Design, Testing, and Implementation of the Marshall Grazing Incidence X-ray Spectrometer Slit-Jaw Context Imaging System

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MaGIXS Overview

The Marshall Grazing Incidence X-ray Spectrometer (MaGIXS) is a NASA sounding rocket payload providing a 0.6 – 2.5 nm spectrum with unprecedented spatial and spectral resolution. The instrument is comprised of a novel optical design, featuring a Wolter 1 grazing mirror in the telescope module focusing the solar image on a slit plate; two corrective optics, a diffraction grating and a low-noise detector make up the spectrometer module. When MaGIXS flies on a suborbital launch in 2020, a slit-jaw camera system will image the sun in extreme ultraviolet (EUV) to soft x-ray wavelengths, providing a reference for pointing the telescope and aligning the data to supporting observations from satellites.

Slit-Jaw Imaging system

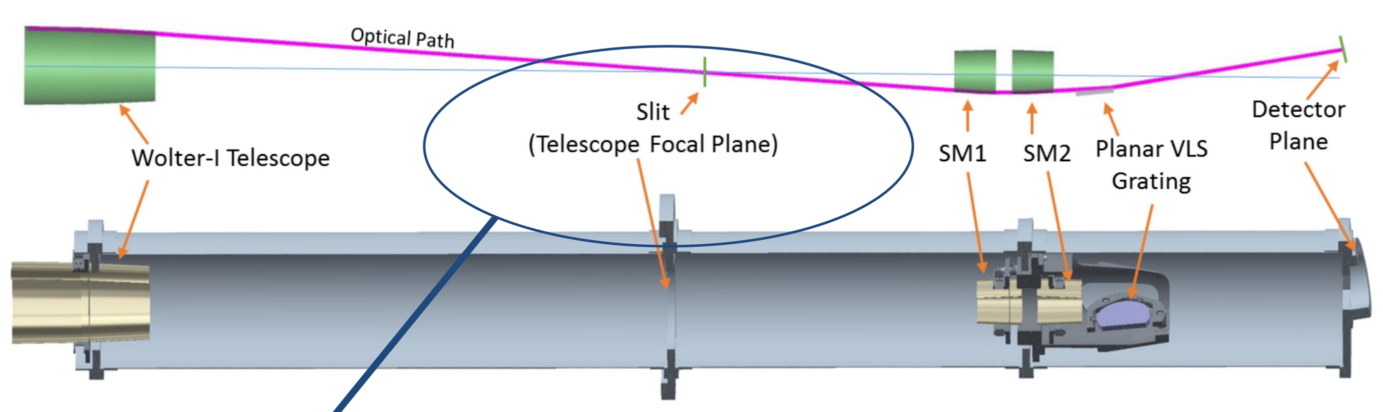
The MaGIXS payload also consists of a context imager, which is used for pointing the instrument at the sun during flight and correlating science data with that from co-observing instruments. In the past, context imagers, e.g. Hi-C H-alpha telescope and CLASP Slit-Jaw Imager, proved to be very successful for coordination of imaging and spectroscopic observations. The MaGIXS Slit-Jaw Imaging System lends its design from the CLASP Slit-Jaw system - both designs rely on imaging the phosfluorescence of the telescope focal plane to locate the slit projected onto the sun.

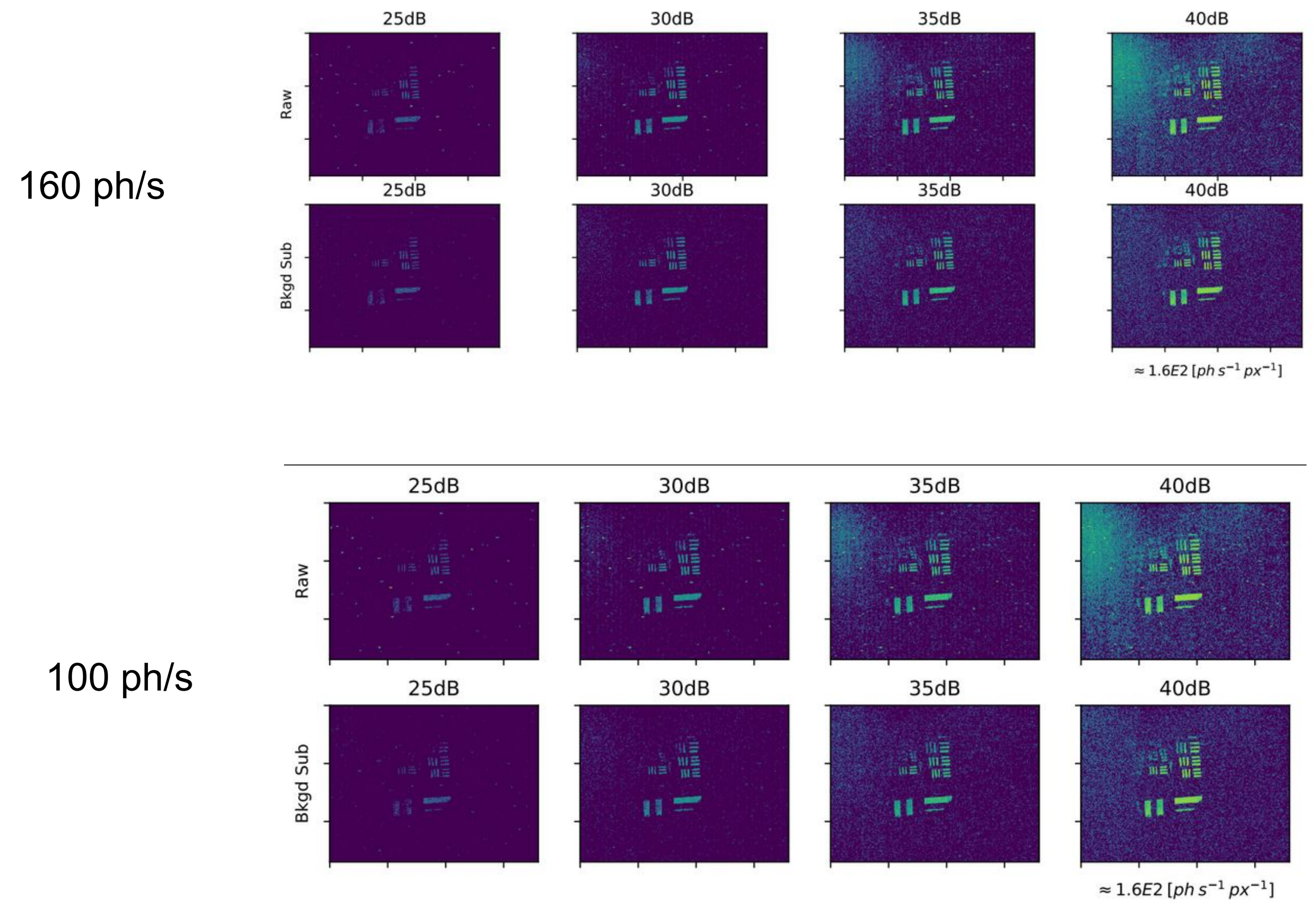
There are two primary challenges for this design.

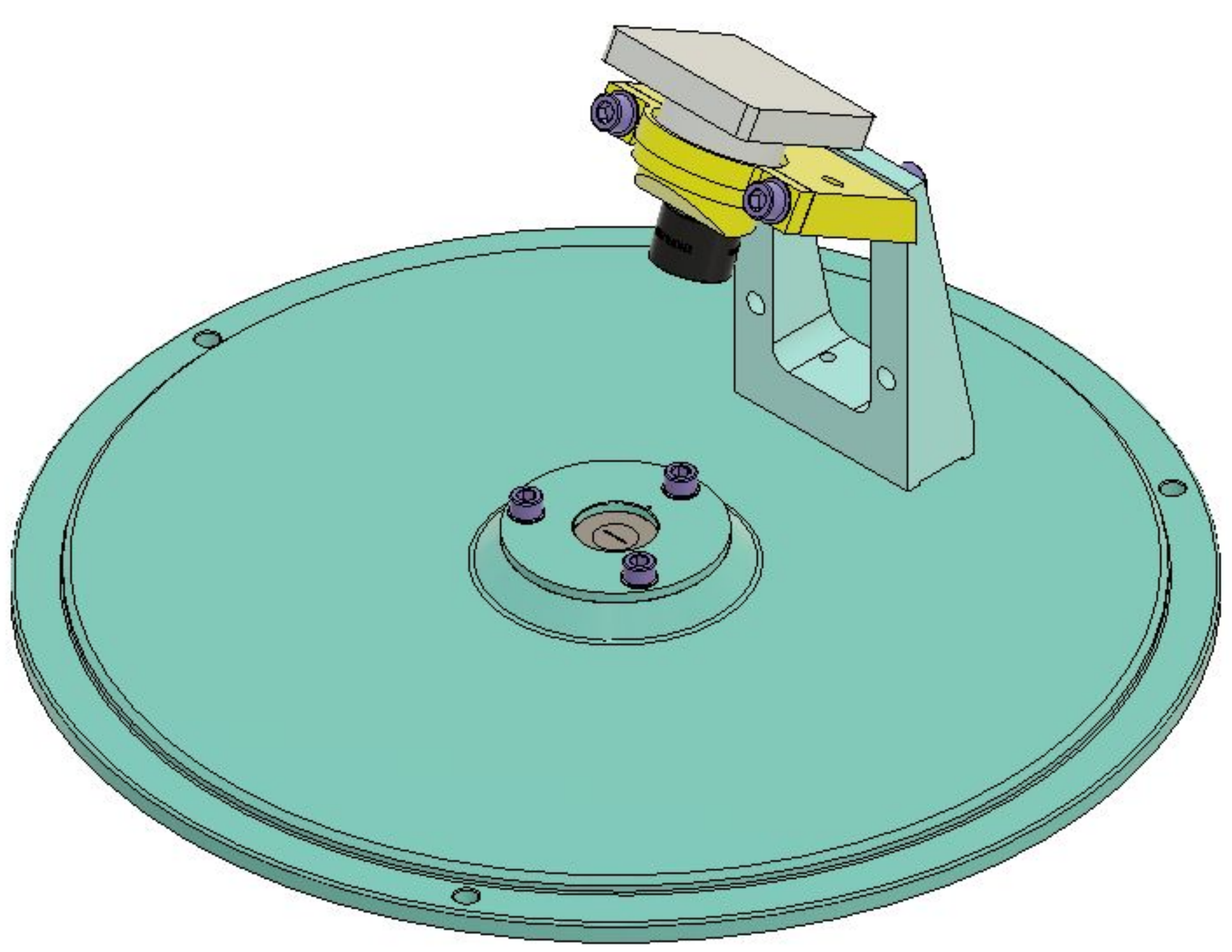
1. The radiometry estimations suggest very low visible light levels reaching the Slit-Jaw system.
2. The off axis mounting position of the camera and lens means significant image distortion and narrow depth of focus.

The goal of this project was to determine a suitable CCD detector and identify a COTS lens that is optimized to address the challenges identified.

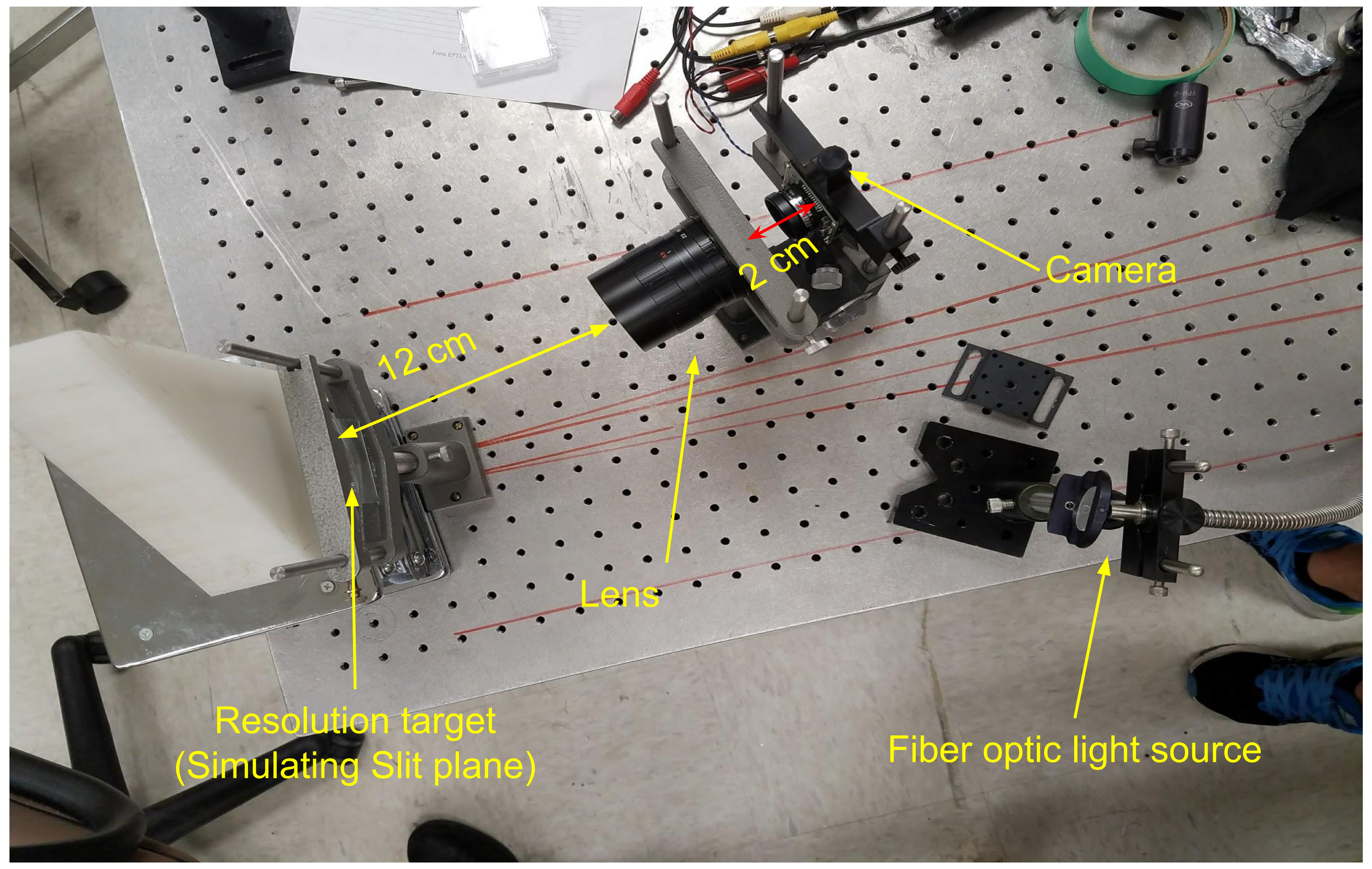
MaGIXS Instrument Design







Mechanical CAD model of slit-jaw flight optics



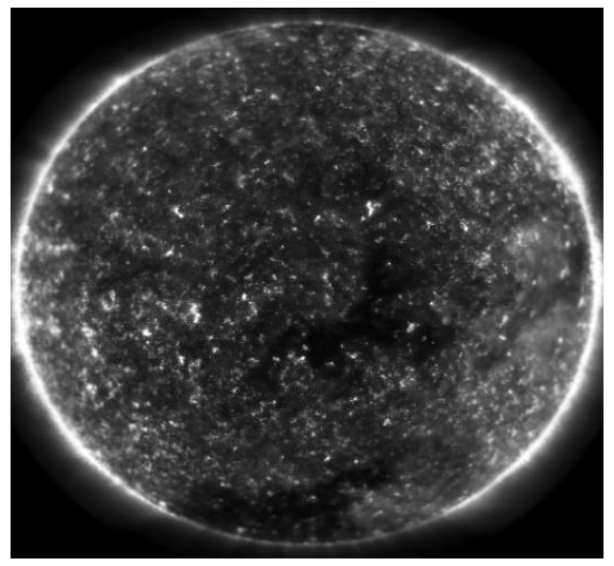
Lab setup for lens and camera testing

Slit-jaw testing and calculations

Tests were conducted with Sony XC-555 and Watec 910BD EIA CDD NSTC TV cameras. A model of the slit-jaw imaging system was set up on a optics bench, where the optical path and opto-mechanical envelope were marked. A resolution target was illuminated by a variable intensity, white-light fiber optic source. The camera output was routed to an analog-to-digital converter/media viewer. The digital video out was connected to a laptop through a FireWire cable where a media viewer was used to display and capture video. Various lenses were tested to determine the distortion caused by the off-axis mounting locations as well as the the field of view and resolution.

Radiometry calculations were performed using estimated values of the emitted solar flux integrated over the EUV band from 100 nm to 10 nm, for the case of an active region. Mirror reflectivity of the grazing incidence mirrors were calculated using the CXRO database. We assume an efficiency of the fluorescent Lumogen coating across the EUV band is 10%. Using this information, the irradiance reaching the Slit-Jaw detector was estimated to be 2.96E−8 sr*cm^2. The irridiance was then converted to photometric units using an approximation at 555 nm, then converterd to radiant intensity (as measured at the slit-jaw plate) in lumens for the purpose of selecting a CCD detector. The Watec camera has a manufacturer quoted sensitivity of 0.0001 lux, with a F1.2 lens, and 0.00005 lux sensitivity with extended integration mode.

Tests with various CS-mount lens are very promising and show that the selected camera is suitable for use on the instrument after pairing with a lens and ruggedizing the system. Spacer adapters make it possible to use the CS-mount lens with a C-mount camera and still focus on a 1 cm^2 target 10 cm away.



Simulated slit-jaw image

Results

Radiometric calculations determined that the irradiance of the light from the Lumogen-coated slit-jaw will be much dimmer than was originally assumed. This realization meant that a low light (high sensitivity) monochrome camera was needed for this application. The Watec 910BD EIA CCD camera was selected and tested in the lab with various lens combinations. Two targets were imaged: a grid of concentric rectangles with dot diameters of 1.0 mm, 0.5 mm and 0.25 mm, and a 1951 Air Force resolution target. The tradeoff between aberration of a lens with a fully-open aperture and the need to gather enough light to avoid dark and grainy images has been addressed by using lenses with a relatively large apertures and short focal lengths. // Final radiometry information

Mounting the camera off the optical axis of the telescope may induce distortion of the solar image. This distortion shall to be quantified and corrected by writing or using existing image correction software. The angle with the optical axis causes one edge of the slit-jaw plate to be slightly farther away than the other, resulting in poor depth of field. Our test show that with a macro lens, the depth of focus is very small, and in this case, the full 1 cm^2 field of view will not be in focus. The outer edges of the image will be out of focus. One solution may be to increase the depth of field digitally through the use of a focus stacking program. This is one solution that the team will investigate. // Context imaging and control flight software

All in all, we demonstrated that the detector has impressively good quality low-noise performance. We also identified candidates for a macro lens that provide good resolution, an adequate FOV, and can easily fit within the defined envelope in the telescope section of the experiment. //More specific science and engineering objectives

Acknowledgments

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