Electronics prototypes for the Giant Magellan Telescope Multi-object Astronomical and Cosmological Spectrograph (GMACS)

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Abstract

We describe the current electronics prototypes for the Flexure Compensation System (FCS) and the Slit Mask Exchange Mechanism (SMEM) for GMACS, a wide-field, multi-object, moderate-resolution optical spectrograph for the Giant Magellan Telescope (GMT). We discuss the details of the FCS and SMEM prototypes, how the prototypes relate to the preliminary conceptual designs of these systems, and what information the prototypes give that can be applied to the final design, as well as the possible next steps for each prototype.

Current GMACS Concept

Important factors for GMACS are its high throughput, simultaneous wide wavelength coverage, accurate and precise sky subtraction, moderate resolution, wide field, and minimized time spent not collecting data. The Flexure Compensation System (FCS) and Slit Mask Exchange Mechanism (SMEM) enhance and support these factors. The FCS maintains the optical alignment of the gratings and camera arms that achieve the simultaneous wide wavelength coverage and adjustable resolution. The SMEM changes the slit masks in the focal plane between exposures for minimal downtime. Prototyping these subsystems help develop and improve the subsystems' designs.

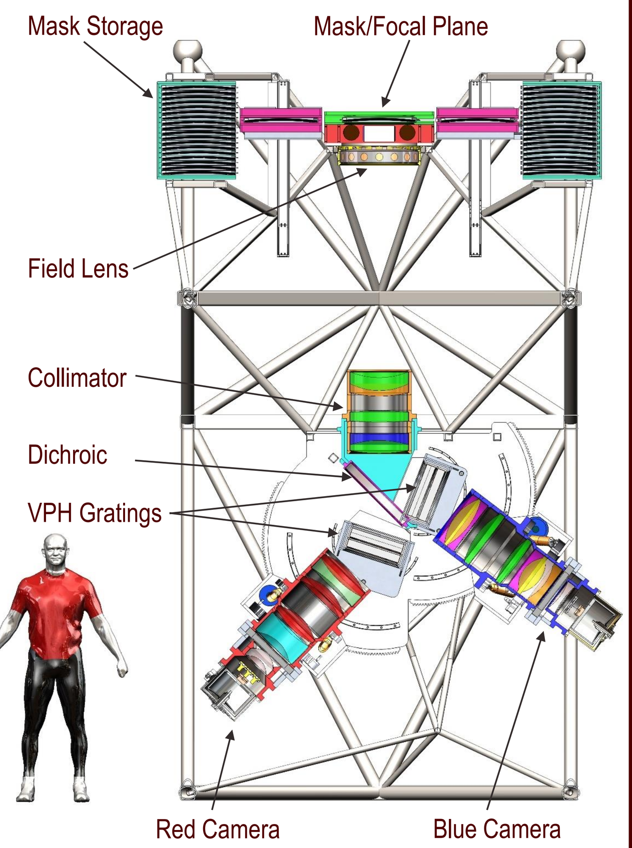

Figure 1. The current design concept[1] for GMACS. Light enters the focal plane at the top of the instrument, passes through the collimator, and is split at the dichroic. From there, the light passes through VPH gratings and enters the red and blue camera arms.

Flexure Compensation System (FCS) Prototype

Under normal conditions, large structures experience some flexure under the structure's own weight. This flexure can usually be predicted and accounted for. However, as the GMT rotates and changes position, the gravity vector on GMACS will change. This changing gravity vector will cause the instrument's flexure to change. If the instrument's flexure changes, the optics become misaligned.[1]

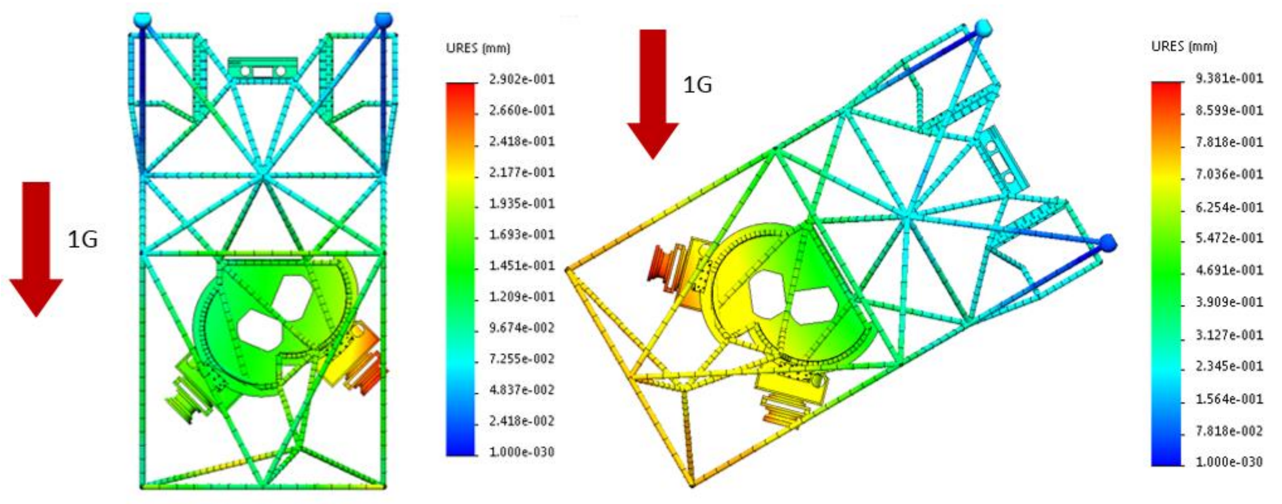

Figure 2. The flexure of GMACS at zenith and when the GMACS is rotated 60 degrees about the X axis. The instrument and camera arms are affected by gravity, forcing the optics out of alignment

To maintain the optics' alignment during telescope operation, the positions of the focal plane, VPH gratings, and camera arms need to be adjusted slightly. The FCS mounts the VPH gratings and camera arms to large hexapods that can adjust the positions of the VPH gratings and camera arms in six dimensions with micrometer precision.

Physik Instrumente (PI) lent an H-840.D2 hexapod with an EtherCAT slave controller. The EtherCAT controller takes motion commands from the EtherCAT master PC and translates them into motion of the individual hexapod actuators. The Beckhoff EtherCAT master PC runs Beckhoff TwinCAT 3.0. The program written for this prototype is controlled by the user through a TwinCAT GUI.

We currently expect that positional feedback to the control system for the hexapods will come from lasers mounted on the VPH gratings and camera arms and pointed at lateral sensors. The sensor measures the displacement of the laser beam relative to the center of the sensor. The sensor returns the X and Y position of the laser beam, and the hexapod moves to recenter the beam. To reflect this in the FCS prototype, a Thorlabs PDP90A lateral sensor is mounted to the hexapod, and a 5 mW 632.8 nm laser points at the center of the lateral sensor.

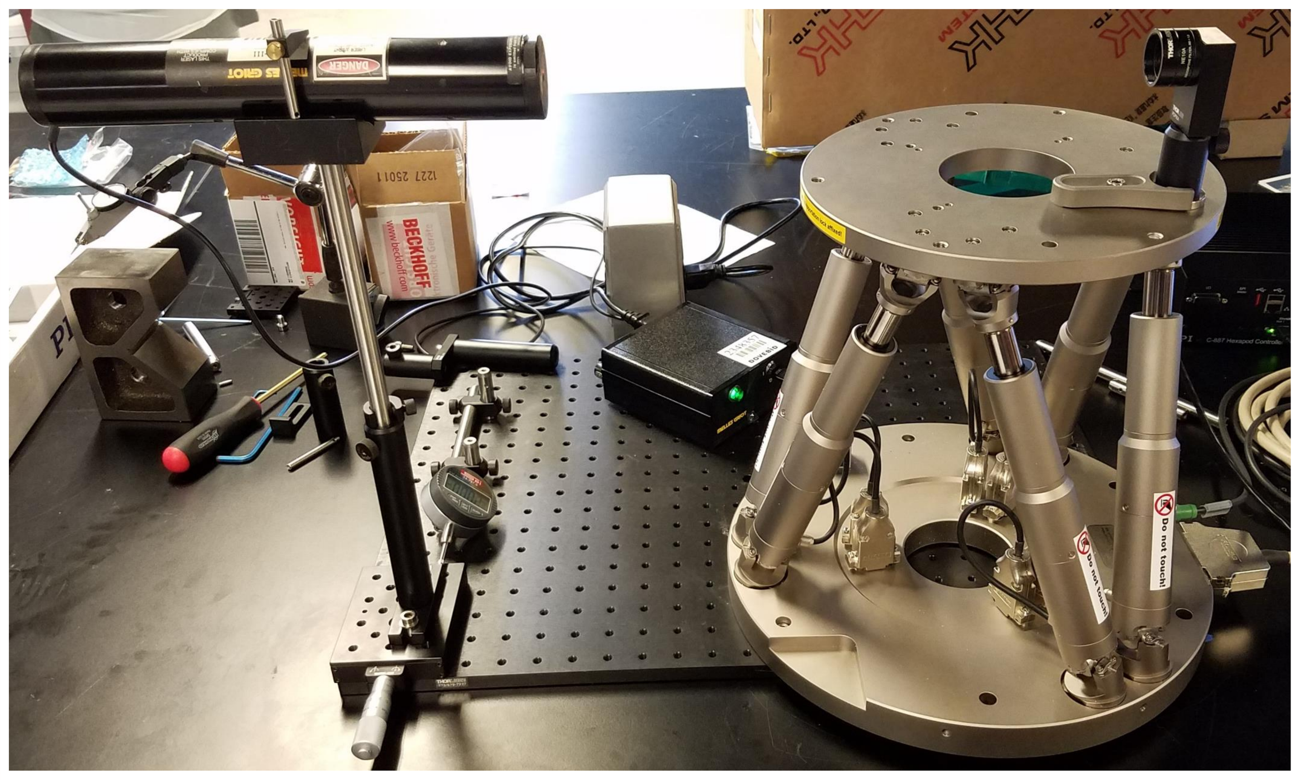

Figure 3. FCS prototype test setup, with the laser on the left and Thorlabs PDP90A lateral sensor mounted to the hexapod on the right.

The laser shines on the lateral sensor, and the sensor sends the coordinates of the beam to the EtherCAT master PC as two analog signals. The analog signals are read by the EL3002 Beckhoff 2-channel analog input terminal, and the position of the beam is calculated and displayed by the program. The program commands the hexapod to move to return the laser beam to the center of the lateral sensor.

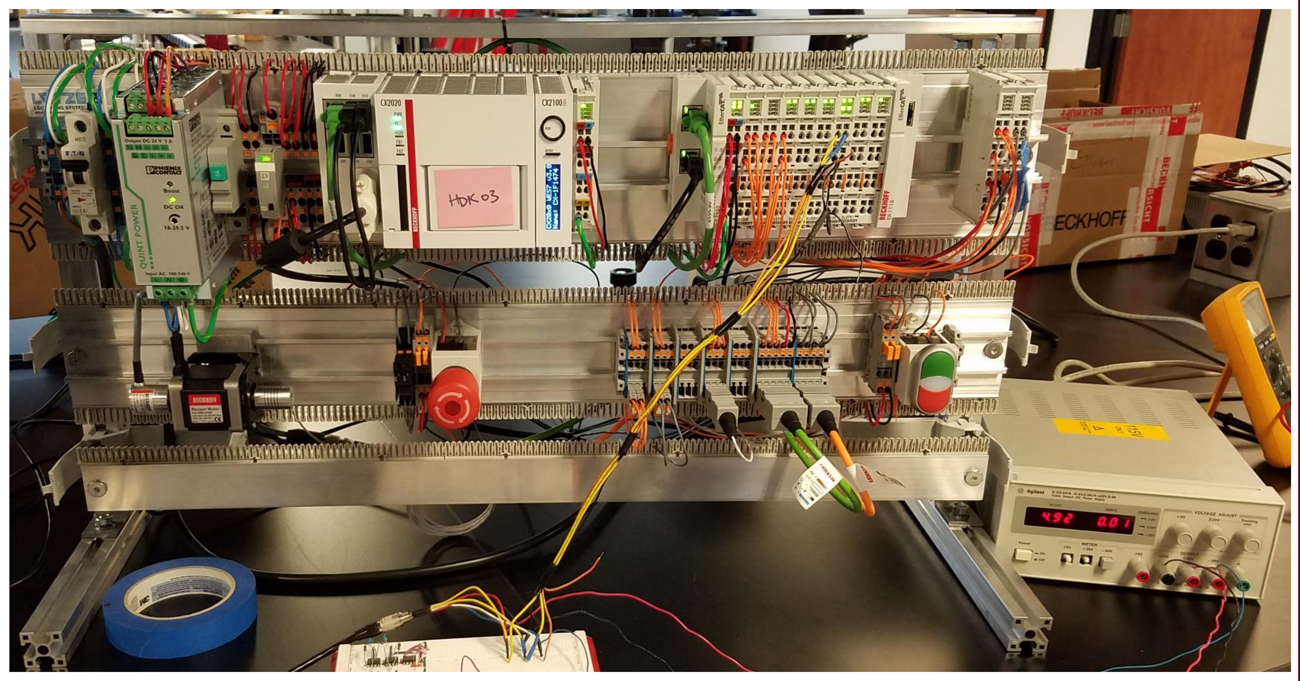

Figure 4. Beckhoff CX2020 EtherCAT master PC and Beckhoff EtherCAT terminals.

Possible next steps for the FCS prototype include PI designing a hexapod capable of holding the GMACS optics and the GMACS team deciding how the laser beam will interact with the optical path or using a different method for positional feedback. The next prototypes need to test the hexapod handling the torque and weight of a camera arm and integration with the GMACS software team's user software.

Slit Mask Exchange Mechanism (SMEM) Prototype

The SMEM is a jukebox style mechanism that retrieves slit masks from the focal plane, places the slit masks in an empty slot in the magazine, retrieves the next slit mask, and places it in the focal plane. Two vertical linear actuators (VLAs) raise and lower the elevator that houses the slit mask in transit. A horizontal linear actuator (HLA) moves the slit mask from the magazine to the elevator and the elevator to the focal plane. On the HLA is a grabber that retrieves the slit mask from the slit mask magazine.

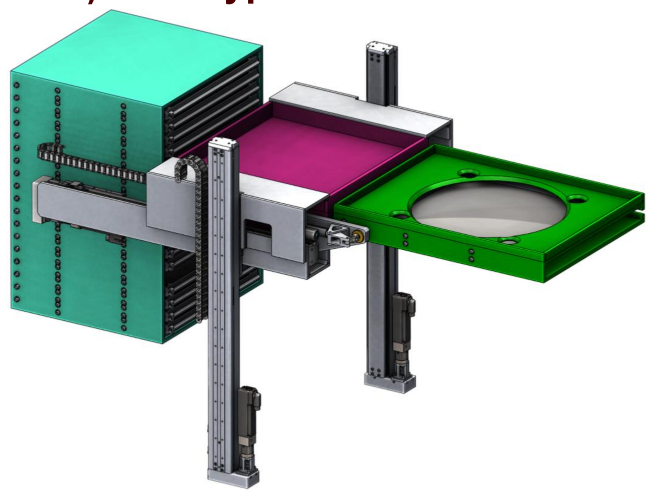

Figure 5. The SMEM has two vertical linear actuators (VLAs), one horizontal linear actuator (HLA), a grabber on the HLA, and a slit mask magazine.

The SMEM prototype is a 90% scale of the horizontal portion of the slit mask elevator. The slit mask holder is mounted on a THK linear actuator, which is powered by a Beckhoff motor controlled by a Beckhoff EtherCAT terminal and Beckhoff EtherCAT master PC.

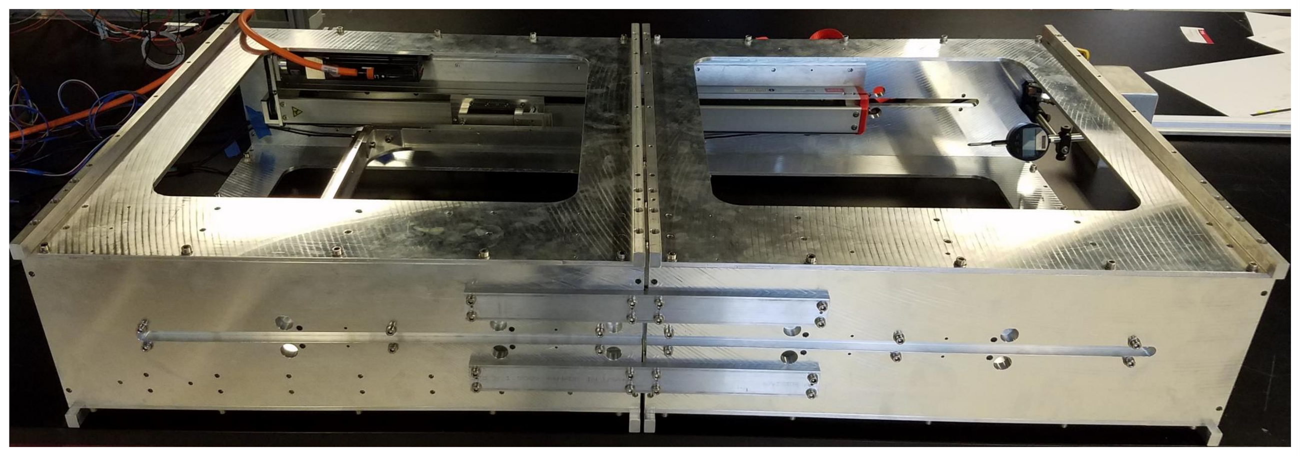

Figure 6. The SMEM prototype with a THK rail and Beckhoff motor.

To simulate the changing gravity vector, the SMEM prototype was ran in several different orientations. The slit mask holder needs to be redesigned to ensure the leading roller does not get caught in the gap when the SMEM is rotated.

A user can control the prototype with one of two GUIs, one created in TwinCAT and one created in Visual Studio C++ in collaboration with the GMACS software team to practice integrating their portions of the GMACS software with the EtherCAT control software.

Possible next steps for the SMEM prototype include adding linear encoding, mounting half of the prototype to two vertical linear actuators (VLAs), and prototyping the slit mask grabber design.

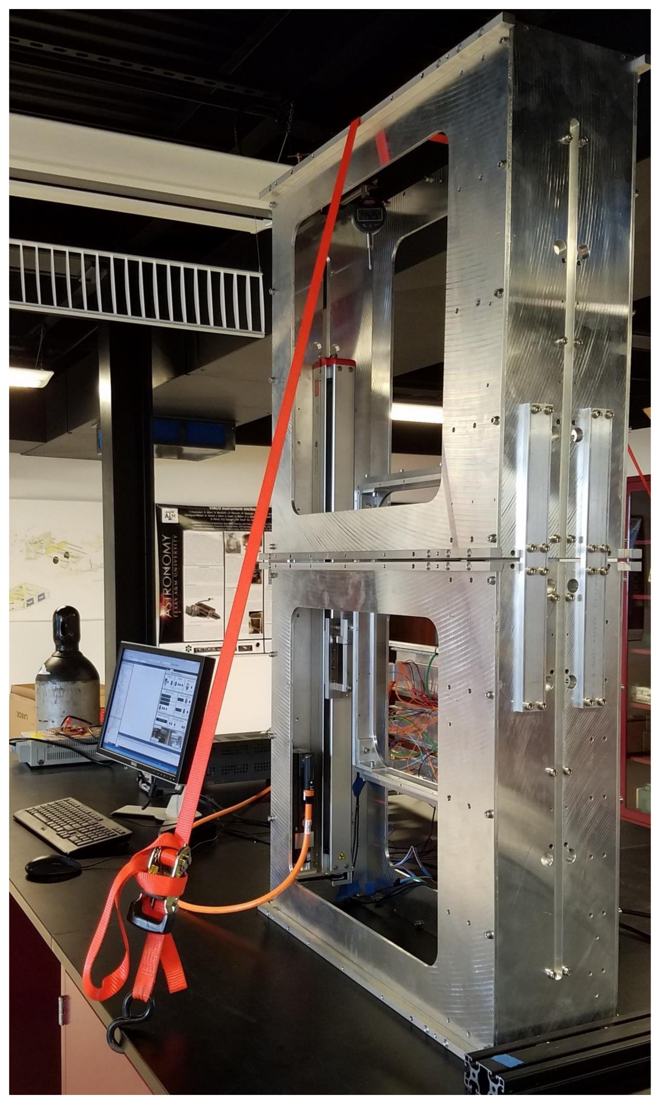

Figure 7. The SMEM prototype rotated.

Improving these prototypes and GMACS's subsystem designs is an iterative process that will continue throughout GMACS's development.

References

[1] Prochaska et al. "Optomechanical design concept for the Giant Magellan Telescope Multi-object Astronomical and Cosmological Spectrograph (GMACS)" Proc. SPIE 9908, Ground-based and Airborne Instrumentation for Astronomy VI, 9908375 (June 30, 2016)

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