Janus: A NASA SIMPLEx mission to explore two NEO Binary Asteroids. D.J. Scheeres[1], J.W. McMahon[1], E.B. Bierhaus[2], J. Wood[2], L.A.M. Benner[3], C.J. Benson[1], C.M. Hartzell[4], P. Hayne[1], R. Jedicke[5], L. Le Corre[6], A. Meyer[1], S. Naidu[3], P. Pravec[7], M. Ravine[8] and K. Sorli[1], [1]The University of Colorado Boulder, USA <scheeres@colorado.edu>, [2]Lockheed Martin Space, USA, [3]Jet Propulsion Laboratory, USA, [4]University of Maryland, USA, [5]University of Hawaii, USA, [6]Planetary Science Institute, USA, [7]Astronomical Institute of the Academy of Sciences, Czech Republic, [8]Malin Space Science Systems Inc, USA

Introduction: Janus is a NASA SIMPLEx mission currently in Phase C/D. The NASA SIMPLEx program is designed around the idea of using secondary launch opportunities to explore interplanetary destinations. SIMPLEx missions are cost-capped at $55M USD, including all Phase E support. They are also classified as Class D missions, meaning that they are tolerant of a higher level of risk as compared to Discovery or New Frontiers mission classes. A simple metric for this risk classification is that SIMPLEx missions are biased towards a 2-sigma level of reliability, whereas the higher risk classifications are biased towards a 3-sigma level of reliability.

The Janus mission was selected in 2019 as a SIMPLEx mission to be co-manifested with the NASA Discovery mission Psyche, scheduled to be launched in August of 2022. Janus will send two spacecraft to fly by Near Earth Objects of interest. The spacecraft will be attached to an ESPA ring. Each of the Janus spacecraft will fly by a separate binary asteroid system in early 2026. The targeted binary asteroid systems are (175706) 1996 FG3 and (35107) 1991 VH, both of which have been observed repeatedly with photometry, spectrometry and radar.

Mission Outline and Instruments: The Janus spacecraft are designed to be plow-mass, low-cost and small, falling into the "small sat" classification. They are being designed and built by Lockheed Martin. Each spacecraft carries two science instruments, a visible and an IR imager, built by Malin Space Science Systems (Fig. 1 and Tab. 1).

The science team members all have experience on asteroid missions or are experienced ground based observers of NEAs. The team is also structured to include both experienced asteroid scientists and early-career scientists. There are also graduate PhD students incorporated into the team to ensure that future scientists are being trained on making contributions to space exploration. The industry team has extensive experience in the design, fabrication and operation of interplanetary spacecraft and instrumentation.

The Janus spacecraft will be launched in August 2022 as a rideshare with the Psyche mission. Each spacecraft will be placed on a 3-year orbit and carry out an Earth gravity assist in August 2025. This sets them up for their respective flybys, occurring in the first quarter of 2026.

Around the time of the asteroid flybys the spacecraft will perform a rigorous remote sensing campaign when the object is a point source and when resolved. On approach and departure asteroid light curves will be observed to precisely determine the orbit and rotational phasing of the bodies, orbit periods and rotation periods. When resolved the spacecraft will track the binary asteroid systems through closest approach, allowing for a combination of absolute surface resolution, relative resolution across the target asteroids and phase angle coverage unparalleled in previous asteroid flyby missions.

Target Binary Asteroids: The Janus target binary asteroids have been observed using Earth-based optical, IR and radar telescopes for over two decades. These observations have provided precise global shape models and orbit information for each system, which in turn have exposed additional questions that require higher resolution observations to address.

(175706) 1996 FG3 Binary 1996 FG3 is a primitive C-Type asteroid. It has been documented to lie in a singly-synchronous state and was the first binary system to be documented to lie in a Binary YORP — Tide equilibrium [1]. Observation of the thermal properties of the secondary will allow us to gain insight into tidal dissipation occurring in the primary body, which will be an unprecedented measurement for a small rubble pile asteroid.

(35107) 1991 VH Binary 1991 VH is a rocky S-Type asteroid. It has a secondary that is not settled into the usually observed, minimum energy singly synchronous state. Instead, the secondary has been seen to exchange angular momentum and energy with the system orbit, leading to an apparent chaotic dynamical evolution [2]. We will use our visible and thermal observations of the secondary and the entire system to better understand why this system is not in a lower-energy state, as most binaries are. Hypotheses for its current unsettled state include a recent close planetary flyby that could have disrupted a stable state [3], that it has evolved into an unstable region in terms of resonances between its orbit and rotation [4], or it has a rigid secondary that has resisted energy dissipation while its orbit has continued to evolve outwards due to tides.

Janus Science Goals: The Janus science goals are to understand the formation and evolutionary mechanics of binary rubble pile asteroids, and to understand the key features of each of the binary asteroid systems outlined above. The Janus science goals will be achieved by combining flyby observations of the target binary asteroids with ground-based observations of the systems, leveraging decades of observations of these binary asteroids. This combination will enable the high resolution imaging and thermal data to be placed into a global context, leveraging all available data to construct an accurate topographical and morphological model of these bodies. In addition, the dynamics of the binary asteroid systems will be fit across the encounter, from approach to departure observations, in order to constrain the mass and inertias of the system components, where possible.

Understanding the formation and evolution of binary asteroids provides a key to understanding the physical evolution of rubble pile asteroids in general. Figure 2 shows a combination of current understandings of how gravitational and non-gravitational forces drive small rubble pile asteroids into the various configurations that are observed in the solar system. A key aspect of these lifecycles is the formation and evolution of binary asteroids as one of the many products from this physical evolution. Thus, by gaining an understanding of binary asteroids and their formation and evolutionary mechanisms, using the Janus observations, it will be possible to gain insight into these larger-scale evolutionary scenarios that have been identified and are represented.

A key question the Janus mission will address is the apparent convergent evolution for both of our binary asteroid systems. Despite being very different asteroid types with different mechanical and morphological properties (as predicted from previous asteroid missions to S-Type and C-Type asteroids), they have both evolved into very similar primary shapes and secondary relative sizes. This indicates that the mechanical forces and effects may play a more significant role than chemistry in driving their evolution.

Conclusions: Janus is a NASA SIMPLEx mission that will launch with the NASA Discovery mission Psyche in August 2022. Its two spacecraft will flyby target binary asteroids 1991 VH and 1996 FG3 in the first quarter of 2026. Scientific results from Janus will provide key insights into and constraints on the mechanics of rubble pile asteroids in general, and binary asteroids in particular.

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References: [1] P. Scheirich et al. Icarus 245: 56-63 (2015); [2] P. Pravec et al. Icarus 267: 267-295 (2016); [3] A.J. Meyer and D.J. Scheeres. Icarus 367: 114554 (2021); [4] S.P. Naidu and J.-L. Margot. AJ 149(2): 80 (2015)

Figure 1: The delivered Janus JCam Suite from MSSS.

Table 1: Instrument specifications.

Instrument	Specifications
Visible Imager	ECAM-M50, 2592 x 1944 pixel CMOS sensor with 2.2 μm pixels, 420-680 nm bandpass, and an electronic rolling shutter.
IR Imager	ECAM-IR3a, 640 x 480 uncooled Long-Wave Infrared (LWIR) microbolometer sensor array with 17 μm pixels and 8-12 μm bandpass.
DVR	ECAM-DVR4, power conditioning, camera control, image processing, compression, subset windowing and storage.

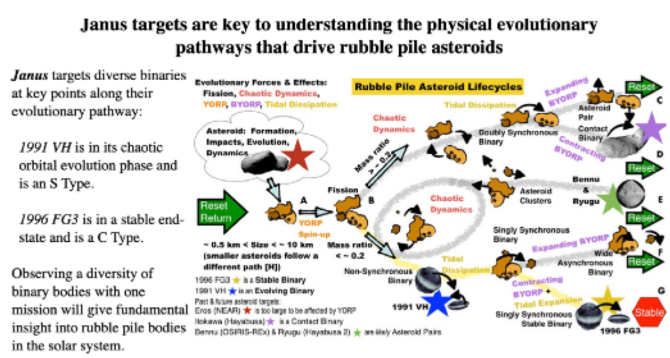

Figure 2: Evolutionary pathways of small rubble pile asteroids.