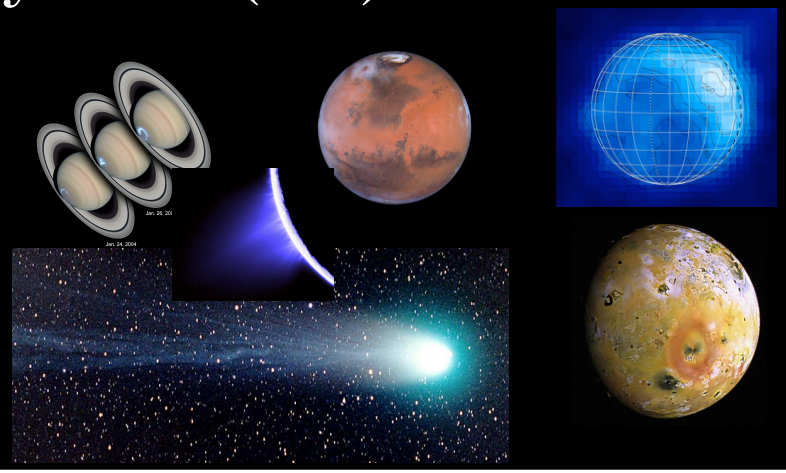
The Telescope for Planetary Science (TPS)

Overview:

POC: Amanda Hendrix, Planetary Science Institute, arh@psi.edu, 310.922.3414

Key collaborators: Heidi Hammel, Mike Wong, John Clarke, Paul Scowen, Jeff Morgenthaler, Glenn Orton, Tim Livengood, Mark Sykes, Susan Benecchi, Makenzie Lystrup, Nick Thomas, Dennis Bodewits, Alessondra Springmann, Will Grundy, Rich Dissly, Faith Vilas, John Stansberry, Mike Davis, Nick Schneider

Goals: Study our solar system and its dynamics, to understand origins, evolution and processes on different spatial and temporal scales, using primarily UV and optical imaging and spectroscopy. Obtain synoptic coverage and provide mission support on solar system targets, with capabilities to do cross-cutting science.



Science Observations: TPS, using its UV and planetary-dedicated capabilities, provides unprecedented access to: the atmospheres & surfaces of the Galilean and Saturnian satellites; Mars; comets; giant planet aurorae; asteroid discovery, tracking and characterization; KBOs; Pluto & moons; giant planet atmospheric dynamics; Mars; Io's atmosphere and torus; Enceladus plume activity & effects…

Key Capabilities: Imaging (0.3-1 μm) using ~1'x1' FOV and angular resolution <0.01". UV spectroscopy (110-320 nm) with improved sensitivity and spatial resolution compared to HST; R~30,000. Position in high-Earth orbit or Lagrangian point.

Opportunities:

- Enable critical UV planetary science – not obtainable with any other facility post-HST
- Provide ample commonalities with other fields (astrophysics, extra-solar planets)
- Complement JWST, ground-based observing programs & missions
- Collaborate with HEO via telescope servicing

Value to NASA:

- This is a valuable opportunity to address fundamental solar system problems that cannot be addressed by "going there." Not all planetary science questions can be answered using deep space probes.
- TPS addresses questions posed in the 2013-2022 Planetary Science Decadal Survey and the NASA Strategic Plan, e.g.:
  - What processes are active in and among solar system objects?
  - How did the solar system form and evolve?
  - What characteristics lead to habitable environments?
  - How and where did life begin and evolve in the solar system?
  - What are characteristics of small bodies and planetary environments that pose hazards or provide resources?
- TPS provides synergy with NASA deep-space missions.
- Serendipitous opportunities (e.g., the Shoemaker-Levy 9 and other Jupiter impacts) can be accommodated.
- Public outreach opportunities are enormous.
  - Experience with HST shows that planetary images are particularly successful public outreach tools.

The Telescope for Planetary Science (TPS)
A Facility with a Focus on our Solar System

Amanda R. Hendrix, Senior Scientist, Planetary Science Institute, arh@psi.edu
Primary category: Planetary Science

The Telescope for Planetary Science (TPS) is a concept for a facility that will focus on addressing and answering compelling science questions within our own solar system. TPS will provide NASA and the community with a telescope for observing our nearest neighbors to address questions that cannot be answered by visiting those objects with deep-space probes. This is a cross-cutting concept: the instrumentation will allow for observations in other fields (e.g. astrophysical targets, exoplanets), but the primary emphasis will – for the first time – be on our solar system. TPS will also be of high value to the human spaceflight program, as future possible human targets will be studied, and human capabilities will be critical for servicing missions. *TPS will provide extremely high science, technological value and innovation, and will be a critical use of NASA capabilities.*

Science Applications and Benefits

The field of planetary science is advanced enormously by the capability to do *in situ* science by sending deep-space probes to planetary targets, yet questions remain that can only be addressed via the use of a dedicated planetary telescope, either due to the time scales or spatial scales involved, or to the need for large numbers of observations. And while much can be achieved using ground-based telescopes, we are solely reliant on space telescopes for deep-UV (<~320 nm) observational facilities. This spectral range is not achievable by JWST, which is optimized for the infrared. The TPS system provides the opportunity to continue what HST has done in UV planetary areas – *but to now do it better* - with improved modern technologies on dedicated planetary targets.

We list here many of the questions and topics *that can only be addressed by TPS*:

• Jupiter system. Mission-related investigations (e.g., post-Juno support, pre-JUICE observations of the Jupiter system) are enhanced and complemented using TPS coverage. Studies of numerous aspects of the system are enabled using TPS's UV capabilities and long-duration coverage on varying timescales, including aurorae and airglow of Galilean satellites, Io and its plasma torus, Europa and its atmosphere, and the Jovian aurorae.

• Comets. Fundamental questions remain, particularly 'which volatiles drive cometary activity as a function of heliocentric distance?' and 'what is the parentage of the species that are typically observed from ground-based observatories?' These questions can be addressed largely using UV spectroscopic observations of numerous cometary targets over large spatial and temporal scales. Furthermore, understanding the inventory of cometary nuclei and studying their internal compositional heterogeneities are important in assessing their role in several solar system processes, including the delivery of volatiles to the early terrestrial planets and the impact hazard at Earth.

• Asteroids. Asteroids, particularly near-Earth objects (NEOs), have been poorly studied thus far in the UV. As potential future targets for human visitation, NEOs should be characterized thoroughly by observing many targets over a wide wavelength range. The UV region is particularly sensitive in studying space weathering effects; UV spectra can be merged with existing visible spectra. All of this relates to composition and physical structure, which in turn are related to mitigation strategies for the impact hazard at Earth.

• KBOs, TNOs, Pluto, other small, primitive bodies. A solar system-dedicated telescope can be used to determine shapes, sizes of small bodies – and also masses from binary orbits – to measure densities without a spacecraft encounter. TPS will replace critical capabilities of HST for mission support purposes at UV and visible wavelengths not accessible to JWST.

• Giant planets. For many aurorae and atmosphere investigations, UV imaging and spectroscopic capabilities are required. A facility dedicated to solar system targets is ideal for studying atmospheric dynamics, including photometric studies of changing planetary conditions of cloud cover related to vertical motions and studies of horizontal motions.

• Saturn system. The wide-field abilities of TPS allow the investigation of Enceladus activity monitoring, system OH observations, and ring-magnetosphere-moon interactions in the post-Cassini era. Titan seasonal variations can be studied via cloud monitoring, haze layer imaging and UV stellar occultations.

• Uranus, Neptune. Synoptic observations of ice giant atmospheres, particularly in the blue, are enabled with TPS.

• Mars, Venus. UV imaging and spectroscopic capabilities on TPS can be used to study airglow (e.g. faint neutral atomic oxygen, hydrogen in upper atmospheres) and aurora for paleoclimate studies and mission support.

• In all of the above areas, one of the prime benefits of TPS is the means to provide rapid follow-up to transient events, a critical aspect of solar system studies. Solar system objects are temporally variable by nature. Making observations of the same object over time is crucial - e.g. disconnections of comet tails, seasonal variations at Mars, volcanic eruptions on Io.

Instrumentation and System Requirements

Two primary instrumentation capabilities are required: high-resolution imaging and spectroscopy in the UV-visible range. The specific instrumentation, electronics, and tracking capabilities require no major new technologies, yet will provide critical observations in the post-HST era, with improvements on HST resolution and sensitivity.

• High resolution imaging. The required FOV is ~1'x1' (large enough for Jupiter, the entire Saturnian ring system, as well as Venus near opposition) with high angular resolution (<0.01") and high sensitivity, critical for measuring the sizes and surface albedo variations of distant objects (e.g., Trojans asteroids and KBOs). Standard filters

spanning 0.3 – 1 μm and a CCD imager would provide high-resolution imaging at wavelengths not accessible to ground-based AO systems. Such a capability will improve upon HST (its pixels don't adequately sample the telescope PSF), and will complement JWST (only diffraction limited longward of 2 μm). Such a system would offer images ~85% sharper at 0.4 μm than JWST at 2 μm. The system could be used to image the surfaces of satellites and primitive bodies, including Triton, Pluto, and Eris, to monitor seasonal changes, and to identify binaries and characterize their orbits, as well as for studies of atmospheric dynamics on other planets (e.g. Neptune, Uranus, Mars). Such a capacity would have other astrophysical applications as well.

• UV spectroscopy (110-320 nm) (slitless or using long narrow slits). This capability is critical for studies of composition of atmospheres and surfaces, chemistry and atmospheric dynamics. High sensitivity is particularly critical at wavelengths shorter than ~230 nm; improvements over HST can be made in this area by increasing the effective area by a factor of 4-10, perhaps by utilizing new solid state detector technologies and coatings. Solar blind detectors are critical for deep-UV investigations. Spectral resolutions of R~30,000 would allow for measurement of Doppler shifts and winds (on Io, for instance), though lower resolutions are adequate for some applications.

• Other requirements. To allow coverage in the UV, the mirrors must be recoated, ideally using aluminum with a MgF_2 overcoat. For TPS, moving target tracking and fine pointing control are critical. Electronics are desired that will allow temporal resolution for UV and visible stellar occultations (~1 msec) for numerous targets; these would enable significant improvement in scale height measurements over those made by HST. TPS will utilize the wide-field capabilities of the new system. For instance, observations of the entire Jovian system, comets, and atmospheric coronae require wide-field viewing. A sunshade is necessary for Venus observing. Orbital location for TPS is flexible. Low-Earth orbit puts undesired constraints on observation timing. High-Earth orbit or especially a Lagrangian point would be ideal, allowing for ample observing time as well as likely option for human servicing.

Crosscutting Capabilities

For optimal scientific results in the field of planetary science, the TPS facility should not be limited by constraints placed on it by other science areas, but it will be amenable to them (e.g., astrophysics, heliophysics). The instrumentation and capabilities of TPS provide much commonality with the needs and interests of astrophysics community, e.g., measurements of H_2 and H emission, the need to get above geocorona and to observe at or below Ly-α, imaging spectroscopy, synoptic monitoring, very high spatial resolution in the UV, and moderate fields of view.

Benefits to NASA.

The benefits of TPS to NASA, the scientific community and the public are wide-ranging. The facility will provide synergy with NASA deep-space missions. Serendipitous opportunities (e.g., the Shoemaker-Levy 9 and other Jupiter impacts) can be accommodated. Furthermore, the public outreach opportunities are enormous. Experience with HST shows that planetary images are particularly successful public outreach tools.