Executive Summary

The solar atmosphere undergoes a fundamental transformation moving outward from the photosphere to the extended corona. One need only compare visible light images of the photosphere containing relatively simple structures, like spots and granulation, to EUV images of the corona that reveal it is teeming with complex loops that constantly evolve and erupt. This change reflects the transition from gas pressure as the dominant force in the photosphere, to magnetism dominating the force balance in the corona. Magnetism structures the corona and heats the coronal plasma to a temperature of several million degrees. The most energetic forms of solar activity, including flares, and coronal mass ejections derive their energy from coronal magnetic fields. These phenomena are collectively responsible for Space Weather that can have dire consequences for human activity in space and on the ground. Despite the important role of magnetism in the solar corona, routine measurements of the strength and direction of coronal magnetic fields are currently not available. Magnetic field measurements in the solar corona are the crucial missing link in our progress towards understanding coronal processes and their role in the generation of space weather that affects communications, GPS systems, space flight, and power transmission.

Coronal magnetic fields are extremely difficult to measure for three important reasons: 1) the magnetic fields in the corona are intrinsically weak; 2) the coronal spectroscopic lines are broader and much dimmer than their photospheric counterparts; and 3) the optically thin corona requires interpretation of magnetic signatures integrated along extended path lengths. These challenges have been addressed recently using greatly improved infrared (IR) detectors, forward models, advanced diagnostic tools, and inversion codes. As a result, we now have the capability to measure the coronal magnetic field. Unfortunately, today’s solar coronagraphs are too small to provide adequate photon flux to obtain measurements at the required spatial and temporal resolution.

The Coronal Solar Magnetism Observatory (COSMO) is a unique ground-based facility designed to address the shortfall in our capability to measure magnetic fields in the solar corona. COSMO comprises three elements. The first two focus on chromospheric and prominence magnetometry (ChroMag), and observing the electron scattered K-corona (K-Cor). The third and central instrument is the 1.5-m aperture Large Coronagraph (LC) that is dedicated to observing the radiation emitted by the corona in a number of visible and near-IR emission lines corresponding to plasma with temperatures in the 0.01 to 5 MK range. The LC post-focus instrumentation will analyze the polarization signatures of the emitted radiation and infer the direction and strength of coronal magnetic fields, as well as the physical properties of the coronal plasma including temperature, density and velocity. The LC employs an innovative refractive design to obtain routine measurements over a large field-of-view at the spatial and temporal resolutions required to address the outstanding problems in coronal physics. It will be the largest refracting telescope in the world. The National Center for Atmospheric Research (NCAR) and
partners at the University of Michigan, the University of Hawaii, George Mason University and the Harvard-Smithsonian Center for Astrophysics will design, build and operate this facility.

This ambitious undertaking is only possible by building on the heritage of prototype instruments developed at the University of Hawaii and at NCAR, and by conducting extensive engineering studies. The documents presented here support the Preliminary Design Review (PDR) for the COSMO LC. Through these documents, we make the case that the COSMO LC has been thoroughly researched. Preliminary designs exist for all major subsystems, all major trade studies have been executed, and all aspects of the project are within current technological capabilities.

The documentation for the PDR is organized according to the graphical roadmap on the next page. Introductory materials are at the top of the chart in red. Moving clockwise, the science and operational requirement documents are shown in orange, with the science requirements document the most important of these. The scientific requirements were generated with extensive input from the community through the COSMO Steering Committee, the decadal survey process, from colleagues at scientific meetings and at COSMO workshops. This input includes a number of use cases that will insure the LC will be capable of addressing the broadest range of scientific investigations. The science requirements document provides the rationale that the COSMO LC should have a field-of-view of 1 degree, a spatial resolution of 2 arcseconds and be capable of measuring the strength of the coronal magnetic field with a precision of 1 Gauss in 15 minutes using the FeXIII emission line at 1074.7nm.

The top level requirements flow into the systems level requirements shown in yellow. These documents evaluate the implications of the top level requirements on the telescope, the post-focus instrumentation, the telescope enclosure, the site and the control system. Significant among these are the requirements on the polarimeter that are developed in the polarimetry requirements document. The system level requirements are supported by the design and analysis documents shown in green. These documents are the foundational blocks upon which the coronagraph will be built. The Flux Budget document presents the light levels for the coronal emission lines that the LC will observe and the resulting errors on the magnetic field strength and other parameters. These errors depend on the telescope collecting area since they are due primarily to photon noise. The science requirements in combination with these errors drive the required aperture of the LC to be 1.5 meters. The Site Analysis and Selection document evaluates the two sites that were considered for the COSMO facility, Mauna Loa and Haleakala, in terms of sky brightness, particulate contamination, seeing and other factors. We find that both sites meet the requirements for the COSMO LC, but the limited available space on Haleakala and the simpler permitting process at the Mauna Loa site led us to select Mauna Loa as the preferred site for COSMO. The trade study on reflecting vs. refracting primary objectives for the LC show that a lens scatters significantly less light than a mirror, and led to our decision to make the LC a lens-based coronagraph. The Optical Design document presents the optical design capable of meeting the challenging requirement of imaging a 1 degree field-of-view taken with a 1.5m aperture.
Additional supporting documents that are referenced in the PDR materials are shown in purple. These include the series of COSMO technical notes and the site environmental and geotechnical report.

These all feed into the assembly, integration and verification plan in blue and the all-important compliance matrix which documents how the preliminary design presented here will meet requirements. The management plan is also presented which presents a detailed costing for the facility with justification.

On the basis of our analyses and input from vendors, we estimate that the COSMO LC including post-focus instrumentation can be constructed for a cost of $23.4M, not including contingency.

This PDR was made possible through the efforts of a dedicated and talented team of engineers and scientists. Their work on various aspects of the project is acknowledged through authorship on documents, and with a list of contributors given in the Appendix. Primary funding for this PDR was provided by the NSF Atmospheric and Geospace Sciences Division and by the National Center for Atmospheric Research through the Director’s Reserve and through base funding. Support of Chinese collaborators was provided by the Chinese Academy of Sciences.