SPACE TELESCOPES FOR SOLAR SYSTEM SCIENCE. A. R. Hendrix[1], K. M.. Sayanagi[2], Cindy L. Young[3], H.-W. Hsu[4], Aki Roberge[5], Giada N. Arney[5], G. van Belle[6], M. H. Wong[7] [1]Planetary Science Institute (ahendrix@psi.edu), [2]Hampton University, [3]NASA Langley Research Center, [5]University of Colorado/LASP, 5NASA Goddard Space Flight Center, [6]Lowell Observatory, [7]University of California, Berkeley/SETI Institute.

1. Background: We advocate for a path forward to address the recommendations to NASA by two National Academies reports regarding the role of a space telescope for solar system science. First, in 2017, *Getting Ready for the Next Planetary Science Decadal Survey* recommended "studies to determine the potential scientific return of a space telescope dedicated to monitoring and studies of solar system bodies …" Second, the 2018 *Mid-Term Review* of the 2013-2022 decadal survey stated that "NASA should conduct an assessment of the role and value of space-based astronomy … for planetary science."

Although NASA did not conduct a study to address these recommendations prior to the ongoing decadal survey, several whitepapers about space telescope concepts were submitted to the survey; these papers serve as a basis for a much-needed detailed study. Our presentation reviews some of the relevant white papers to advocate for a comprehensive studies of mission concepts that address the National Academies recommendations.

2. Science Needs: Space telescopes offer critical values to solar system observations by enabling high-spatial resolution, high-sensitivity observations in the visible and UV wavelengths that cannot be attained by ground-based observatories [1] across multiple bodies. The Hubble Space Telescope revolutionized the telescopic observations of the solar system targets; future space telescopes configured to fill the specific needs of solar system observations would a) transform our understanding of time-dependent phenomena in our solar system that cannot be studied under current programs to observe and visit new targets and b) enable a comprehensive survey and spectral characterization of minor bodies across the solar system, which requires a large time allocation not supported by existing facilities. The time-domain phenomena to be explored are critically reliant on high spatial resolution UV-visible observations, which would enable: (1) identifying and observing worlds that are volcanically active while seeking to understand the drivers of this activity and the compositions of magma and volcanic tephra, (2) understanding the dynamic processes shaping minor body populations and what the compositions of minor bodies can reveal about early solar system migration history and radial variations within the solar nebula, (3) a comparative planetology approach towards understanding atmospheric energy transport across the range of examples offered in our own solar system, including giant planets and Venus, (4) studying the outer planets as natural laboratories to understand how planetary magnetospheres interact with the solar wind and internal plasma sources, (5) a better knowledge of evolving planetary ring phenomena to increase our understanding of the dynamic history of our own solar system and physical processes that lead to planet formation in protoplanetary disks, and (6) a time-series characterization of cometary evolution and processes throughout the orbit, including close to perihelion.

3. LUVOIR: a Future Astrophysics Telescope Concept: The Large UV/Optical/Infrared Surveyor (LUVOIR) is a mature concept for a large, multi-purpose space telescope, and is one of four Large Mission Concepts studied for the 2020 Astrophysics Decadal Survey that could operate in the 2040s. The potential for advancing solar system science with each one of these missions would be maximized by the inclusion of solar system scientists in science working groups and development teams, as has been done for JWST[2] and LUVOIR.

Science goals for LUVOIR include finding dozens of potentially Earth-like exoplanets and detecting signs of habitability and life. Another key goal is to place the solar system in the general context of diverse exoplanets. With its unprecedented resolution and sensitivity, LUVOIR can provide near-flyby quality imaging of Solar System worlds from Venus to Pluto over long timescales and with flexible cadence, monitor the ocean moons of the outer Solar System for cryovolcanic activity, and perform a survey for trans-Neptunian objects as small as 2 km in diameter.

The LUVOIR concept has two distinct variants: LUVOIR-A, with a 15-m primary mirror, and LUVOIR-B, with an 8-m mirror. The records and results of this work were submitted to NASA HQ and Astro2020 in the form of a Final Report[3] and a white paper submitted to the Planetary Decadal survey[4]. LUVOIR could offer an opportunity for a partnership on a cross-disciplinary mission early in its development.

4. Upcoming Gap in Planetary UV Astronomy: The Hubble Space Telescope (HST)'s impending end will create a gap in planetary observations. HST fills the

[1] Young et al. 2020 (https://bit.ly/2Y2zRFF)
[2] Hammel et al. 2020 (https://bit.ly/2Sa8yWz)
[3] Available at https://www.luvoirtelescope.org/
[4] Roberge et al. 2020 (https://bit.ly/2HDpbrN)

high-resolution, high-sensitivity UV/visible observation needs today. The upcoming JWST and Roman telescopes do not have UV observation capabilities; thus, the end of HST will create a gap in UV until a space telescope like LUVOIR becomes available in the 2040s. A space telescope dedicated to solar system science could enable revolutionary advance in surveying temporary dynamic phenomena as well as comprehensively characterizing diverse groups of small-bodies while filling the critical gap in UV observation capability.

5. CHARISMA Concept: A space telescope dedicated to solar system science can satisfy the UV-Visible observation needs after HST's end. In particular, deployable and in-Space Assembly (iSA) technologies have the potential to enable a sparse aperture telescope with an effective aperture of up to 10 meters – a white paper was submitted to advocate for *Caroline Herschel high Angular Resolution Imaging/Spectroscopy Multiple Aperture* (CHARISMA) telescope concept[5]. A sparse-aperture design optimized for moderate sensitivity and high spatial resolution is uniquely advantageous for solar system observations. The diffraction limit enabled by a 10-meter class aperture combined with the high-cadence observations offered by a dedicated telescope would enable new revolutionary advances in understanding time-dependent phenomena in the solar system. Deployable/iSA technologies needed for the telescope would be synergistic with future large astrophysics missions like LUVOIR and space-based interferometers.

6. Jupiter L1 Observatory Concept: The Jupiter System L1 Observatory concept, on the other hand, adapts a hybrid approach to send an observatory to be placed at the Sun-Jupiter first Lagrangian point, about 0.35 AU from Jupiter toward the sun, to achieve simultaneous remote sensing and field-and-particle measurements to maximize the temporal coverage of the jovian system. The New Frontiers class mission concept [6] focuses on the time-domain sciences, including the weather systems and deep interior structure of Jupiter, ionosphere-magnetosphere-solar wind coupling, activities of Galilean moons, and impact flashes on Jupiter. This concept also brings unique advantages to study jovian irregular satellites, upstream solar wind, interplanetary/interstellar dust populations, and other minor bodies that are critical to understand the current and past interactions between the jovian system and the solar system that cannot be achieved otherwise. The observatory concept will provide high synergistic values to current and future missions with broad scientific implications regarding solar system evolution, exoplanets, and astrophysics studies, and could serve as a strategic facility for the planetary science and exploration in the coming decade.

7. LightBeam Concept: Synergy with Space-borne Interferometer: LightBeam is a mission concept for smallsat (ESPA Grande-class) aimed at providing flyby-like imaging data on primitive bodies throughout the solar system, at single milliarcsecond scales – more than an order of magnitude greater angular resolution than JWST will deliver[7]. Specific areas of emphasis for LightBeam will be near-earth objects, main belt asteroids, and Jupiter Trojans. For single objects, LightBeam will assess sizes, shapes, and surface composition; for binary objects, the mission will also map orbits to provide measures of component mass and infer interior composition and structure.

The mission concept has been undergoing development by partners *Made In Space* and Lowell Observatory under a NASA SBIR study. LightBeam will be a simple optical interferometer which leverages in-situ manufacturing by the spacecraft of the booms that hold the outboard mirrors of the interferometer, allowing a lightweight 50-m optical structure to be launched inside of a 1-m^3 ESPA Grande-class mass & volume. Emphasizing precision tracking of input optics, sensitivity from long coherence times from space-based operations, and elements of manufacturing technology that *Made In Space* has already flight-proven, Lightbeam will demonstrate a enabling new approach to space-based observatories, as well as delivering science results.

8. Recommendations: We recommend the upcoming Planetary Science and Astrobiology Decadal Survey examine the need to survey the diverse temporally dynamic phenomena of the solar system using a space telescope. The survey should first examine the impact of the upcoming gap in the UV coverage after the end of HST, the benefit of space telescopes for solar system observations, and define the roles of future large astrophysics space telescopes like LUVOIR as well as a dedicated space telescope like CHARISMA. Technological readiness of these concepts should also be examined; some technologies may be demonstrated using a SmallSat like LightBeam. Lastly, a future space telescope does not have to be restricted to cis-Earth space; concepts such as the Jupiter L1 Observatory that strategically places a moderate aperture show promise in intensively studying various temporally dynamic phenomena on a target system.

[5] Sayanagi et al. 2020 (https://bit.ly/338yDf5)
[6] Hsu et al. 2020 (https://bit.ly/341NOWI)
[7] van Belle et al. 2020 (https://bit.ly/36dArVO)