
OBJ	STANDARD		Infinity	16539		180	0
STO	STANDARD	180 mm DESIGN HOLE	Infinity	1490.5		180.0462	0
2	COORDBRK		-	0		-	-
3	STANDARD	CONCAVE MIRROR #1	-636.4	-245.6	MIRROR	1355.021	-0.9
4	COORDBRK		-	0		-	-
5	STANDARD	CONVEX MIRROR #2	-166.2	1808.543	MIRROR	404.8824	-1.08
6	COORDBRK		-	0		-	-
IMA	STANDARD		Infinity			69.5206	

SURFACE DATA DETAIL:

```
Surface OBJ      : STANDARD
 Scattering      : None
Surface STO      : STANDARD
 Comment         : 180MM DESIGN HOLE
 Scattering      : None
Surface   2      : COORDBRK
 Decenter X      :                0
 Decenter Y      :              594
 Tilt About X    :             -3.1
 Tilt About Y    :                0
 Tilt About Z    :                0
 Order           : Decenter then tilt
 Scattering      : None
Surface   3      : STANDARD
 Comment         : CONCAVE MIRROR #1
 Scattering      : None
Surface   4      : COORDBRK
 Decenter X      :                0
 Decenter Y      :              7.5
 Tilt About X    :             -5.8
 Tilt About Y    :                0
 Tilt About Z    :                0
 Order           : Decenter then tilt
 Scattering      : None
Surface   5      : STANDARD
 Comment         : CONVEX MIRROR #2
 Scattering      : None
Surface   6      : COORDBRK
 Decenter X      :                0
 Decenter Y      :       -134.34914
 Tilt About X    :       -1.0642649
 Tilt About Y    :                0
 Tilt About Z    :                0
 Order           : Decenter then tilt
 Scattering      : None
Surface IMA      : STANDARD
 Scattering      : None
```

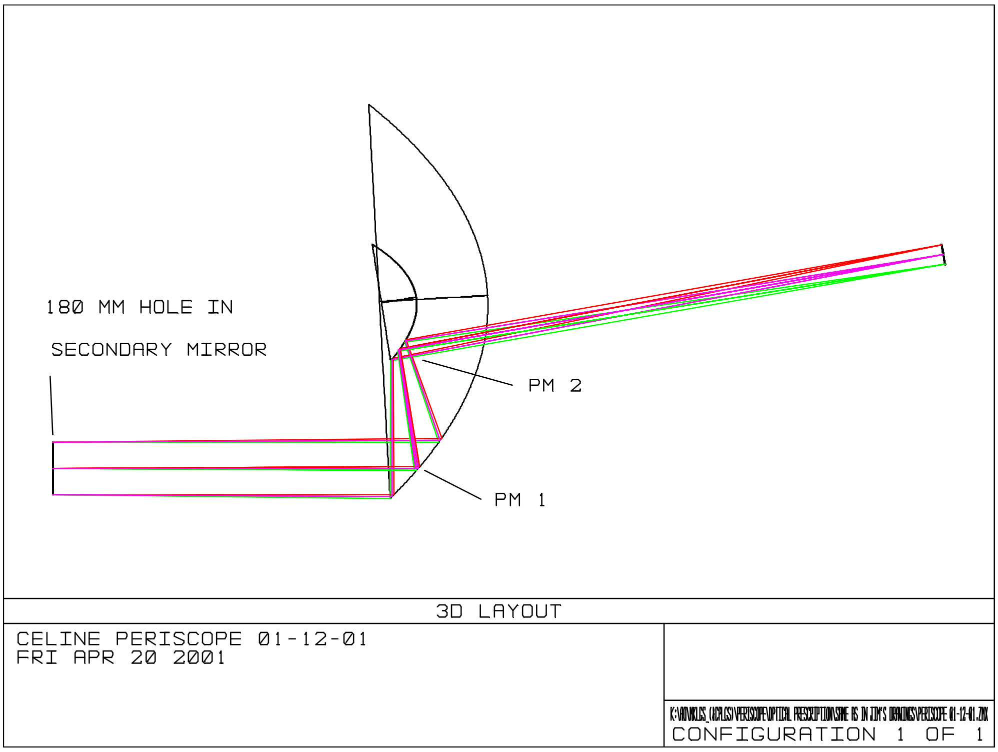

Figure 1 **Side view, parent optics, for Periscope**

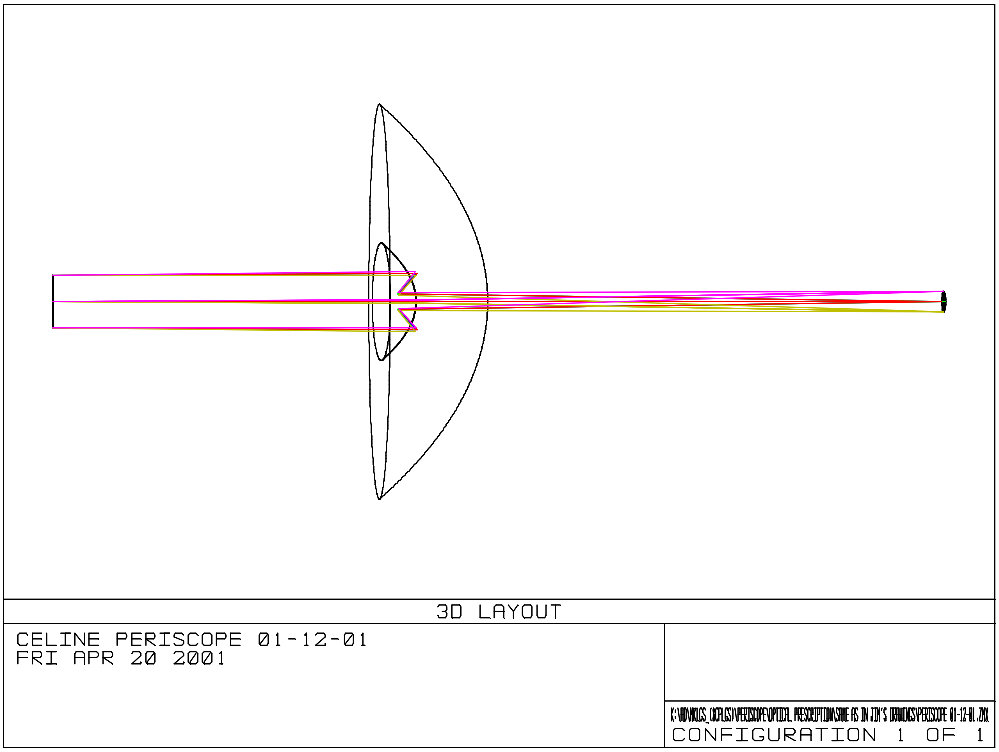

Figure 2 **Top view, parent optics, for Periscope**

4.2. Drawings

The following drawing are referenced throughout this document:

ICR03.DWG	Electronics box interface for the secondary support structure
PERISCOPE10.DWG	Central hole clearance for the f/16 secondary mirror assembly
PERISCOPE11.DWG	Conceptual periscope bracketry for the secondary support structure
PERISCOPE12.DWG	Stack up assembly for the secondary support structure
PERISCOPE13.DWG	Periscope orientation for the secondary support structure
SUBSTRATE01.DWG	Mounting concept for the periscope assembly mirrors
TELESCOPE01.DWG	3D view of the Gemini 8M telescope