Appendix A: Prototype Telescope Specifications

Functional Description

The primary function of the telescope is to efficiently deliver laser light to the far field on axis, while maintaining optical pathlength stability through the telescope.

The application is for a transceiver. It will simultaneously transmit 1 W of power and receive 100 pW. The transmitted signal power should back-scatter less power than is received.

The application is for a precision displacement measurement system. The optical pathlength through the telescope must be stable to interferometric tolerances over the time for enabling science measurements (0.1 to 10^{-4} Hz).

The high-level characteristics of the telescope are:

- unobstructed reflecting telescope
- Afocal 40X magnification
- 200mm primary mirror circular diameter
- nominal 5 mm circular diameter collimated beam to the optical bench
- focus adjustment to be used in a set-and-forget mode. (Active or passive.) The eventual flight model will require an electronically-adjustable mechanism. This prototype does not necessarily require this feature, but the telescope should be designed so that the focus may be adjusted manually to meet WFE (requirement 13), with accommodations for a motorized adjustment. Note that the adjustment mechanism must not spoil the pathlength stability performance.

Critical Requirements

The driving requirements of the Telescope Subsystem are given in **Table 1**.

	Parameter	**Derived From**	**eLISA/NGO**
1	Wavelength		1064 nm
2	Wave front quality over field of view	Pointing	≦ λ/□□□RMS
3	Field-of-Regard[1]	Orbits	+/- 20 μrad (large aperture)
4	Field-of-View[2]	Stray light	+/- 8 μrad (large aperture)
5	Afocal magnification	short arm interferometer	200/5 = 40x
6	Optical throughput	Shot noise	>0.85
7	Stop Diameter (D) (large aperture)	Noise/ pointing	200 mm diameter
8	Stop location (large aperture)	Pointing	Entrance of beam tube or primary mirror
9	Exit pupil location (small aperture)	Pointing	140 mm (on axis) behind primary mirror
10	Exit pupil diameter (small aperture)	optical bench	5 mm
11	Focus adjustment	pointing	maintain WFE from room T (300K) to operating (230K) (Verify by model)
12	Mechanical envelope	spacecraft volume	≤ 450 mm length x 300 mm

			height x 250 mm wide
The following two requirements should be verified by analysis, not tested explicitly:			
13	Telescope subsystem optical path length[3] stability under flight conditions[4]	Path length Noise/ Pointing	$< 4.3 \times 10^{-12}$ m RMS with temperature fluctuations of TBD at 1.2×10^{-5} Hz
14	Scattered Light	Displacement noise	$< 10^{-10}$ of transmitted power into the receiver FOV

Table 1: Summary of critical requirements for the Telescope Subsystem

Notes for Table 1: [Requirements (13) and (14) are the most challenging]

1) The Field of Regard is the range of angles over which we need to be able receive signals over the full orbit. The telescope should meet all specifications over this Field of Regard except for scattered light .

2) The Field of View is the range of angles over which we will be making measurements under closed-loop tracking in Science Mode. The telescope should meet all specifications over this Field Of View including scattered light.

3) Optical path length is the net total path length through the telescope as experienced by either the transmitted or received beam from input pupil to exit pupil, averaged over the field, which can be defined as the accumulated phase divided by the wavenumber ($2\pi/\lambda$), where lambda is the design wavelength, 1064 nm. The key specification is the stability with time. The absolute value is less important.

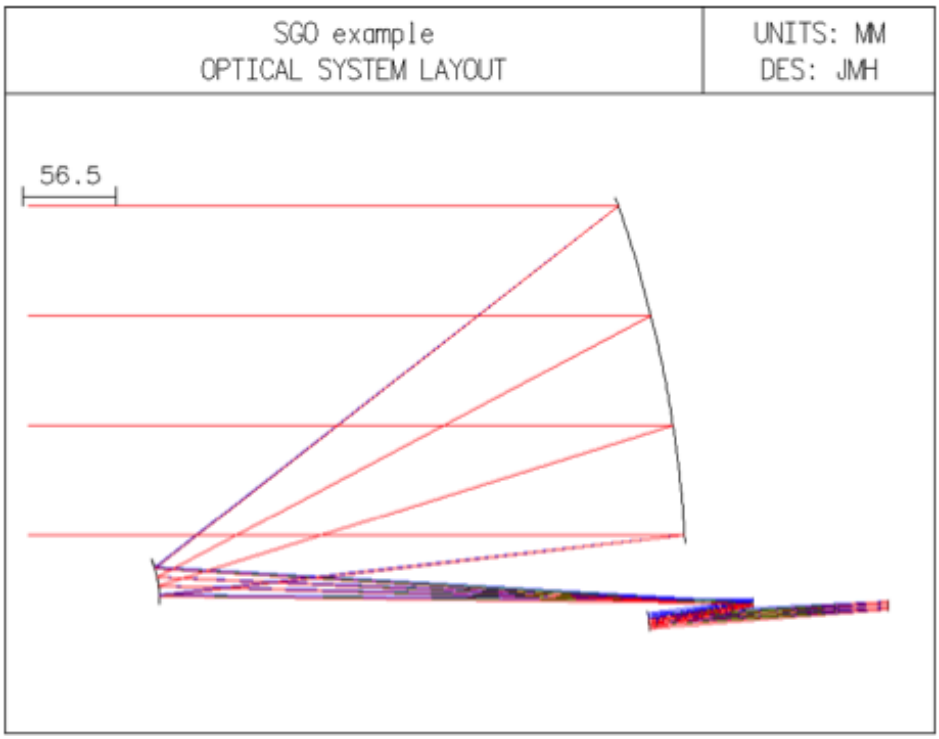
4) Flight conditions for the purposes of this prototype are defined as a 300K soak temperature. Compliance to be verified by analysis. Includes stability of focus adjustment mechanism.

Example Starting Design

The following basic optical design may be used as a starting point for a final design that is optimized to meet the above specifications. The design includes a prescription, a layout, and the results of a trace of the gutray that can serve as a check.

SGO Example Prescription:

				GLOBAL COORDINATES with respect to PRIMARY MIRROR VERTEX					
Surface	radius	thickness	conic	X	Y	Z	A	B	C
PM (stop)	-697.548	-320.000	-1.00138	0	0	0	0	0	0
SM	-63.045	330.000	-1.44065	0	0	-320	0	0	0
Internal Image	0.000	-0.031	0	0	0	10	0	0	0
M3	715.959	-64.233	0	0	2	40.243085	-3.76364	0	0
M4	184.353	146.073	-1.0983	0	-2.216279	-23.85110 9	-3.76364	0	0
Exit Pupil	0	0	0	0	7.372053	121.90688 9	-3.76364	0	0



SGO Example gut ray trace (as a check):

GUT RAY trace data

LOCAL SURFACE COORDS

Surface	X	Y	Z	TANX	TANY	LENGTH
PM (stop)	0	140	-14.049	0	-157.303	-14.049
SM	0	11.59431	-1.06219	0	-2.00577	332.7839
Internal		-1.17E-0				
Image	0	5	0	0	-2.00577	331.2652
M3	0	-3.07353	0.006597	0	-173.739	30.50159
M4	0	-10.0914	0.276181	0	0.004188	64.34698
Exit Pupil	0	-10.0808	0	0	0.004188	145.7969