An Airborne Infrared Spectrometer (AIR-Spec) for Solar Eclipse Observations

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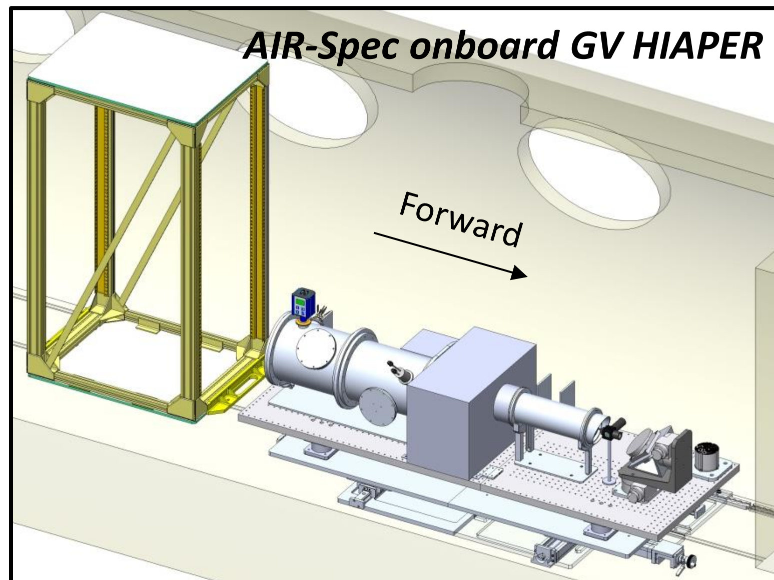
AIR-Spec Mission

AIR-Spec will measure **5 magnetically sensitive coronal emission lines** during the **2017 total solar eclipse** from the **NSF/NCAR GV HIAPER**.

- Opens an IR window into the solar corona
  - First time for high resolution, high sensitivity coronal imaging spectroscopy, 1.4 – 4 µm
  - Pathfinder for observations of coronal magnetic fields
- Provides a platform for high-resolution stabilized imaging on GV HIAPER
  - Enables new science in solar and atmospheric physics

*NSF/NCAR **G**ulfstream-**V** **H**igh-performance **I**nstrumented **A**irborne **P**latform for **E**nvironmental **R**esearch (GV HIAPER)*

https://www.ucar.edu/communications/staffnotes/0504/hiaper.html



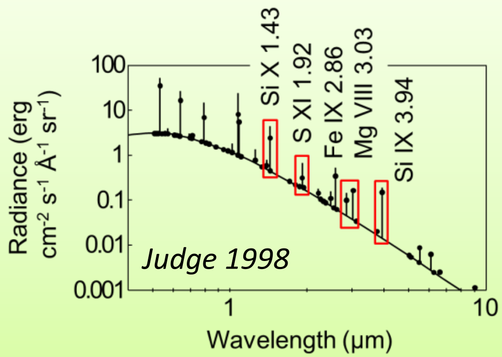
Outline

- Science goals
- Experiment overview
- Instrument design
  - Optical system
  - Predicted optical performance
  - Image stabilization system
  - Predicted stabilization performance
- Mission planning
  - Flight track
  - Observation plan
  - Test flight sequences

Science Goals

Success Criteria

1. Identify one of the following spectral lines:
   Si X: 1.43 µm, **Si XI**: 1.92 µm, **Fe IX**: 2.86 µm, **Mg VIII**: 3.03 µm, **Si IX**: 3.94 µm
2. Demonstrate successful operation of the spectrometer during the eclipse or a test flight

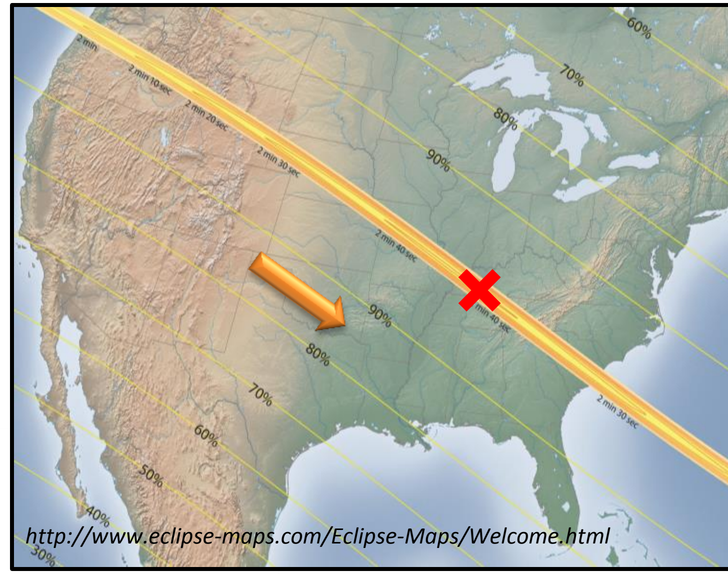


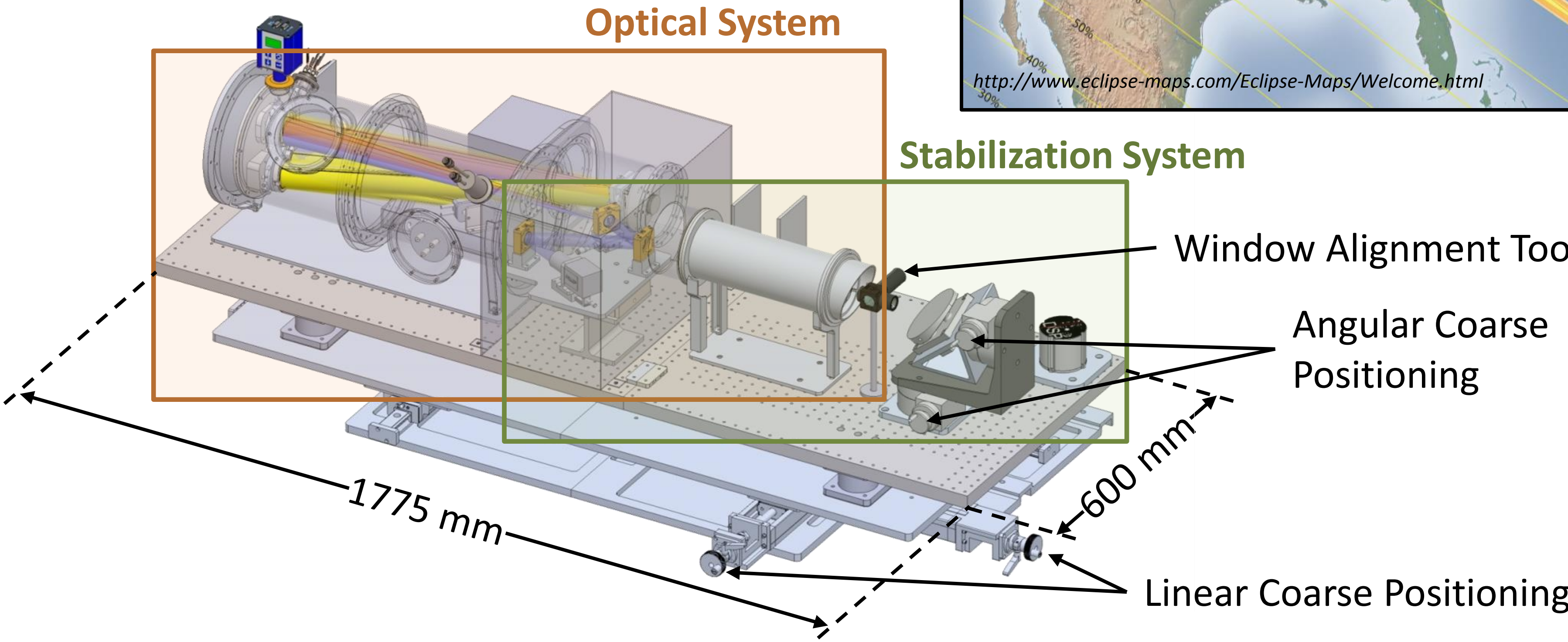
Science Goals

1. Identify line strengths as a function of position in the solar corona
   – Can any of these magnetically sensitive lines be used by future instrumentation to constrain the magnetic structure of the corona?
2. Search for high frequency waves in multiple lines at multiple locations in the corona
   – These waves are candidates for heating and acceleration of the solar wind
3. Identify large scale flows in the corona, particularly in polar coronal holes
   – Three lines are expected to be strong in coronal hole plasmas because they are excited in part by scattered photospheric light
   – Line profile analysis will probe the origins of the fast and slow solar wind
4. Complement ground based eclipse observations to provide detailed plasma diagnostics throughout the corona
   – AIR-Spec will measure IR emission of ions also observed in the visible and EUV
   – The combined measurements will give insight into plasma heating and acceleration at radial distances inaccessible with existing or planned spectrometers

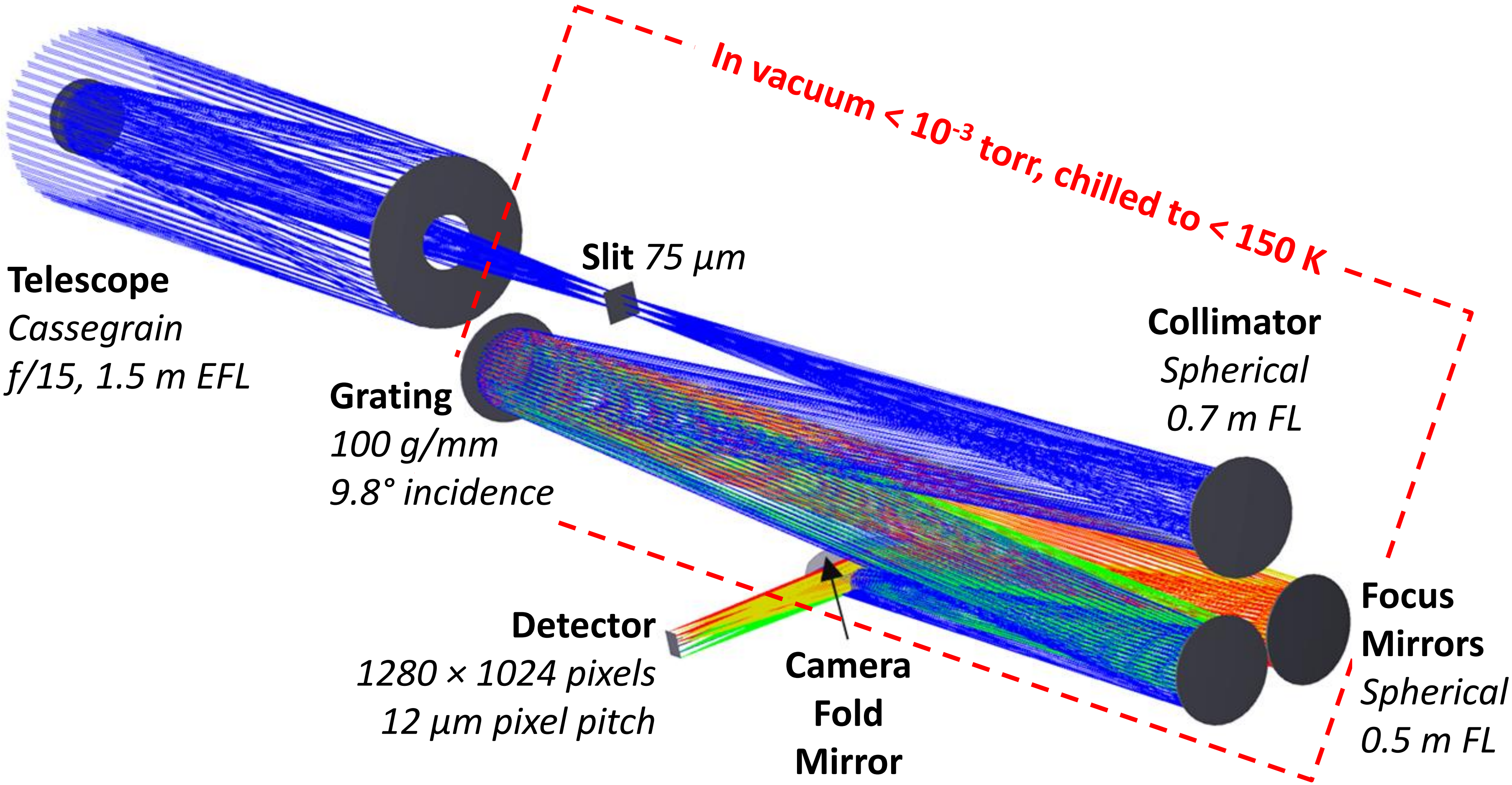
Experiment Overview

- Total solar eclipse on August 21, 2017
  - 4 minute duration in the air
- Platform: NSF/NCAR HIAPER GV
  - 50,000 ft, 900 km/hr
  - 5.9 inch ZnSe viewport
- Location: SW Kentucky (near max duration)
- Time: near local noon



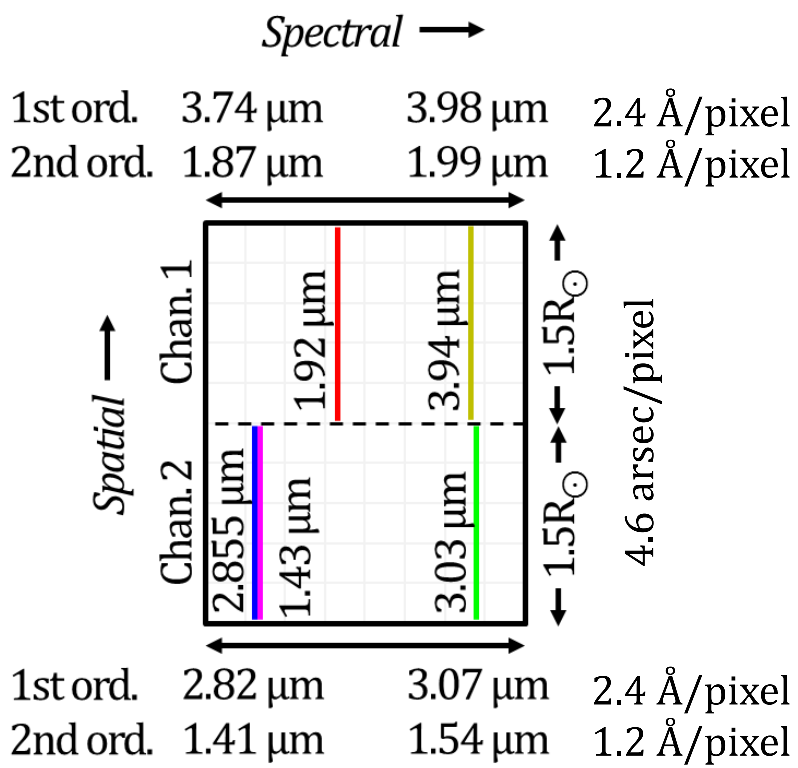


Optical Design

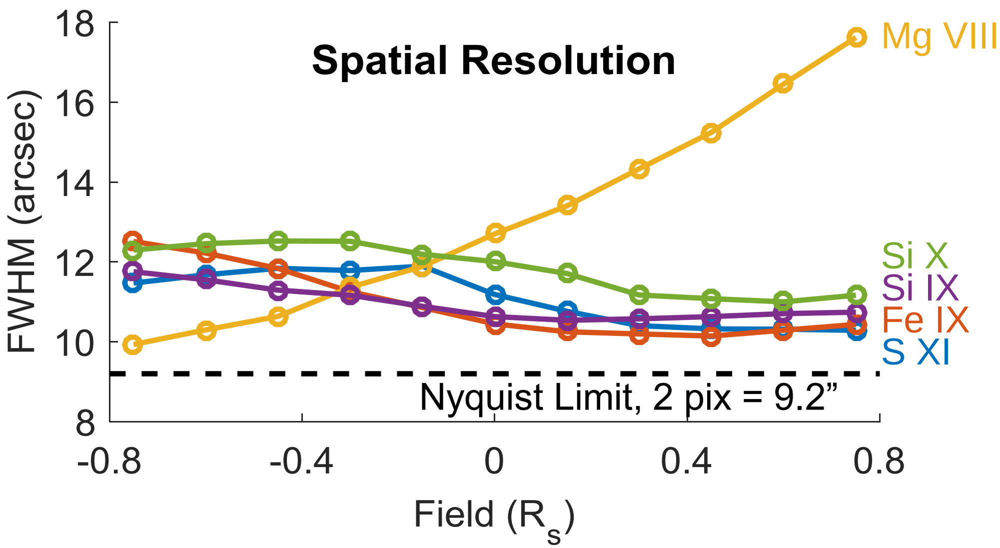


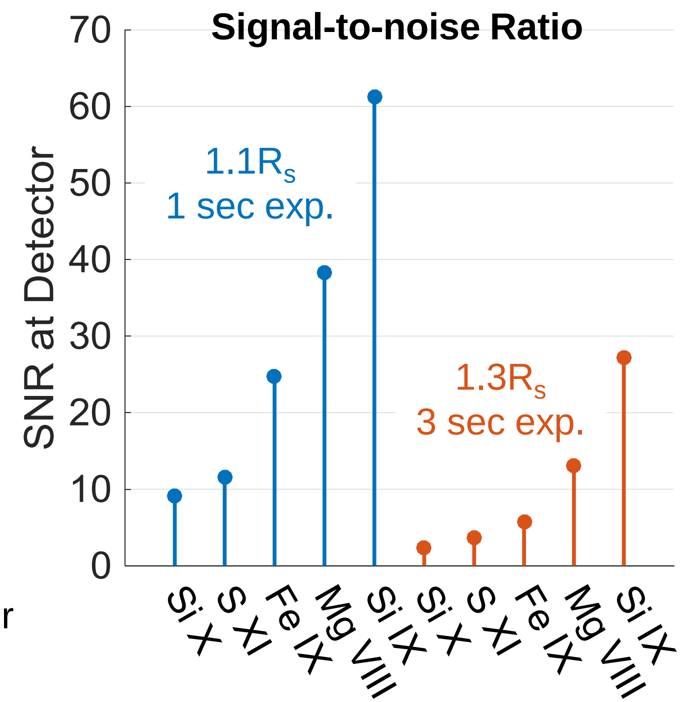
IR Camera and Image

- IR Cameras modified IRC912
- InSb focal plane
  - 1 – 5.3 µm sensitivity
  - 1280 x 1024 pixels, 12 µm each
  - 50,000 e⁻ well depth
  - 95% quantum efficiency
- Closed-cycle cooler < 50 K
- Thermal background reduction
  - Cold aperture limits FOV
  - Bandpass filter removes light from 3.1 to 3.7 µm and above 4 µm



Predicted Optical Performance





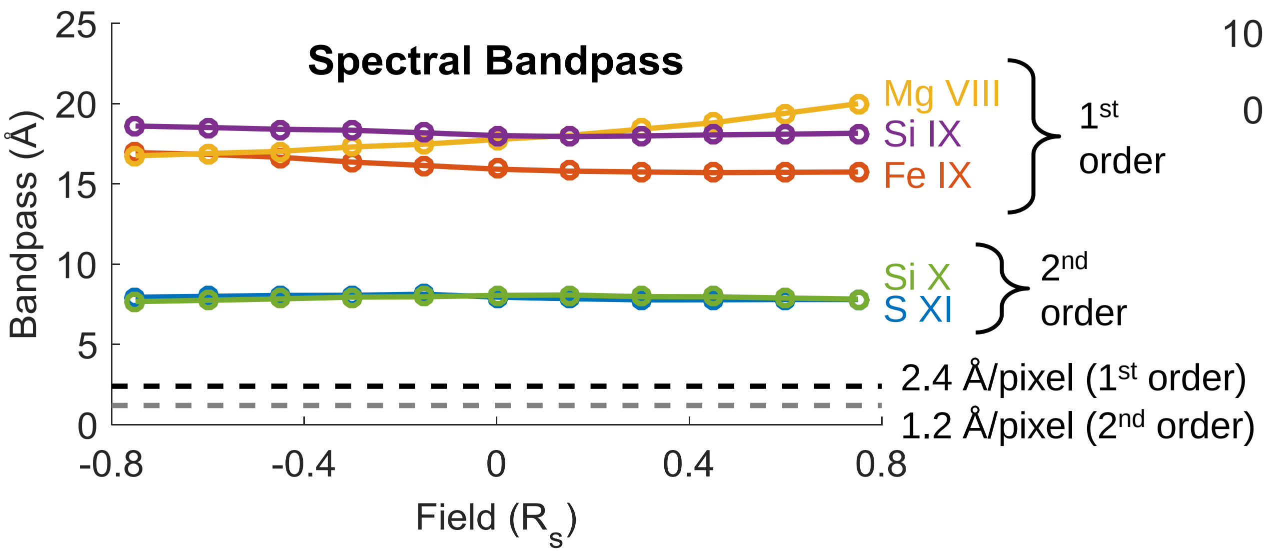
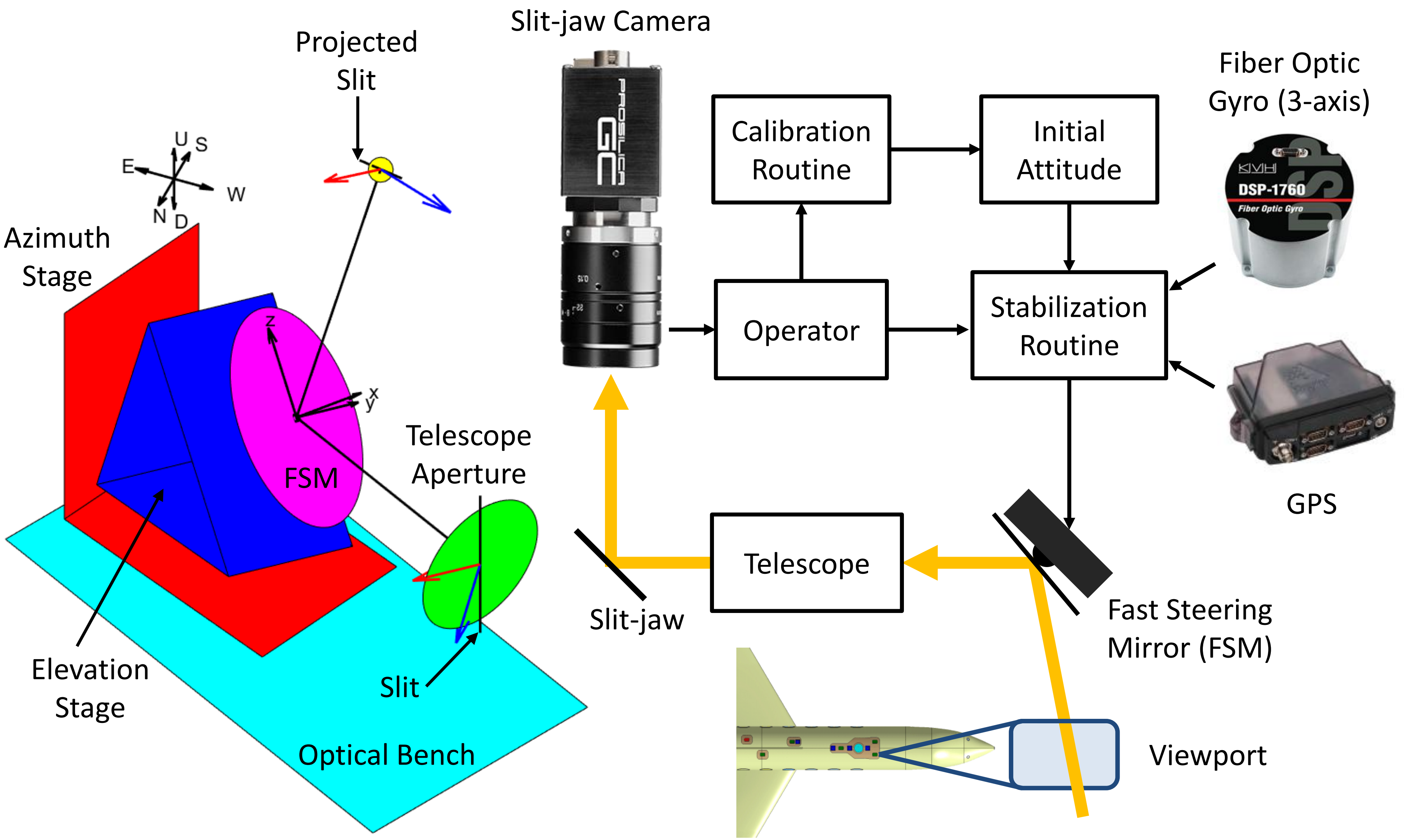
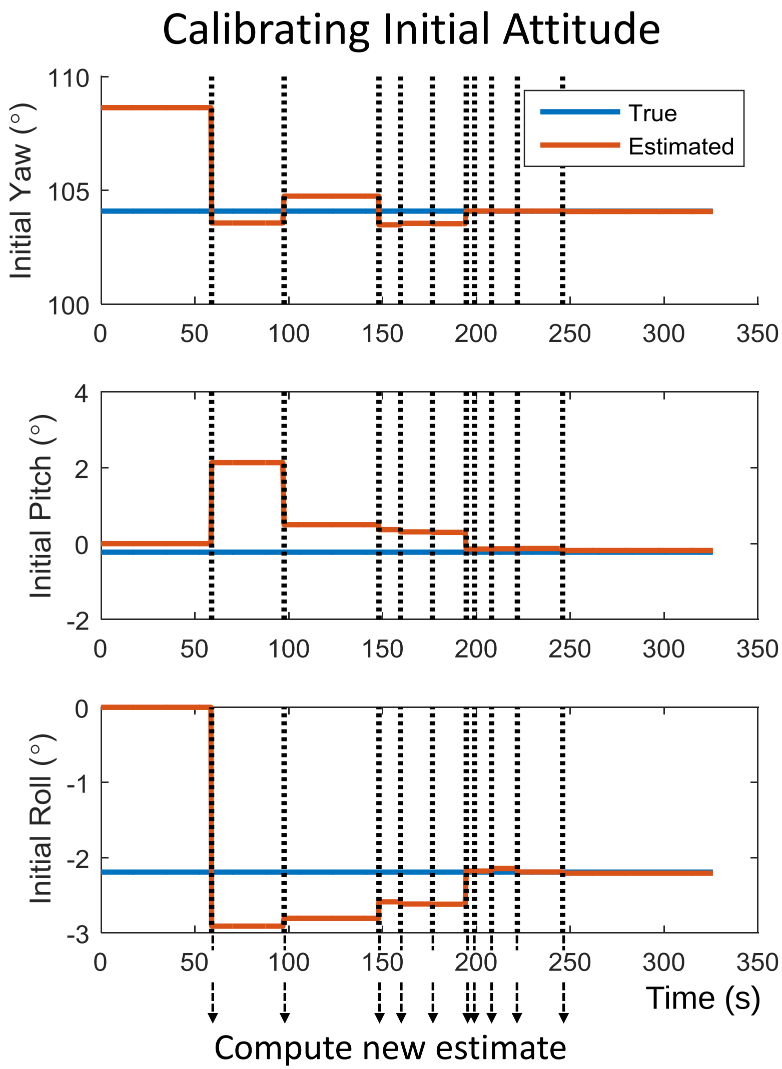
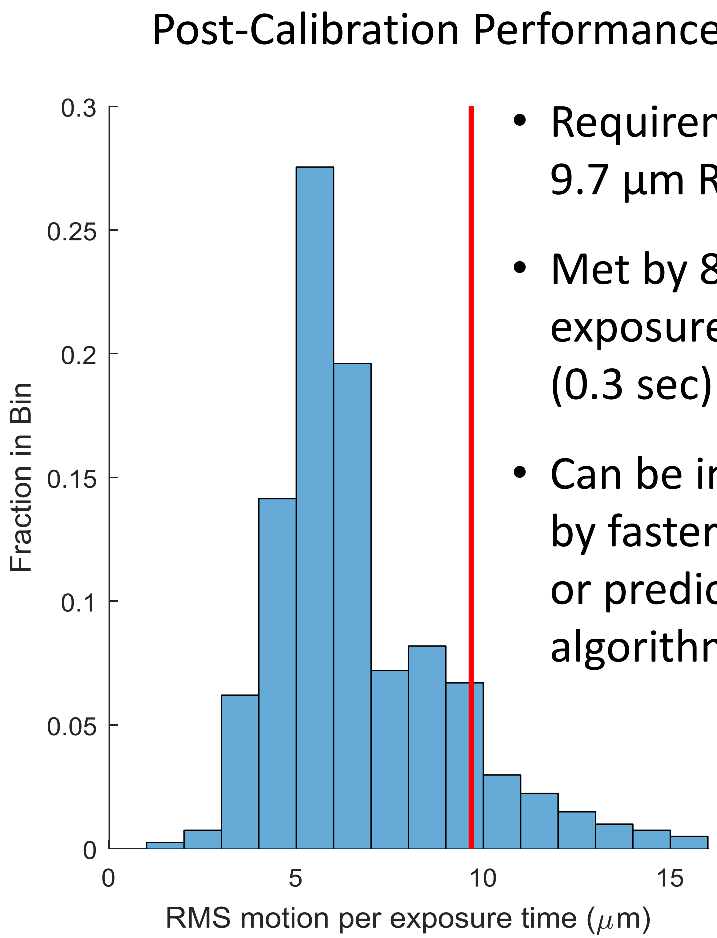


Image Stabilization System



Stabilization Performance





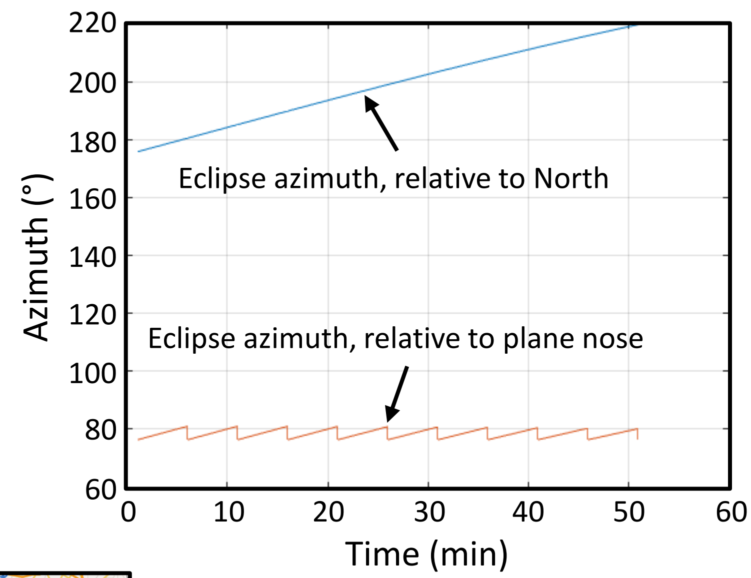
- Requirement: 9.7 µm RMS
- Met by 89% of exposure times (0.3 sec)
- Can be improved by faster sampling or predictive algorithm

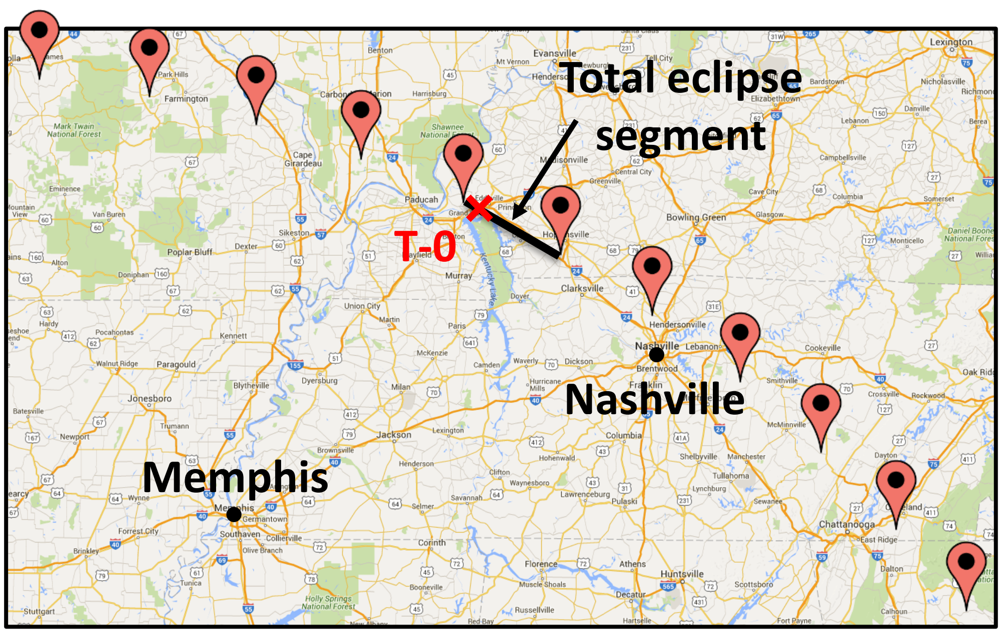
Flight Track

Eclipse observation requirements:

1. Plane is straight and level during totality
2. Coarse positioning happens >15 minutes before totality
3. Coarse positioning happens with the partial eclipse in the window

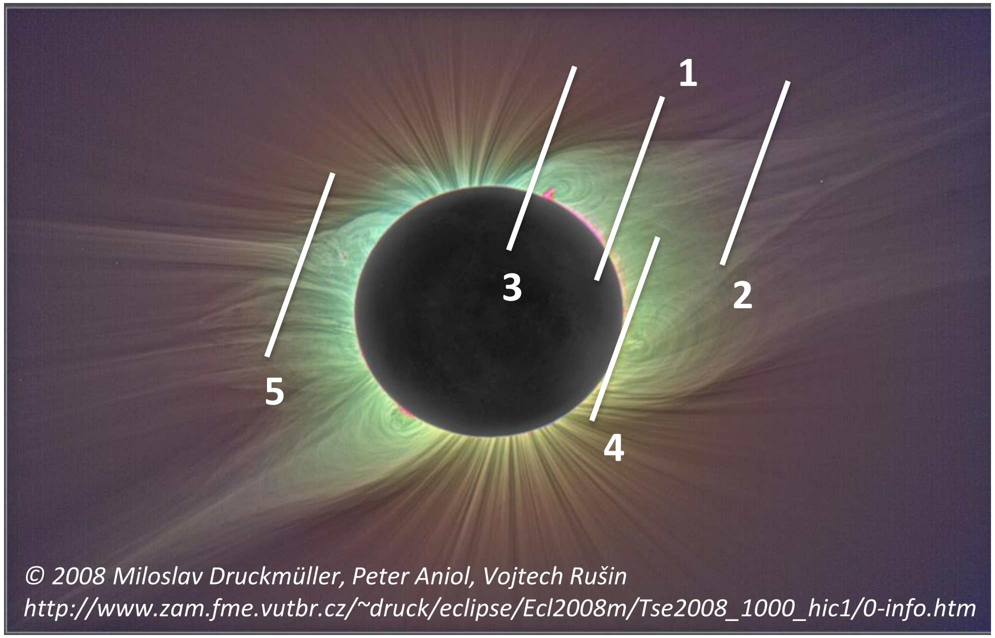
➔ Turn the plane to compensate for the changing azimuth of the sun: **circular course into and out of totality**





- 5 minute linear segments
- 910 km/hr ground speed
- Starts 20 minutes before totality
- Ends 25 minutes after totality

Draft Observing Plan



Slit Position	Move & Settle (s)	Time on Target (s)	Exposure Time (s)	Number of Images	Description
1		130	0.3	433	Initial slit position based on slit jaw image. Low corona across streamer if possible.
2	5	65	0.3	217	High corona extending in coronal hole.
3	5	45	0.3	150	Coronal Hole
4	5	45	0.003	15000	Flash spectrum at solar limb
	15	**285**	**Total Time (s)**		**300**
5	5	120	0.3	400	Data taken after 3rd contact

Test Flight Sequences

Flight Sequence	*Dates*	*Target*	*Goals*
1	November 2016	Moon	Test image stabilization and flight path timing
2	April 2017	Sun	Test overall system performance, measure photospheric absorption lines as proof of concept
3	August 2017	Sun	Test overall system performance, refine procedures leading up to the eclipse
	August 21, 2017	**Eclipse**	**Science flight**

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