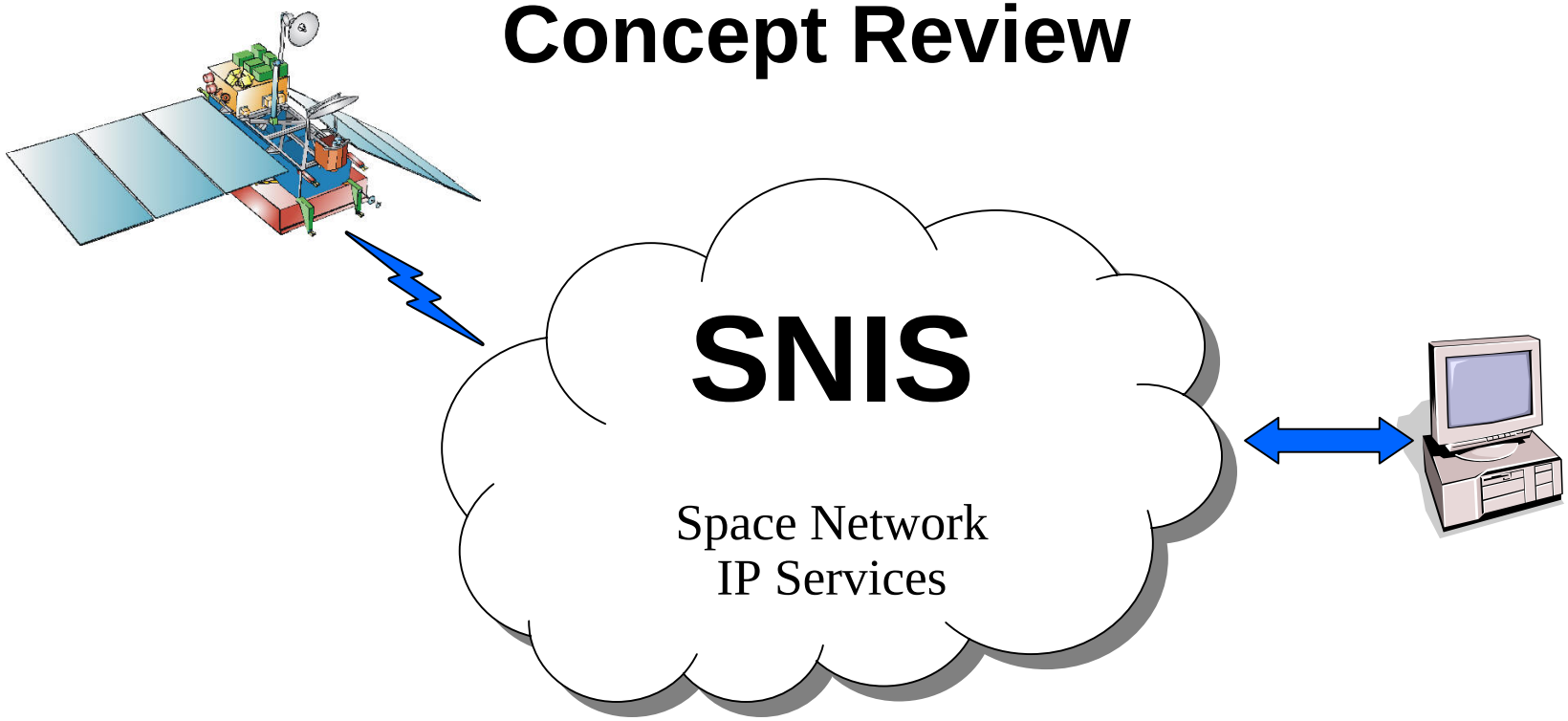
Space Network
Internet Protocol (IP) Services (SNIS)
Concept Review



February 27, 2004

Agenda

- Introduction
- Operational Concepts & Scenarios
- Preliminary Architecture
- Product Planning
- Risks & Risk Mitigation
- Summary & Action Items

Section 1
Introduction

Purpose of this Review

- **Conduct a review of the SNIS Product concept, to include:**
  - Product description and background
  - High-level requirements, preliminary architecture, and operational concepts/scenarios
  - Product planning status
  - Risks and issues
- **Solicit comments from user community**
- **Obtain concurrence from management before proceeding**

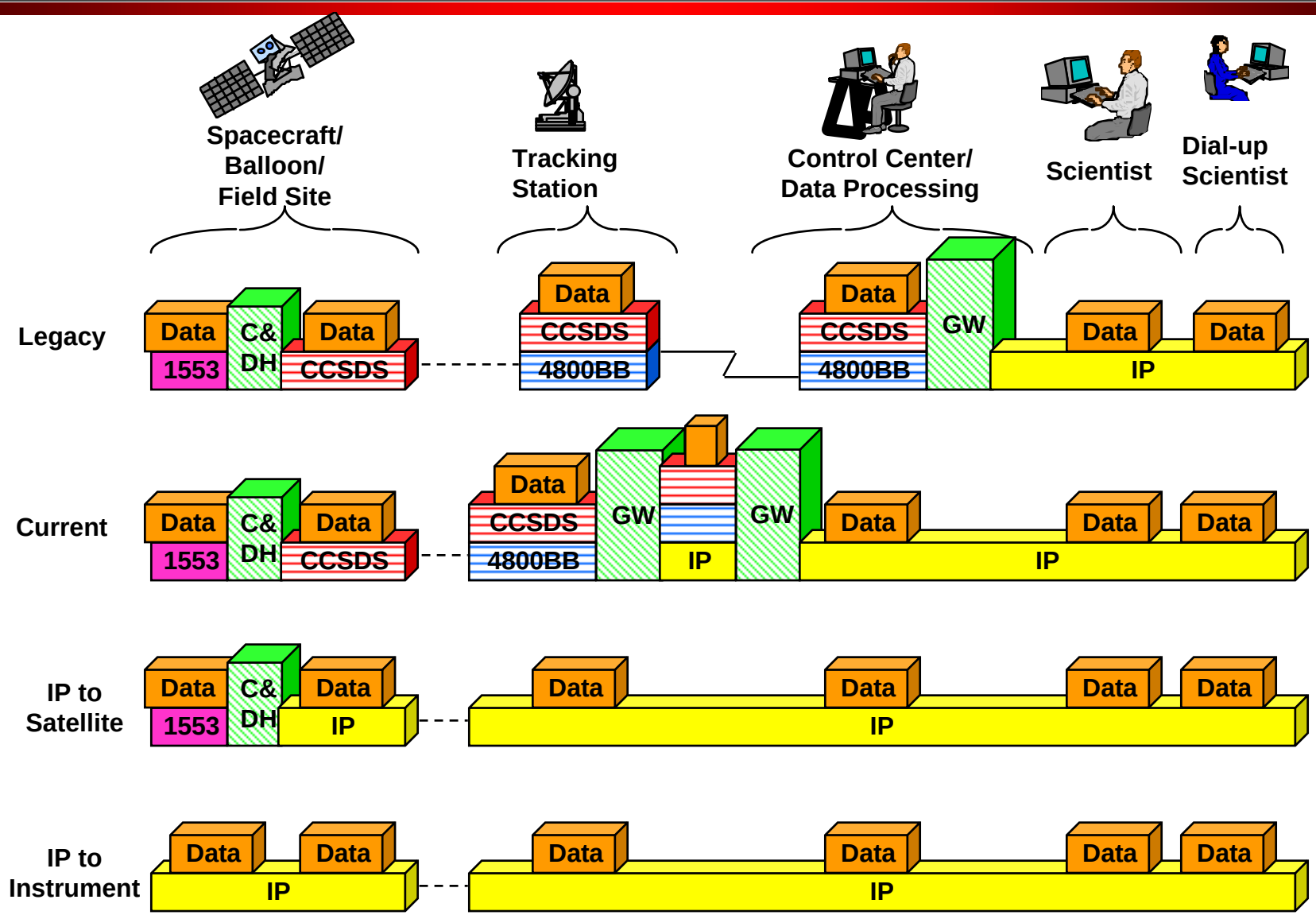
What is SNIS?

- **SNIS is an SN Product that will accomplish the following:**
  - Makes spacecraft systems look and operate just like any other nodes on the IONET
  - Provide operational IP services that were previously supported in test and demonstration modes
  - Enables end-to-end, standard IP communication between all mission resources (e.g. spacecraft, control center, Principal Investigators (PIs))
  - Enables low-cost individual security solutions tailored to meet the specific needs of each SN mission
  - Provides more privacy between SN missions on the IONET

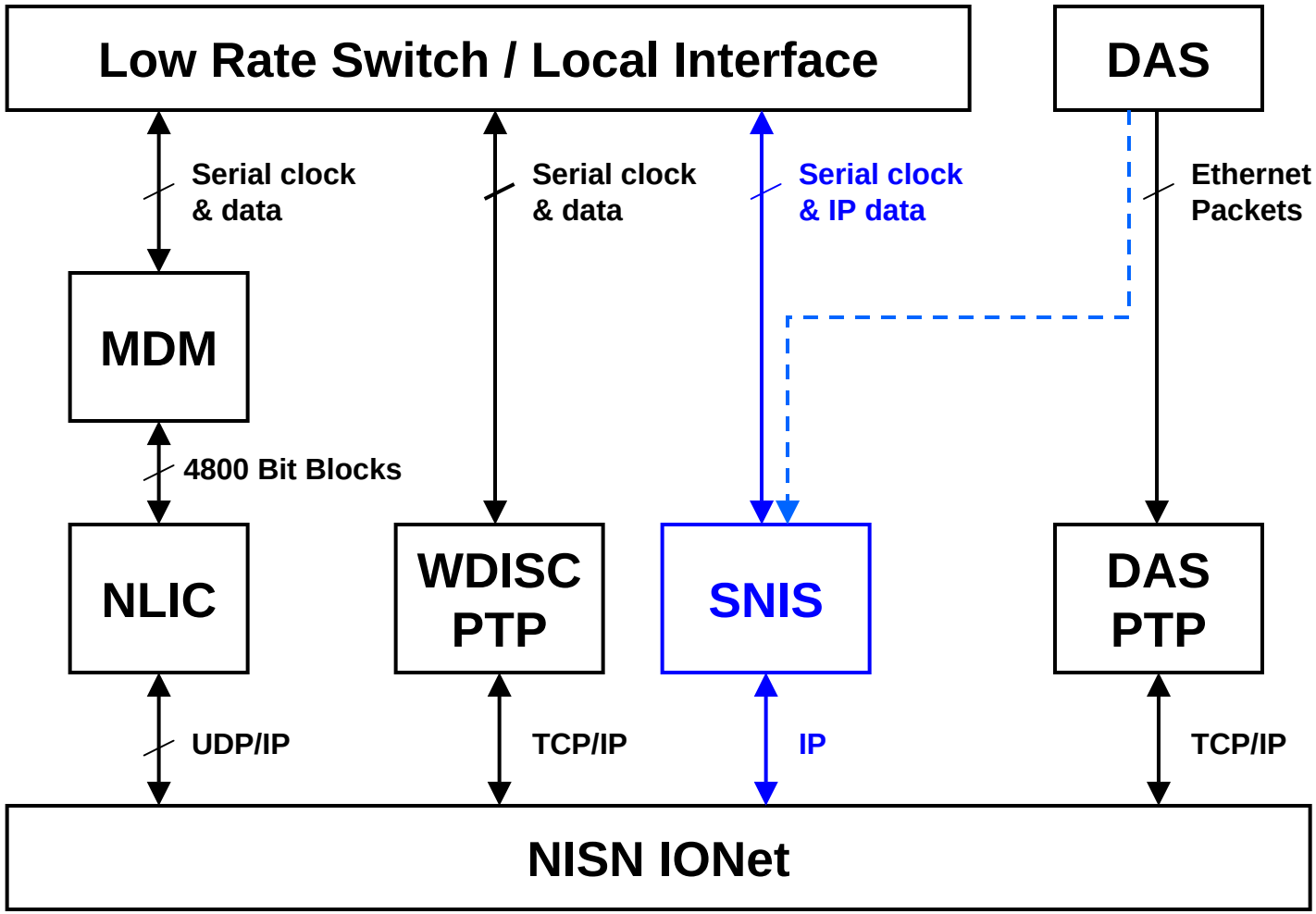
SN History as an Internet Service Provider

- **SN has been supporting a daily IP connection to the South Pole since 1997 (South Pole TDRSS relay (SPTR))**
- **Multiple ground demonstrations and activities have been done since (TILT, eclipses, OMNI, demonstrations)**
- **The LPT CANDOS experiment onboard STS-107 demonstrated SN/GN IP support to an orbiting user**

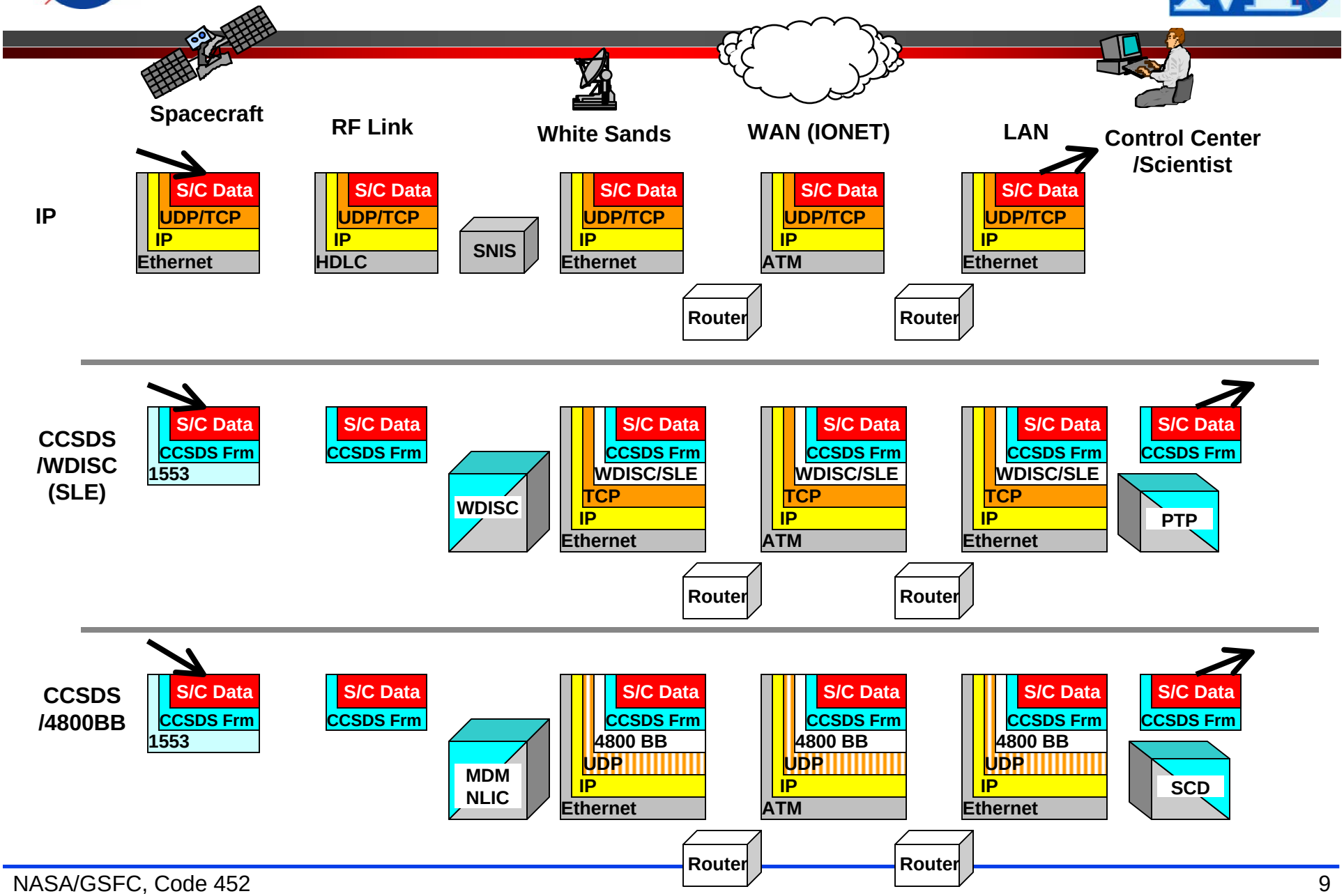
End-to-End Space Link Evolution



WSC Low Rate Data Interfaces



IP / WDISC / 4800BB Comparison



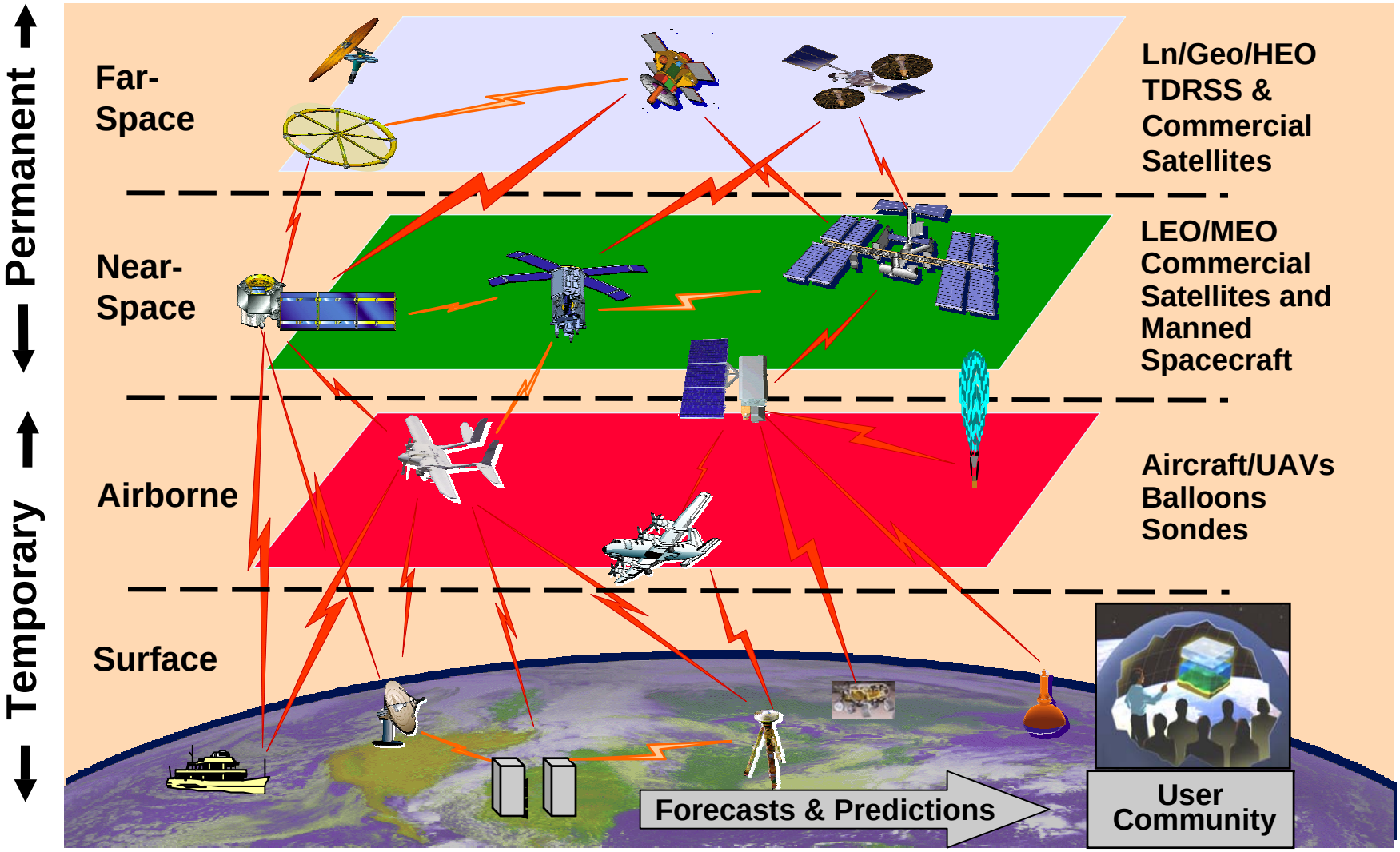
SNIS-WDISC Comparison

- **WDISC & DAS PTPs provide a gateway between the RF link and TCP/IP on the IONET**
  - Spacecraft indicates source of data (e.g. SCID, channel, APID)
  - PTP is configured before each pass to determine where to send user data over ground network
  - Spacecraft cannot dynamically address data to various ground systems or to other spacecraft
- **SNIS supports end-to-end IP protocols with both source and destination address**
  - Spacecraft identifies source of data (e.g. IP address, port number)
  - Spacecraft inserts destination address (addr/port) that can be used by the overall network to deliver data anywhere
  - Ground systems use standard IP routing mechanisms to automatically forward packets to their destination (e.g. control centers, PIs, or other spacecraft)
  - Spacecraft can dynamically address data anywhere
  - Ground data routing is fully data driven

Future Space Networking

- **Future Space IP Systems**
  - Commercial ground stations
  - SNIS
  - TacSat & DoD Secret Internet Protocol Router Network (SIPRNET)
  - Transformational Communication Architecture (TCA) using IPv6 over satellite links
- **Potential Future SN IP Users**
  - South Pole
  - Sensor Web
  - CEV/Lunar Missions (Code T)
  - ISS attached payloads
  - Global Precipitation Measurement (GPM) mission
  - Long Duration Balloon Program/Ultra Long Duration Balloon Program

Earth Science Sensorweb



GPM Mission

- **The Global Precipitation Measurement (GPM) mission is an SN customer that is baselining the following:**
  - IP space-ground communications (w/ HDLC framing)
  - Onboard Ethernet network
  - File transfer protocol
- **Key GPM mission dates:**
  - Mission Confirmation Review: Jan 2007
  - Launch of the Core Spacecraft: August 2011
- **The SNIS Product is coordinating with the GPM mission to ensure that SNIS will be capable of supporting GPM requirements and operations concepts**

Section 2
Operational Concepts & Scenarios

SNIS Product Overview

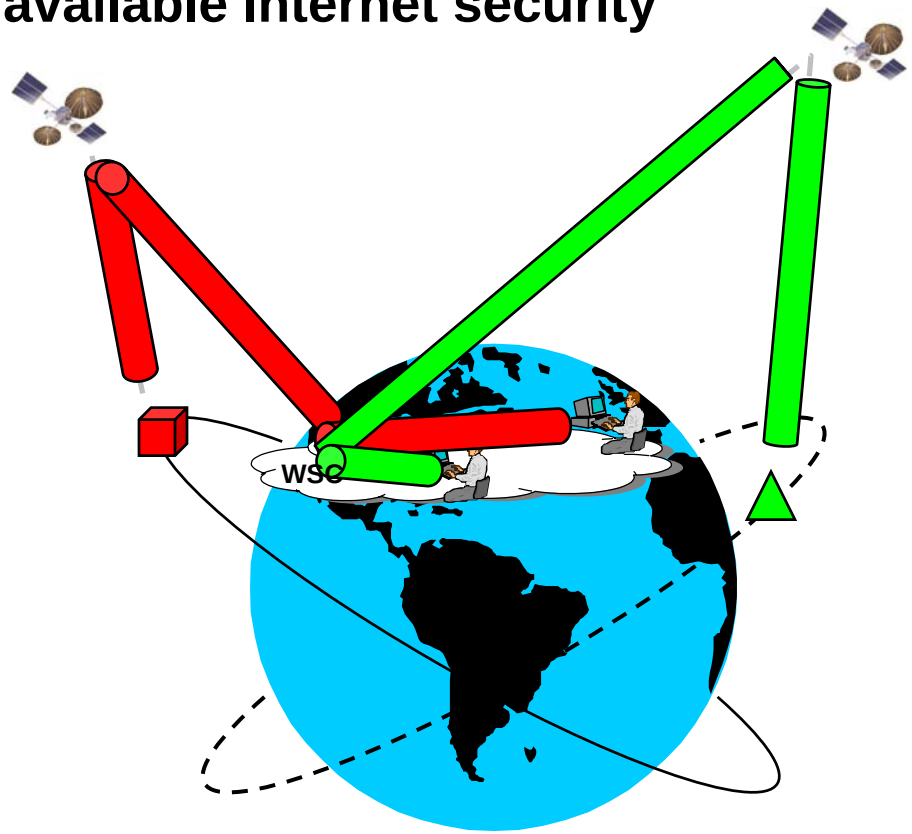
- **The primary function of the SNIS Product is to make spacecraft systems look and operate just like any other nodes on the IONET**
- **The SNIS Product will enable the following concepts:**
  - Data driven data distribution
  - File delivery (real-time and store and forward)
  - Time services
  - Spacecraft intercommunication
  - Distributed processing across spacecraft
  - Long-term system interoperability
  - Enhanced security options

SNIS Operational Scenarios

- Security
- Mobile network connectivity
- Science alert
- Virtual crosslink
- Direct file delivery
- Clock correlation
- Store and forward file delivery

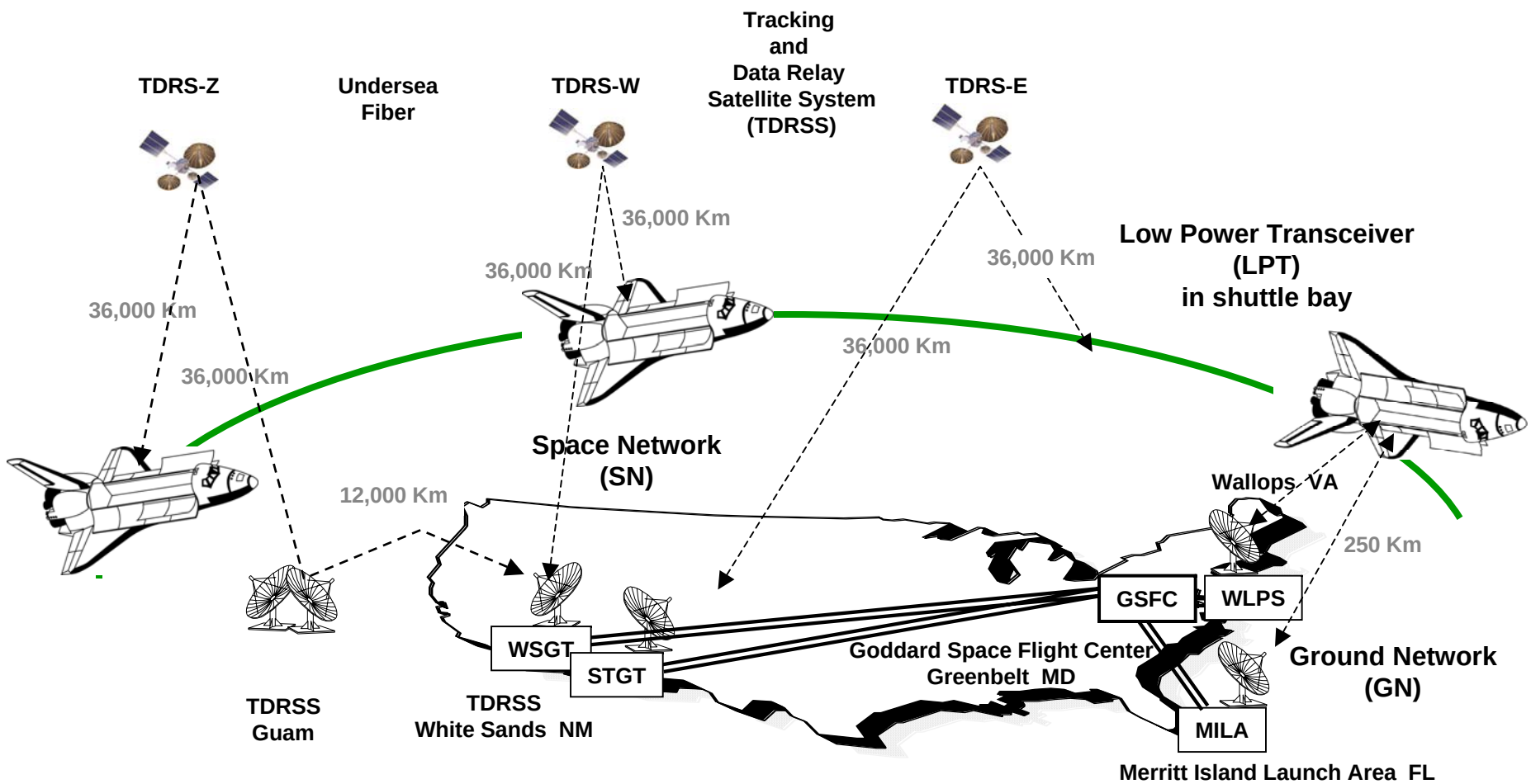
Security

- **Work with Code 297 to select and implement range of security solutions for use by missions**
  - i.e. IPsec, VPNs, SSH, SCP
- **SNIS allows mission to use available Internet security solutions**
- **Some security mechanisms transparent to WSC**
- **Some security mechanisms may require WSC router support**
- **Overall increase in privacy and end-to-end security for missions**



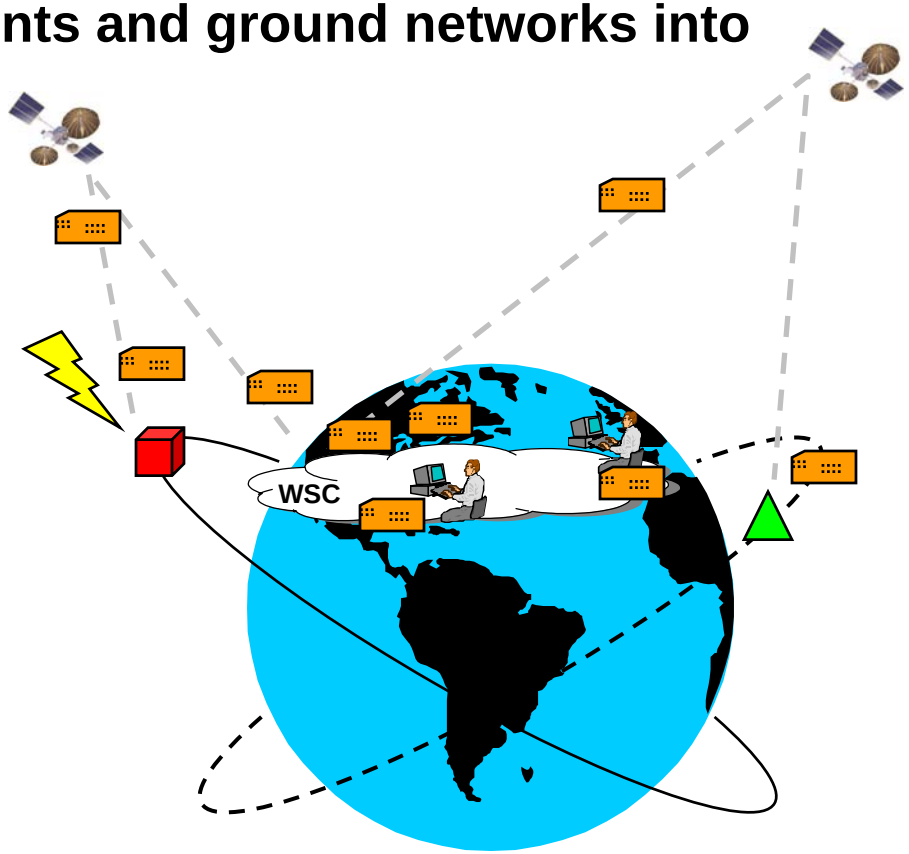
Mobile Network Connectivity

(CANDOS demonstration)



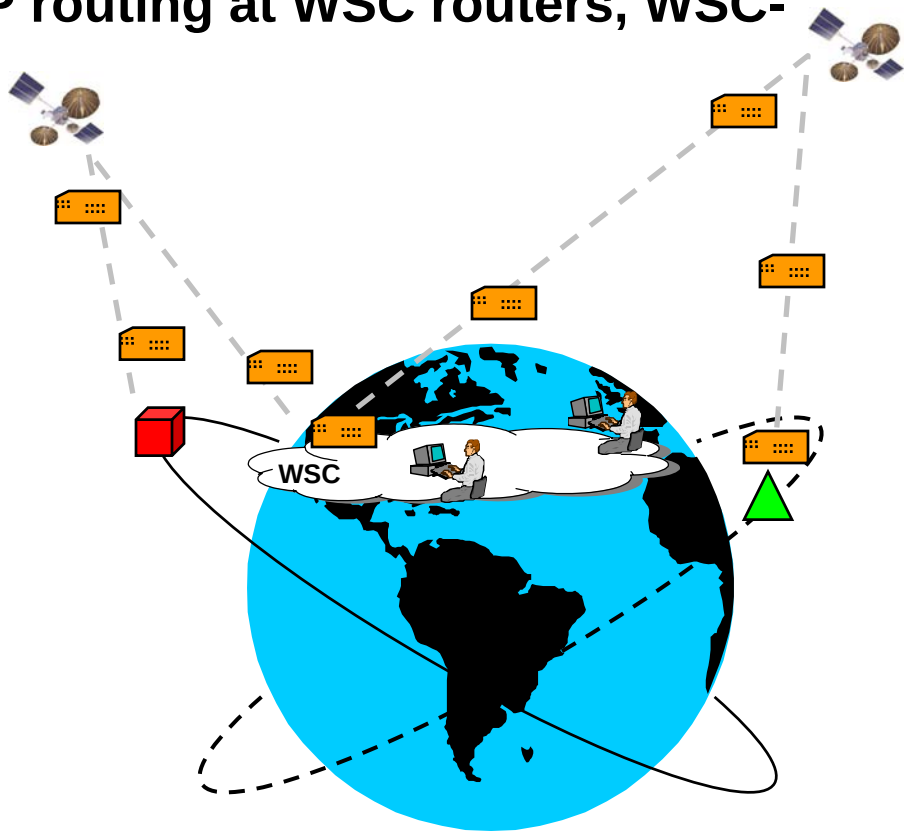
Science Alert

- **One spacecraft detects alert and wants to send notification to many other ground/space systems across an IP network**
  - Gamma Ray burst
- **SNIS connects space elements and ground networks into one addressable network**
- **Spacecraft addresses alert packet to one or more addresses**
- **Packet relays through TDRSS to WSC**
- **Address causes router at WSC to send alert packets to one or more network nodes**



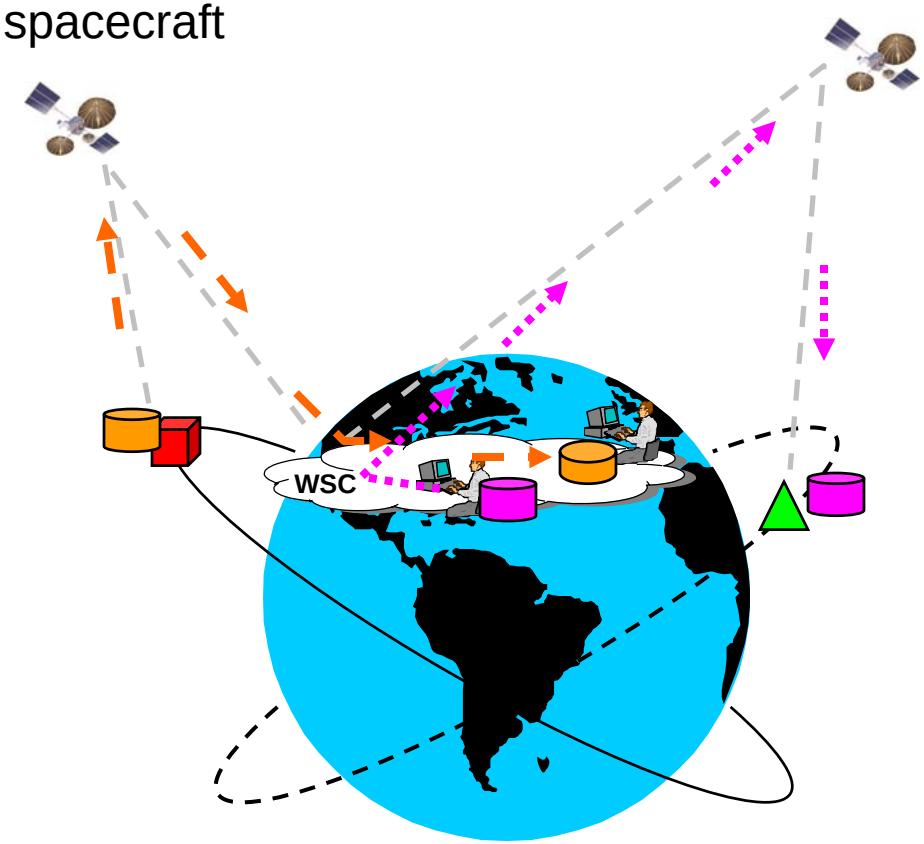
Virtual Crosslink

- **Combination of TDRSS links and ground network provide real-time crosslink between multiple spacecraft**
  - Sensorweb
- **Spacecraft->TDRS->WSC, IP routing at WSC routers, WSC->TDRS->2nd spacecraft**
- **Possible to connect to spacecraft on opposite sides of the earth**
- **No data destination configuration required at WSC**
- **Routing between systems handled by standard automated Internet techniques**



Direct File Delivery

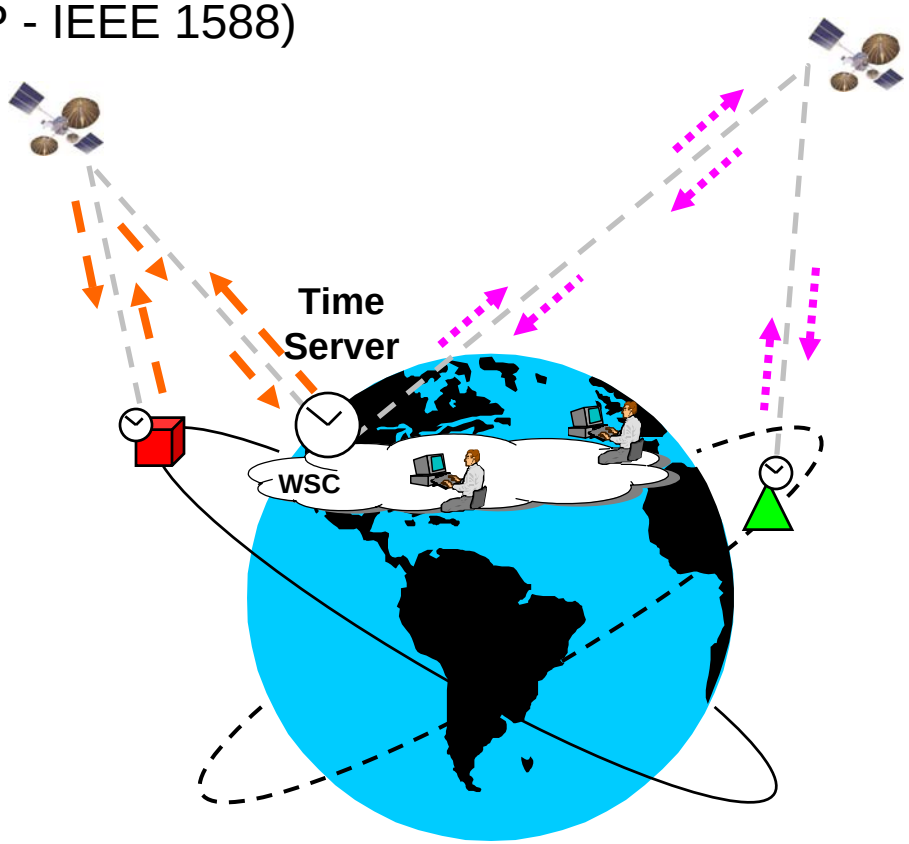
- **File of data collected by instrument onboard spacecraft**
- **During TDRSS contact, files transferred:**
  - Spacecraft to ground MOC or end user
  - Ground MOC or end user to spacecraft
  - Spacecraft-to-spacecraft
- **File transfers performed using appropriate protocols, (e.g. FTP, SCP, MDP, CFDP, NORM)**
- **Transfers direct from spacecraft to destination**
- **No storage at WSC**



Clock Correlation

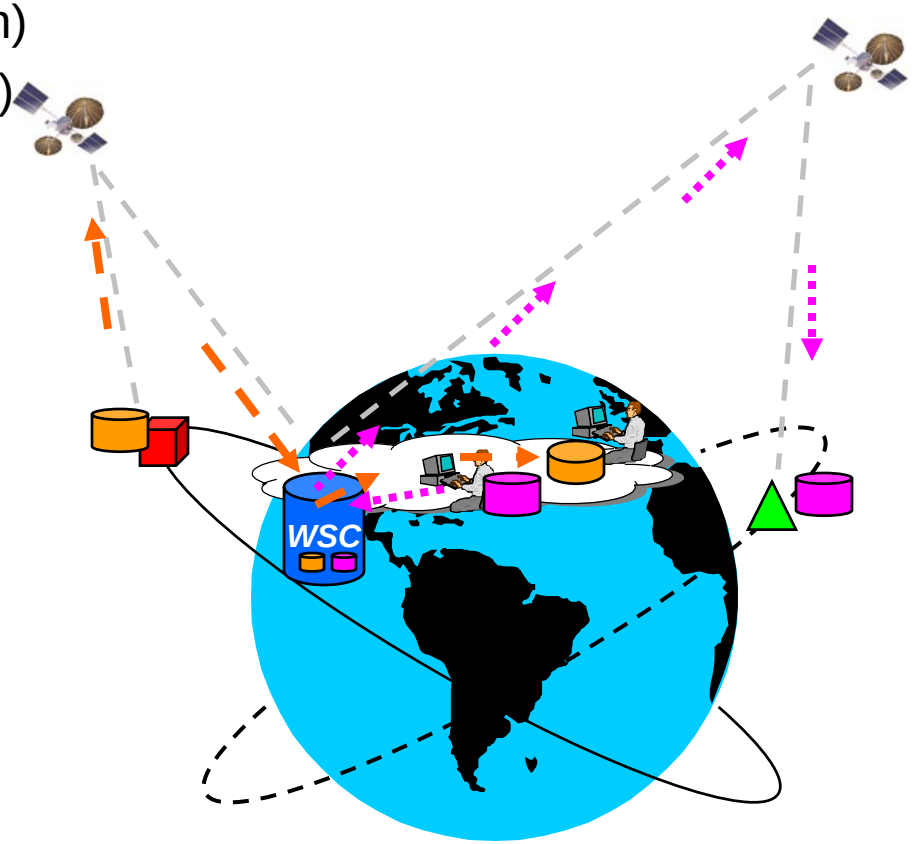
- **Time server at WSC for use by spacecraft**
- **Standard, automated protocol for spacecraft clock sync**
  - Network Time Protocol (NTP)
  - Precision Time Protocol (PTP - IEEE 1588)

- **Protocols determine delays each way and deliver accurate time**
- **Exact accuracy needs study but 50 us to 1 ms expected**
- **Spacecraft then timestamp data and no ground time stamping needed**



Store & Forward File Delivery

- **File of data collected by instrument onboard spacecraft**
- **During TDRSS contact, files moved to/from storage at WSC:**
  - WSC manual or automated forwarding (e.g. login or email)
  - Spacecraft to/from WSC (return)
  - Ground user to/from WSC (fwd)
  - S/C to S/C (non-realtime)
- **File transfers performed using appropriate protocols, (e.g. FTP, SCP, MDP, CFDP, NORM)**
- **Transfers from spacecraft to WSC and ground user to WSC, forwarded to destination later**
- **General purpose file storage at WSC for use by missions**



Section 3
Preliminary Architecture

SNIS High-level Requirements

- **Support the following TDRSS services and data rates:**
  - Multiple Access (MA) Return (to include Demand Access System (DAS)): 0.1 to 300 kbps
  - S-band Single Access (SSA) Return: 0.1 to 6 Mbps
  - K-band Single Access (KSA) Return: 0.1 to 7 Mbps
  - MA Forward: 0.1 to 300 kbps
  - SSA Forward: 0.1 to 6 Mbps
  - KSA Forward: 0.1 to 7 Mbps
- **Interface with:**
  - White Sands Complex (WSC) Low Rate Switches
  - DAS Demodulators
  - NISN IONet
  - WSC scheduling, control, and status systems
- **Support the standard Internet protocols**
- **Support Mobile IP and Mobile routing operations**
- **Support required security protocols (NPR 2810.1, GPG 2810.1)**

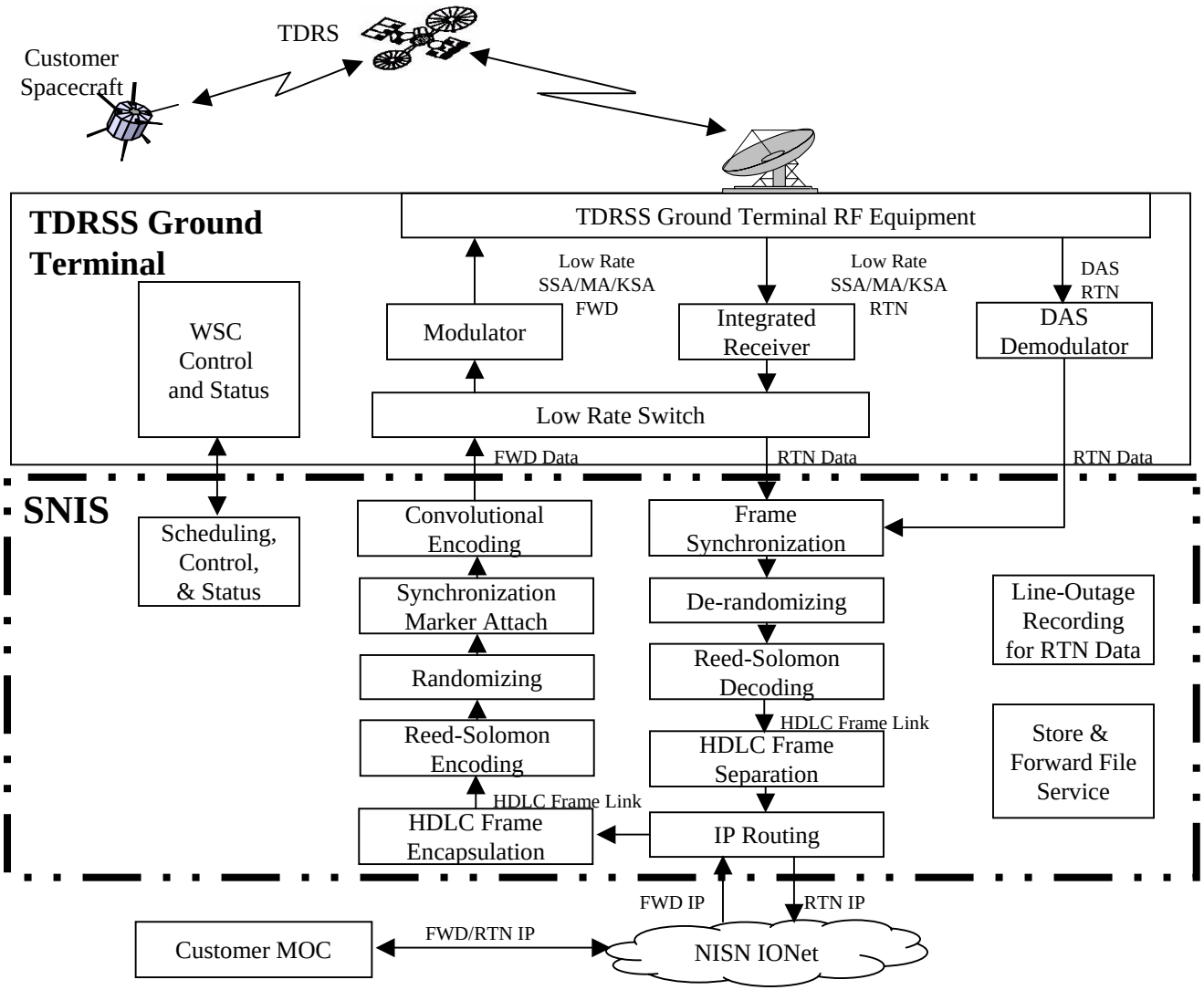
SNIS High-level Requirements

- **Provide the following data processing functions:**
  - Reed-Solomon encoding (Forward)/decoding (Return)
  - Randomization (Forward)/de-randomization (Return)
  - Sync marker attachment (Forward)/frame synchronization (Return)
  - Convolutional encoding (Forward)
- **Encapsulate Forward link IP packets into HDLC frames**
- **Perform HDLC frame separation on Return link data**
- **Provide the capability to be scheduled by the Network Control Center Data System (NCCDS) and DAS Controller (DASCON)**
- **Provide automated operation of all SNIS functions via the TDRSS ground terminal's control and status monitoring system**
- **Provide line outage recording capability**
- **Provide network time synchronization services**
- **Provide file store & forward and rate buffering services**
- **Meet TDRSS reliability and availability requirements**

SNIS Product Design Goals

- State-of-the art design that maximizes flexibility and reliability
- Modular and scalable to allow for future requirements expansion with minimal impact to facility and subsystems
- Maximize use of COTS products at WSC
- Minimize need for custom network equipment at user sites

SNIS Reference Architecture



Section 4
Product Planning

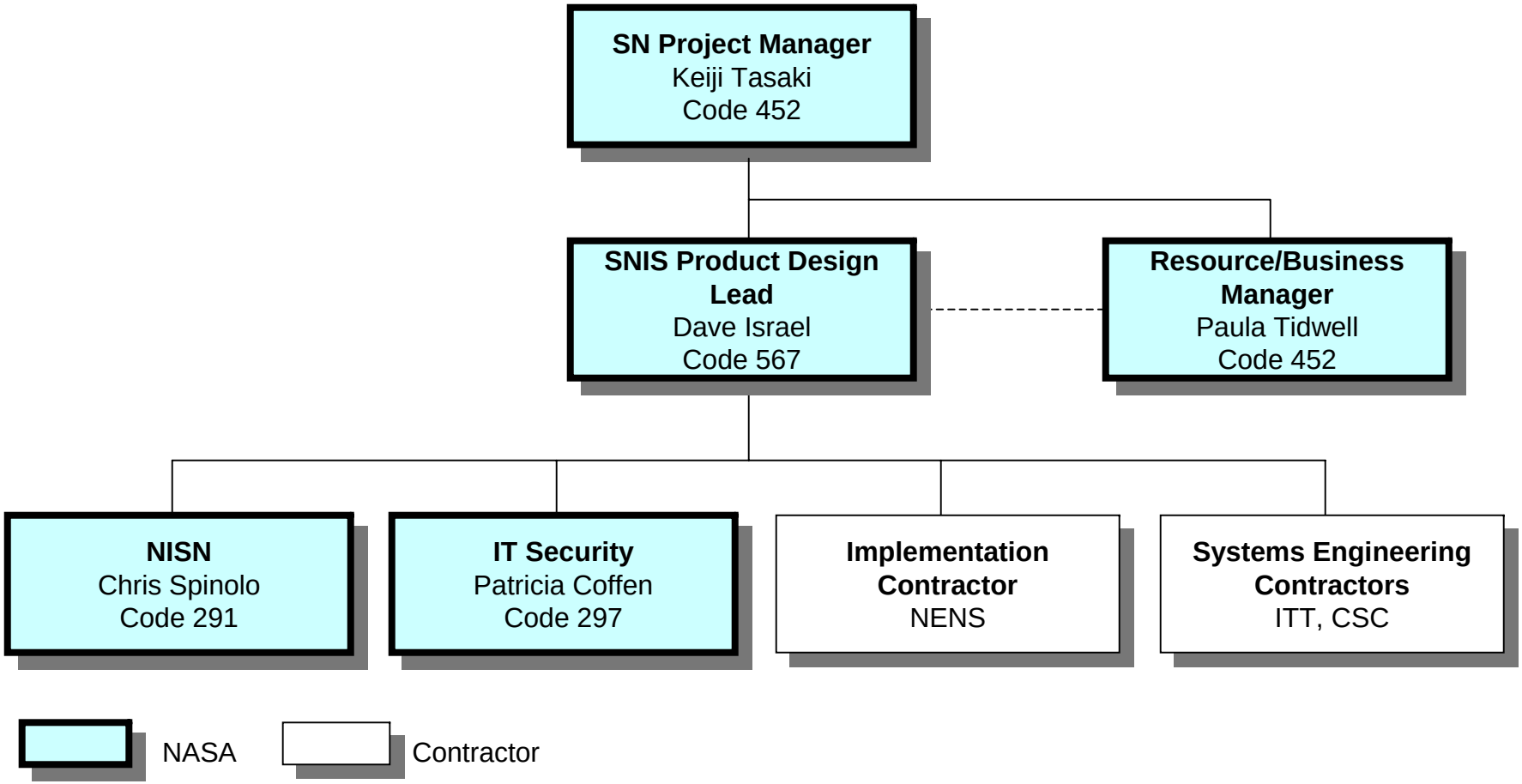
Product Planning Status

- **SNIS High-level requirements and operations concept documented in the White Paper "Space Network (SN) Internet Protocol (IP) Services (SNIS) High-Level Concepts and Requirements," dated December 4, 2003.**

- **The SN Project has provided funding to develop the initial SNIS Product documentation and to perform limited prototype development and test.**

- **SNIS documentation currently in development:**
  - 452-PCD-SNIS, the SNIS Project Commitment Document (PCD)
  - 452-PMP-SNIS, the SNIS Product Management Plan (PMP)
  - 452-OCD-SNIS, the SNIS Operations Concept Document (OCD)
  - 452-SRD-SNIS, the SNIS System Requirements Document (SRD)

Product Organization



Schedule & Implementation Approach

- **SNIS High-level Schedule:**
  - Implementation start: May 2004
  - System Requirements Review (SRR): July 2004
  - System Design Review (SDR): November 2004
  - Implementation Complete/Operations readiness Review (ORR): December 2005
  - Complete Transition to Operations/Sustaining Engineering: March 2006

- **The SNIS Product will be developed, tested, and transitioned into SN support via a task order under the Near Earth Network Services (NENS) contract**

Section 5
Risks & Risk Mitigation

Risk/Risk Mitigation

- **RISK #1**
- **Risk: SNIS requirements to interface with diverse scheduling, control, and monitoring systems could result in complex design and implementation (ADPE, DASCON, SWSI, SNAS, IPNOC, UPS)**
- **Consequence: High (schedule delay, increased complexity)**
- **Likelihood: High**
- **Mitigation:**
  - Early involvement of NENS contractor
  - Coordination with SNAS
  - Coordination with NISN

Risk/Risk Mitigation

- **RISK #2**
- **Risk: Security requirements not completely defined, new requirements may be incompatible with architecture**
- **Consequence: High (architectural change)**
- **Likelihood: Low**
- **Mitigation:**
  - Ongoing coordination, planning, prototyping, analysis with NISN, Code 297, and missions

Risk/Risk Mitigation

- **RISK #3**
- **Risk: Required Channel coding/router interface not commercially available**
- **Consequence: Moderate (schedule delay)**
- **Likelihood: Moderate**
- **Mitigation:**
  - Ground Station Router Interface Device (GRID) technology development available for Industry tech transfer.
  - Received Avtec proposal for PTP-based implementation
  - Possible Cisco solution also identified

Risk/Risk Mitigation

- **RISK #4**
- **Risk: Mobile IP or other two-way protocols may require bi-directional communications on the same router serial port**
- **Consequence: Moderate (architectural change)**
- **Likelihood: Low to Moderate**
- **Mitigation:**
  - Set up testbed to verify performance/proposed architecture
  - Confirm results with Cisco engineers

Risk/Risk Mitigation

- **RISK #5**
- **Risk: Network time protocol precision not well characterized for space mission environments**
- **Consequence: Moderate (reduced user base)**
- **Likelihood: Low**
- **Mitigation:**
  - Prototype and analyze to determine issues and limits
  - Work with missions to understand and define needs

Section 6
Summary & Action Items

Summary and Action Items

- **Summary:**
  - SNIS Product planning is proceeding
  - Requirements definition is in progress
  - Risk areas have been identified and assessed
  - Mitigation plans have been developed and are being executed

- **Next Steps:**
  - Complete documentation development
  - Initiate NENS task
  - Conduct the SNIS SRR in July 2004

- **Action Items**

SNIS Contact Information

- **SNIS Product Design Lead**
  - Dave.Israel@nasa.gov
  - NASA/GSFC Code 567.3
  - (301) 286-5294

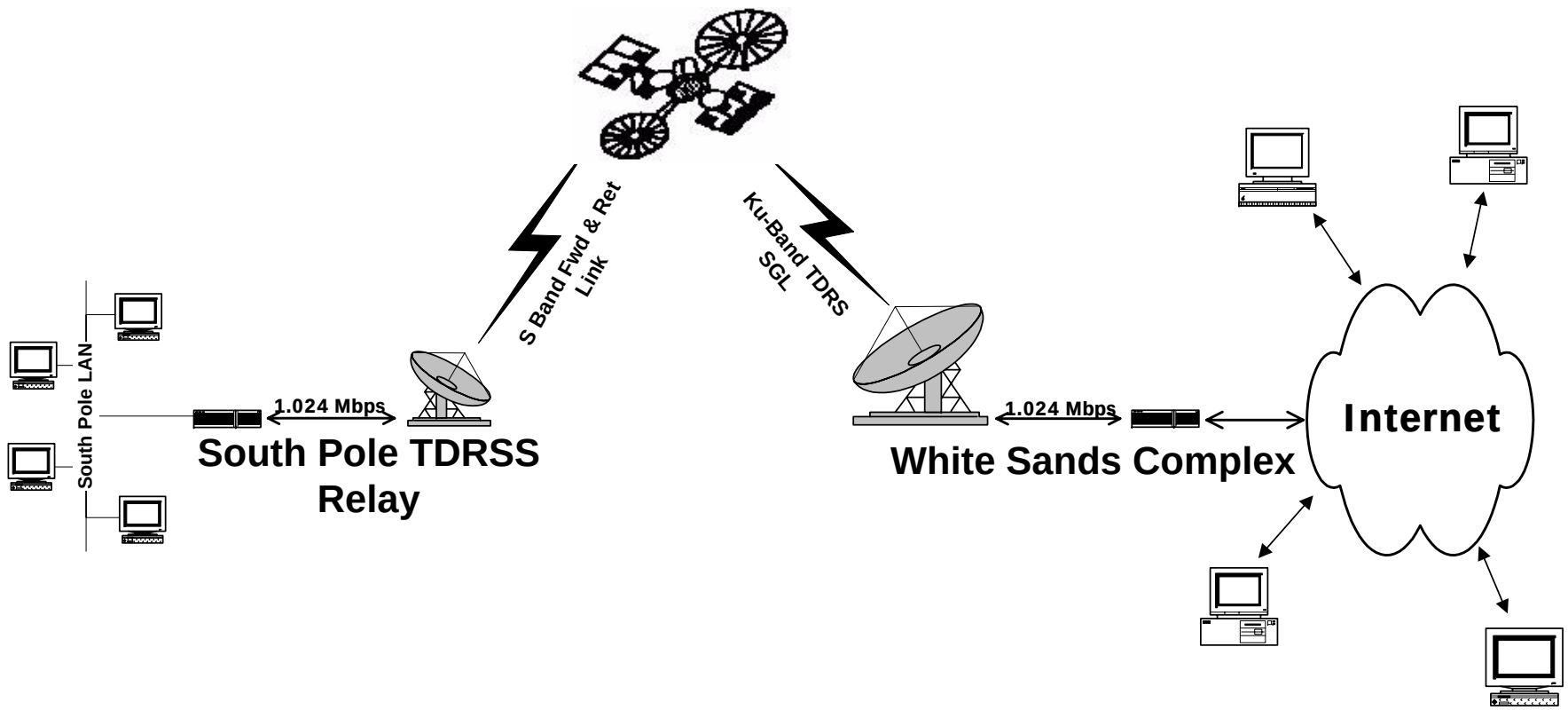
- **SNIS web server**
  - http://snis.gsfc.nasa.gov/

Acronyms

ADP	Automated data Processing equipment
APID	Application Process Identifier
BOF	Birds of a Feather
CANDOS	Communication and Navigation Demonstration On Shuttle
CCSDS	Consultative Committee for Space Data Systems
CEV	Crew Exploration Vehicle
CFDP	CCSDS File Delivery Protocol
COTS	Commercial Off-the Shelf
DAS	Demand Access System
DASCON	Demand Access System Controller
FTP	File Transfer Protocol
GN	Ground Network
GPM	Global Precipitation Measurement mission
GRID	Ground Station Router Interface Device
GSFC	Goddard Space Flight Center
HDLC	High-level Data Link Control
IONET	Internet Protocol Operational Network
IP	Internet Protocol
IPSec	Internet Protocol Security
ISP	Internet Service Provider
ISS	International Space Station
KSA	K-band Single Access
LAN	Local Area Network
LDBP	Long Duration Balloon Project
LEO	Low Earth Orbit
LPT	Low Power Transceiver
LRS	Low Rate Switch
MA	Multiple Access
MDM	Multiplexer/Demultiplexer
MDP	Multicast Dissemination Protocol
MILA	Merritt Island Launch Area
NCCDS	Network Control Center Data System
NENS	Near Earth Network Services
NISN	NASA Integrated Services Network
NLIC	NISN Local Area InterfaceCard
NORM	NACK-Oriented Reliable Multicast
NTP	Network Time Protocol
OCD	Operations Concept Document
OMNI	Operating Missions as Nodes on the Internet
ORR	Operations Readiness Review
PCD	Project Commitment Document
PDL	Product Design Lead
PI	Principal Investigator
PMP	Product Management Plan
PTP	Programmable Telemetry Processor
PTP	Precision Time Protocol
S/C	Spacecraft
SCID	Spacecraft ID
SCP	Secure Copy Protocol
SCPS	Space Communications Protocol Standards
SDR	System Design review
SLE	Space Link Extensiom
SN	Space Network
SNAS	Space Network Access System
SNIS	Space Network IP Services
SPTR	South Pole TDRSS Relay
SRD	System Requirements Document
SRR	System Requirements Review
SSA	S-band Single Access
SSH	Secure Shell
STGT	Second TDRSS Ground Terminal
TCA	Transformational Communication Architecture
TCP/IP	Transmission Control Protocol/Internet Protocol
TDM	Time Division Multiplexing
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TILT	TDRSS Internet Link Terminal
UAV	Unmanned Aerial Vehicle
UDP	User Datagram Protocol
ULDBP	Ultra-Long Duration Balloon Project
VPN	Virtual Private Network
WAN	Wide Area Network
WDISC	WSC Data Interface Capability
WSC	White Sands Complex
WSGT	White Sands Ground Terminal

BACKUP

SPTR IP Connection



Other TDRSS IP Users/Demonstrations

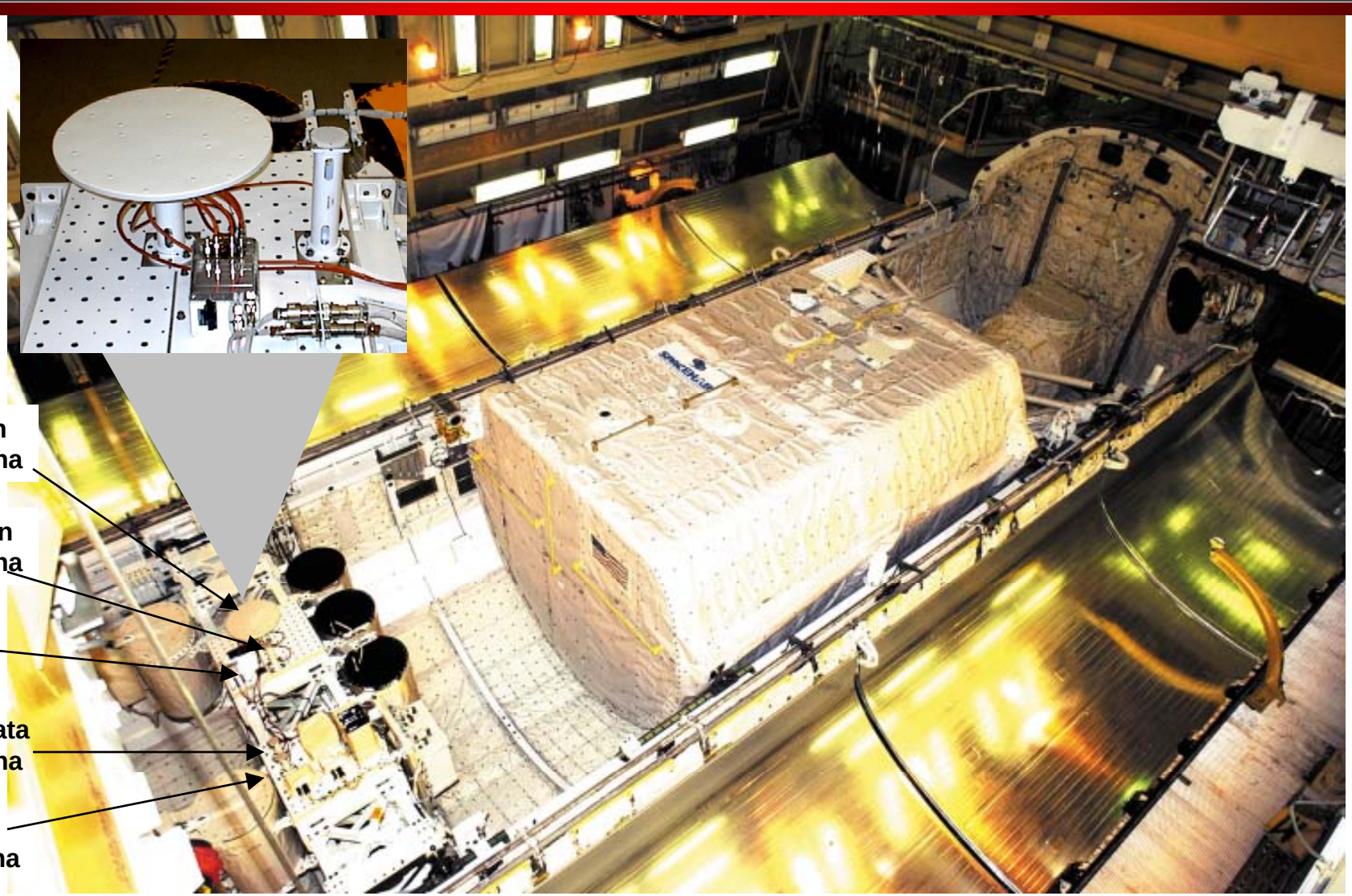
- Once the SPTR infrastructure was installed at White Sands, the opportunity for other IP users existed
- User hardware was either TDRSS Internet Link Terminal (TILT) or the ECOMM Internet Terminal
- Other demonstrations have also used the Low Power Transceiver (LPT)

Feb 1998	Eclipse webcast from Aruba
Nov 1998 – Sep ‘02	OMNI Demonstrations
Apr 1999	North Pole Expedition
Aug 1999	Eclipse webcast from Black Sea
Sep 1999	President Clinton in New Zealand
Nov 1999	JSC Inspection Day 1999
Dec 1999	Yosemite/West Virginia
Nov 2000	JSC Inspection Day 2000
Apr 2001	Women Quest North Pole Webcast
Jul - Dec 2001	USCG Healy Arctic Research Cruise
Jan 2003	STS-107 CANDOS
Apr 2003	North Pole Expedition

TDRSS ISP Photo Gallery

Clockwise from top left: SPTR antennas at the South Pole, ECOMM check out during North Pole Expedition, The OMNI Van, TILT in Istanbul during Eclipse '99 support

CANDOS LPT/IP Tests on STS-107



CANDOS IP Experiments

Experiment	UDP Protocols	TCP Protocols
Automated IP routing to current ground station antenna	Mobile IP- Automatically setup IP routing tunnels to multiple stations/antennas (SN and GN)	
Real-time Telemetry Delivery	UDP status packets - to monitor status of LPT over two-way and one-way links addressed to multiple destination addresses	
Onboard Clock Synchronization	Network Time Protocol (NTP) - synchronize and maintain onboard clock referenced to ground time servers	
Commanding	UDP Blind Commanding - Send UDP command packets to LPT over one-way uplink without Mobile IP or a two-way link	Secure Shell (SSH) & Telnet - login and control experiments from multiple locations
Reliable File Transfer	Multicast Dissemination Protocol (MDP) - perform reliable file transfer over both two-way and one-way communication links	Secure Copy (SCP) and File Transfer Protocol (FTP) - reliably transfer files to and from LPT during SN and GN two-way contacts

SNIS Space Environment Issues

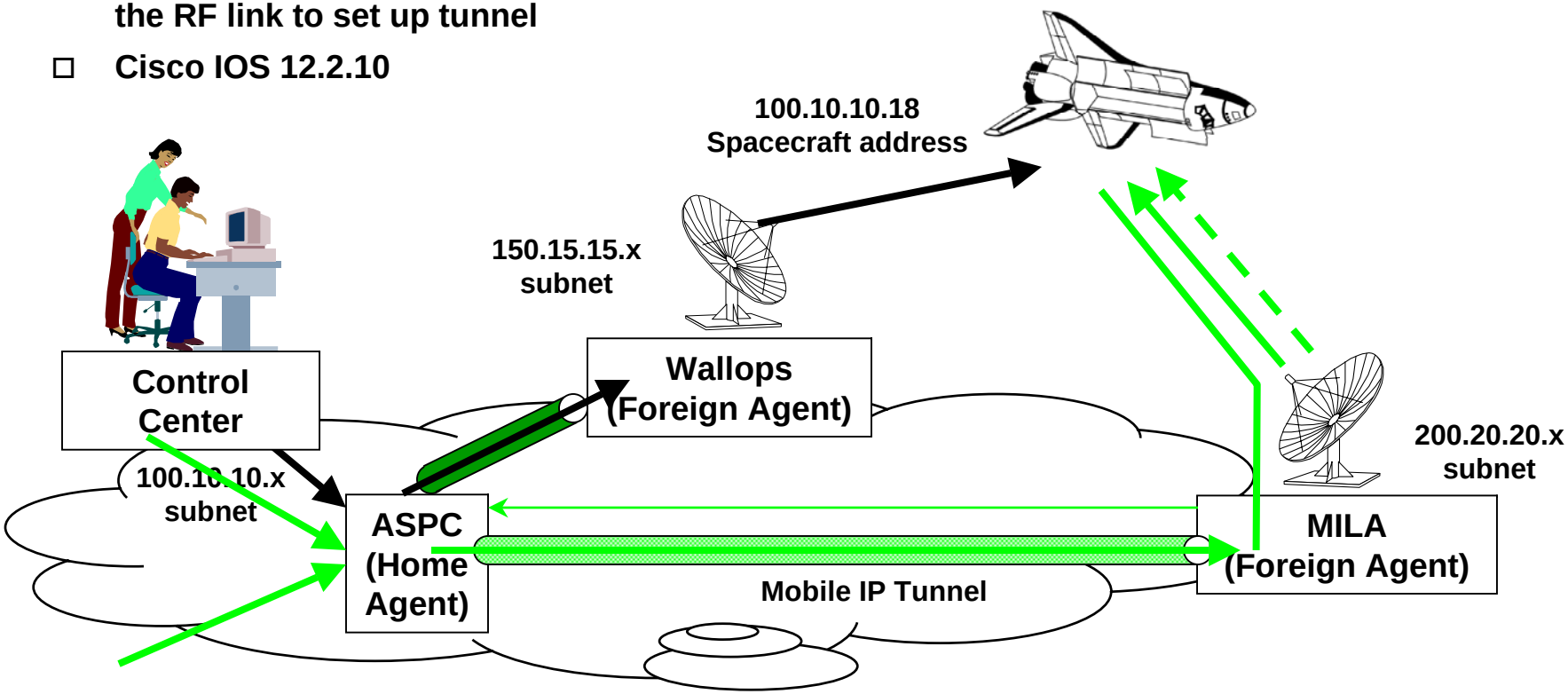
- **TDM and CCSDS frames work over one-way links since they just wrap data and send it**
  - No two-way handshakes
  - No impact from propagation delay or distance
- **UDP packets over IP work exactly link TDM and CCSDS frames**
  - Wrap data and send it
  - No impact from propagation delay or distance
- **TCP reliable delivery mechanism requires two-way handshakes exactly like CCSDS COP-1 telecommand protocol**
  - These are both impacted by propagation delay and distance
  - Normal 1 Kbps uplink rates causes so much delay that propagation delay and distance aren't noticed
  - 125 bytes = 1000 bits, at 1 Kbps there is a 1 second one-way delay just to clock the bits out

WSC Low Rate Data Interfaces

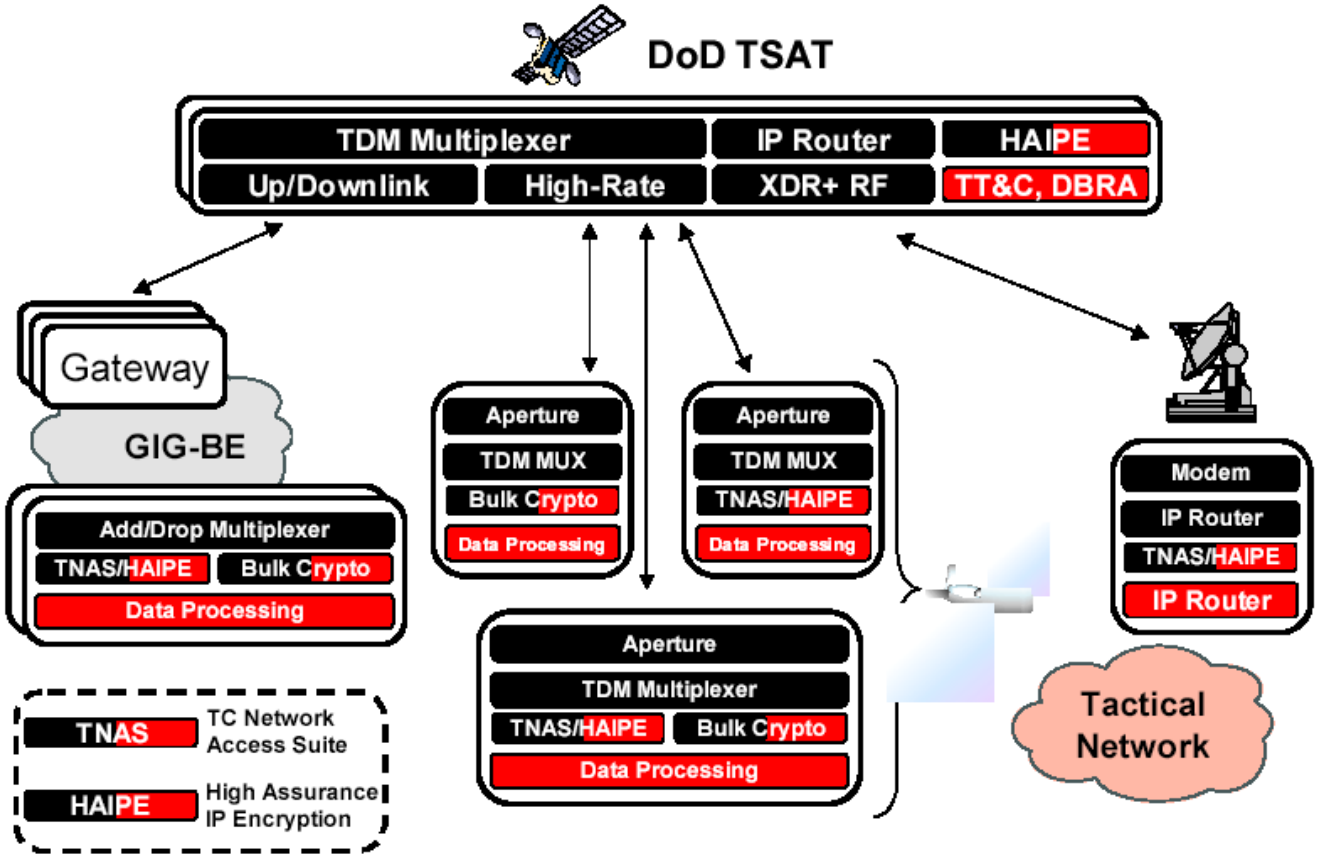
	WDISC	DAS	MDM
Data Rates	**☐ Up to 50 kbps per channel Forward** **☐ Up to 512 kbps per channel Return**	**Up to 150 kbps per channel Return**	**☐ Up to 7 Mbps per channel Forward** **☐ Up to 7 Mbps per channel Return**
Telemetry Transfer Protocol	**TCP/IP**	**TCP/IP**	**UDP encapsulated 4800 bit blocks**
CCSDS Ground Transport Header	**☐ IPDU** **☐ SFDU** **☐ LEO-T**	**☐ Asynchronous (no header)** **☐ SFDU** **☐ AXAF-I** **☐ ACE** **☐ LEO-T** **☐ IPDU**	
Playback Support	**Playback via FTP from disk**	**Playback via spooler from disk**	**Playback via line outage recorder**
Expandable to SLE	**Yes**	**Yes**	**No**

Mobile IP

- Downlink data is routed normally
- Need to automatically determine which ground station to send commands through (same problem for cars, PDAs, laptops)
- Mobile device registration with ground agents supports automatic uplink routing configuration
- Robust protocol worked under non-optimal links, only needed to get 3 packets across the RF link to set up tunnel
- Cisco IOS 12.2.10



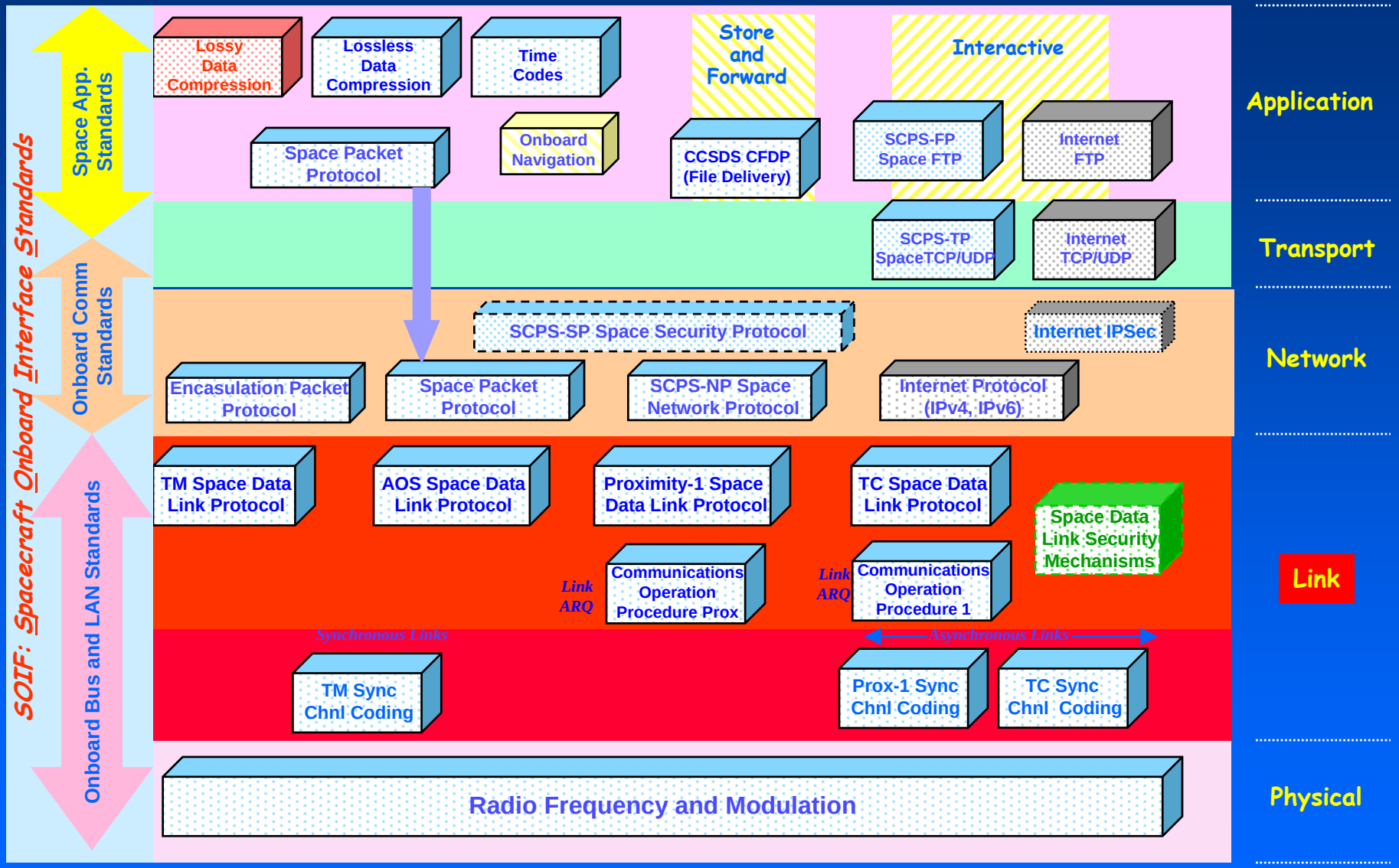
TCA



Networking Transformation
Scalable, Reliable, Robust, Dynamic

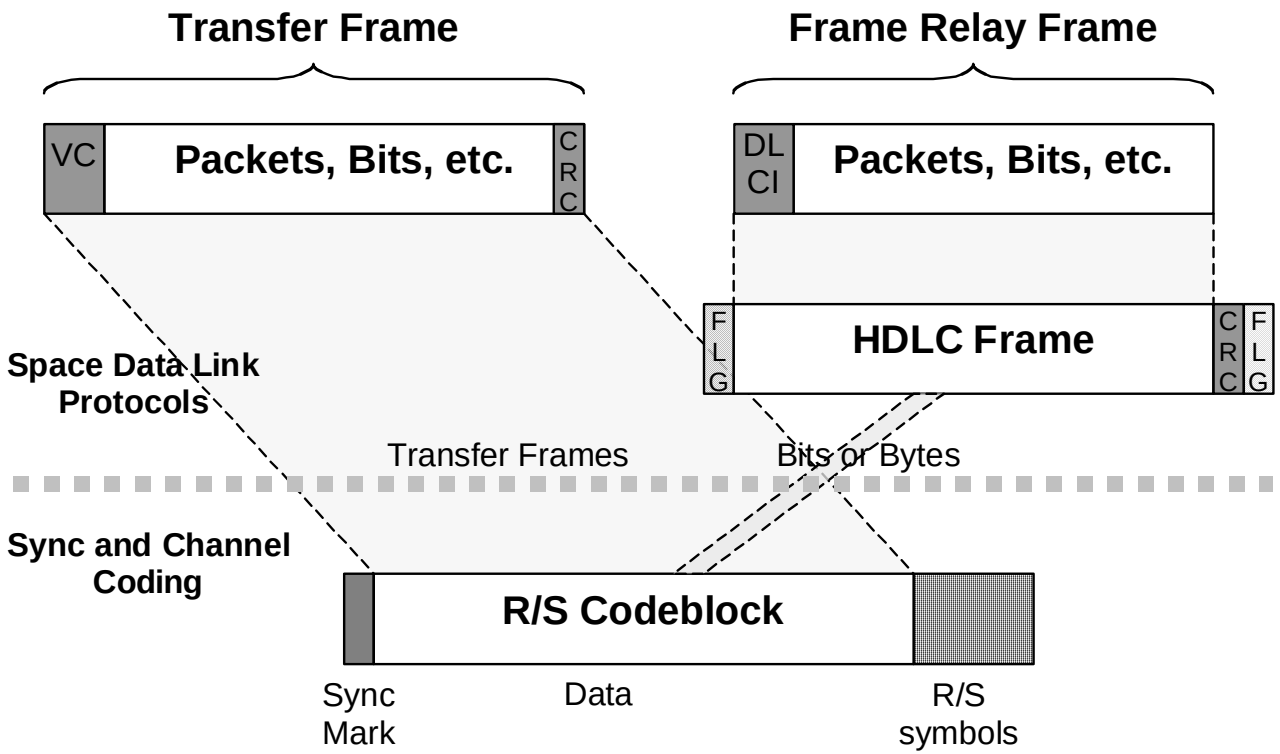
From "CCSDS Link Layer Protocol Suite", Greg Kazz, SIW Presentation 6/4/03

Networked CCSDS Space/Ground Communications Protocol Stack



Reed Solomon with CCSDS and HDLC

- CCSDS VCDUs and HDLC frames both work with Reed/Solomon coding
- CCSDS uses the R/S frame sync to find VCDUs
- HDLC has its own frame sync and CRC check



SNIS Relationship to SCPS

- **SCPS-FP can operate over standard IP**
  - Operates at application level
- **SCPS-TP can operate over standard IP**
  - May require custom gateway at WSC for connection splitting
- **SCPS-SP is a modified set of standard IP security**
  - Requires custom security gateway at WSC
- **SCPS-NP is a replacement for IP**
  - Requires custom routing gateway at WSC