Janus: A mission concept to explore two NEO Binary Asteroids

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Janus Mission Selected for Phase A/B!

- Janus was submitted to the inaugural SIMPLEx call for proposals
  - Launch provided on an upcoming mission, e.g., Lucy or Psyche, for interplanetary missions
  - Up to $55M for a given mission

- Proposals were submitted July 2018 (12 total submissions)
- Announcement made last Wednesday… Janus is selected for Phase A/B! (1/3)
Janus observes two binary asteroid systems at a higher spatial resolution and greater phase angle coverage than any previous asteroid flyby mission. Named for the Roman god of duality, depicted with two faces looking to the past & future.
The *Janus* Science Objectives and corresponding Mission Implementation are focused and simple

<table>
<thead>
<tr>
<th>Science Objectives</th>
<th>Mission Overview</th>
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</thead>
<tbody>
<tr>
<td><strong>Janus science goals address key Cross-Cutting NASA Themes</strong></td>
<td><strong>Science Implementation Requirements</strong></td>
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<tr>
<td><strong>Solar System Workings:</strong></td>
<td>• Fly by two binary asteroids at low speed with favorable illumination conditions</td>
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<td>How do rubble pile asteroids evolve over time?</td>
<td>• Image the system components at high resolution across a diversity of phase angles</td>
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<td><strong>Building New Worlds:</strong></td>
<td><strong>Mission Design &amp; Implementation</strong></td>
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<tr>
<td>What properties do microgravity aggregates have?</td>
<td>• Launch: Psyche Rideshare August 2022</td>
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<td><strong>Goal I:</strong> Identify and understand the processes that lead to binary asteroid formation.</td>
<td>• Earth Gravity Assist: August 2025</td>
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<td><strong>Goal II:</strong> Test and evaluate theories for binary asteroid evolution by studying the unique dynamical states of binary asteroid systems.</td>
<td>• Binary Asteroid Flybys:</td>
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<td>• 1991 VH: March 3, 2026</td>
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<td>• 1996 FG3: April 20, 2026</td>
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<td></td>
<td>• End of flight operations May 31, 2026 (45 months)</td>
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<td>• Science evaluation through December 31, 2026</td>
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Janus Science Goals and Objectives

• **Goal I**: Identify and understand the processes that lead to binary asteroid formation
  – **SO1**: Identify evidence in support of and constrain specific models of binary asteroid formation.
  – **SO2**: Estimate and constrain binary system parameters and mass models.

• **Goal II**: Test and evaluate theories for binary asteroid evolution by studying the unique dynamical states of the binary asteroid systems.
  – **SO3**: 1996 FG3 — Measure the secondary BYORP Coefficient and constrain the tidal dissipation rate of the system primary.
  – **SO4**: 1991 VH — Test hypotheses to explain the system’s unsettled state.
The Janus mission targets are well studied and diverse, enabling precision flybys and meaningful comparisons to expose the fundamental processes of binary asteroid formation.

Target Binary Asteroids: (175706) 1996 FG3 and (35107) 1991 VH

Ideal Targets Enable Janus’ Science Goals

- Binary near-Earth asteroids that have been subject to multiple transitions and have similar shapes and morphologies
- Distinct systems that lie at different evolutionary stages and which have different compositional properties
- Both have been extensively characterized by ground-based observations providing known mass, shape, rotation and orbit
- Potentially Hazardous Asteroids

A rocky S-Type in an excited state and a non-synchronous secondary rotation state
A primitive C-Type in a long-term stable state and a synchronous secondary
Janus targets are key to understanding the physical evolutionary pathways that drive binary rubble pile asteroids

Janus targets diverse binaries at key points along their evolutionary pathway:

*1991 VH* is in its chaotic orbital evolution phase and is an S Type.

*1996 FG3* is in a stable end-state and is a C Type.

Observing the diversity of binary bodies with one mission will give fundamental insight into rubble pile bodies in the solar system.
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**Evolutionary Forces & Effects:**
Fission, Chaotic Dynamics, YORP, BYORP, Tidal Dissipation

**Rubble Pile Asteroid Lifecycles**

~ 0.5 km < Size < ~ 10 km (smaller asteroids follow a different path [H])

1996 FG3 ★ is a Stable Binary
1991 VH ★ is an Evolving Binary
Past & future asteroid targets:
Eros (NEAR) ★ is too large to be affected by YORP
Itokawa (Hayabusa) ★ is a Contact Binary
Bennu (OSIRIS-REx) & Ryugu (Hayabusa 2) ★ are likely Asteroid Pairs
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The *Janus* instrument suite has high-heritage and proven performance

The *Janus* instrument suite is provided by Malin SSS and supports visible and near-IR imaging of our target binaries. The DVR allows for flexibility in imaging, on-board data compression and selective downloading of images taken through the flyby.

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<thead>
<tr>
<th>Instrument</th>
<th>Description</th>
<th>Heritage</th>
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<tbody>
<tr>
<td>Visible Imager</td>
<td>ECAM-M50, 2592 x 1944 pixel CMOS sensor with 2.2 µm pixels, 420-680 nm bandpass, and an electronic rolling shutter</td>
<td>OSIRIS-REx, Undisclosed Mission</td>
</tr>
<tr>
<td>Infrared Imager</td>
<td>ECAM-IR3a, 640 x 480 pixel uncooled Long-Wave Infrared (LWIR) microbolometer sensor array with 8-12 µm bandpass, integral Read-Out Integrated Circuit (ROIC) and 17µm pixels.</td>
<td>Undisclosed Mission</td>
</tr>
<tr>
<td>DVR</td>
<td>ECAM-DVR4, power conditioning, camera control, image processing, compression, subset windowing, and storage.</td>
<td>OSIRIS-REx, Undisclosed Mission</td>
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Janus Provides Data to Advance Planetary Science

• Flyby data provide the needed resolutions and coverage to address fundamental science objectives for size, shape, bulk properties, and fundamental surface processes
  – Significant contribution to small-body science, and planetary formation

• Flybys naturally provide a range of phase angles, incidence angles, and emission angles
  – High-phase angle imaging (typically approach and departure) provides shape and surface geomorphology
  – Low-phase angle imaging (typically near closest approach) provides information on albedo and shape
  – Existing radar shape models can be leveraged to provide decameter structure on which to hang our high-resolution flyby images
Janus targets reside in a Sweet Spot between science and mission implementation

• We know enough about our target asteroids to pose fundamental science questions, and architect a sound mission implementation

• Science knowledge
  – Spectral classes: sampling two binary systems of very different spectral classes
  – Binary states: stable vs. excited
  – Decameter shape models to enable computation of key geophysical parameters

• Mission implementation knowledge
  – The orbits of the binary pairs around the Sun are well-known to enable accurate encounter targeting
  – The orbits of the secondary around the primary enable targeting specific secondary orientation relative to the primary at the time of flyby
  – Decameter shape models to enable detailed planning
Summary

- **Janus** is a University of Colorado / Lockheed Martin mission concept selected by NASA for Phase A/B development.
- **Janus** will provide the first high resolution, scientific observations of NEO binary asteroid systems that span mineralogical and dynamical diversity.
- **Janus** can provide insight into the mechanics of rubble pile bodies, and into microgravity geophysical processes in general.