Interoperating Network Communications Architecture (INCA)

a Technology Development, Demonstration, and Deployment (TD^3) Mission to Extend Commercial Networks to Cis-Lunar Space

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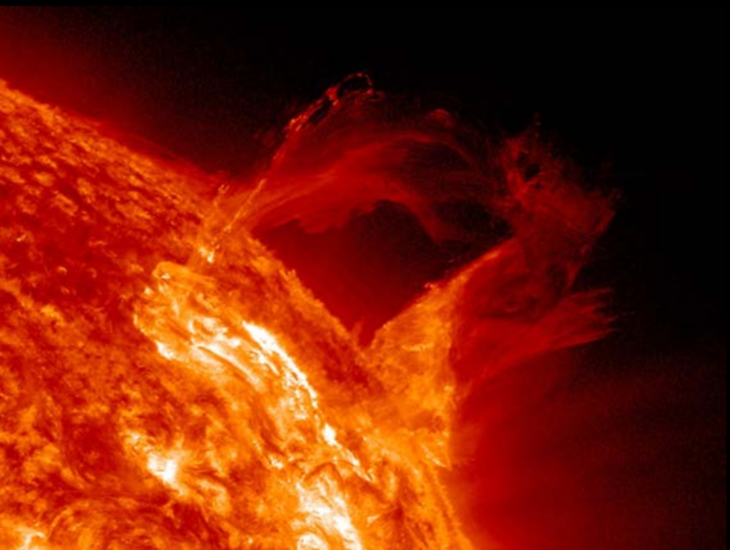
Outline

- The Challenges . . .
- The Technology Development Push . . .
- The Mission Requirements Pull . . .
- The TD^3 Mission Set
- The Path Forward . . .



Challenges . . .

- Technological windows are narrowing
- Quality of Service (QoS) will be the primary driver
  → performance, availability, and security
- Scheduled →Dynamic Allocation of Bandwidth
- Readily replaceable or repairable systems/elements
- Scale of the Market is growing in all sectors
- Flight systems are evolving in two directions simultaneously

  → Smallsat Constellations

  → Immortal Platforms

Challenges . . .

- Commercial Infrastructure for Cis-Lunar Space
  → Earth-LEO-MEO-HEO-GEO-L_x-HLO-MLO-LLO-Lunar

- Interoperability
  - Earth facing
  - On-orbit operations
  - Space facing
  - Beyond Earth orbit

Technology Development Push . . .

INCA can foster the following TD^3 elements:

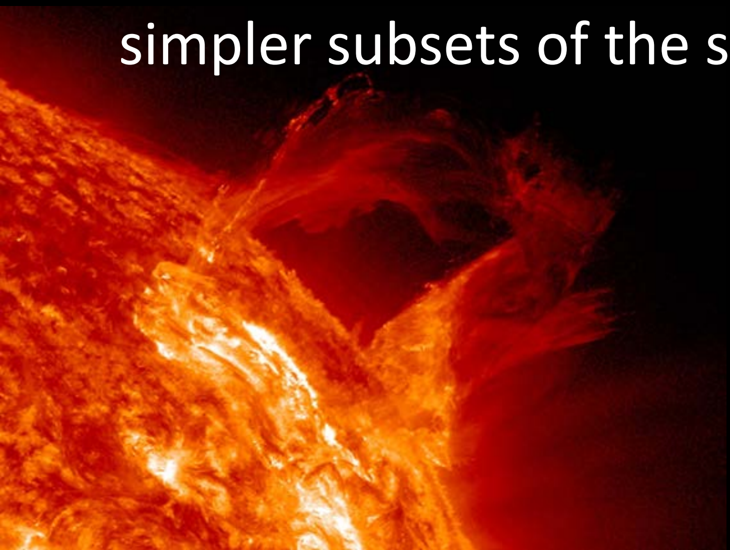
- Delay & Disturbance Tolerant Networking (DTN) as a service
- Software Defined Radio (SDR)
- Unification of RF & Optical Electronics Packages
- Near realtime link characterization
- Dynamic scheduling of links
- Web acceleration
- QoS routing & pervasively networked gateways
- multi-core thermally managed computer resources for virtualized functions,
- Xrosslink protocol for near-realtime state models,
- Interoperating node standardization & interface kits

Technology Development Push . . .

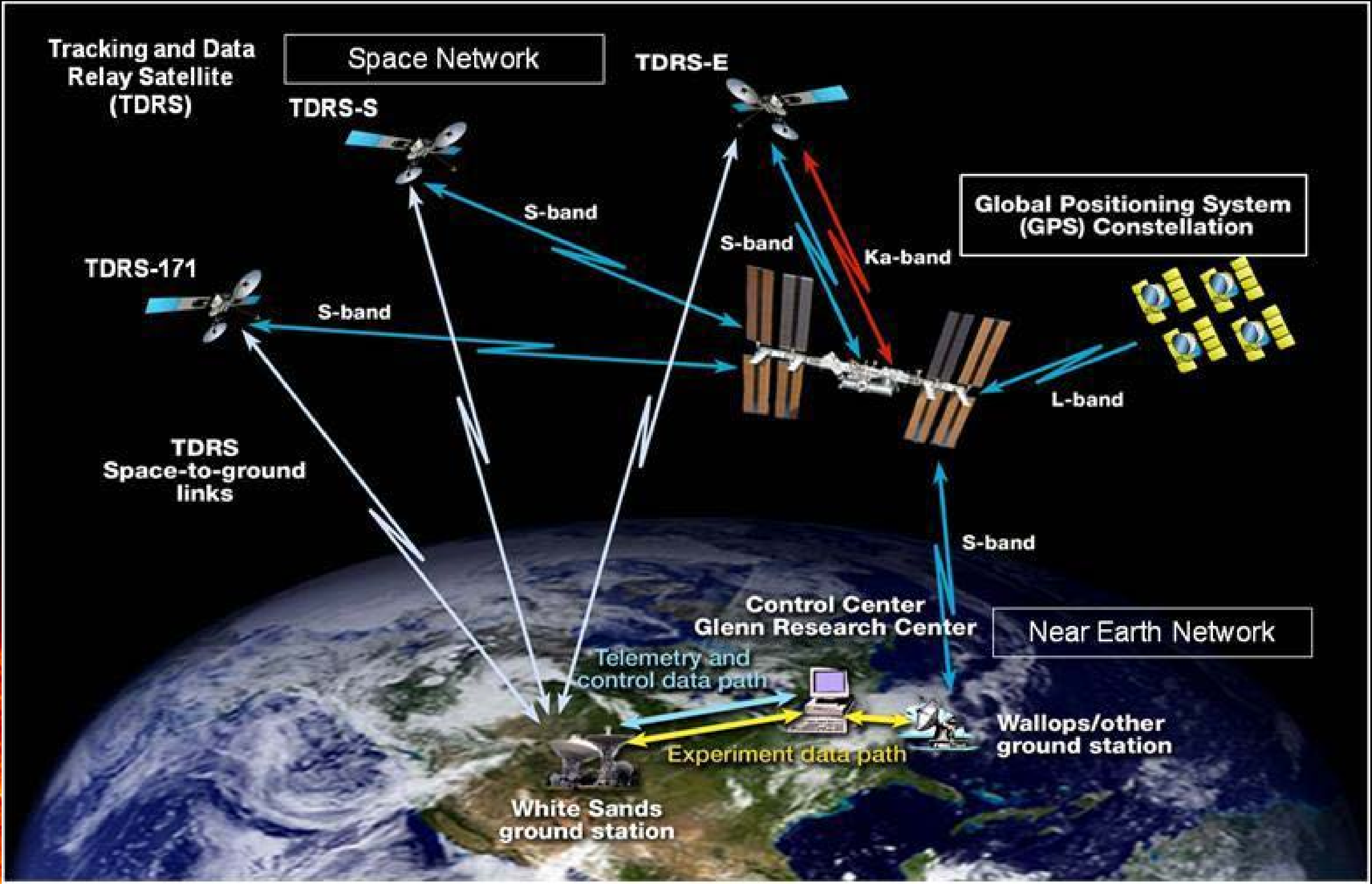
INCA nodes are defined as a combination of:

- Hardware
- Software
- Interface Specifications
- Operational Guidelines

If you can make the International Space Station an interoperating node all other potential nodes regardless of whether they are in space, flying, fixed, ground mobile, portable, or hand held are simpler subsets of the same problem.

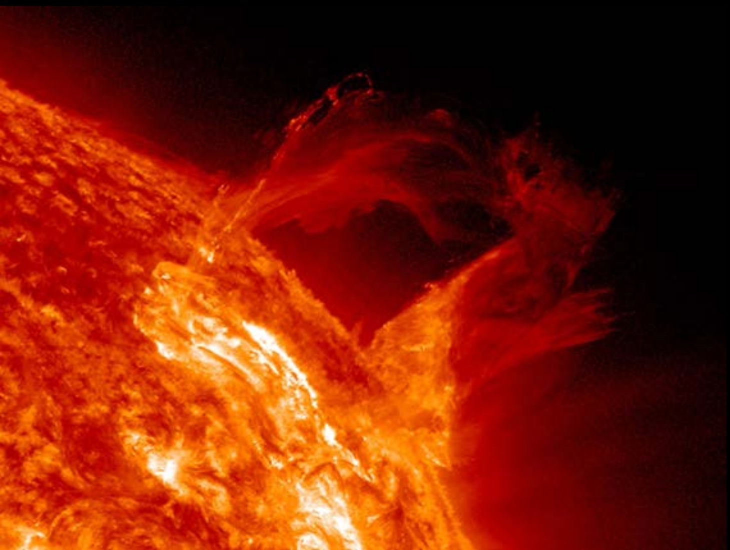


NASA SCaN & ISS Example



Mission Requirements Pull . . .

- Infrastructure is expensive
- Infrastructure is even more expensive if you do not build what is required the first time, and it becomes progressively more so
- Investment in TD^3 missions can deliver real requirements and substantive mission enhancing if not mission enabling capability for each increment of resources invested
- TD^3 missions allow for the buy down of cost, schedule, and technical risk associated with larger scale infrastructure



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

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

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

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

A set of TD^3 missions proposed for the International Space Station (ISS) which:

- leverages available resources to serve as a testbed,

  Characterize → Optimize → Operationalize
- has an integral evolutionary path from experiment to infrastructure, and
- helps to mitigate perceived cost, schedule, and technical risk associated with the accommodation and use of new communications technologies.

XISP-Inc Evolving TD^3 Mission Set

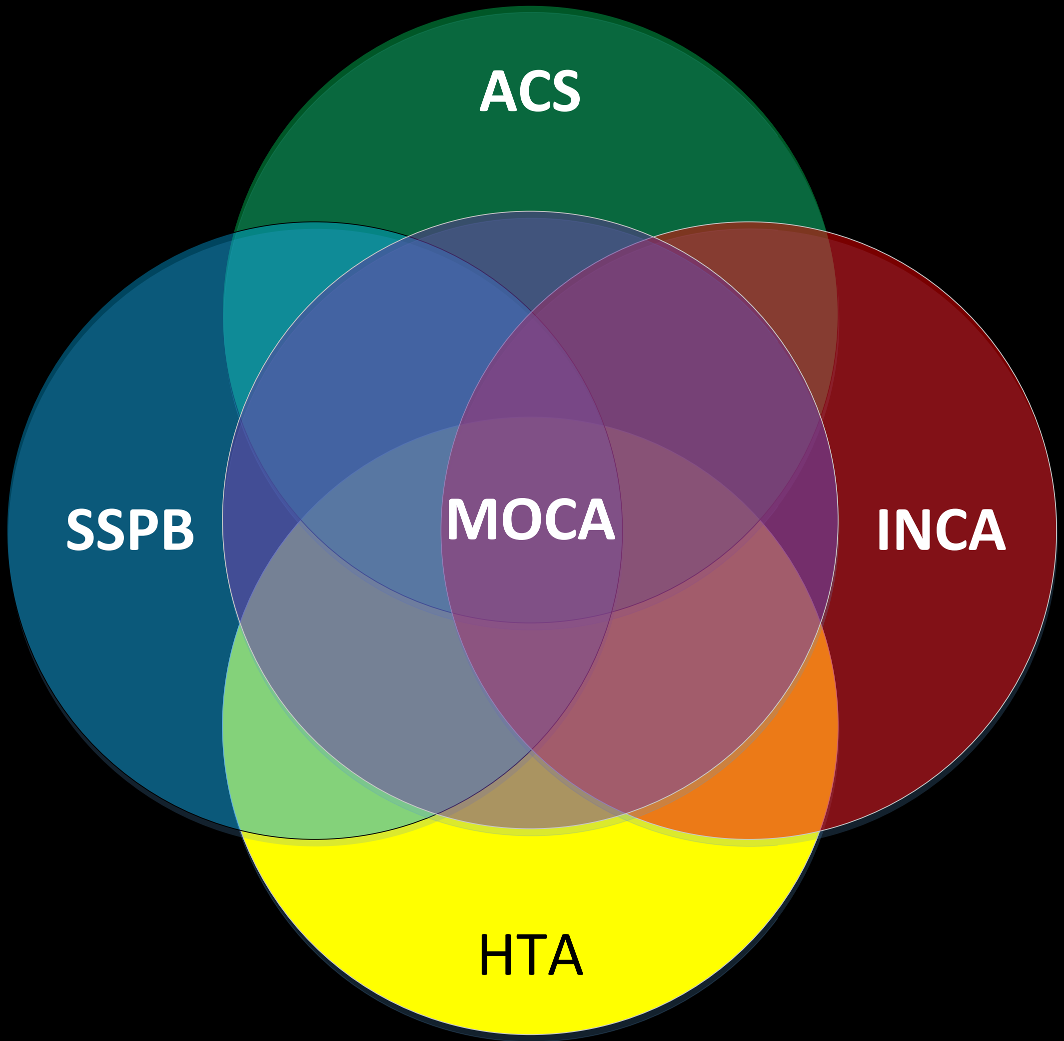
Alpha CubeSat (ACS)

Space-to-Space Power Beaming (SSPB)

Halfway To Anywhere (HTA)

Interoperable Network Communication Architecture (INCA)

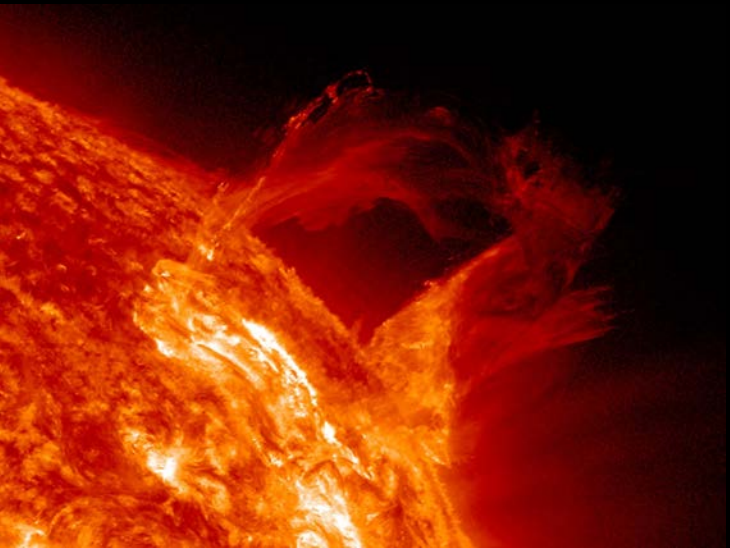
Mission Operations Control Applications (MOCA)



Interoperable Network Communications Architecture (INCA)

INCA elements can support:

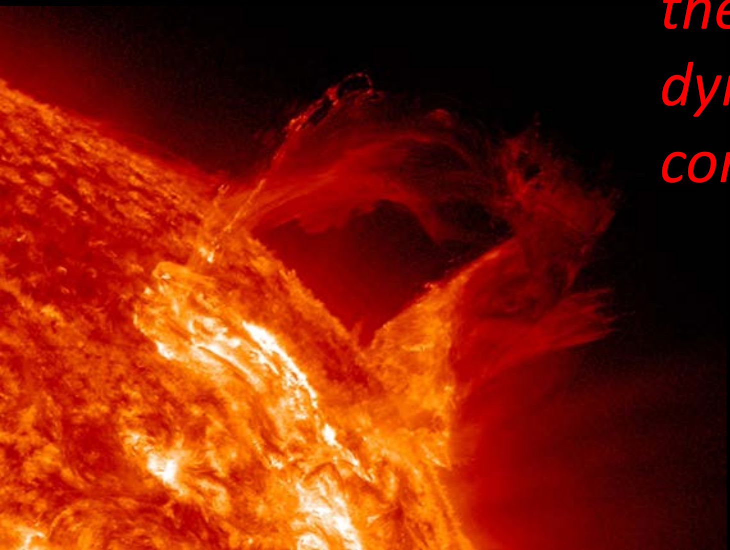
- Enhanced automated/autonomous Communications & Navigation state models,
- Dynamically assignable and characterizable resources,
- QoS driven virtualized function support , and
- Cost effective Earth facing, on-orbit, and beyond Earth ad hoc mesh mission support/networks.



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.

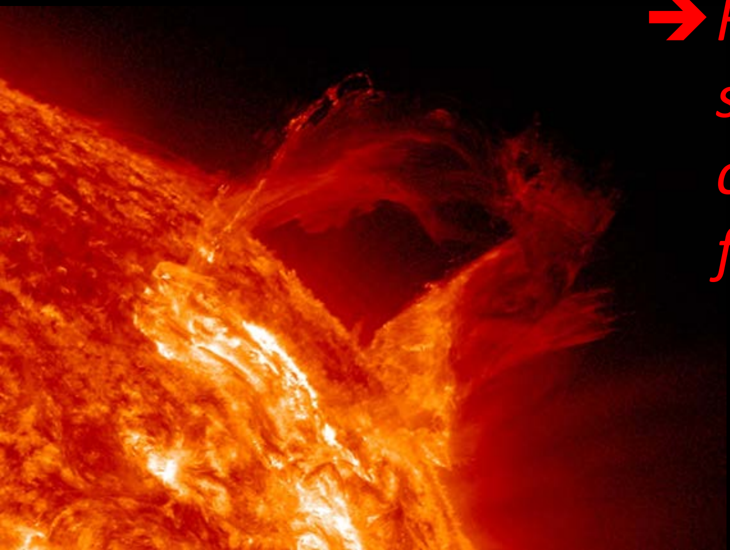
→ *SSPB forges a TD^3 path to Space-to-Space and Space-to-Alternate surface electrical, communications, and navigation utilities.*

→ *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.*



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

XISP-Inc Crosslink Protocol (XLINK)

OSI 7 Layer Model	Layer Examples	Pervasively Networked QoS Based Gateway	Input / Output	Process Examples	DOD 4 Layer Model
FUNCTION		Function Models	⇄	State Management	FUNCTION
APPLICATION	End User Layer(s)	Application Models	⇄	DHCP, DNS, FTP, HTTP, IMAP4, POP3, SMTP, SNMP, SSH, NTP	Process / Application
PRESENTATION	Syntax Layer	Presentation Models	⇄	IPSEC/AES – Encrypt/Decrypt	
SESSION	Sync & Send to Ports	Session Models	⇄	DTN – Bundle/Unbundle	
TRANSPORT	TCP	Transport Models	⇄	TCP, UDP	Host-to-Host
NETWORK	Packets	Network Models	⇄	IPv4, IPv6, OSPF, ICMP, IGMP, ARP, RARP, BOOTP	Internet
DATA LINK	Frames	Data Link Models	⇄	802.11, ATM, PPTP, L2TP, 10/100/1000 BaseT, 4/10/40G	Network
PHYSICAL	Physical Structure	Physical Models	⇄	Fiber Optic, Coaxial, Twisted Pair, Space Wire	

INCA Pervasively Networked Gateway w/QoS Based Routing

Internal Networks

- Ethernet 10/100/1000/10000
- 802.11 A/B/G/N
- Fiber Optic Link SA/MA
- MIL-STD-1553
- Bluetooth
- SpaceWire

- Phase I - Terrestrial (Simulation)
- Phase II - SCaN Testbed (Simulation)
- Phase III - ISS (Real)

Gateway

Xrosslink Internet Services Protocol

- Sense Networks
- Establish Links
- Characterize Links
- Define Link Contexts
- Model QoS Available
- Advertise QoS Available

Function Models

Application Models

Presentation Models

Session Models

Transport Models

Network Models

Data Link Models

Physical Models

Phase I thru III Simulation --> Real

External Networks

TDRSS*
S-Band Rx 300 kbps/Tx 6 Mbps
Ku-Band Rx 25 Mbps/Tx 300 Mbps
Ka-Band Rx 50 Mbps/Tx 300 Mbps

Other Infrastructure Ku/Ka Bands
Relay & Space-to-Ground

Satellite S Band
Relay & Space-to-Ground

Amateur Radio VHF

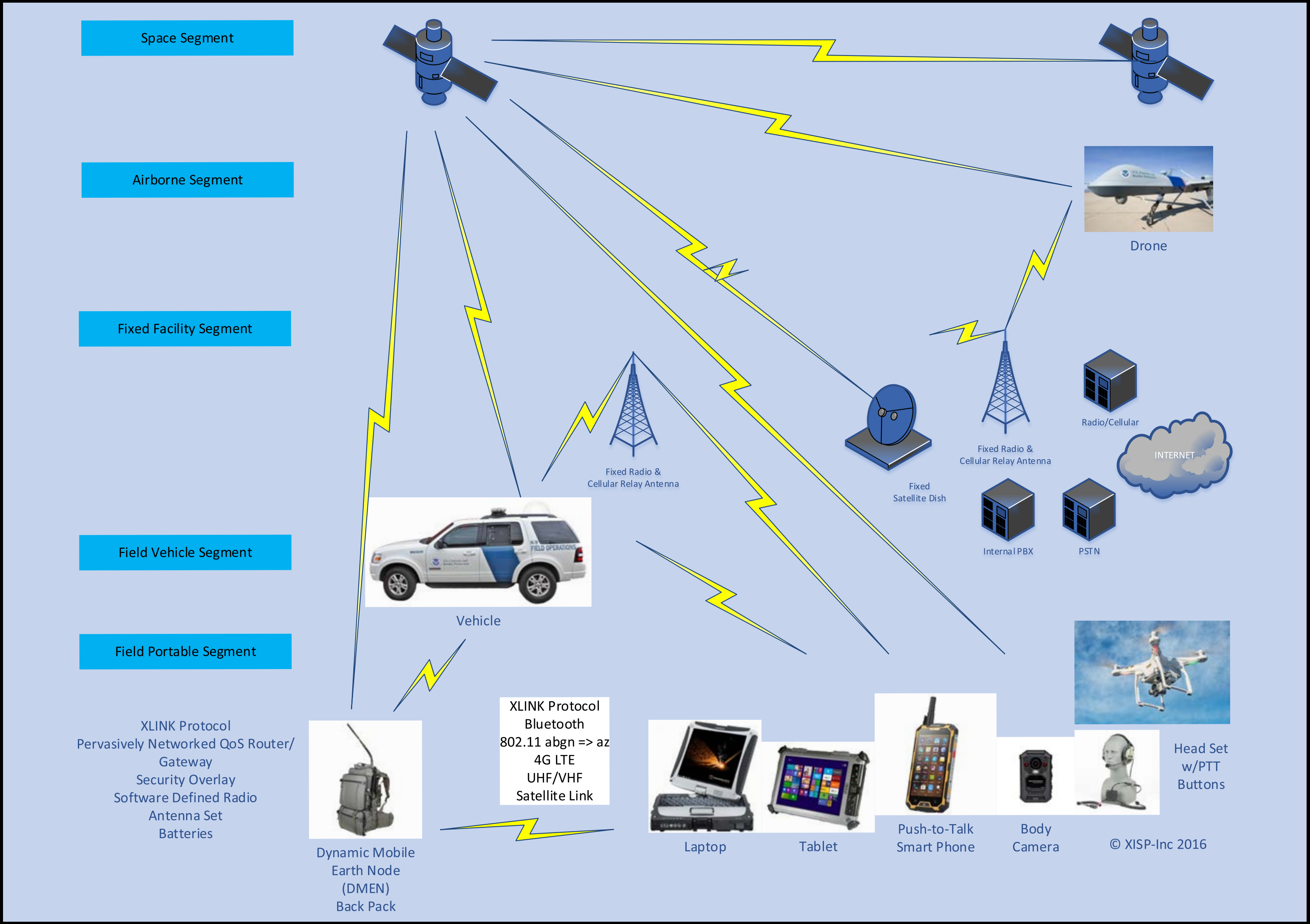
Proximity Operations UHF

GPS L Band

Optical Links FSO

- Phase I - Terrestrial (Simulation)
- Phase II - SCaN Testbed (Real)
- Phase III - ISS (Real)

Earth Facing INCA System Concept of Operations Example



INCA Proposed 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

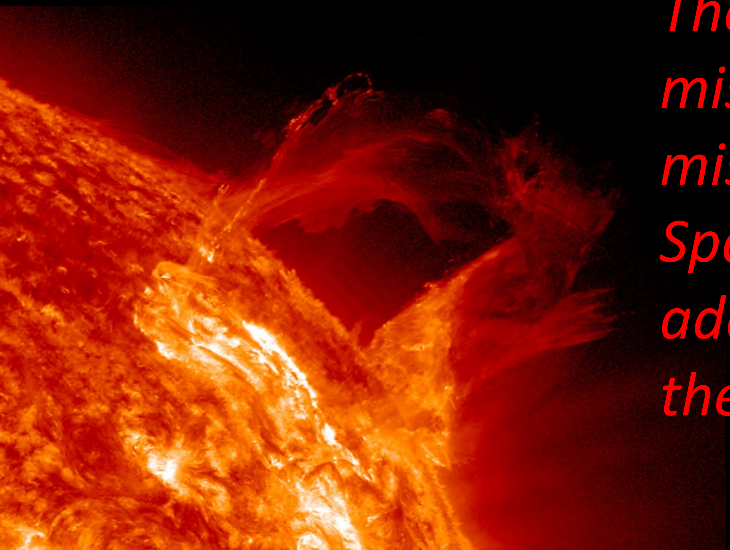
Function Model
Interoperating Space Node Interface Kit
- Hardware Requirements
- Software Requirements
- Specifications
- Operational Guidelines

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 a combination of an existing Space Act Agreement with NASA ARC and additional authority under negotiation with the NASA Headquarters SCaN office.