PLANETARY SCIENCE AT IRTF: FUTURE DIRECTIONS

The NASA Infrared Telescope Facility (IRTF) is a 3.0-meter infrared telescope located at an altitude of approximately 13,600 feet near the summit of Maunakea on the island of Hawaii. Observing time is open to the entire astronomical community, with 50% of the time reserved for observations of solar system objects and the balance for observations outside the solar system ('astrophysics'). NASA's strategy in operating a dedicated, ground-based observatory continues to be the support of NASA's missions and science goals (Fast 2018, Hasan 2018).

Planetary Defense (Presentations: Fast 2018, Moscovitz 2018, Thomas 2018)

The detection, characterization, and mitigation of potential asteroid impactors is one of the key functions of NASA, as recognized by the January 2016 creation of the Planetary Defense Coordination Office (PDCO) within the agency. IRTF plays a key role in the characterization of near-Earth objects (NEOs) and remains a vital asset in NASA's planetary defense efforts providing capabilities that are unduplicated with other NASA assets. Below, we discuss the key elements that make the IRTF so important and possible enhancements to consider that may make it more effective in a planetary defense role.

Characterization of NEOs: A full understanding of the impact risk posed by hazardous NEOs is predicated on knowing the physical properties of the NEO population. Important parameters include composition, spin rate, albedo, density and size. Impact hazard assessment models estimate that for small diameter NEOs (<100 m) those with metallic composition cause significant damage. In contrast, NEOs larger than absolute magnitude H = 21.9 (roughly 200 m diameter) hydrous C-type objects caused the greatest damage, and anhydrous S-types caused the least damage, and metallic objects caused moderate damage. The extent of damage depends on composition in different size regimes and hence the NASA IRTF role in constraining the composition is critical for NEO impact hazard assessment. In many cases, these parameters can be correlated — for instance, an asteroid found to be in the C spectral class can fairly safely be assumed to have an albedo in the 4-12% range, compositions similar to some carbonaceous chondrites, and a density of <2000 kg/m^3. Combining the assumed albedo with a value for the absolute magnitude (which is generated at discovery and subsequently refined) provides a size and, combining the density with a value for macroporosity (often ~30-40% for NEOs), provides a mass estimate. If the asteroid were found to be in the S spectral class, the assumed albedo, composition, and density would be different, and so would the derived values. Many IRTF spectroscopic observations have contributed to our greater understanding of the relationship between spectral class and other physical properties (e.g., Thomas *et al.* 2011, 2014). While simultaneous lightcurve measurements to measure rotational period and infer some shape information can be and have been made with the IRTF, the facility does not provide unique capabilities for that technique.

Instrumentation: The medium-resolution spectrograph, SpeX, has been a true workhorse instrument in characterizing NEOs, with surveys in prism mode (0.70-2.52 µm) being consistently supported by the Time Allocation Committee (TAC), enabling over a thousand NEOs to be spectrally analyzed. This particular wavelength region is key for characterizing asteroids and providing the inferences mentioned above. In addition, thermal flux from NEOs is sometimes measurable near 2.5 µm, providing a direct constraint on albedos (e.g., Rivkin *et al*. 2005, Reddy *et al*. 2012). The IRTF MIT-Hawaii Near-Earth Object Spectroscopic Survey (MITHNEOS) is the largest publicly available database of NEO spectra with calibrated data from roughly 200 observing runs. Since 2017 all new SpeX data are pipelined to the IRTF data archive hosted by the Infrared Science Archive (IRSA) at the Infrared Processing and Analysis Center (IPAC) at Caltech.

Measurements of NEOs beyond 2.52 µm with SpeX are more challenging. The long wavelength crossed-dispersed (LXD) modes allow observations to the 4-5 µm region, which are dominated by thermal flux, and thus provide better estimation of albedos (Howell *et al*. 2018). However, the limiting magnitude in the LXD modes is typically brighter than prism mode by about 5 magnitudes. The tradeoffs between the SpeX modes in terms of the importance of better measurement of albedo vs. composition vary situationally, but the modes provide complementary information, and the fact that both can be used with little time spent switching between them is a strength of the IRTF. Unfortunately, a very small percentage of the NEO population that make a close flyby of the Earth can be observed in the LXD modes since they are often fainter than the LXD limiting magnitude. At these wavelengths sensitivity is limited by increased sky and telescope background emission. A solution is to reduce point source image size with an adaptive optics system, ideally using an adaptive secondary. Sensitivity gains of up to two magnitudes would be possible.

Visitor instruments currently provide IRTF's mid-IR capabilities. Consequently, availability is limited. The Broadband Array Spectrograph System (BASS) is a 2.9-13 µm instrument that is a PI-led IRTF visitor instrument available to the community on a collaborative basis, and therefore is only available at IRTF for discreet, scheduled periods of time. The Mid-Infrared Spectrometer and Imager (MIRSI) is currently being refurbished and converted from a visitor instrument into a facility instrument. The addition of an optical CCD channel will enable MIRSI to directly measure asteroid albedos and sizes using their blackbody curves, and improve the albedo-composition correlation for the NEO population. Current estimates suggest that MIRSI will be able to observe about 250 NEOs per year. All characterization efforts would benefit from new instruments with additional wavelength coverage including visible (<0.7 µm) and mid-infrared (>5 µm) wavelengths.

The MIT Optical Rapid Imaging System (MORIS) has been a welcome and useful addition to SpeX since 2012. MORIS has enabled more precise guiding on faint targets (e.g., small NEOs), which has improved overall observing efficiency with SpeX. It has also enabled some lightcurve observations to be done simultaneously with spectral observations.

However, many recently discovered NEOs have large positional errors and cannot be recovered with the relatively small one arcminute FOV of MORIS. This makes an observer dependent on other observatories to recover the object and JPL Horizons to quickly update the coordinates before characterization can be done. This wait can make the difference between successfully characterizing an object and missing the opportunity. With a larger FOV, observers could target newly discovered NEOs for characterization, and additional field stars for reference would also improve the photometric precision of the lightcurves. Since the FOV of MORIS cannot be increased without rebuilding significant parts of SpeX and MORIS the addition of a smaller aperture wider field finder (such as a C14 telescope plus camera) piggybacked on the main telescope would be viable solution in the near-term for planetary defense. (The telescope limits the FOV of all Cassegrain instruments to about 3 arcminutes.)

Future NEO characterization would benefit from a SpeX follow-on instrument, such as the proposed Spectrograph Express (SPECTRE) instrument. SPECTRE would provide low-resolution ($R \approx 100$) spectra from 0.4-4 μm simultaneously with high throughput and no moving parts. The low spectral resolution is optimal for small body spectral characterization and the wide wavelength region would enable more in-depth spectral characterization of NEOs in a time-efficient manner. As currently conceived, SPECTRE could gather observations of objects 0.5 magnitudes fainter than SpeX which would enable characterization of smaller NEOs and would lengthen the observing windows during which an NEO could be observed. The biggest advantage of SPECTRE is the efficiency of simultaneous coverage from 0.4-4.0 μm and increased efficiency in object acquisition (point and shoot). With no mechanisms, calibration flats and arcs could be acquired just once per night and the three arcminute CCD FOV is an order of magnitude larger than the current SpeX plus MORIS configuration. The 0.4-4.0 μm simultaneous coverage would of critical for mineralogical characterization of weakly featured asteroids such as C types that have diagnostic absorption features in the visible (0.7 μm) and in the mid-IR (3 μm).

Scheduling: The IRTF is the only non-queue observing facility known to the community that enables flexible scheduling. Other facilities are willing to break the nights into halves (or possibly quarters on request), but the IRTF has for many years supported a more complicated and efficient schedule involving multiple programs per night, that enables targeted science and maximizes the scientific output of the observatory. For NEOs, the scheduling allows for planned observations of specific targets near peak observability and for predetermined cadences (as with MITHNEOS) that enable observations of newly discovered objects at specific intervals, as well as rapid turnaround target-of-opportunity observations of newly-discovered close-approach NEOs. The dedication of the IRTF to supporting planetary defense has been shown by the consistent approval of NEO observing programs. We encourage the IRTF to maintain their support of flexible scheduling and support for NEO observations.

Non-sidereal Tracking: A key capability of the IRTF is its ability to easily and routinely track at high non-sidereal rates (up to 60"/sec i.e. four times the sidereal rate). Such capabilities are not available at most observatories around the world. As the IRTF improves hardware, telescope balance, adds new instruments, etc., it is important to maintain the fast non-sidereal tracking capability in order to maintain this critical advantage for NEO observations. IRTF also allows telescope operators to make adjustments to the non-sidereal rates while observing. For newly discovered targets with large errors on non-sidereal rates, the ability to make adjustments to the JPL Horizons rates enables the acquisition of targets that would otherwise be missed by IRTF (and likely all other facilities).

Mission Support: Observations in support of NASA missions have been a hallmark of the IRTF since its beginning. IRTF has provided ground-based characterization for several past NASA and international missions to NEOs including the NEAR-Shoemaker mission to asteroid Eros and the Hayabusa mission to asteroid Itokawa. IRTF has also helped in supporting current missions to NEOs including NASA's OSIRIS-REx mission to Bennu and the Japanese Space Agency's Hayabusa2 mission to Ryugu. We note that the establishment of the PDCO and the development of planetary defense missions such as DART and NEOCam provide additional opportunities for IRTF to undertake mission support. The consensus among the workshop participants was that planetary defense missions receive consideration for support from IRTF similar to what would be considered appropriate were they science missions.

Small Bodies (Presentations: Bosh 2018, Faggi 2018, Mumma 2018, Protopapa 2018, Takir 2018, Trilling 2018, Woodward 2018)

Small bodies – asteroids, comets, centaurs, and trans-Neptunian objects (TNOs) – are the leftovers of the formation and evolution of our Solar System. By studying each of these sub-populations through spectroscopy and photometry, we gain critical information regarding the environments where they formed. For decades, the IRTF has been a vital asset for small body mission planning, mission support, planetary defense, and science in general. Missions enable extremely detailed and, in most cases, unprecedented measurements on individual targets, but the numbers visited by missions are limited. The IRTF is uniquely positioned to play a paramount role in ground-based remote sensing observations of small bodies for decades to come.

Asteroids: Several IRTF/SpeX programs have used the LXD mode to measure the 1.67-4.2 μm spectra of dark asteroids located in and beyond the main asteroid belt ($2.5 < a < 4$ AU), including asteroids from the Hilda family and the Cybele group. In addition, IRTF has been successfully used to study asteroid families to understand their origin and compositional affinities to specific meteorite types (e.g., Reddy *et al*. 2010, 2011, 2014; McGraw *et al.* 2018). Asteroid mission support is another area where IRTF excels. IRTF spectra have been used to calibrate instruments and

provide pre-arrival characterization for several NASA and international missions including the Dawn mission to asteroid Vesta and dwarf planet Ceres, the Psyche mission to asteroid Psyche and the Lucy mission to the Trojan asteroids.
Future Needs: A majority of the main belt asteroids observed with the current SpeX instrument have a diameter >75 km. Currently, the LXD mode cannot be used for observing low-albedo asteroids with a diameter smaller than ~75 km. A higher sensitivity instrument such as SPRECTRE might be the best path forward to make more main-belt asteroids accessible to spectroscopy and enhance asteroid science in the decades to come.

Centaurs and Tran-Neptunian Objects (TNOs): The wavelength coverage (0.70-5.3 μm) and the resolving power (*R*=100-2500) of IRTF/SpeX are ideal to investigate the ice composition in Centaurs and TNOs, like H_2O, CH_4, NH_3, CO, or CO_2, which present broad and diagnostic features in the wavelength range covered by SpeX. The low dead-time of MORIS allows time-critical visible photometry, especially in the case of stellar occultations. Some binary TNOs can undergo mutual events with the primary passing in front or behind the secondary; these are rare and generally require a coordinated campaign to record the full event. IRTF played a crucial role in the worldwide campaign to observe the first mutual event detected for the Sila-Nunam system (Benecchi *et al*. 2014). The simultaneous use of MORIS and SpeX is particularly powerful for stellar occultations by atmospheres, such as for studying Pluto's atmosphere (Gulbis *et al*. 2015).
Future Needs: Currently on IRTF, only brighter TNOs and Centaurs are observable for photometry and spectroscopy purposes ($V \approx 22$ mag for photometry and $V \approx 19$ mag for spectroscopy). Future spectroscopic studies of fainter objects require the development of new and upgraded instruments with adaptive optics: i) Visible spectroscopy in the range 0.3-0.7 microns to characterize complex organics (tholins), which have a distinct dark red to yellow color at visible wavelengths (Cruikshank *et al*. 2005), identify aqueous alteration materials with characteristic absorption bands at about 0.3 and 0.6 μm (Barucci *et al*. 2008); and assess the temporal changes of these elements (e.g., Smith *et al.* 1989). ii) Low resolution ($R \approx 100$) prism spectrograph observations covering the wavelength range 0.3-4.2 μm at once are needed to break the degeneracy of modeling results and provide quantitative information on the abundance and textural properties of the materials on the surface of TNOs (Protopapa *et al*. 2008). iii) The photometry of TNOs/Centaurs with IRTF will benefit from a larger field of view. The workshop participants supported the development of the SPECTRE instrument with adaptive optics as a complementary follow-on to SpeX that would enable IRTF to go fainter and wider in wavelength coverage to advance Centaur/TNO science.

Comets: High-resolution spectroscopy in the *K*-, *L*-, and *M*-bands is important for studying the composition of comets because of the simultaneous fluorescence emissions of water, organics and nitriles (e.g., H_2CO, CH_3OH, CH_4, C_2H_2, C_2H_6, HCN, NH_3). Several features position the IRTF as a powerful facility for observing comets: i) the unique ability to guide on sources during daytime, ii) the ability to observe at small solar

elongation, iii) the fact that 50% of the entire observing time is allocated for observations of Solar System objects, iv) prompt response to target of opportunity (ToO) and director discretionary time (DDT) requests to efficiently sample a significant population of newly-discovered comets, and especially with v) the new high-resolution immersion echelle spectrograph (iSHELL), which covers the 1-5 μm range, with improved sensitivity, high spectral resolving power (R=80,000), and broader spectral coverage per setting, compared with other instruments available on IRTF and elsewhere.
Future needs: Despite the advent of the 30-m class telescopes, there will be a shortage of high-resolution spectrographs covering the 3-5 μm wavelength range in almost all the upcoming ground-based facilities. The combination of the high-performance capabilities of iSHELL, along with the above-mentioned unique advantages of the IRTF facility, offers a competitive suite to perform detailed studies of cometary composition today and in the future. IRTF could be even more competitive in delivering cometary science if new spectroscopic techniques, such as Integral Field Unit (IFU) spectroscopy, would be offered to the community (see the following section). The combination of high-resolution spectroscopy along with the possibility of performing detailed maps of cometary comae on a facility heavily committed to Solar System studies would provide a paradigm shift in understanding and characterizing molecular outgassing in comets. Additionally, a thermal IR (8-14 μm) low- to medium-resolution spectrograph would permit studies of cometary dust compositions together with emissions from molecular bending modes. This could be fulfilled by a facility version of BASS.

Small Bodies Mission Support: As noted earlier, IRTF has played a vital role in providing ground-based support for several NASA and international asteroid missions. The IRTF's role in cometary missions is equally important where it has supported the Giotto, Rosetta/Philae, Deep Impact, EPOXI and StardustNExT missions. IRTF/SpeX also has played a remarkable role in investigating the temporal variations on TNOs. Overall, these measurements have provided observational constraints to further understand the origins of these bodies and their subsequent histories, and have provided critical support to several spacecraft missions, including New Horizons to the Pluto system. The IRTF will be critical for identifying the targets of high interest for future missions and will potentially complement several large surveys, such as the Large Synoptic Survey Telescope (LSST).

Planetary Atmospheres (Presentations: Kostiuk 2018, Lee 2018, Novak 2018, Orton 2018, Sakanoi 2018, Villanueva 2018)

Through a mixture of facility and visitor instrumentation IRTF offers an unmatched 0.5-26 μm suite of imaging and spectroscopic (R=10-10^7) capabilities to study planetary atmospheres. In particular, high-resolution spectroscopy has proved to be an extremely effective niche for IRTF. High resolving power (R=20,000-100,000) in the infrared is required to separate and measure molecular species in planetary atmospheres and to discriminate against telluric contamination. At 1-5 μm these capabilities have been provided by the facility instruments CSHELL (1993-2016) and iSHELL (2016-), and at 5-25 μm mainly by the visitor instrument TEXES (2000-). Ultra-high resolving powers ($R > 10^6$) are needed to fully resolve line profiles to provide unique information on the variability of temperature and abundance, measure planetary scale wind velocities, and to separate planetary features from telluric features by Doppler shifts (e.g. as needed to measure ozone on Mars). These capabilities are provided by the visitor mid-IR heterodyne spectrometers IRHS (1984-2000) and HIPWAC (2000-). Broader molecular features can be studied with medium- and low-resolution spectroscopy. This is currently done with SpeX at 0.7-5.4 μm and with the visitor instrument BASS at 3-14 μm. SpeX, iSHELL and TEXES are slit spectrographs but they have been successfully used to obtain three-dimensional image cubes by scanning the slit across a planetary disk. In addition, the EXES instrument, developed for SOFIA, was first tested on IRTF.

Infrared imaging with the facility 1-5 μm cameras and visitor mid-IR cameras have provided a several decades-long monitoring of the dynamical process in planetary atmospheres (e.g. Sanchez-Lavega *et al*. 2008 and Fletcher *et al*. 2017), supplementing the higher resolution but shorter timescale imaging provided by spaceflight missions. (Note that planetary seasons last decades in the outer solar system). Following the accidental loss of NSFCAM in 2014, 1-5 μm imaging is now provided by the slit-viewer in SpeX. Unfortunately, the circular variable filter (CVF) imaging capability with NSFCAM (1-5 μm $R \approx 100$ imaging at any wavelength of choice) has not been replaced. Planetary CVF imaging with NSFCAM was an important IRTF capability. It has been partially replaced by adding additional narrow-band filters to SpeX.

Mission Support: Mission support observations from IRTF have been important both to support planned mission operations and to backup mission operations when there are problems. IRTF provided critical imaging during the Galileo probe entry at Jupiter when problems with the high gain antenna and data tape recorder prevented the orbiter from imaging the probe entry site. The IRTF images showed that the probe had entered the atmosphere through a 5 μm 'hot spot', explaining the very unexpected low water abundance measured by the atmospheric probe (Orton *et al*. 1996). More recently, the Akatsuki spacecraft ended up in an unplanned highly eccentric orbit of Venus preventing timely global context observations but which IRTF could provide. Both these examples illustrate important operational features of IRTF that need to be maintained: daytime observing at small solar elongations and flexible scheduling. Other notable mission support observations include the first direct measurement of (prograde) winds on Titan using mid-IR heterodyne IRHS observations (Kostiuk *et al*. 2001) to help with trajectory planning for the Huygens atmospheric probe; the first direct imaging of Io's electrodynamic footprint on Jupiter that allowed imaging of the flux tube by Galileo (Connerney *et al*. 1993); and regular near- and mid-IR global imaging of Jupiter and Saturn for feature tracking and to provide context for high spatial resolution imaging by the Galileo, Cassini and Juno missions (Orton 2018).

The Atmospheres of Venus, Mars, Titan and Pluto: As a result of past and current capabilities, IRTF has been able to make major contributions to the science of planetary atmospheres. For solid body atmospheres some highlights include the following: Evidence for an expansion of Pluto's atmosphere from observations of a stellar occultation with SpeX (Elliot *et al*. 2000). TEXES measurements of propane on Titan (Roe et al. 2003) illustrated the limitations of current modeling and importantly drove follow-up laboratory work. Imaging spectroscopy using TEXES mapped the global distribution of H_2O_2 on Mars in overall agreement with photochemical models (Encrenaz *et al*. 2004). Measurement of the ozone abundance on Mars with IRHS and HIPWAC bridged a long gap between mission measurements and provided data essential for developing models of Martian photochemistry and dynamics (Fast *et al*. 2005). CSHELL detected an apparent strong release of methane on Mars during its northern summer in 2003 (Mumma *et al*. 2009) and drove planning for mission instrumentation. IRHS and HIPWAC observed the non-LTE effects of solar heating and the winds in the thermosphere and mesosphere of Venus (Kostiuk et al. 2010). CSHELL observations of Mars showed isotopic enrichment and evidence for the global loss of water and ancient reservoirs (Villanueva *et al*. 2015).

Gas Giant and Ice Giant Atmospheres: Highlights include the following: The atmospheric effects of the 1994 collisions of comet Shoemaker-Levy 9 fragments with Jupiter was observed by a suite of facility and visitor instruments during an IRTF observing campaign (Orton *et al*. 1995). The study of the aurora of Jupiter (e.g. decadal variability measured by Kostiuk 2018 using IRHS and HIPWAC) and Saturn in the near- and mid-IR and the first H_3^+ images of Jupiter's aurora (Baron and Owen 1990) probe from the stratospheres to the magnetospheres of these planets through imaging and high-resolution spectroscopy. TEXES measurements of ethane (C_2H_6)) in Saturn illustrated the limitations of current modeling and importantly drove laboratory work (Greathouse *et al*. 2005). The detection of ethane in the atmospheres of Neptune and Uranus probes the atmospheric dynamics of these ice giant planets (Hammel *et al*. 2006). The heating of Jupiter's upper atmosphere was measured above the Great Red Spot (O'Donoghue *et al*. 2016). Water abundance in Jupiter at 2-9 times the solar abundance was measured using iSHELL (Bjoraker *et al*. 2018), much higher than the Galileo probe abundance measurement and consistent with enrichment by icy planetesimals. The first observations of the infrared aurora of Uranus (Melin *et al*. 2019) were made using iSHELL. Uranus and Neptune are proxies for ice giant exoplanets.

Future Needs – Adaptive Optics: Future work could be enhanced by adaptive optics (AO) at wavelengths up to 5 µm. At longer wavelengths AO is of limited use since IRTF is effectively diffraction limited. For example, observations of Venus using SpeX imaging with filters in the 1.74 µm and 2.26 µm CO_2 windows supports cloud tracking. If these observations are enhanced with AO, the 0.18" spatial resolution at 2 µm would provide about 250 spatial resolution elements across Venus' disk (48 km resolution). This resolution is similar to the Akatsuki spacecraft, but currently there is no ground-based system capable of matching this. However, such observations would be limited to periods around quadrature given the challenges of AO in twilight and daylight. AO imaging with SpeX could also map trace species such as CO, OCS, and H_2O, although SO_2 imaging a *K* would be out of reach at the medium spectral resolution of SpeX. AO would also be very useful for much improved spatial resolution on Uranus (4" diameter), Neptune (2"), Titan (1") and Pluto (1"), particularly if coupled with an IFU (e.g. the proposed SPECTRE with *R*=100 and FOV 7"x7" – effectively a global narrow-band imager covering 0.4-4 µm in one shot).

Future Needs – Spatially Resolved High-Resolution Spectroscopy: As a future capability a strong science case can be made for spatially resolved high-resolution spectroscopy (R=50,000-100,000) of planetary atmospheres and comets. Currently this capability is partially satisfied by slit scanning with iSHELL and TEXES but with significant limitations due planetary rotation, slit placement and background variation. An IFU-fed high-resolution spectrograph would be able to *spatially* map many molecular species and molecular states (e.g. Villanueva 2018). The 2-25 µm wavelength range covers many molecular species and molecular states (including isotopes, trace gases, parent volatiles, hyper-volatiles etc.) measurable in planetary atmospheres and comets (e.g. see Villanueva 2018). In particular, at *R*=20,000-100,000 the 2-5 µm range will remain competitive with space-based instruments due the lower thermal background and increased complexity and larger size of ground-based instrumentation. A purpose-built 2-5 µm spectrograph could map a 10" x 10" FOV with an instantaneous wavelength range of about 0.05 µm at 5 µm. (This compares to iSHELL with a narrow and 15"-long slit with an instantaneous wavelength range of 0.5 µm at 5 µm.) When coupled with AO at 1-5 µm this would provide a powerful but very specialized capability.

Future Needs - Instruments: Both the IFU-fed 0.4-4 µm low-resolution spectrograph (SPECTRE) and the IFU-fed 2-5 µm high-resolution spectrograph proposed concepts would add significant new capability to IRTF. SPECTRE is optimized for small bodies and point sources and mitigates against slit losses and collects simultaneous sky background for improved sensitivity. The IFU-fed high-resolution spectrograph is optimized for mapping extended objects such as planets and comets (there are no slit losses and no simultaneous sky background measurement for extended objects). Both these new and current capabilities would be strongly enhanced with continuing image quality improvements and a future 1-5 µm AO system. Major contributions have been made to planetary atmospheric science through the IRTF's visitor instrument program, primarily with mid-IR instruments (currently TEXES, HIPWAC and BASS). It is important to maintain this program and encourage new visitor instruments. The upgraded facility mid-IR camera MIRSI (formerly a visitor instrument) will soon be back online and will add the capability of mid-IR and simultaneous optical imaging of planetary atmospheres. Consideration could also be given to converting TEXES to a facility instrument, allowing year-round availability to planetary observers (TEXES is currently available for only about one month per semester).

Future Needs – Operations: Daytime observing of planets at small solar elongations and flexible scheduling are critical IRTF operational features that need to be maintained. Also, the willingness of IRTF to respond to community requests to schedule weeks-long observing campaigns (e.g the S-L 9 Jupiter impact campaign and several comet apparition campaigns) with TAC-competed guaranteed observing time is also highly valued and needs to be maintained.

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