Eos, Transactions, American Geophysical Union, Vol. 81, No. 10, March 7, 2000, Pages 101, 105

Low-cost Airborne Astronomy Imager to Begin Research Phase

For decades, airborne astronomy and geophysical observations have proven useful adjuncts to ground-based and space-based instrumentation, particularly for optical and infrared studies [e.g., *Larson*, 1995]. Compared to ground-based instruments, airborne research platforms offer superior atmospheric transmission, the ability to reach remote and often otherwise inaccessible locations over the Earth, and virtually guaranteed good weather for observing the sky. Airborne platforms also offer substantial cost advantages over space-based instruments. With funding from Southwest Research Institute (SwRI) and NASA, we have developed the hardware and techniques to routinely conduct valuable astronomical and aeronomical observations from high-performance, two-seater military-type aircraft. These platforms cost far less than larger, more conventional airborne platforms, offering savings that are often of an order of 10:1 per flight hour. Smaller platforms based throughout the world eliminate the need for expensive, campaign-style movement of specialized large aircraft and logistics support teams, and can react faster to transient events. The Southwest Ultraviolet Imaging System–Airborne (SWUIS-A) imager has been flight tested in 14 airborne missions since 1997. With initial systems development and operational trials completed, a vigorous operational research phase is beginning.

SWUIS-A consists of an image-intensified charge-coupled device (ICCD) camera with broad-band response from the near-ultraviolet to the near infrared; high-quality foreoptics; a miniaturized video recorder; an aircraft-to-camera power and telemetry interface with associated camera controls (called the PIB); and associated cables, filters, and other minor equipment. Video is output to the recorder in RS-170, super-VHS format; in-flight voice log commentary and GPS-derived time-code is also output to the data tape. Along with pointing and instrument field-of-view selection, CCD intensifier gain, video gain, and other controls are available to the instrument scientist in the aircraft. Wavelength bandpass resolution is achieved through the use of interference filters. Recently, a real-time GPS position receiver/data recording capability was added, and a quick-look data reduction software pipeline has been created and validated over the past 16 months.

SWUIS-A's suite of selectable foreoptics gives it high-quality, variable-focal-length/ variable-field-of-view (FOV) capabilities. Available FOVs range from 50° to 2.1°. The SWUIS-A ICCD camera frames at 60 Hz interleaved video rates—a key requirement for both jitter compensation and high time resolution, which is useful for occultation, lightning, and auroral studies. Broadband SWUIS-A coaded images can exceed a limiting magnitude of V=10.5 in <1 s with dark sky conditions. SWUIS-A is a more compact, airborne version of the NASA-funded SWUIS telescope/imag-

Fig. 1. (Top panel) NASA F/A-18B aircraft used for flight testing the SWUIS-A instrument system at the Dryden Flight Research Center in Edwards, California, USA. The SWUIS-A flight astronomer operates the instrument from the rear cockpit. (Bottom panel) The SWUIS-A system integrated into a NASA F/A-18B. The aircraft-to-camera power and telemetry interface (PIB) and LCD monitor are visible just in front of the stick. White cables running from the PIB to the right side of the cockpit connect to the aircraft power supply and video tape recorder. The Xybion ICCD camera is mounted above the instrument panel glare shield. On this flight, the 85 mm f/1.4 foreoptic was mounted on the camera, here with a foam light baffle attached.

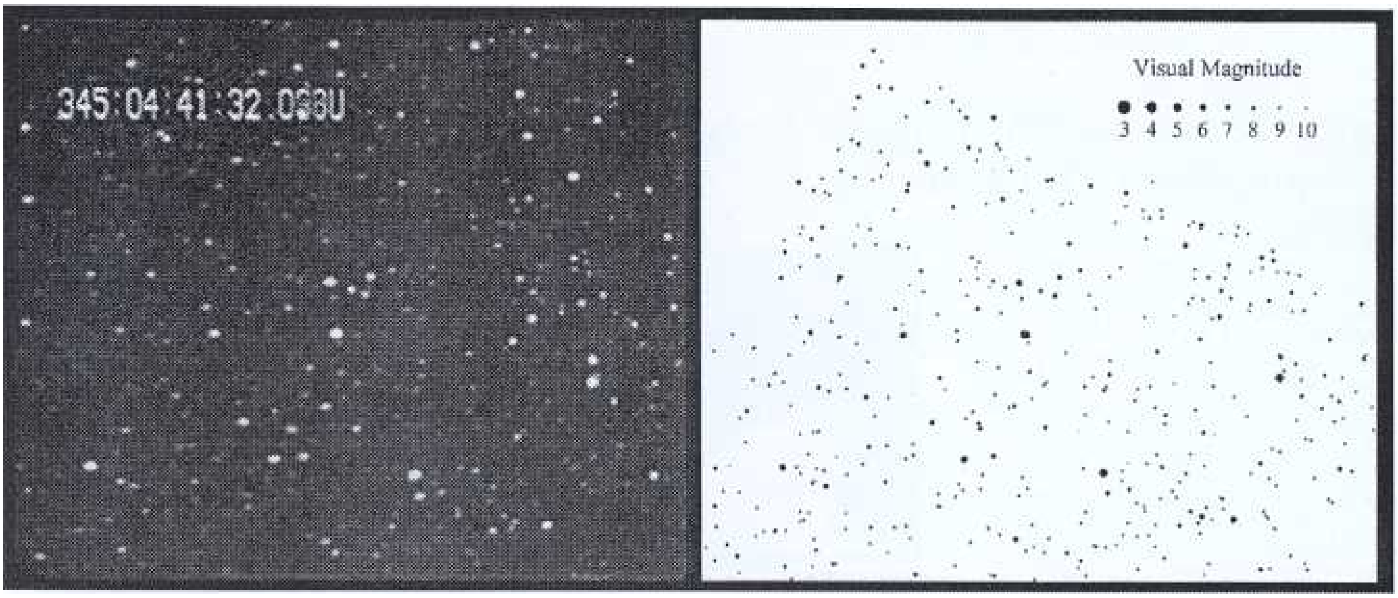

Fig. 2. A SWUIS-A image of the star field surrounding the 10th magnitude star SAO 77824, which was occulted by the asteroid 245 Vera on the evening of December 10, 1998.

ing system that was developed as a mid-deck experiment to conduct astronomical observations aboard the Space Shuttle [e.g., *Stern et al.*, 1999; *Slater et al.*, 1999].

SWUIS-A airborne observations are conducted with the astronomer on board, which provides a Space Shuttle-like "payload specialist" capability to "close-the-loop" in real time on the research performed during each mission. Flight training for the two SWUIS-A payload specialists (Principal Investigator Stern and Co-Investigator Durda) was funded largely with SwRI internal research grants totaling over $70 thousand and included intensive Federal Aviation Administration and NASA flight physicals, various aircraft systems training courses, altitude chamber training, aircraft egress and ejection seat training, water survival school, and aircraft certification check rides. We also created and validated a detailed, 17-page instrument operations checklist and streamlined the process of astronomical and flight planning necessary to bring a SWUIS-A mission to a successful conclusion.

As noted above, 14 successful SWUIS-A missions have been flown to date; in every case SWUIS-A performed flawlessly. These missions included five high-altitude flights in a NASA WB-57 to observe comet Hale-Bopp in mid-1997, a single mission in November 1998 aboard the U.S. Air Force's Flying Infrared Signatures Technology Aircraft (FISTA) to study the Leonid meteor shower, and eight missions in NASA F-18 aircraft to perfect techniques for observing asteroid and planetary occultations over oceans where ground-based facilities cannot be placed. Plans are in development to transition SWUIS-A to F-15/16 and U-2 aircraft as well, in part due to their unique technical capabilities, and in part to broaden the available flight opportunities for research.

Additional observations of asteroid occultations are planned for the intensive research phase that is about to begin, including events involving 45 Eugenia, which was recently discovered to have a small, orbiting satellite [*Merline et al.*, 1999]. Future SWUIS-A airborne missions aboard high-altitude aircraft such as two-seater U-2s will take advantage of the instrument's ability to look near (and soon, even at) the Sun to search for Vulcanoids—a putative population of small asteroids circling the Sun inside Mercury's orbit—and to observe spectra and breakup mechanics of Sun-grazing comets.

Eventually, SWUIS-A could be used to detect and track space debris that might pose a hazard to satellites, the Space Shuttle, and the International Space Station. SWUIS-A also could be used to study a wide variety of terrestrial aeronomical phenomena, including lightning and sprites, aurora, and ozone, and in future studies of meteoroid showers, missile tests, and other phenomena of interest. We encourage interested users of SWUIS-A, including researchers, operational remote sensing users, and the education and public outreach community to contact us to discuss possible collaborative projects.

Few institutions can now match the capabilities that have been developed for SWUIS-A airborne, scientist-in-the-loop research missions using comparatively inexpensive, high-performance aircraft. For more information on the SWUIS-A system, or for proposals to fly SWUIS-A, contact the authors at SwRI in Boulder, Colorado, USA, or visit the SWUIS Web site at http://www.boulder.swri.edu/swuis/. Detailed information about the airborne missions and operations checklist can be viewed at http://www.boulder.swri.edu/swuis/instr.html.

Authors

Alan Stern, Daniel D. Durda, and Bill Tomlinson, Southwest Research Institute (SwRI), Boulder Colo., and San Antonio Tex., USA; E-mail: alan@boulder.swri.edu; and Faith Vilas, Johnson Space Center (JSC), Houston, Tex., USA

References

Larson, H. P., The NASA Airborne Astronomy Program, in *Proc. Airborne Astronomy Symposium on the Galactic Ecosystem: From Gas to Stars to Dust, ASP Confr. Series, 73*, 591, 1995.

Merline, W. J., et al., Discovery of a moon orbiting the asteroid 45 Eugenia, *Nature, 401*, 565, 1999.

Slater, D. C., et al., *SWUIS–A compact astronomical UV/VIS/IR imaging system for manned space-based platforms including the Space Shuttle and the International Space Station*, Proc. Space Technology and Applications International Forum, STAIF-99, Albuquerque, N. Mex., 1999.

Stern, S. A., W. C. Colwell, M. C. Festou, P. M. Tamblyn, J. Wm. Parker, P. R. Weissman, and L. J. Paxton, Hale-Bopp (C/1995 O1) near 2.3 AU Post-Perihelion: SWUIS measurements of the H_2O and dust production, *Astronom. J., 118*, 1120, 1999.