

Wide Field Imaging Spectrometer (WFIS) – Instrument Design and First Field Tests. H. R. Pollock¹, R. E. Haring¹, B. Sutin¹, J. Mustard², and J. Boardman³, ¹Hamilton Sundstrand, 2771 N. Garey Ave, Pomona, CA 91767 randy.pollock@hs.utc.com/ robert.haring@hs.utc.com/ brian.sutin@hs.utc.com, ²Brown University, Department of Geological Sciences, Box 1846, Brown University, Providence, RI 02912, John_Mustard@brown.edu, ³AIG Inc, 4450 Arapahoe Ave. Suite 100, Boulder CO 80303, boardman@aigllc.com

Introduction: WFIS is a new instrument concept that provides hyperspectral images with a compact system. WFIS is an all-reflective, wide-field-of-view imaging spectrometer [1]. WFIS was originally developed for high spectral resolution Earth science applications associated with atmospheric monitoring, but also works well in near-field applications (e.g. planetary landers). A flight-like opto-mechanical WFIS engineering model was constructed and has been used to demonstrate data collection techniques and to provide representative data for simulations for future applications.

Instrument Design: WFIS consists of three major components: an extremely wide field-of-view telescope, a pair of field mirrors and a modified Offner spectrometer. This system provides an unprecedented swath for an all-reflective system (Figure 1). By avoiding refractive elements, it is much easier to

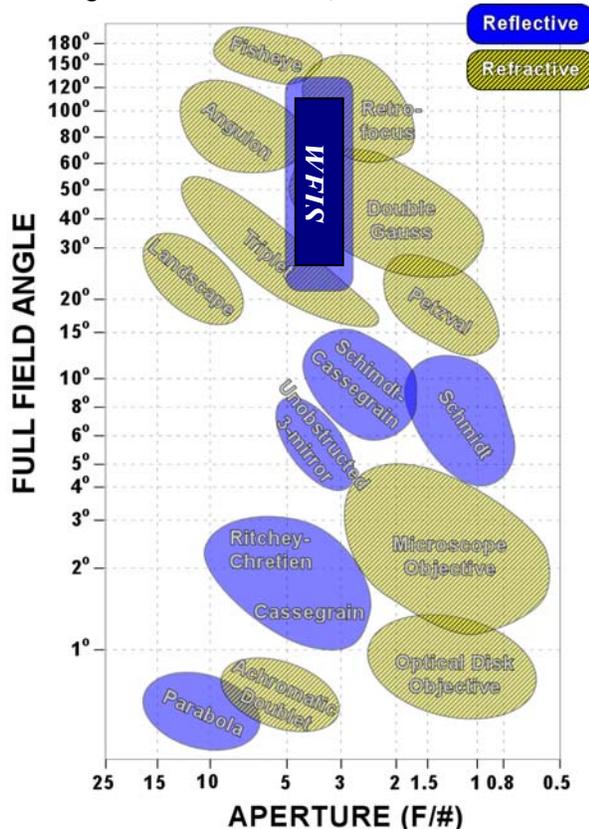


Figure 1: WFIS provides a much higher field of view than traditional reflective optical systems, while still providing a fast system for high sensitivity observations.

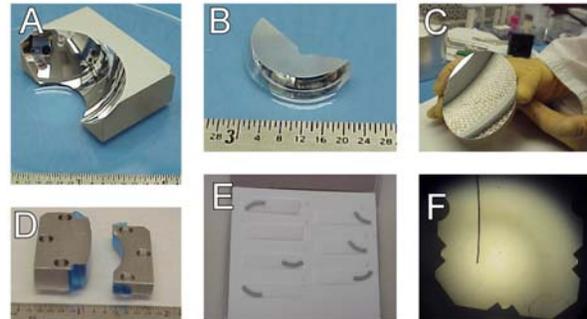


Figure 2: WFIS optical elements: A) Telescope secondary mirror, B) Telescope primary mirror, C) Collimator mirror, D) Field mirrors, E) Slits, and F) Slits (magnified).

achieve excellent spectral performance over a wide range of wavelengths (i.e. no chromatic aberration to correct).

Telescope. The telescope is a two mirror Schwarzschild telescope (Figure 2A&B). This provides an unobstructed system with uniform imaging quality over the entire 120° swath. The telescope ends with a slit (Figure 2E&F). This slit serves as the field stop of the system and the entrance slit of the spectrometer. The slit is curved to match the Schwarzschild image plane.

Field Mirrors. To match the curved slit to a flat focal plane, WFIS uses a pair of field mirrors (Figure 2D). The first field mirror is an anamorphic off-axis aspheric surface that is “potato chip” shaped (the vertices of the two radii of curvature are on opposite sides of the surface). The second field mirror is a convex aspheric toroid with both vertices on the same side of the substrate. The result is that – when viewed from behind these mirrors – the slit appears to be flat – exactly what is needed for coupling with a traditional 2D area array.

Spectrometer. WFIS uses a modified Offner spectrometer. It consists of a single-mirror collimator, a convex holographic grating and a single-mirror camera. This maintains the low f/# of the front-end and minimizes the volume requirements. It also provides a system with minimal keystone and spectral smile [2]. A two-band order isolation filter allows the instrument to operate over more than a single free-spectral range.

Instrument Parameters: As a technology demonstration, WFIS was designed to operate in the visible and near infrared (limited by the silicon CCD). It covers from 360 to 1,000 nanometers with a spectral resolution of ~1.0 nanometers. Since the system is all



Figure 3: WFIS (black box in center of picture) on its rotary stage cradle during the first outdoor imaging experiment.

lution of ~ 1.0 nanometers. Since the system is all reflective, it can easily be adapted to any wavelength range through changes in the surface coatings and the detector. The spatial resolution is 1.0 milliradian.

Experiment Design: Since WFIS is a “push-broom” spectrometer – only imaging in one dimension – it requires motion to build up a two-dimensional image. In typical push-broom applications, scanning is provided by the motion of a spacecraft (e.g. CRISM) or aircraft (e.g. AVIRIS).

A special cradle was designed to allow WFIS to be mounted with its slit vertical. In this configuration, it scans $\pm 60^\circ$ around the horizon with a simple rotary table (Figure 3). The rotary table motion is synced to the frame time of the focal plane to avoid motion blur.

The first “field” experiment was conducted in June of 2004 (Figure 4). The system provided excellent image quality for targets in the fore-ground (~ 1 meter) to the distance (~ 20 meters). The spectra clearly shows water vapor and oxygen absorption bands as well as clearly distinguishing between different materials and even different species of plants.

Experiment Goals: Due to the extremely large amount of data collected by imaging spectrometers, planetary applications will require on-board data processing. Most existing hyperspectral data sets have constant spatial resolution over the entire field of regard. In this application, WFIS has a constant angular resolution, but variable spatial resolution. This complicates autonomous feature recognition – spectra from the foreground are less likely to be mixtures than those from the horizon. Data analysis studies are on-going.

Conclusion: WFIS offers a significant advance from traditional point spectrometers. It can generate two-dimensional images with a simple rotary stage much faster and with better image reconstruction than point spectrometers. The existing unit will be invaluable in generating test data sets for various applications.

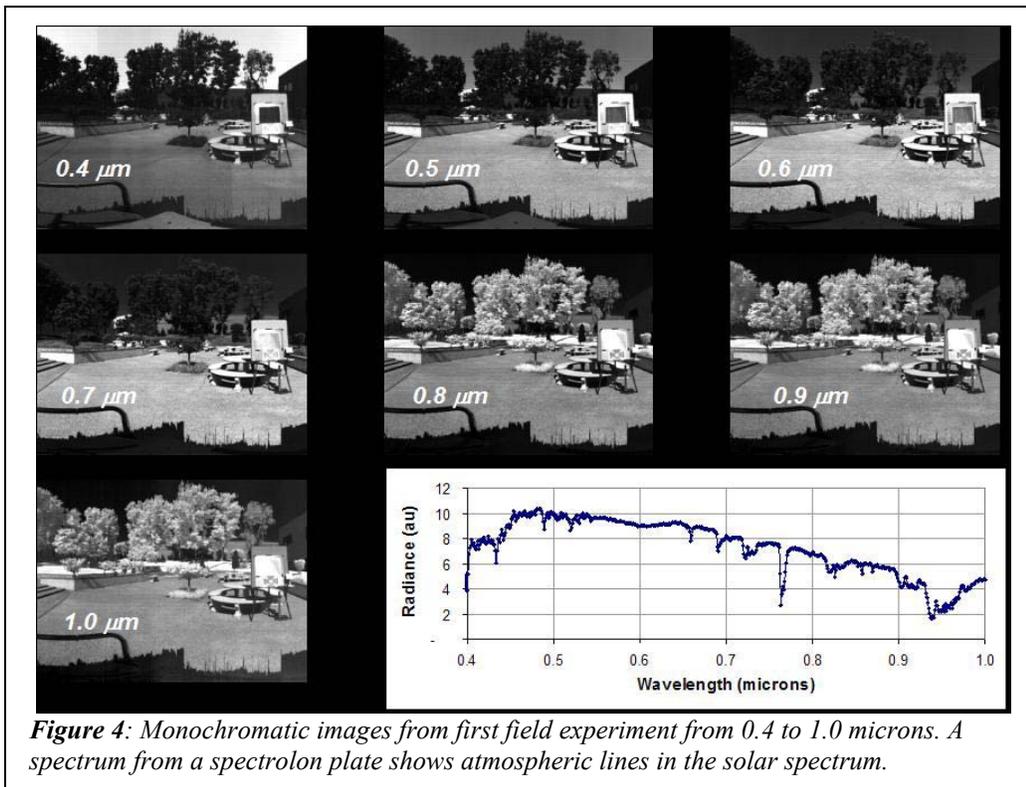


Figure 4: Monochromatic images from first field experiment from 0.4 to 1.0 microns. A spectrum from a spectrolon plate shows atmospheric lines in the solar spectrum.

References:

- [1] Macenka, S. A.; Hartmann; U. G.; Haring; R. E.; Roeder; H. A., Wide field-of-view imaging spectrometer, United States Patent #5,768,040, 1998
- [2] Haring, R., Pollock, R., and Cross, R., SPIE proceedings "Infrared Spaceborne Remote Sensing XI, Volume 5152 pages 51-60, 2003