INSTRUMENTATION DEVELOPMENT AT THE UNIVERSITY OF HAWAII, INSTITUTE FOR ASTRONOMY

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Abstract. *This paper gives a broad overview of the technology development and survey telescope operations at the Institute for Astronomy of the University of Hawaii. The technologies include optical CCD mosaics, infrared detector arrays, cryogenic instruments and adaptive optics.*

Introduction. The University of Hawaii owns and operates several telescopes on Maunakea on the island of Hawaii, and Haleakala, on the island of Maui. To equip these telescopes, and to collaborate with other telescopes located on these two sides, and elsewhere, the Institute for Astronomy (IfA) has established a vigorous program of technology development for the past 40 years. This presentation will give a broad overview of our technology expertise and discusses the overlap between classical astronomy, planetary defense, and space domain awareness.

Detector Development. The development of imaging sensors, CCDs for optical wavelengths and infrared detector arrays, started in the 1980s by D. Hall and K. Hodapp. For both types of detectors, the IfA collaborated with industrial partners for the actual fabrication of devices, and contributed our expertise in astronomical performance specifications and data acquisition methods to guide the development of new detectors from concept to scientific characterization. This long-term effort resulted in the development of the HAWAII series of HgCdTe detector arrays produced by the Rockwell Science Center, now Teledyne Imaging Sensors. The resulting HAWAII-1, HAWAII-2, HAWAII-1RG, HAWAII-2RG and ultimately the 4K HAWAII-4RG detectors have been used in multiple ground-based instruments and several space missions. Most notably, all but one of the science detectors in the James-Webb Space Telescope are HAWAII-2RG detectors.

In recent years, our attention (M. Bottom) is focused on the development of avalanche photodiode detector arrays in combination with Leonardo in the U.K. These detector avalanche multiply photoelectrons and are already achieving sub-one-electron effective read noise, primarily for wavefront-sensing applications, at this stage of their development.

For optical CCDs, the IfA (G. Luppino), pioneered the building of large focal plane assemblies using many, closely spaced CCD detectors. The crowning achievement of this development are the focal planes of the two Pan-STARRS survey telescopes, each with a 60 CCD focal plane assembly, developed by J. Tonry and P. Onaka.

Adaptive Optics. In the area of adaptive optics, the IfA lead the development of curvature-sensing wavefront sensors and the matching dimorph deformable mirrors, starting in the 1990s and lead by F. Roddier and C. Roddier. This technology offered an economical solution to achieve moderate levels of AO correction at near-infrared wavelengths. At present, Mark Chun is developing ground-layer adaptive optics systems that are optimized to correct turbulence near the ground and in the telescope itself. We have already demonstrated that with the turbulence profile of the atmosphere above Maunakea, image quality of the order of 0.3 arcsec can be achieved at visible wavelengths and over fields of view of a good fraction of a square degree.

C. Baranec is currently upgrading the Robo-AO system for the UH 2.2-m telescope. Following a prototype used at several other telescopes, including the 1.5-m telescope at Mt. Palomar and the 2.1-m at Kitt Peak, this system is intended to be a highly efficient, robotic system that allows to observe hundreds of objects per night without operator intervention. The system uses a commercial near-UV pulsed Raleigh-scattering laser to generate an artificial guide star. We have demonstrated routine diffraction-limited performance at visible wavelengths with this instrument. A copy of our system is currently being built for the U.S. Naval Observatory.

Cryogenic Instruments. Over the past decades, the IfA has built numerous optical and infrared instruments, including facility instruments for 8-10 m class telescopes, in particular the infrared camera and spectrographs IRCS for Subaru, NIRI for Gemini, the

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High-contrast camera for adaptive optics (HiCIAO) for Subaru and participated in the Infrared Doppler Instrument (IRD) for Subaru. Our solar group on Maui is just completing two major instruments for the 4-m DKIST solar telescope on Haleakala, CryoNIRSP (J. Kuhn) and DL-NIRSP (H. Lin).

Sky Surveys. One of the strong area of expertise at the IfA that has grown over the past 20 years is the design and operation of major astronomical survey and monitoring projects.

The Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) is currently operating two 1.8-m survey telescopes with Gigapixel CCD mosaic focal planes. At present, this effort is funded by NASA's planetary defense program and is aimed at discovering most potentially hazardous asteroids. In fact, the two Pan-STARRS telescopes are the most productive system in terms of discovery rate for such asteroids. A large fraction of the time on the UH 2.2-m telescope (M. Chun) is currently being used for the follow-up astrometry of asteroids discovered by Pan-STARRS and the IfA has developed leading expertise in this area (D. Tholen).

With similar goals, the Asteroid Terrestrial Impact Last Alert System, ATLAS, lead by J. Tonry, at present has four 50-cm telescopes, two in Hawaii, one each in Chile and South Africa, monitoring the sky at least once per night. This higher cadence than Pan-STARRS is designed to catch small asteroids not previously known during their final plunge towards Earth, within only days before impact. The intent is obviously to provide some warning and possibly allow evacuations of the impact area. We have plans to further expand this system of telescopes and to potentially build mobile units that could be very useful for (near) Space Domain Awareness.

The ASAS-SN system, at the IfA lead by B. Shappee consists of multiple even smaller 14-cm cameras distributed all over the Earth primarily for search and follow-up of supernovae, but generating huge volumes of data on many other transient phenomena.

The IfA has built leading expertise (L. Denneau, E. Magnier) in designing and operating data reduction pipelines and archival systems to process the huge amount of imaging data produced by these large sky-monitoring projects.

The 3.8 m UKIRT telescope (K. Hodapp), still bearing its traditional name of United Kingdom Infrared Telescope, is equipped with one of the largest infrared cameras in the world, using the HAWAII-2 HgCdTe arrays. This camera is currently being used by the U.S. Naval Observatory to conduct infrared surveys of the northern sky, to complement the work already completed by European Southern Observatories (ESO) on the southern hemisphere. USNO has almost completed the survey in the K band, and is currently doing the H-band survey. UKIRT has also been used by Lockheed Martin and USNO for space debris and individual satellite characterization.

The IfA also operates the 3-m NASA Infrared Telescope Facility (IRTF) under contract from NASA and is providing the instrumentation for this telescope. As part of their mission, time-critical observations of planets are being performed, some during daytime, and the IfA has developed substantial experience in the challenges of daytime observing.

Future Plans. Our long-terms plans include the upgrades of some of our instruments with large detector arrays, the implementation of ground-layer adaptive optics with adaptive secondary mirror at several telescope with multi-laser artificial guide stars, and possibly expanding these systems for daytime use for planetary observations and even near-solar adaptive optics. All of these technologies are similarly useful for space domain awareness.