Neutron Star Interior Composition Explorer (NICE)

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What happens when you pack 1.4 solar masses into a volume the size of New York City?
NICE Mission Overview

A flagship astrophysics experiment on the International Space Station: Understanding ultra-dense matter through soft X-ray timing

- **Science:** A proposed International Space Station (ISS) payload dedicated to the study of **neutron stars**—a fundamental investigation of extremes in gravity, material density, and electromagnetic fields.
- **Spacecraft:** Hosted on the ISS Express Logistics Carrier
- **Launch:** JAXA H-II-B or NASA TBD
- **Duration:** 18 (min.12) months
- **Cost:** $36M
- **Team:** NASA GSFC and ARC, MIT. Science co-Is from USRA, UMCP, UMBC, NRL, CfA, McGill, SUNY, MSU, F&M, NRAO, UNAM.
NICE Science Objectives

Neutron stars—Unique environments in which all four fundamental forces of Nature are simultaneously important.

- To address NASA and National Academy of Sciences strategic questions
- To resolve the nature of ultradense matter at the threshold of collapse to a black hole
- To reveal interior composition, dynamic processes, and radiation mechanisms of neutron stars.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Measurements</th>
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<tbody>
<tr>
<td>Structure—Reveal the nature of matter in the interiors of neutron stars.</td>
<td>Neutron star radii to ±5%. Cooling timescales.</td>
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<td>Dynamics—Uncover the physics responsible for the dynamic behavior of neutron stars.</td>
<td>Stability of pulsars as clocks. Properties of outbursts, oscillations, and precession.</td>
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<td>Energetics—Determine how energy is extracted from neutron stars.</td>
<td>Intrinsic radiation patterns, spectra, and luminosities.</td>
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**NICE Science Measurements**

A Comprehensive Understanding of Neutron Star Structure, Dynamics, and Energetics

**Structure:** The unknown equation of state (EOS) of dense matter governs global properties such as radius for a given mass. NICE will reveal the nature of matter at supranuclear densities.

**Dynamics:** NICE will reveal the bulk properties of neutron star crusts and the role of quantum fluids in time-dependent phenomena.

**Energetics:** Enormous magnetic fields drive particle flows and radiation across the electromagnetic spectrum. NICE will pinpoint radiation sites and mechanisms.

Thermal lightcurve modeling and pulsation searches to constrain the mass-radius relationship...

Asteroseismology, timing stability...

Nonthermal pulse shapes and spectra...
NICE Instrument Design
Technology with strong heritage, including actual flight and build-to-print hardware

- **Optics**: 56 grazing-incidence X-ray “concentrators”
- **Detectors**: 56 associated avalanche photodiode assemblies
- **Timing**: GPS position and absolute time reference to UTC
- **Pointing**: Active, star-tracker reference
- **Environment**:
  - Tolerant of ISS vibrations
  - Contamination-insensitive, with safe-stow capability
- **Mass**: 165 kg
- **Power**:
  - @ 28 V: 80 W (avg.), 107 W (peak)
  - @ 120 V: 295 W (avg.), 504 W (peak)
- **Data Rate**: 2 kbps (avg.), 4.8 Mbps (peak, for ~100 sec durations).
NICE Instrument Performance
High-throughput, low-background soft X-ray timing and spectroscopy

- **Bandpass**: 0.4–10 keV
- **Effective area**:
  - 2300 cm² @ 1.5 keV,
  - 600 cm² @ 6 keV
  XMM-like collecting area (2x timing-capable EPIC-PN camera)
- **Energy resolution**:
  - 20% @ 1 keV,
  - 5% @ 6 keV
  4x better than RXTE
- **Timing resolution**: 100 nsec absolute
  50x better than RXTE
- **Spatial resolution**: 3 arcmin
- **Background**: Dominated by diffuse cosmic XRB (soft)
- **Sensitivity**: $2.2 \times 10^{-14}$ ergs/s/cm²
  (0.4–10 keV, $5\sigma$ in 10 ksec for steady source)
  ~20x better than RXTE.
Why NICE Now?

**Science**

- Superior combination of X-ray timing and spectroscopy advances neutron star science beyond discoveries of *Chandra*, *RXTE*, and *XMM*
- High resolution timing provides continuity for much *RXTE* science, new capability in the soft X-ray band
- Coordinated science with *GLAST* increases return on investment.

**Opportunity**

International Space Station provides:

- A stable platform for arcminute astronomy
- Established infrastructure (power, comm, etc.) that reduces risk
- Generous resources that simplify design and reduce cost.

**Technology**

- NICE will demonstrate X-ray pulsar navigation (XNAV), potentially a low-cost Solar system-wide navigation solution for the Vision for Space Exploration.