Emerging Technologies for Autonomous Space Navigation

Opportunities for Technology Development, Demonstration, and Deployment Missions with XISP-Inc

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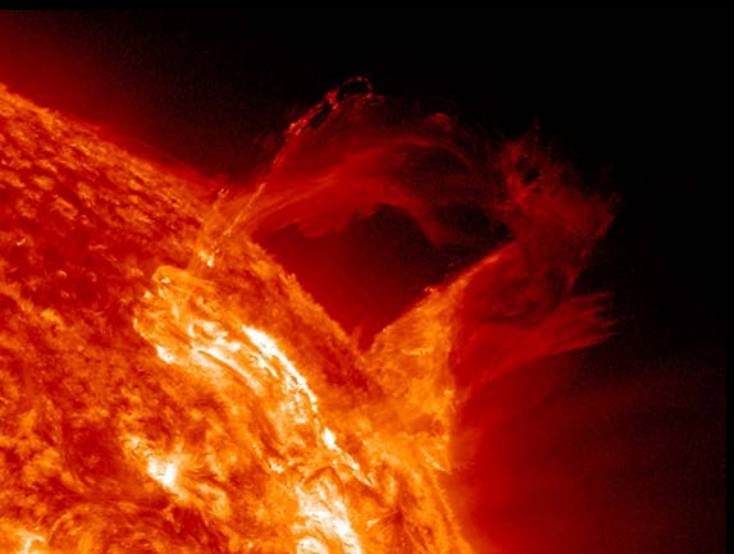
Outline

- What is XISP-Inc?
- XISP-Inc mission set mapped to SCaN portfolio
- Intersection with SCaN emerging technologies
- Path forward



XISP-Inc Introduction

- Xtraordinary Innovative Space Partnerships, Inc. (XISP-Inc) is a for profit company based in Cabin John, Maryland
- XISP-Inc is focused on the definition and execution of Technology Development, Demonstration, and Deployment (TD^3) Missions
- Our missions leverage the resources of the International Space Station and its supporting systems to foster space development.
- Our missions are public-private partnerships proceeding under existing and pending NASA Space Act Agreement authority.

XISP-Inc Evolving TD^3 Mission Set

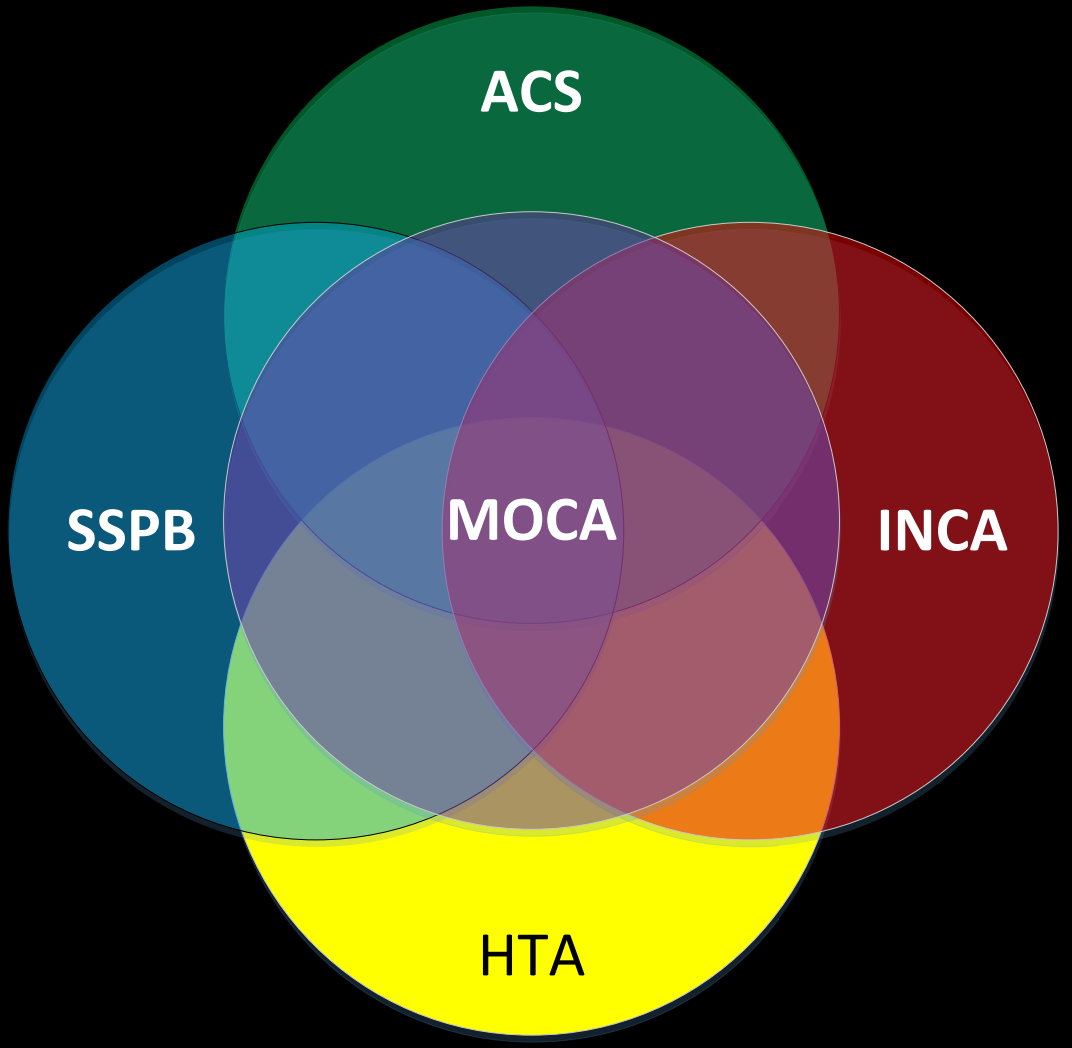
Alpha CubeSat (ACS)

Space-to-Space Power Beaming (SSPB)

Halfway To Anywhere (HTA)

Interoperable Network Communication Architecture (INCA)

Mission Operations Control Applications (MOCA)



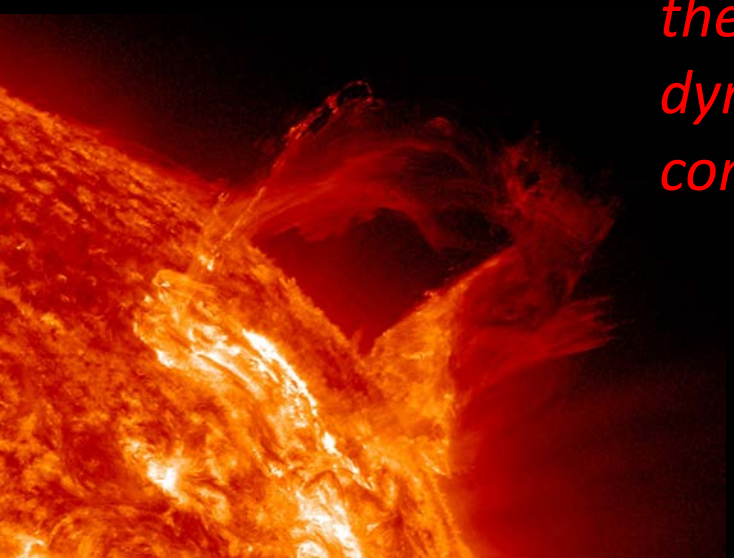
Interoperable Network Communication Architecture (INCA)

- INCA can provide the following TD^3 elements:
  - web accelerator,
  - QoS routing/pervasively networked gateway,
  - multi-core thermally managed computer resources for virtualized functions,
  - Xrosslink protocol for near-realtime state models,
  - relay interface kits, for ACS, HTA, MOCA, and SSPB
- INCA elements can support:
  - Enhanced automated/autonomous Communications & Navigation state models,
  - Dynamically assignable and characterizable resources,
  - QoS driven virtualized function support , and
  - Cost effective Earth facing, on-orbit, and beyond Earth ad hoc mesh mission support/networks.

➔ *INCA can be a TD^3 driver for the Next Gen Architecture*

Mission Operations Control Applications (MOCA)

- MOCA provides TD^3 near realtime state models, mutable locus of control, and virtual operations center for ACS, HTA, INCA, and SSPB
- MOCA facilitates crewed, tele-operated/shared control, and autonomous in situ operations reducing crew time required for experiments and increasing ISS and ground operations productivity.



➔ *MOCA can be a resource for furthering the TD^3 of "AutoNAV" and the evolution to dynamically scheduled QoS driven communications and navigation services.*

Alpha Cube Satellite (ACS)

- ACS provides a technology development, demonstration, and deployment (TD3) spacecraft bus for HTA, INCA, MOCA, and SSPB
- ACS Low cost highly configurable small spacecraft for Earth facing, Cislunar infrastructure, and beyond Earth orbit applications.
- TD^3 work includes: beyond Earth Orbit SDR through Ka Band and more (W band, laser, etc.), laser retroreflector host and testbed, user hardware & software extensible linux based avionics system (GN&C, ACS, Power, DMS), non-toxic propulsion systems, Virtual Operations Center (based on Open Web MCT & Xrosslink protocol), reflectarray solar/TX&Rx/Rectenna

➔ *ACS is low cost extensible Comm and Nav infrastructure suitable for prototyping applications/services on-orbit, in Cis-lunar space, and beyond.*

Space-to-Space Power Beaming (SSPB)

- SSPB provides TD^3 radiant energy beaming testbed, and electrical as well as other utilities (Comm, Nav, etc.) as applicable for ACS, HTA, INCA, and MOCA
- SSPB retire real and perceived technical, cost, and schedule risk associated with radiant energy beaming utilities
- SSPB mission evolution supports ISS co-orbiting free-flyers, Earth facing platforms and/or fractionated systems with LEO/MEO/GEO power augmentation and alternate bus systems, Cis-lunar and lunar surface operations, asteroidal assay mission operations and propulsion augmentation.

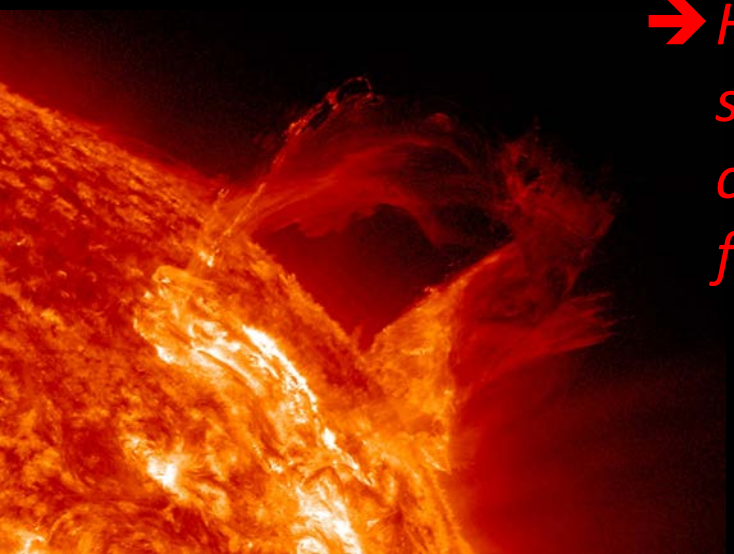
➔ *SSPB forges a TD^3 path to Space-to-Space and Space-to-Alternate surface electrical, communications, and navigation utilities.*

➔ *SSPB work is intended to be frequency agnostic from Ka band through optical.*

Halfway To Anywhere (HTA)

- HTA provides TD^3 propulsion testbed, trajectory insertion bus, alternate minimum energy trajectories, and resonance orbits for ACS, INCA, MOCA and SSPB.
- *HTA leads to the use of ISS as a transportation node for low cost, readily deployable Earth orbit, cislunar and beyond Earth orbit mission support.*

➔ *HTA helps draws out the requirements for space-to-space electrical, communications, and navigation utilities for LEO/MEO/GEO, and beyond.*

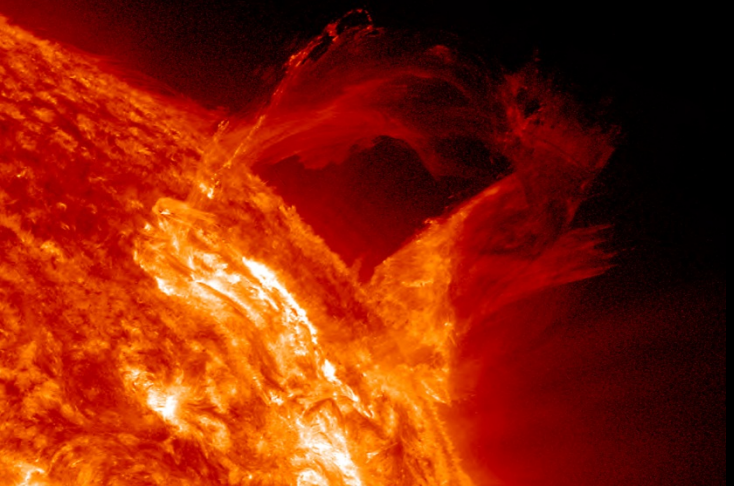


SCaN Technology Road Map Connections

- Supporting a mutable locus of control for communications and navigation services
  - Autonomy: Ground ➔ Spacecraft
  - Automation: Crew ➔ Automated System
- Navigation markers/beacons – uses of advanced laser retroreflectors to extend GNSS, time, and dynamically allocated ad hoc communications services beyond Earth orbit
- Convergence of RF and Optical electronics with SDR
- Structuring and ordering the knowledge bases and constraint propagation can facilitate the evolution of AutoNAV
- Use of near realtime state models to make evolution of AutoNAV tractable ➔ AutoNAV in a box with AI
- Could radioactive carbon diamond power be used to create an atomic clock on a gumstick card?

Opportunities

- Formalize cooperation on mission set with extensions to existing or new space act agreements
- Mission development cooperation/collaboration
  - Technology development
  - Technology demonstration
  - Technology deployment for actual mission support
- Ground test cooperation/collaboration
  - Creative use of KaBOOM facility, Next Gen support, etc.
- Cooperation/Collaboration with other missions



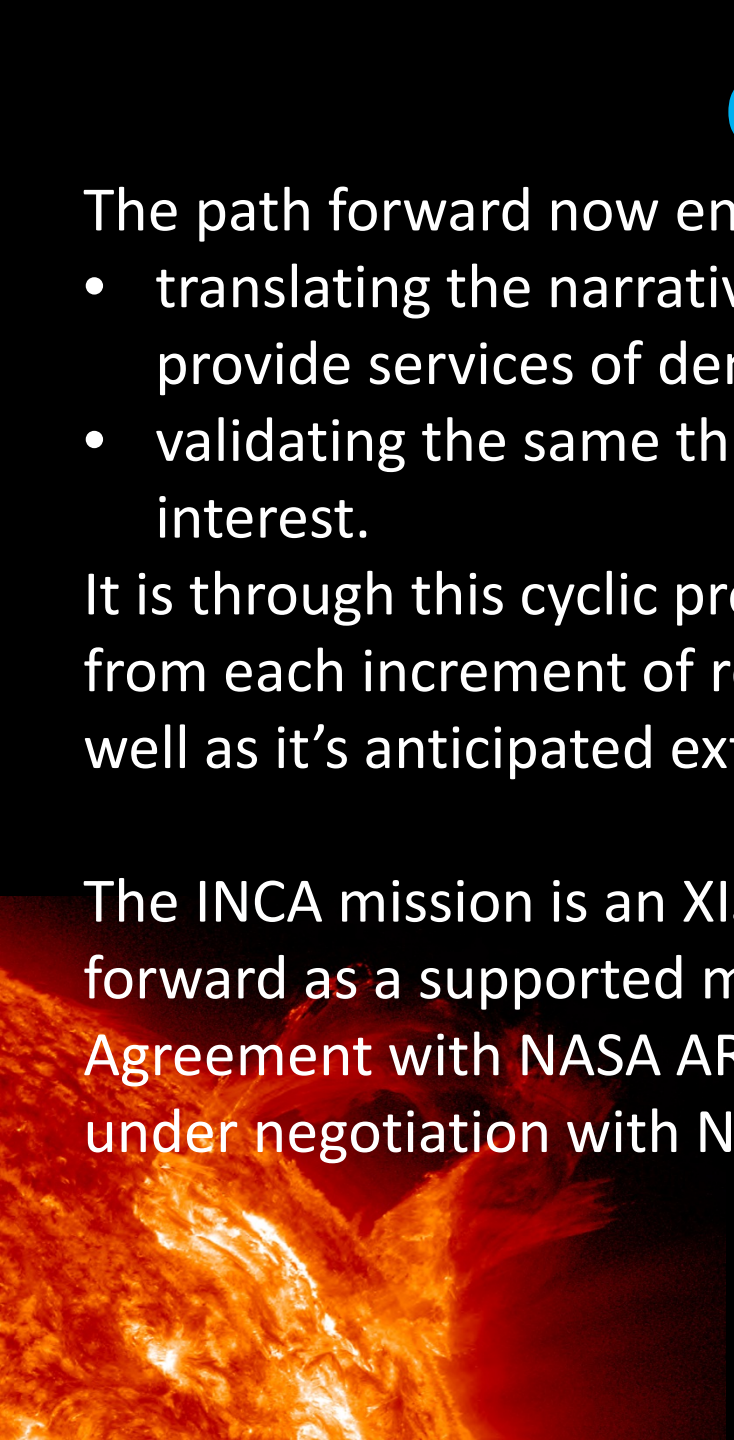
Conclusion

The path forward now entails:

- translating the narrative into actually building real systems that provide services of demonstrable value, and
- validating the same through peer review in the communities of interest.

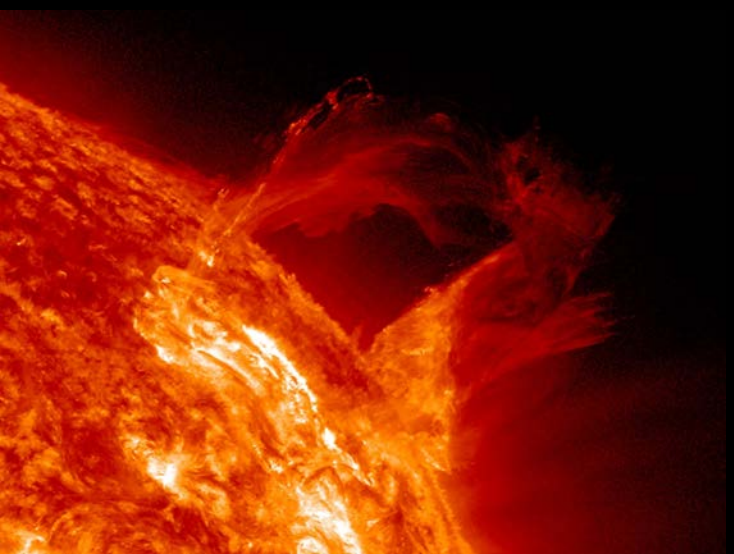
It is through this cyclic process that maximum value can be derived from each increment of resources committed to this mission set as well as it's anticipated extensions and follow-ons.

The INCA mission is an XISP-Inc commercial mission moving forward as a supported mission under an existing Space Act Agreement with NASA ARC and a Space Act Umbrella Agreement under negotiation with NASA Headquarters.



Backup Charts

- INCA Experiment Narratives
- INCA Iteration & Recursion Diagram

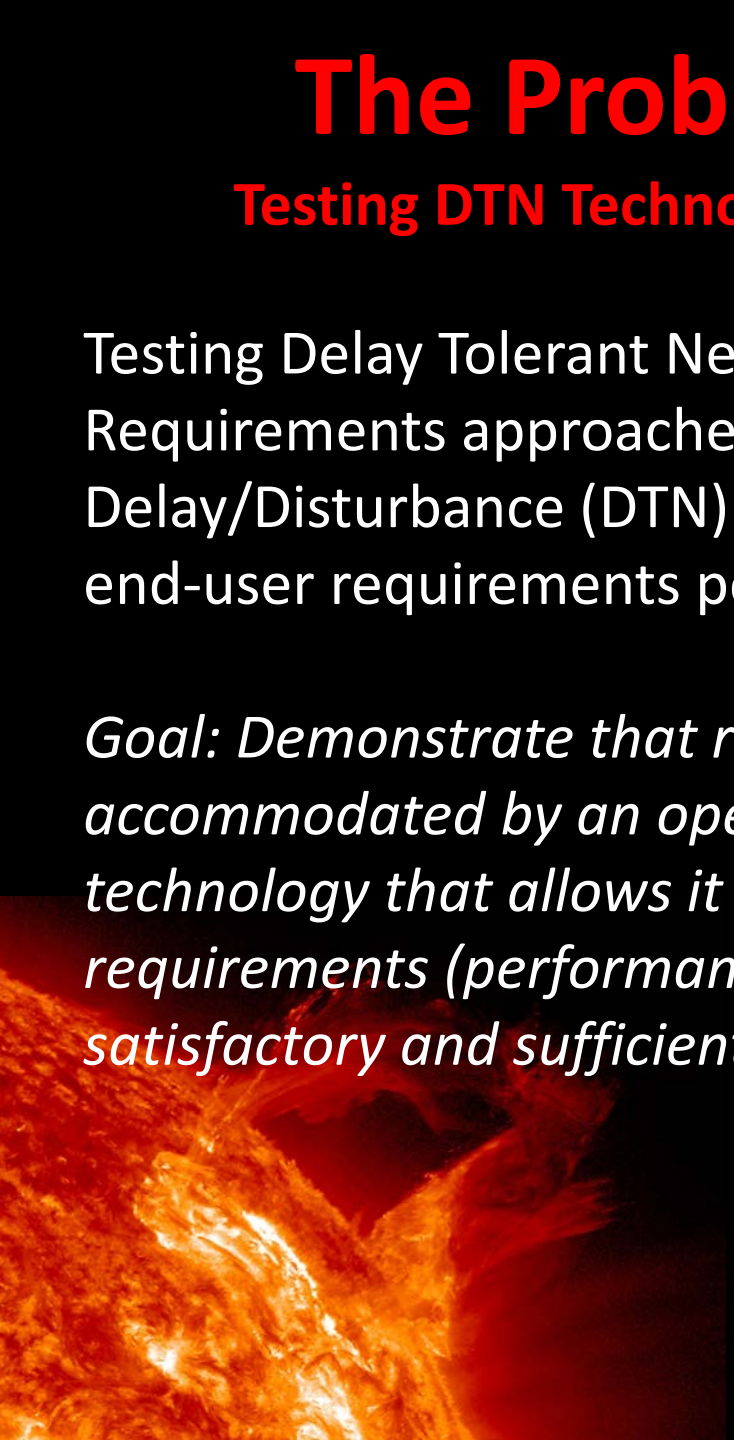


The Problem Addressed . . .

Testing DTN Technology with Real World Requirements

Testing Delay Tolerant Networking Technology with Real World Requirements approaches the problem of maturation of Delay/Disturbance (DTN) technology and facilitating its use from an end-user requirements perspective.

Goal: Demonstrate that real world requirements can be accommodated by an operational implementation of DTN technology that allows it to be used as tool that meets customer requirements (performance, availability, and security) in a satisfactory and sufficient manner



Virtualize a Single Function and Test it's Efficacy in Near Realtime

The Problem Addressed . . .

Pervasively Networked DTN Gateway

A Pervasively Networked DTN Gateway approaches the problem of maturation of DTN technology and facilitating its use from an infrastructure perspective.

Goal: A pervasively networked point-of-presence gateway supporting quality of service based routing (performance, availability, and security) on all available internal and external networks accessible on the International Space Station for payload use consistent with operational guidelines.

Virtualize Multiple Functions and create an automated orbital telco central office prototype

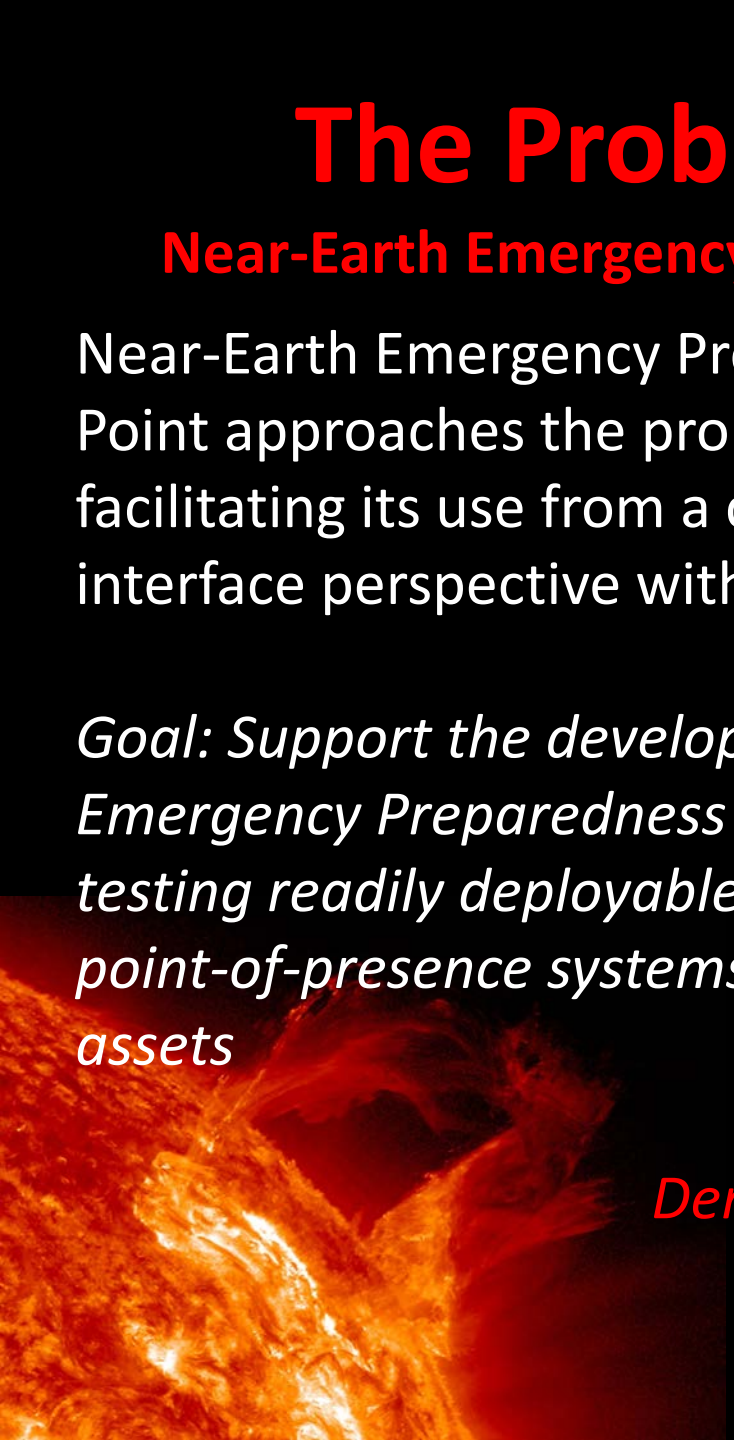
The Problem Addressed . . .

Near-Earth Emergency Preparedness and Response Network

Near-Earth Emergency Preparedness and Response Network Focal Point approaches the problem of maturation of DTN technology and facilitating its use from a cooperating / interoperating network interface perspective with an emphasis on terrestrial applications.

Goal: Support the development and implementation of a Near-Earth Emergency Preparedness and Response Network by prototyping and testing readily deployable pervasively networked highly mobile point-of-presence systems including dynamically schedulable space assets

Demonstrate Earth Facing Applications



The Problem Addressed . . .

Cislunar Pervasively Networked Communications

Cislunar Pervasively Networked Communications Technology Development approaches the problem of maturation of DTN technology and facilitating its use from a cooperating/interoperating network interface perspective with an emphasis on Cislunar applications.

Support the development and implementation of a Cislunar Communications Network by prototyping and testing readily integratable interface kits for allowing new - and where possible - existing space systems to be become cooperating / interoperating nodes interacting with pervasively networked point-of-presence systems.

Demonstrate Space Facing Applications

The Solution Proposed - 1

A set of technology development missions proposed for the International Space Station (ISS) which:

1. leverages available resources to serve as a testbed,
2. has an integral evolutionary path from experiment to infrastructure, and
3. helps to mitigate perceived cost, schedule, and technical risk associated with the accommodation and use of new communications technologies.

The Solution Proposed – 2

INCA Experiment Elements

Function: Internet Banking
Purpose: Source of Real World Performance/Availability/Security Requirements
Value: Testing, which supports the verification, and validation of INCA Architecture with real interoperating network requirements

Function: Pervasively Networked DTN Gateway
Purpose: Enables INCA QoS Based Routing
Value: Testing INCA Architecture for LEO/MEO/GEO Use

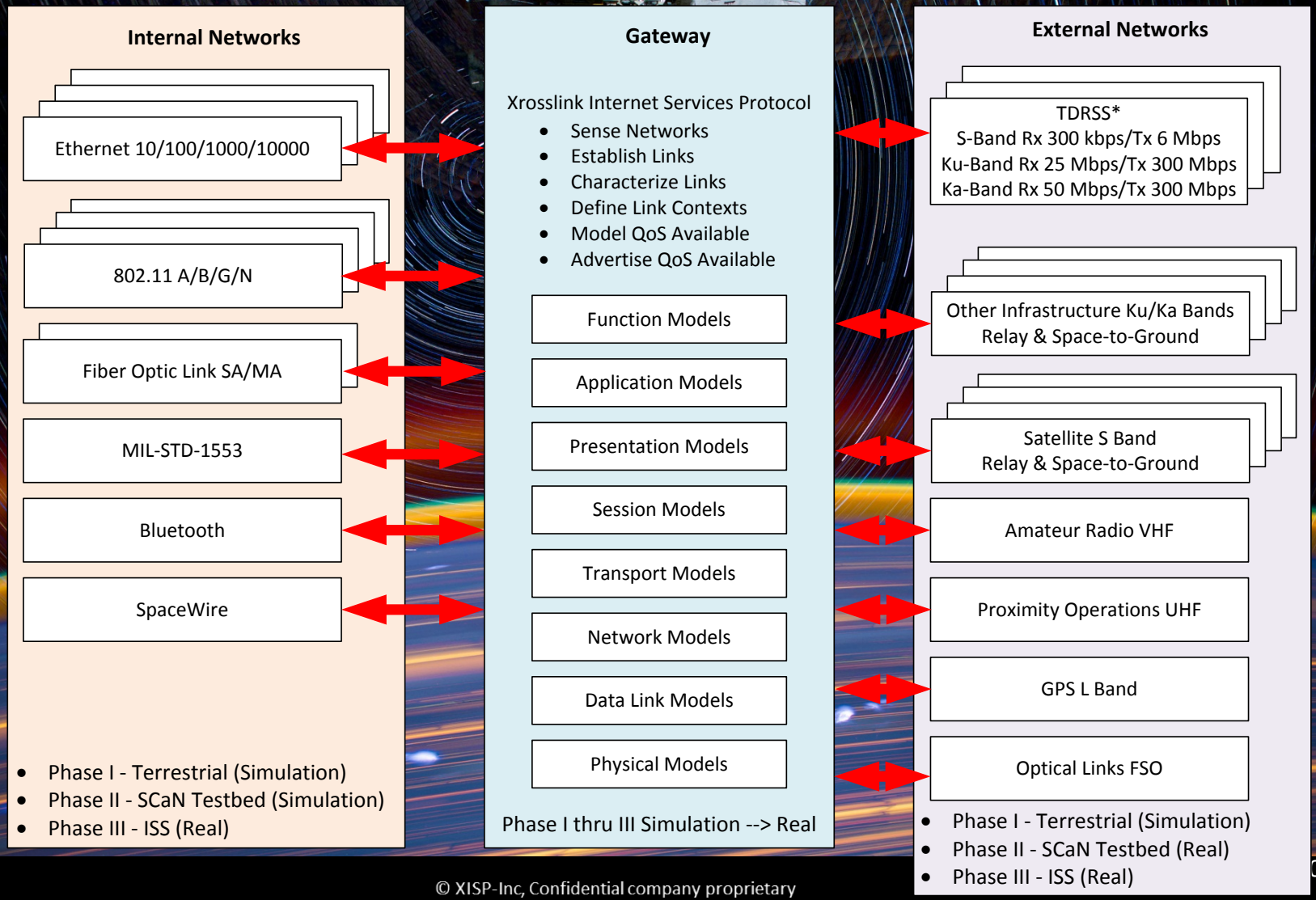
ITERATIVE & RECURSIVE

Function: Cis-Lunar Pervasively Networked Communications Interface
Purpose: Enables & Demonstrates BEO Application
Value: Testing INCA Architecture for BEO Flight Project Use

Function: Near-Earth Emergency Preparedness and Response Network
Purpose: Enables & Demonstrates Terrestrial Application
Value: Testing INCA Architecture for Terrestrial Use

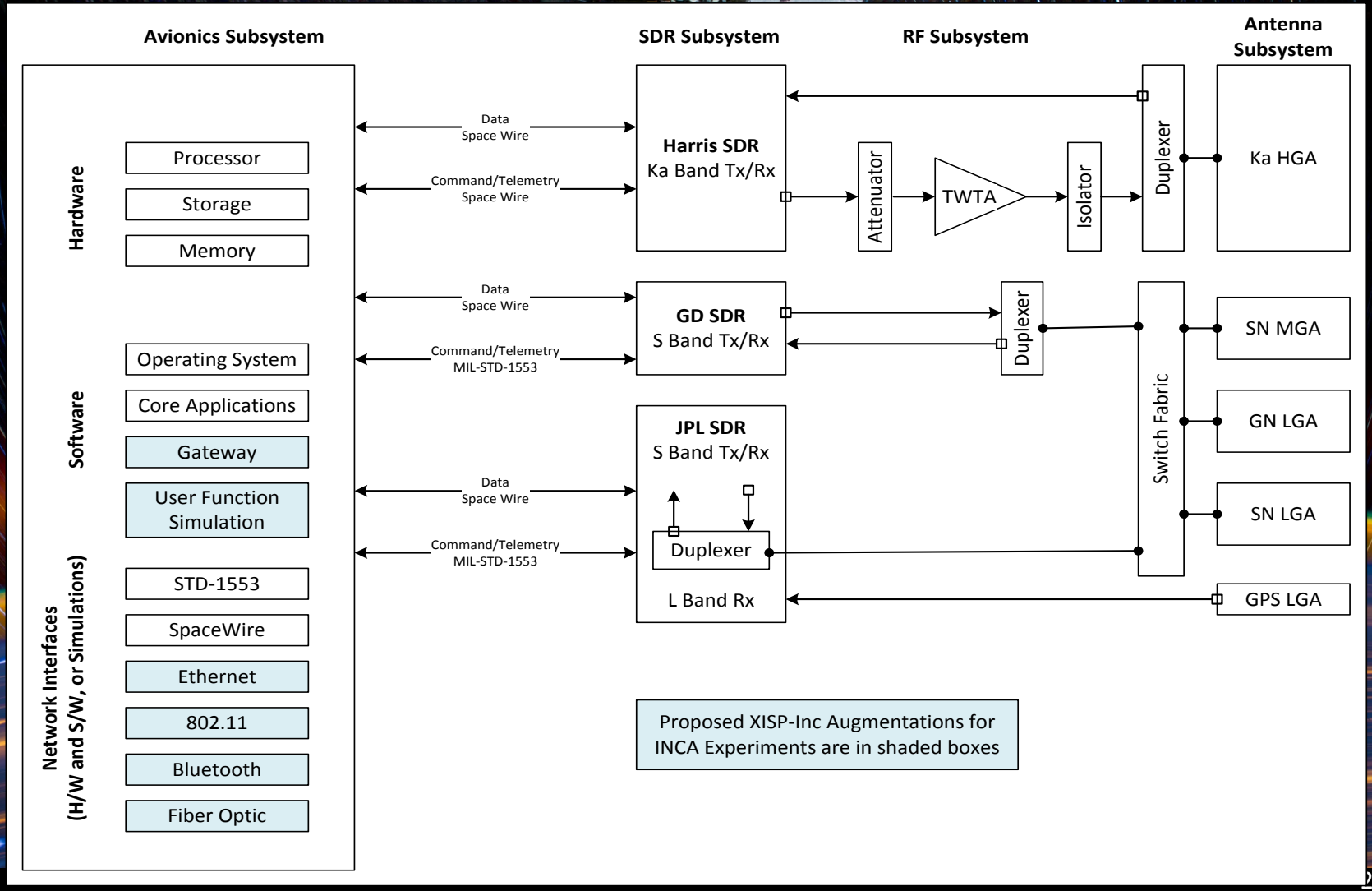
The Solution Proposed – 3

INCA Pervasively Networked Gateway w/Quality of Service (QoS) Based Routing



The Solution Proposed – 4

INCA Augmented SCaN Testbed Functional Block Diagram



The Solution Proposed – 5

INCA Augmented Space Qualified Intel ® Next Unit of Computing (NUC)

Possible Applications– 1

INCA Proposed Function Implementation

MISSION ANNEX 1
Testing DTN with Real World Requirements

Function Model
Website Access w/ defined QoS Requirements
- End User Command Stream
- QoS Requirements Baseline
- QoS Measurement
Performance/Availability/Security
- State Models
- Operational Guidelines
- Processed Data Storage
- Linked Page Implementation

Xrosslink Internet Services Protocol
- Defined Network
- Establish Link
- Characterize Link
- Define Link Context
- Model QoS Available
- Advertise QoS Available

MISSION ANNEX 2
Pervasively Networked Gateway w/QoS Based Routing

Function Model
Pervasively Networked Gateway w/ QoS Based Routing
- End User Command Stream
- QoS Requirements Baseline
- QoS Measurement
Performance/Availability/Security
- State Models
- Operational Guidelines
- Processed Data Storage
- Linked Page Implementation

Xrosslink Internet Services Protocol
- Sense Networks
- Establish Links
- Characterize Links
- Define Link Contexts
- Model QoS Available
- Advertise QoS Available

Possible Applications – 2

INCA Proposed Function Implementation (Continued)

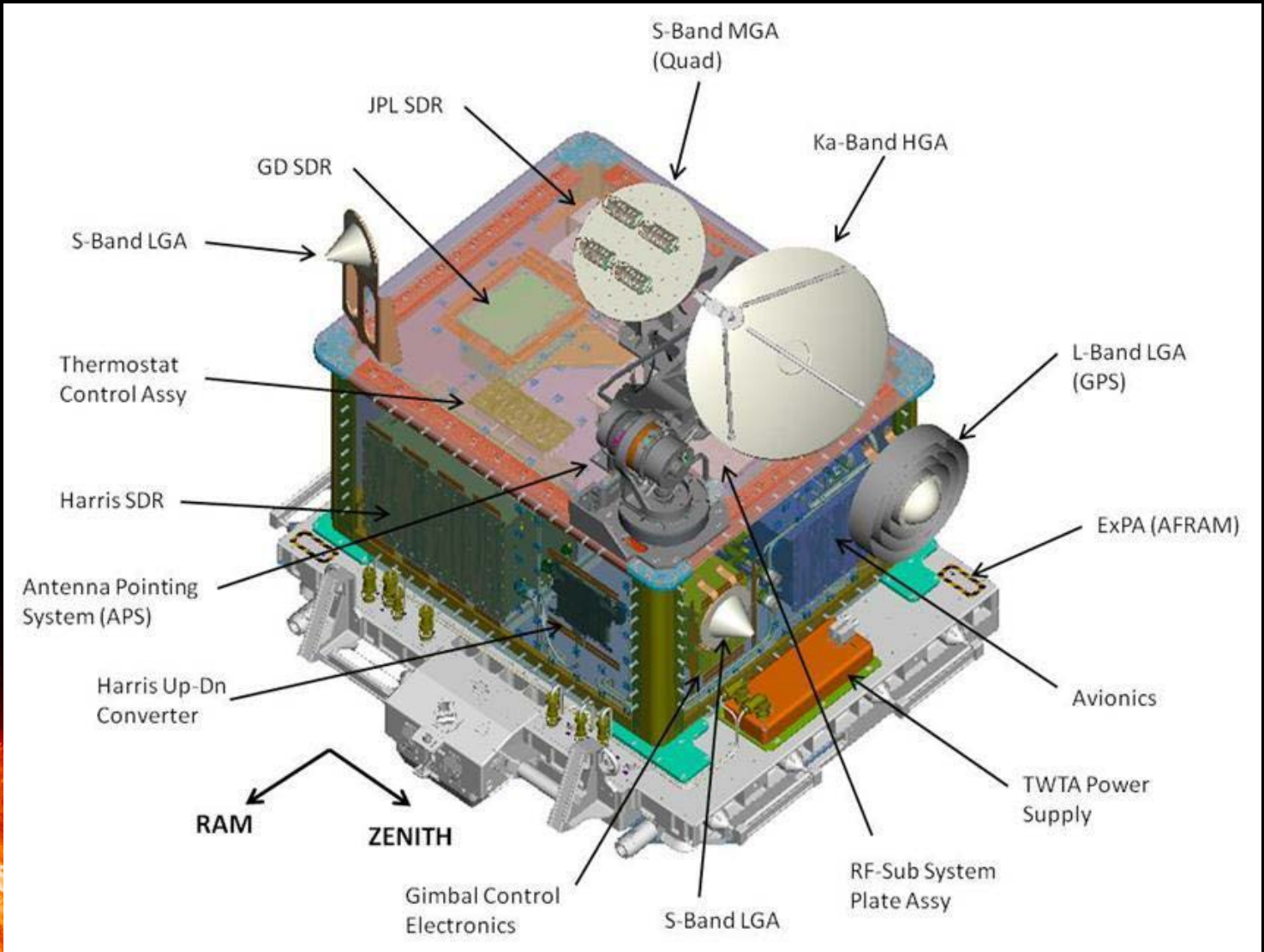
MISSION ANNEX 3
Near Earth Emergency Preparedness and Response Network

Function Model
Interoperating Earth Node Interface Kit
- Hardware Requirements
- Software Requirements
- Specifications
- Operational Guidelines

MISSION ANNEX 4
Cis-Lunar Pervasively Networked Communications Technology Development

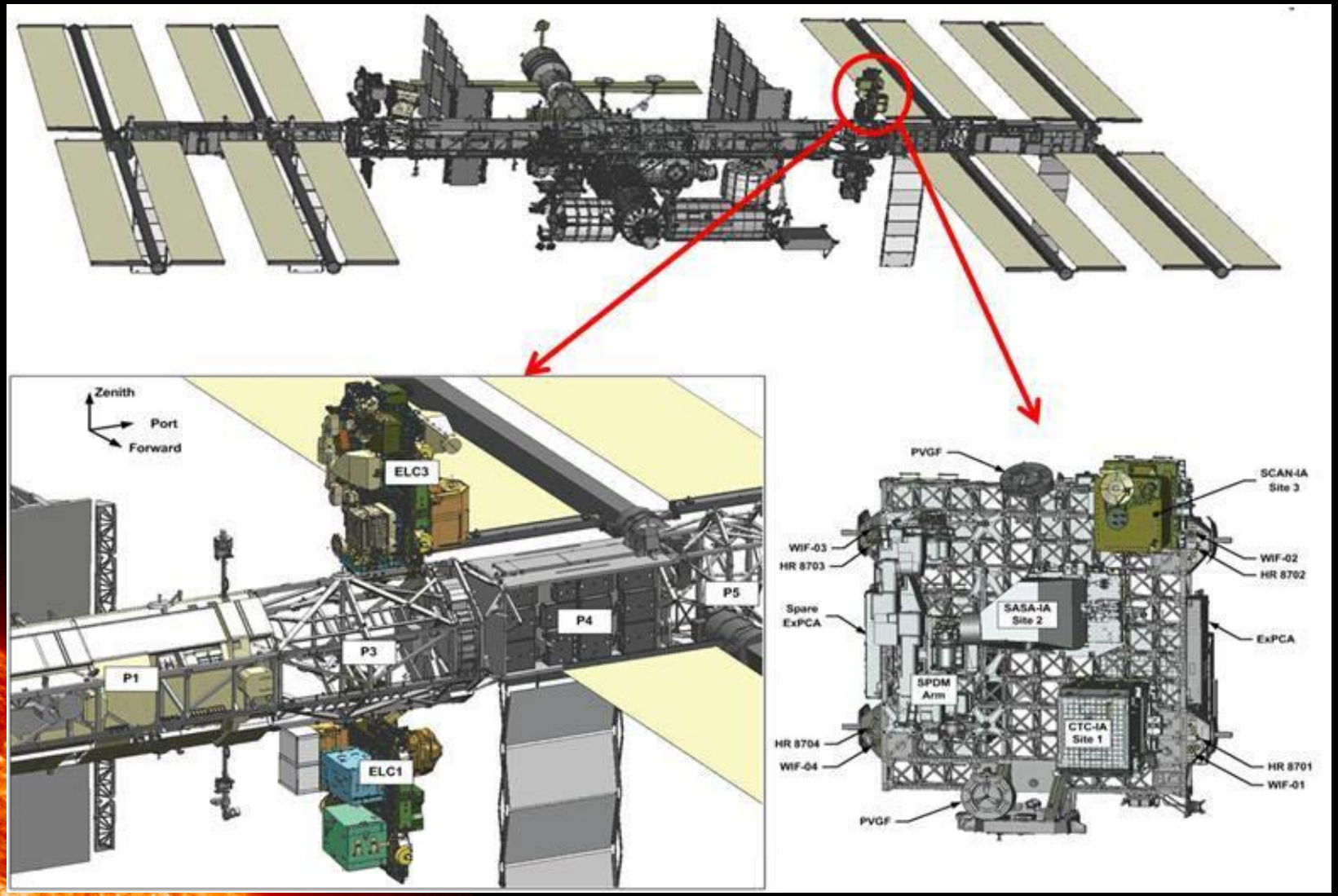
Function Model
Interoperating Space Node Interface Kit
- Hardware Requirements
- Software Requirements
- Specifications
- Operational Guidelines

ISS SCaN Testbed Components



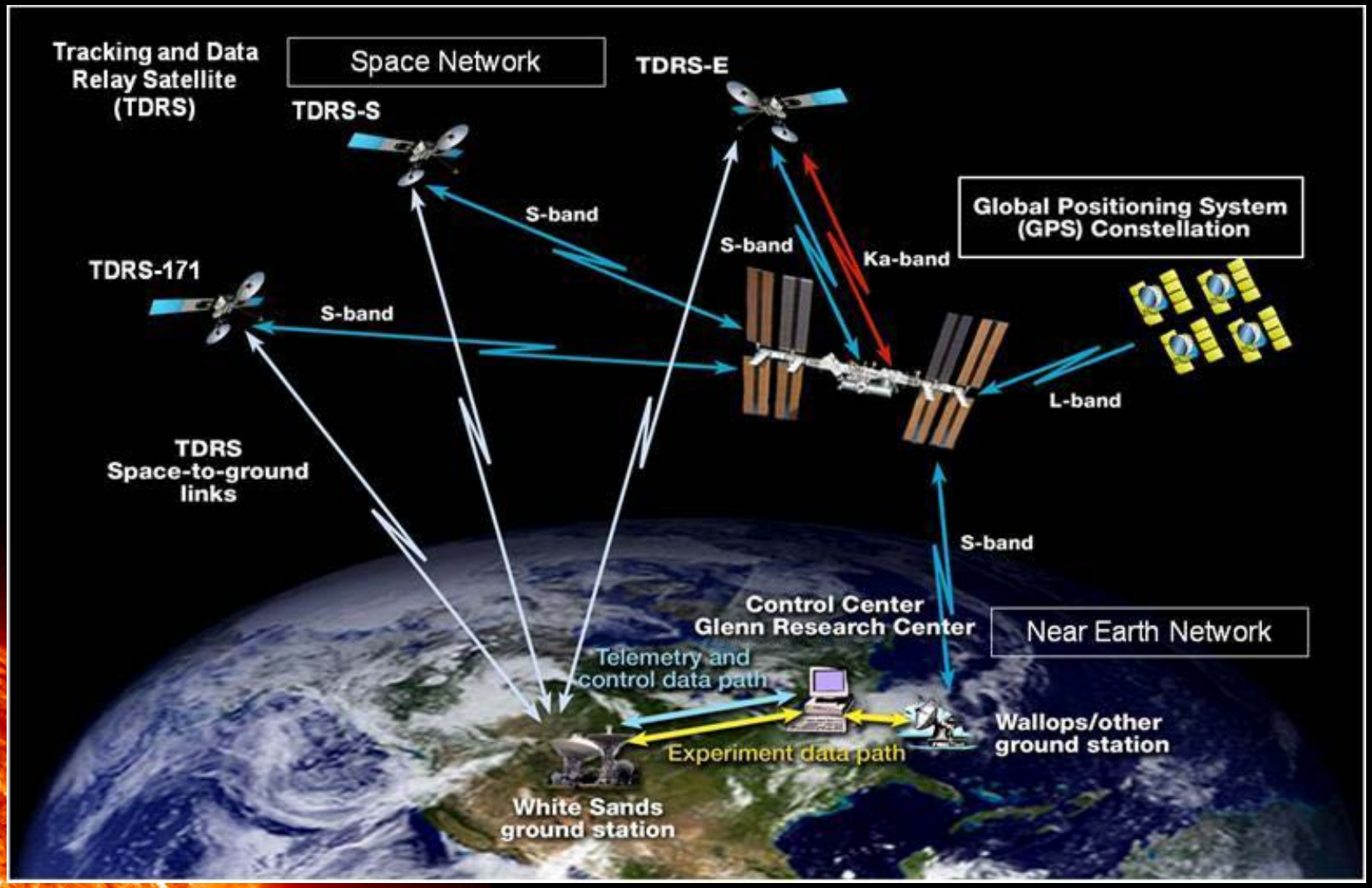
Courtesy of NASA

ISS SCaN Testbed Location



Courtesy of NASA

SCaN Testbed System Overview



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