OBSERVING THE IRREGULAR MOONS OF URANUS BY THE URANUS ORBITER PROBE MISSION, PART 1: SCIENCE OBJECTIVES AND POTENTIAL GROUND-BASED SUPPORT. A. J. Verbiscer[1], T. Denk[2], S. Mottola[2], S. B. Porter[3], [1]Univ. of Virginia (Dept. of Astronomy, P.O. Box 40032, Charlottesville VA 22904 USA), [2]DLR (German Aerospace Center), Berlin, Germany, [3]Southwest Research Institute, Boulder, Colorado, USA.

Introduction: This abstract (Part 1) and its companion by Denk *et al.* (Part 2) [1] present the benefits of observing the Irregular moons of Uranus from a spacecraft in orbit around the planet. Here, we describe science objectives and the potential of ground-based observations of Uranian Irregulars to support the Uranus Orbiter Probe (UOP) mission.

The Uranian Irregular Moon System: Uranus has nine currently-known Irregular moons [2, 3]. Eight of these are on retrograde orbits, and one is on a prograde path (Table 1). They range in size from ~18 to ~160 km in diameter and follow eccentric orbits with mean semi-major axes between 167 and 824 Uranus radii (~4.3 to ~$20.9 \cdot 10^6$ km) [4]. Relative to the orbit plane of Uranus around the Sun, the Uranian Irregulars have highly tilted orbits. Most are faint and positioned in the sky close to their bright host planet, so studying these objects from Earth is extremely difficult and requires large apertures to obtain a useful signal-to-noise ratio (SNR).

In contrast, the Jovian and Saturnian systems have far more irregular satellites: 87 and 66, respectively. The differences between the population sizes of the Irregular moon systems of the gas and ice giant planets may be due in part to Uranus' larger heliocentric distance makes it more difficult to detect smaller bodies. So far, only Uranian irregulars with diameters ≳18 km have been detected ([5] give ~7 km as the limit of their survey). Similarly, the Jovian and Saturnian systems have nine Irregulars ≳10 km, so it's likely that Uranus harbors hundreds of Irregular moons >1 km.

Ground-based Observations: While the orbital elements of these objects are well known [3], very little is known on their basic physical properties. Sizes are primarily estimated from apparent magnitudes and assumed albedos [5], except for Sycorax and Caliban, whose sizes were determined from Herschel and Spitzer [6, 7] measurements of their thermal fluxes. Other properties, especially colors, were reported by [8-11], but with limited SNR. Rotation curves (light curves) and periods of five Uranian Irregulars from K2 data have been published by [7] (see also Table in [1]).

The increased aperture sizes of the extremely large telescopes (ELTs) coming online by the end of this decade will increase the SNR, and these new facilities could detect many more fainter, and therefore smaller, Irregulars. The Vera Rubin Observatory's LSST can obtain long-term measurements of the satellite reflectance variations with rotation (light curves) and determine rotation periods at least for the brighter moons with $R \lesssim 24$.

The Uranus system crosses the galactic plane in 2032-2033, providing numerous background stars for Irregular moons to occult [12]. Stellar occultations by small bodies, e.g., contact-binary Kuiper belt object (486958) Arrokoth [13] and Trojan asteroid (11351) Leucus [13], have been used to measure their shapes and sizes in support of NASA's New Horizons and Lucy missions, respectively. Similar campaigns to observe stellar occultations by the Uranian Irregular satellites could provide first-order shapes and sizes (and therefore albedo), informing planetesimal formation mechanisms since the Uranian Irregulars are likely very primitive.

Observing Irregular Moons From Spacecraft: Only UOP can obtain more shape information from light curves acquired at high solar phase angles. The companion abstract (Part 2) [1] presents Cassini's campaign to observe Saturn's Irregulars [15], the upcoming JUICE campaign in the Jupiter system, and how the UOP mission might conduct such observations.

References: [1]Denk+ 2023 this conference; [2] Gladman+ 1998 *Nature*; [3] Brozović&Jacobson 2022 *AJ*; [4] Sheppard+ 2005 *AJ*; [5] https://sites.google.com/carnegiescience.edu/sheppard/moons/uranusmoons; [6] Lellouch+ 2013 *A&A*; [7] Farkas-Takács+ 2017 *AJ*; [8] Romon+ 2001 *A&A*; [9] Rettig+ 2001 *Icarus*; [10] Grav+ 2004 *ApJL*; [11] Maris+ 2007 *A&A*; [12]Porter+ 2023 this conference; [13] Buie+ 2019 *AJ*; [14] Buie+ 2021 *PSJ*; [15] Denk&Mottola 2019 *Icarus*; [16] MPC https://www.minorplanetcenter.net/cgi-bin/natsats.cgi.

Table: Uranian Irregular moons: Orbital elements, orbit periods, apparent and absolute magnitudes.

Satellite	JPL Code	*a* [Gm]	*e* []	*i* [°]	*P* [d]	*R* [mag]	*H* [mag]
Margaret	723	14.07	0.68	58	1648	25.2	12.7
Francisco	722	4.28	0.14	147	267	25.0	12.9
Caliban	716	7.23	0.20	142	580	22.4	9.0
Stephano	720	8.00	0.22	144	677	24.1	11.6
Trinculo	721	8.51	0.22	167	750	25.4	12.7
Sycorax	717	12.18	0.52	159	1289	20.8	7.5
Prospero	718	16.27	0.44	152	1980	23.2	10.5
Setebos	719	17.44	0.59	158	2229	23.3	10.7
Ferdinand	724	20.65	0.40	170	2816	25.1	12.5

Notes: Orbital elements and periods (*a*, *e*, *i*, *P*) from JPL SSD URA116 [3]. The longest period is 7.7 years or ~1/11th Uranus orbit around the Sun. *R* magnitudes from [5]; *H* (absolute *V* magnitude) values from [16].