

National Aeronautics and Space Administration



Pulsar Navigation & X-ray Communication Demonstrations with the NICER Payload on ISS

Presented by
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for the NICER/XNAV team

1st Annual ISS R&D Conference
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Station Explorer for X-Ray Timing and Navigation Technology (SEXTANT)
NASA GSFC

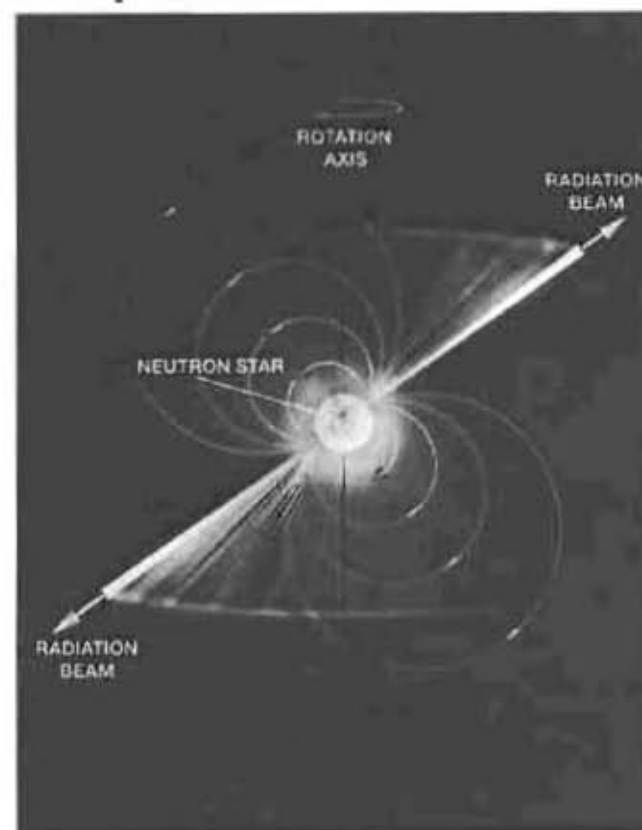
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Outline

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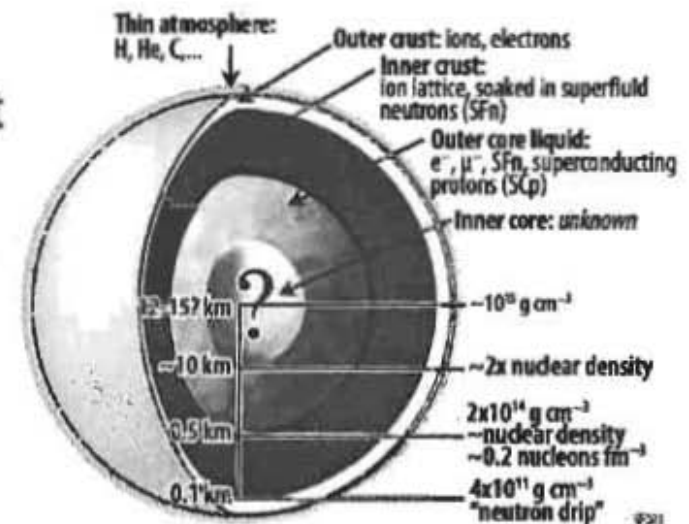
- Neutron-star Interior Composition ExploreR
- Mission naming
- People
- Mission commonality
- Goals
 - Navigation
 - ◆ Ground testbed
 - Communication
- Challenges
- Future activity



NICER — Science Objectives



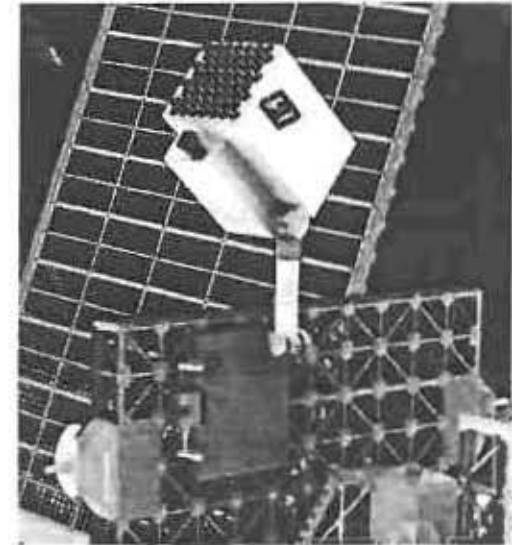
- Address NASA and National Academy of Sciences strategic questions
 - Resolve the nature of *ultra-dense* matter at the threshold of collapse to a black hole
 - **Structure**—Reveal the nature of matter in the interiors of neutron stars
 - **Dynamics**—Uncover the physics responsible for the dynamic behavior of neutron stars
 - **Energetics**—Determine how energy is extracted from neutron stars



Project Names & Definitions

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- **NICER — Neutron-star Interior Composition ExploreR**
 - ISS ELC Explorer Payload (2016/09/02)
 - Observe pulsars in X-ray part of EM spectrum
 - Determine pulsar radii and masses
 - SMD selected *purely* on science (Phase A)
- **SEXTANT — Station Explorer for X-Ray Timing and Navigation Technology**
 - Same instrument used for NICER
 - Navigation (XNAV) and communication (XCOM)
 - ◊ XCOM: payload is X-ray receiver
 - ◊ XNAV: advanced algorithms, measurement processing
 - Enhanced avionics/algorithms required over NICER baseline



Project Team Overview



■ NICER

- Keith Gendreau, Zaven Arzoumanian, Fotis Gavriil

■ XNAV

- Jason Mitchell, Monther Hasounah, John Gaebler, Dennis Woodfork, Luke Winternitz, Jennifer Valdez

■ XCOM

- Wai Fong, Victor Sank, David Fisher

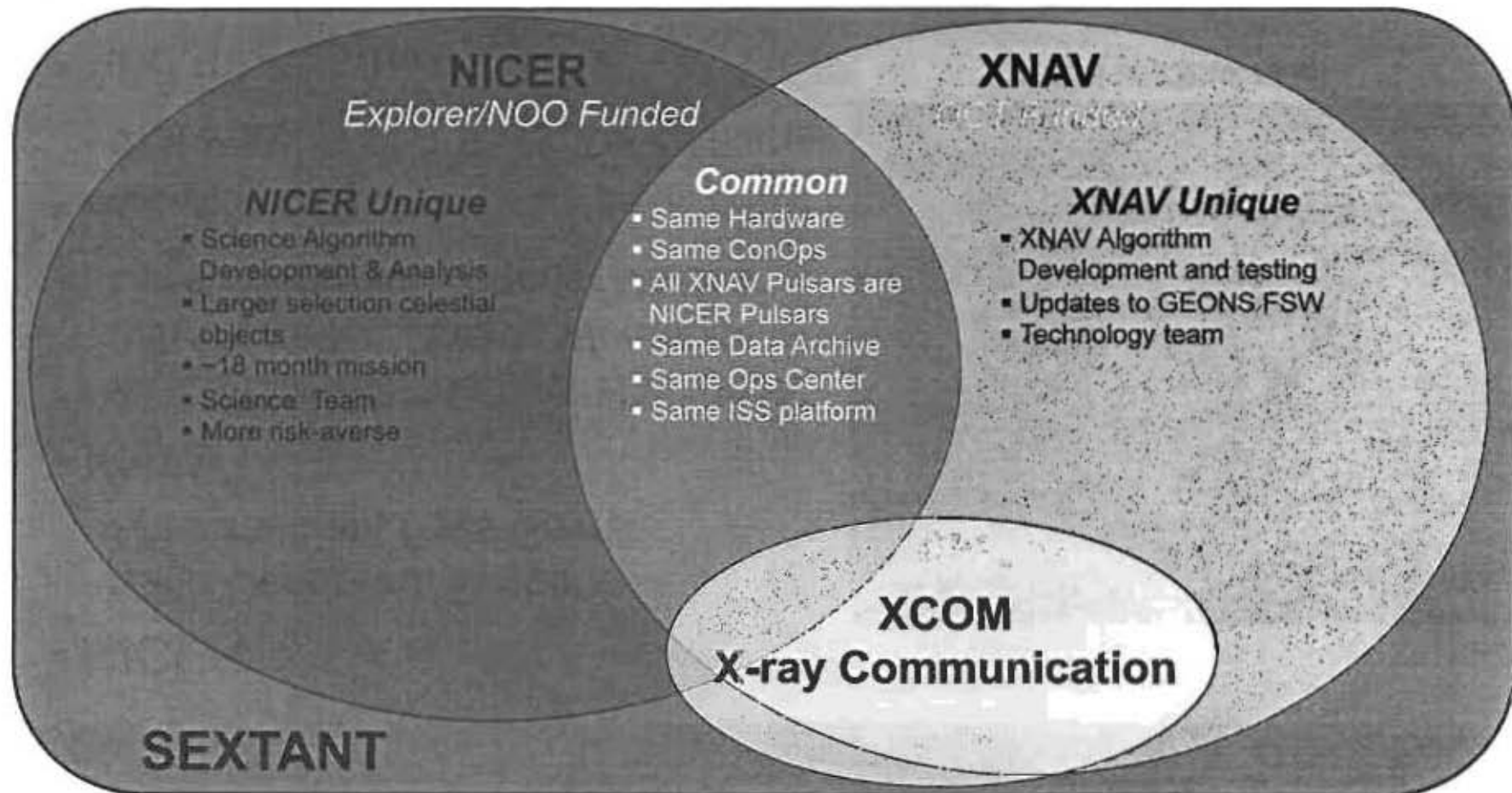
■ And many, many more!

- many external partners too!



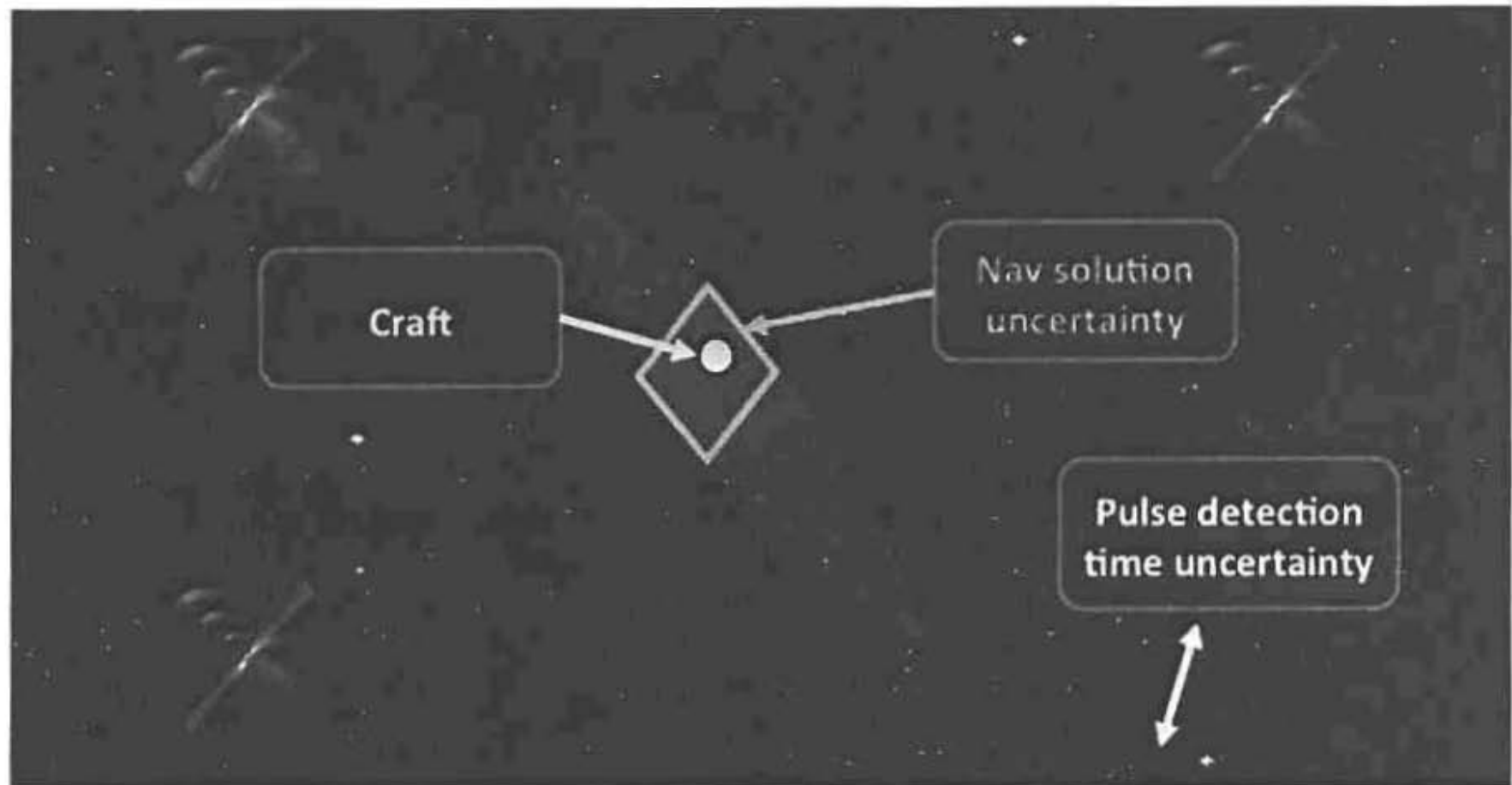
Portion of XNAV Team

Mission Commonality: SEXTANT = NICER + XNAV + XCOM



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Basic Navigation



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XNAV Concept



▪ Precise timing enables improved navigation

- Pulsars: rapidly spinning neutron stars
- Millisecond pulsars (MSPs)
 - ♦ rival atomic clocks as time-keepers
 - ♦ accuracy & stability
- Potentially provide *galaxy-wide* time-base
 - ♦ GPS-like navigation capability throughout solar system

Crab Pulsar (slowed), Cambridge University, Lucky Image Group

▪ Measurement

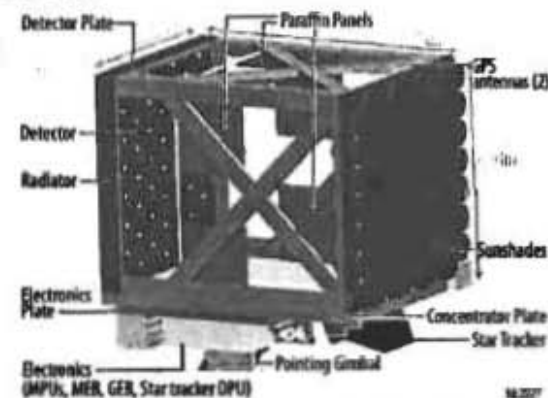
- Precisely time tag X-ray photons
- Pulse arrival time, i.e., pulsar *pseudo-range*
- Stitch sequence together for autonomous navigation solution

▪ Interested agencies: NASA, DoD (DARPA), NIST

SEXTANT / XNAV Goals



- Provide *1st on-orbit demo* of XNAV concept
 - LEO worst case scenario
 - Real-time 1D range < 1 km from 2–3 pulsars / orbit
 - XNAV-only 3D position to ~500 m @ 1 day
 - Understand sky distribution effect on dilution of precision
 - Long-term characterization of pulsar clock stabilities
 - Characterization of additional candidate pulsars
- Other benefits
 - Active X-ray timing observatory, RXTE decommissioned
 - Improved sensitivity over RXTE, XMM-Newton



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SEXTANT / XNAV Elements

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- Improved X-ray concentrator optics
 - Large collecting area, small volume
- Silicon drift detectors
 - Time resolution < 200 ns
- Algorithms
 - Relativistic time-transfer, pulsar range estimator, XOD
- GSFC Navigator GPS technology
 - Precise reference to UTC
- MSP Emulator
 - Miniaturized modulated X-ray source
 - EDU time-tagging X-ray photon detector



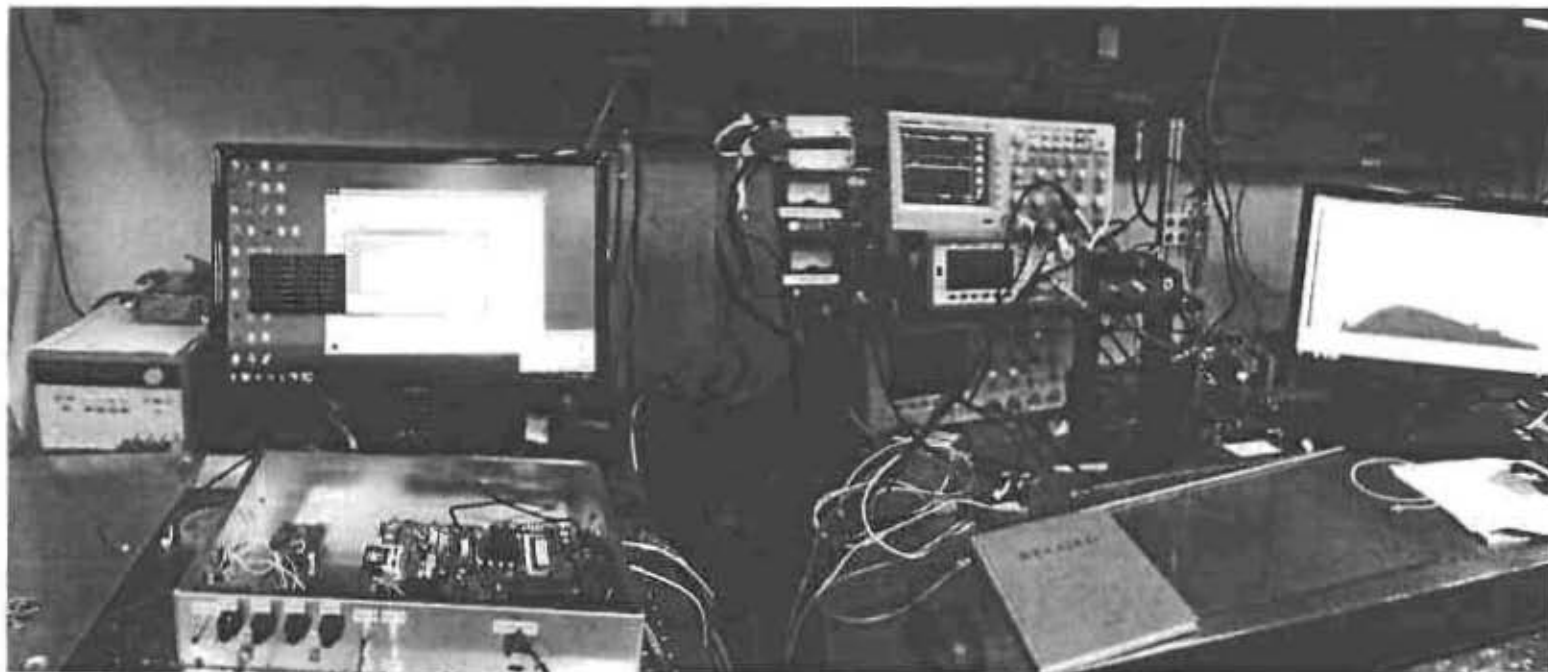
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Goddard XNAV Laboratory Testbed (GXLT)



- Guided incremental multi-milestone development plan
- Leverages Goddard GN&C (Code 590) software tools
 - Mission design: General Mission Analysis Tool (GMAT)
 - Orbit determination:
 - ◆ Orbit-determination toolbox (ODTBX) for MATLAB
 - ◆ Goddard Enhanced On-board Navigation System (GEONS) flight software
 - GPS receiver (Navigator GPS) design and expertise
- Support algorithm development & testing
- Prepare & transition algorithms to flight software
- Standardized interfaces defined to foster collaboration

Current GXLT Progress

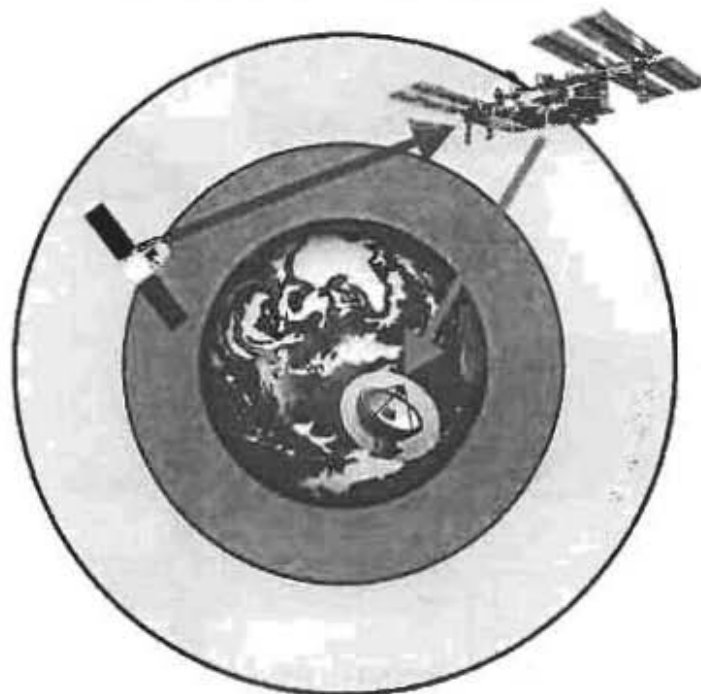


Real-time MSP emulation

XCOM Experiment Concept

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Range: 25 to 1000 km

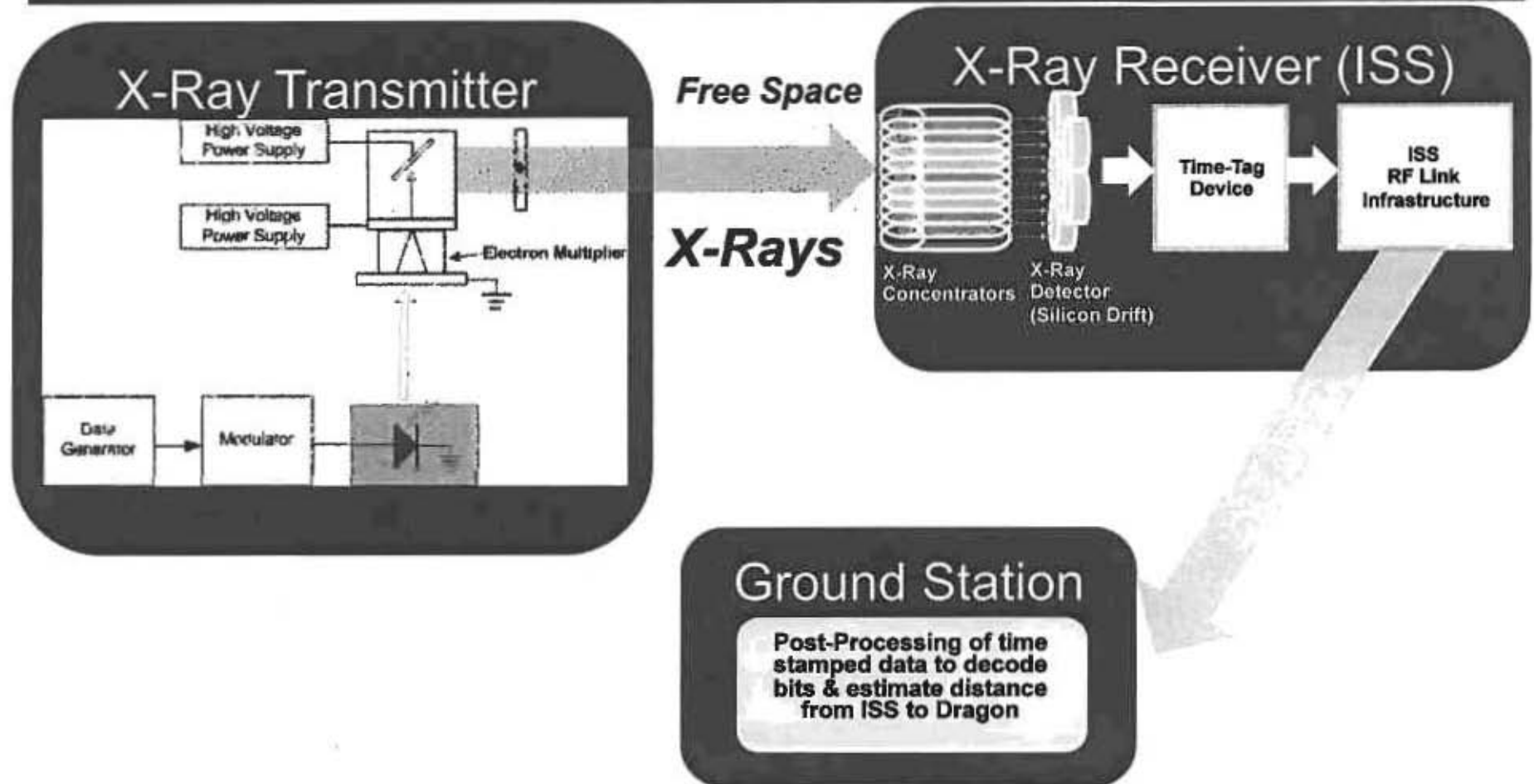


- X-Ray link from service craft (Dragon) to ISS
- RF link from ISS to ground

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X-ray Comm. Link System Block Diagram

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Technical Challenges



- Launch: HTV or Dragon
 - Huzzah to SpaceX
- Address Crab PSR high photon count rates
- Observing sufficient photons from low-count-rate pulsars
 - accurate measurements challenging in high dynamics
- Choice of coordinate time
 - TDB vs. TCB
- GPS and timing accuracy on ISS
 - Multi-path effects from geometry
 - SV visibility & geometry
 - High time accuracy

Future Activity



- Complete Step 2 concept study report
 - Due mid-Sep 2012
- Demonstrate GXLT, real-time, hardware-in-the-loop
- Broad improvements to modeling fidelity
- Extensive algorithm testing
- EDU hardware integration
- Flight software development & integration
- S/C integration & test