Ground Systems Architectures Workshop (GSAW) 2011

NASA Space Network (SN) Ground Segment Sustainment (SGSS) Architecture based on DoD Architecture Framework

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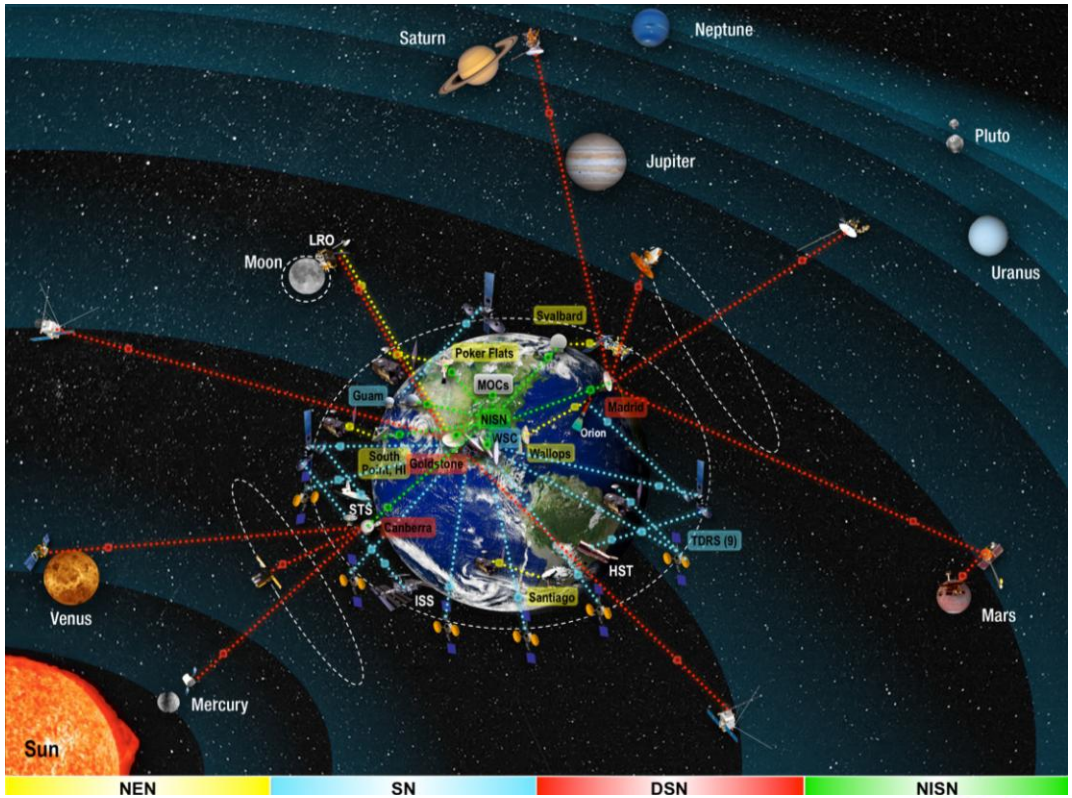
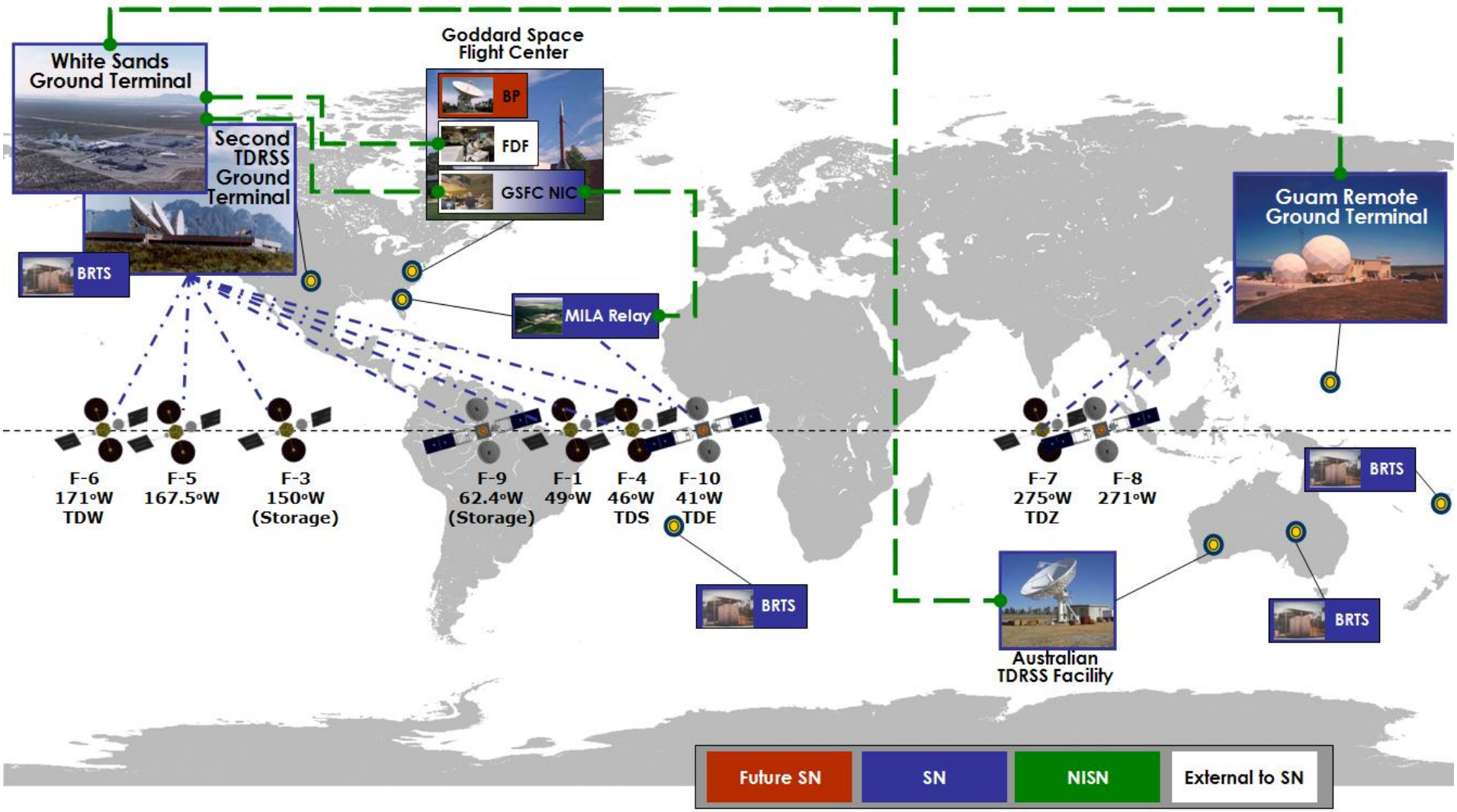
SN Overview

- NASA's Space Network (SN) is a GEO-based relay system providing tracking and data transfer services for NASA LEO missions and other users.
  - Also known as the Tracking and Data Relay Satellite System (TDRSS)
  - Unique capabilities include: Global coverage (100% for orbits between 73 and 9,000 km); High data rates (S, Ku, and Ka-band data services); and High-precision tracking and clock-correlation services

- Multiple generations of spacecraft comprise the TDRS Fleet
- Multiple ground terminals and other support facilities form the SN Ground Segment
- The SN is a highly complex system-of-systems that has evolved over time; the SN operates with high-availability and mission-criticality; modifying it is not easy or straightforward

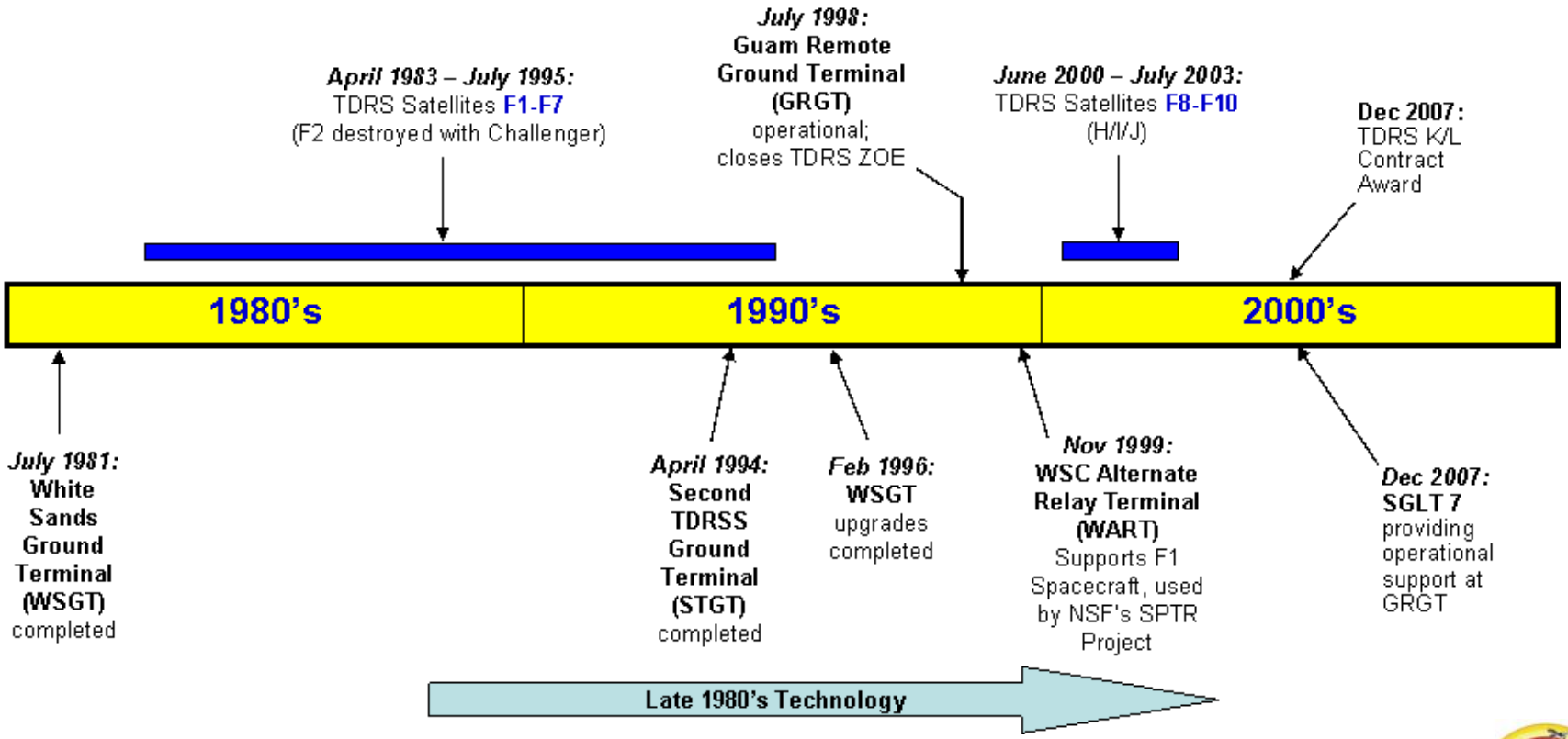


Geographic Locations of SN Elements



SN Ground Segment History

- The current SNGS dates back to the early 1980s with the building of the White Sands Ground Terminal (WSGT) at the White Sands Complex (WSC). In 1994, the WSC was augmented with a Second TDRSS Ground Terminal (STGT) including newer technology, and then in 1996 WSGT was upgraded based on the STGT technology.



SN Ground Segment: Challenges & Response

The current SN Ground Segment uses equipment and communications protocols that are becoming obsolete and difficult to operate, maintain, and replace. Vendors no longer support a large portion of the hardware and software being used in the SN Ground Segment, and the low inventory level of spares poses risks to the maintenance and availability of the network and its services.

The existing SN Ground Segment does not include many of the needed features for support of the Constellation Program, nor does it have the inherent capacity to manage the additional TDRS spacecraft being launched.

The age of the SN Ground Segment and the risks associated with operating and maintaining the system led NASA's Office of Space Communications and Navigation (SCaN) to initiate a sustainment effort for the core elements of the SN Ground Segment.

The SCaN Program established the SGSS project with a Mission:

To implement a modern ground segment that will enable the SN to continue delivery of high quality services to the SN community, meet stakeholder requirements and reduce required operations and maintenance resources.

Project: Early Architecture Purpose

- **Purposes:**
  1. The architecture helped to visualize several aspects of the SGSS requirements:
     - Relationships between requirements through functional flow and hierarchy (i.e. OV-5)
     - Interface requirements with external user and support elements (i.e. OV-2)
     - Feasibility of requirements through notional physical and software views
  2. The architecture aids in establishing the lists of needed equipment and services within In-House Cost Estimation (IHCE) activities
  3. The architecture helped the SGSS project to be a "smart buyer" in understanding the challenges and complexities in meeting the requirements that an implementation contractor will face
  4. The architecture provided the context and framework for how SGSS requirements were provided to industry in the SRD

- **NASA created a notional architecture while working on the SGSS contract RFP**
  - This was not meant to limit potential alternative functional architectures
  - This was for the project's early internal-use; **the awarded contractor is implementing their own architecture, not this architecture**

Use of DoDAF in SGSS Planning

- **DoDAF 1.5 views were employed for several purposes**
  - Visualizing the functional decompositions
  - Depicting the needed interactions between elements
  - Understanding the needed interfaces both internally and externally

- **CCSDS Reference Architecture for Space Data Systems (RASDS) Communication Viewpoint is also helpful in supplementing the DoDAF views**

- **Views were produced at different levels of system decomposition in order to gradually drill-down all the way from high-level context into element-specific detail**

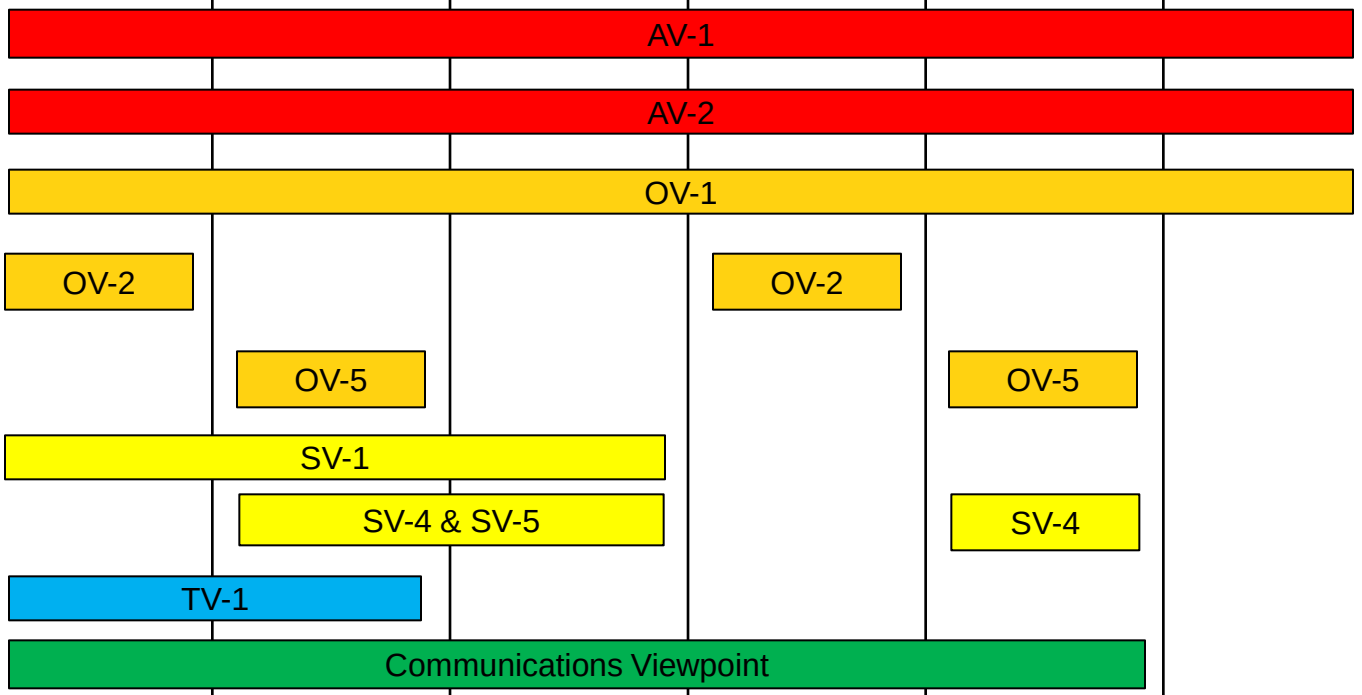
Selected Viewpoints & Their Roles

- **Diagrams:**
  - DoDAF AV-1 Overview and Summary Information – includes scope, purpose, intended uses, summary information of the architecture
  - DoDAF OV-1 High-Level Operational Concept – describes the overall operational concept of the system and its relevant environment
  - DoDAF OV-2 Operational Node Connectivity Description – defines operational nodes, activities performed at each node, and connectivies needed for information flow between nodes
  - DoDAF OV-5 Operational Activity Model – describes activities, relationships among activities, inputs/outputs, and performing nodes
  - DoDAF SV-1 Systems Interface Description – depicts system nodes and the systems resident at them to support the operational nodes of the OV-2
  - RASDS Communications Viewpoint – represents the protocol concerns and presents the system from a communications stack perspective

- **Tables:**
  - DoDAF AV-2 for establishing terminology
  - DoDAF TV-1 for cataloguing needed interface and support protocols

Selected Architecture Product Scope

	What	How	Where	Who	When	Why
	Data	Function	Network	People	Time	Motivation
Selected DoDAF and RASDS Architecture Products						



Hierarchical Architecture Description

- **Due to the multiple purposes of the architecture, views at different levels of detail were needed**
  - This adapted DoDAF standard practice in order to meet project needs and manage complexity
  - The ideas is similar to the Vitech CORE tool's idea of "peeling the onion"
    - CORE was used in order to manage architecture data during this work, however graphics tools were used in conjunction to produce presentation material

- **Context views established system scope and purpose:**
  - AV-1, OV-1, and External Interfaces OV-2
- **Top-level views established the system's decomposition into elements and their functional roles**
- **System-detail views documented the activities performed by the elements in combination, the needed flows, and planned deployment of systems**
  - OV-2, SV-1, TV-1
- **Element-level detail views documented specific per-element assumptions**
  - Per-element: OV-2, OV-5 Activity Hierarchy and Activity Flow views, SV-4 (physical and software components)

SGSS Hierarchical Architecture Description Contents

Level-1: Context

SGSS is a single box; this level is used to understand how SGSS as a whole fits in with the rest of SN, or the outside world; no detail internal to SGSS is shown

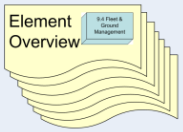
1.0 Context, External Interfaces

Level-2: Top-Level

The top-level decomposition into SGSS's top WBS elements is described; brief descriptions of the functions needed to be performed by each element within SGSS are given

2.0 Top-Level Functional Decomposition

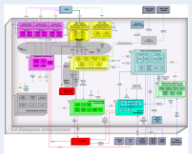
Element Overview



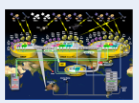
Level-3: System Detail

The main flows between boxes are traced, the external interfaces are shown with specific boxes, rather than the SGSS in-general; notional physical allocation of top-level elements to facilities begins

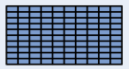
3.0 Reference Functional Architecture



3.1 Notional Physical SV-1, Notional Site Diagrams; System Software Architecture



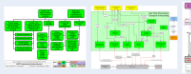
3.2 Interfaces & Protocols: Interfaces Roadmap, IRDs Roadmap, Technical Standards View (TV-1)



Level-4: Element Detail

Each element's functional decomposition, functional flows, interfaces with other elements, and notional physical contents are described in focused products

4.1.X Element OV-5 Hierarchy, OV-5 Flow, OV-2, OV-3



4.2.X Notional Element Physical Views; Element Software Architecture

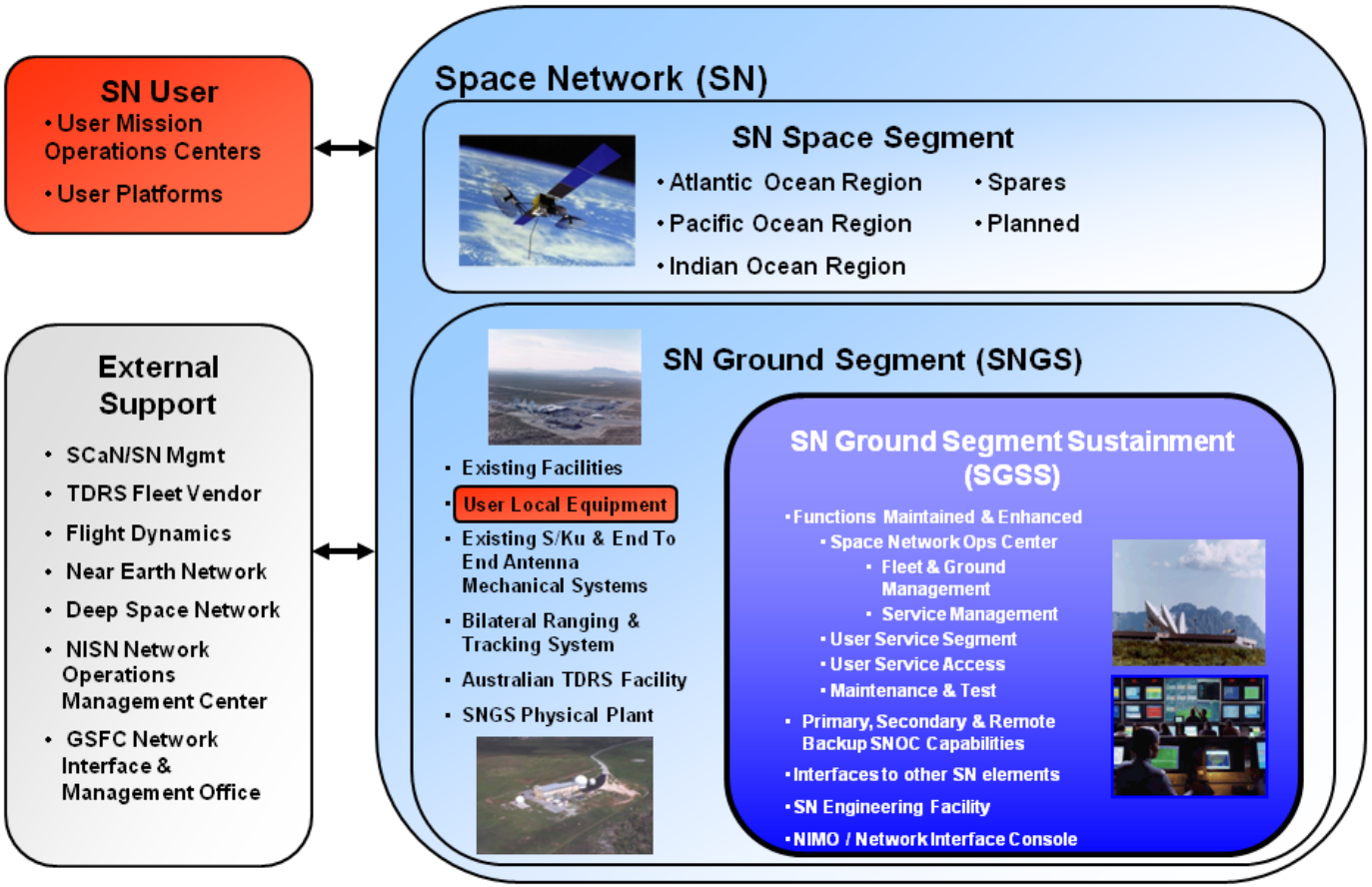
4.3.X Communications Views

Graphical Enhancement of AV-1

- **In this and other NASA architecture projects, we have found the need to enhance the DoDAF 1.5 AV-1, which is primarily textual in common practice**

- **Our enhancement is a graphical AV-1 that clearly establishes system scope and context within the set of users and external support organizations**
  - Similar to a context diagram from classical systems engineering
  - A color scheme established early and used throughout the rest of the architecture visually allows easy identification of elements
  - System of Systems complexity makes this a useful product
  - This provides an early, graphical view of external interfaces that the system will need to support
  - This graphic fits very well alongside the other textual AV-1 data about the architecture and architecture description

SGSS DoDAF AV-1



Critical but out-of-scope systems are identified

External users versus support entities are classified

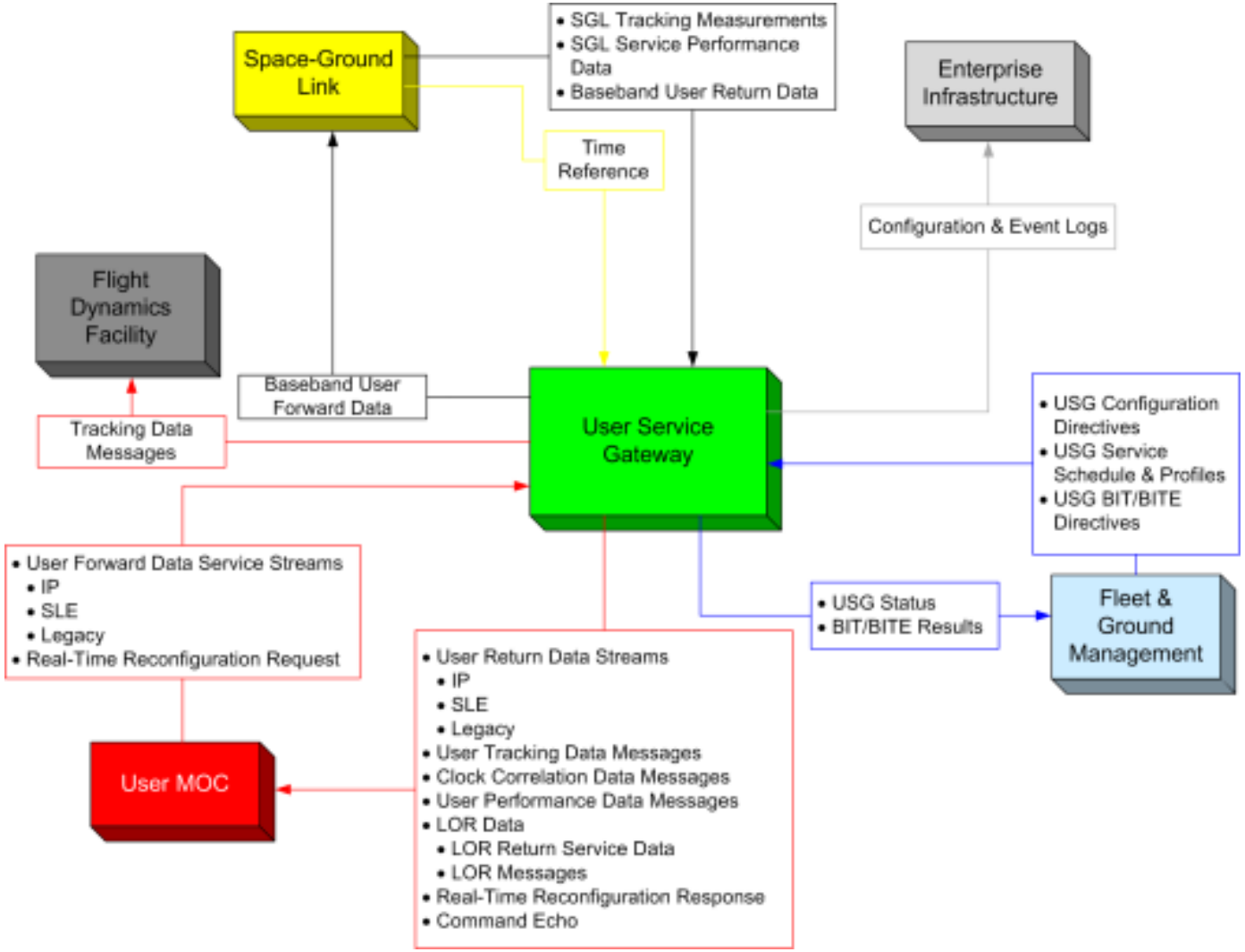
In-scope system modifications are identified

Space Network Ground Segment Sustainment (SGSS)		SGSS	User
SGSS Context Diagram, Scoping SGSS Within SN & SNGS			
Type: DoDAF AV-1	Revision 11 (June 2, 2009)	Other SN	Other External

Color scheme is used throughout architecture

**Sample only and does not represent current project plans.*

SGSS DoDAF OV-2



OV-2 is very helpful in establishing that the information exchanges and interfaces are commonly understood both externally and between elements

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SGSS DoDAF OV-5

OV-5 hierarchies are very helpful at element-level in order to make sure functionalities are complete and not assumed redundantly between elements

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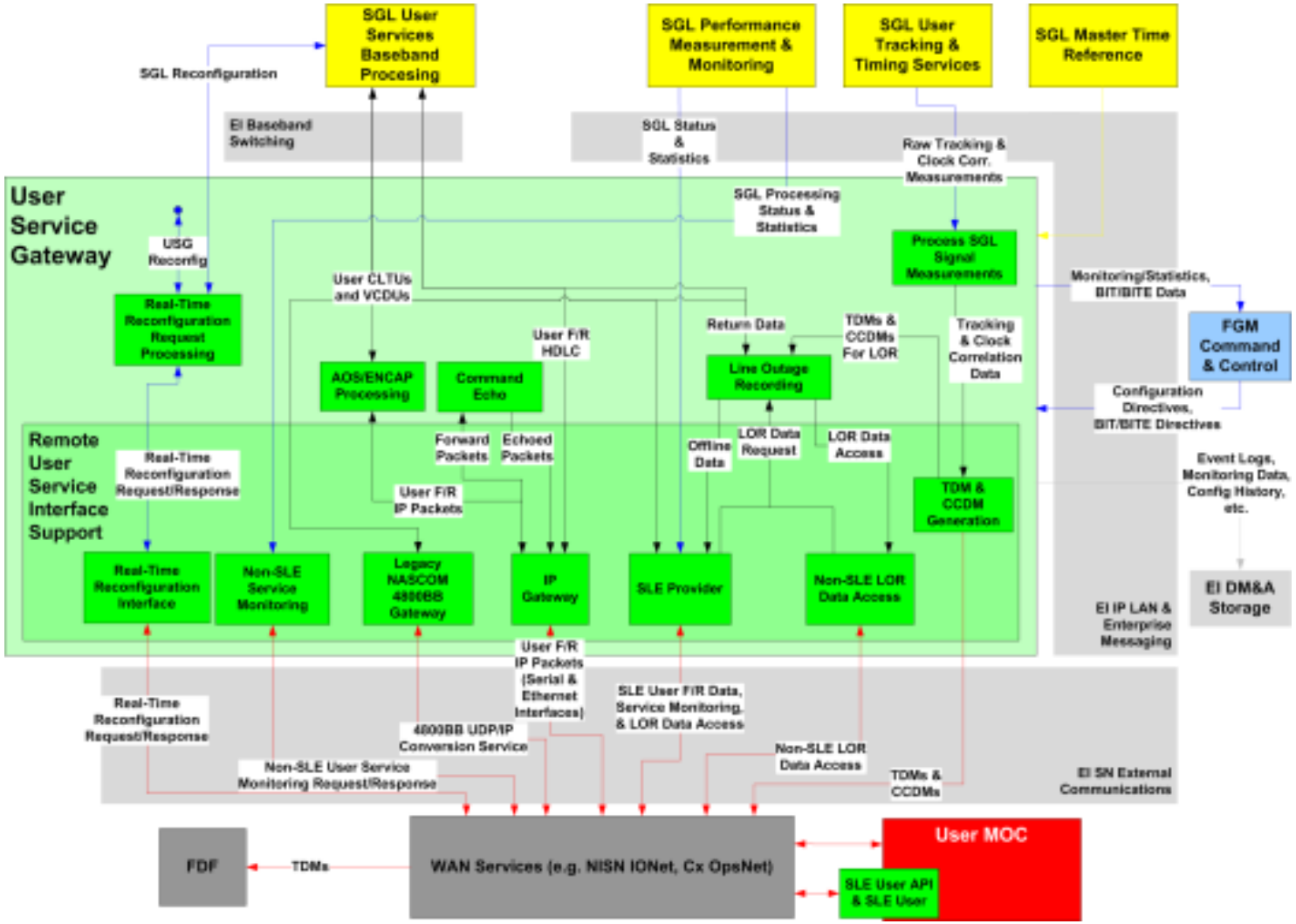
SGSS DoDAF OV-5



OV-5 flow diagrams were helpful in finding and describing the necessary functional flows

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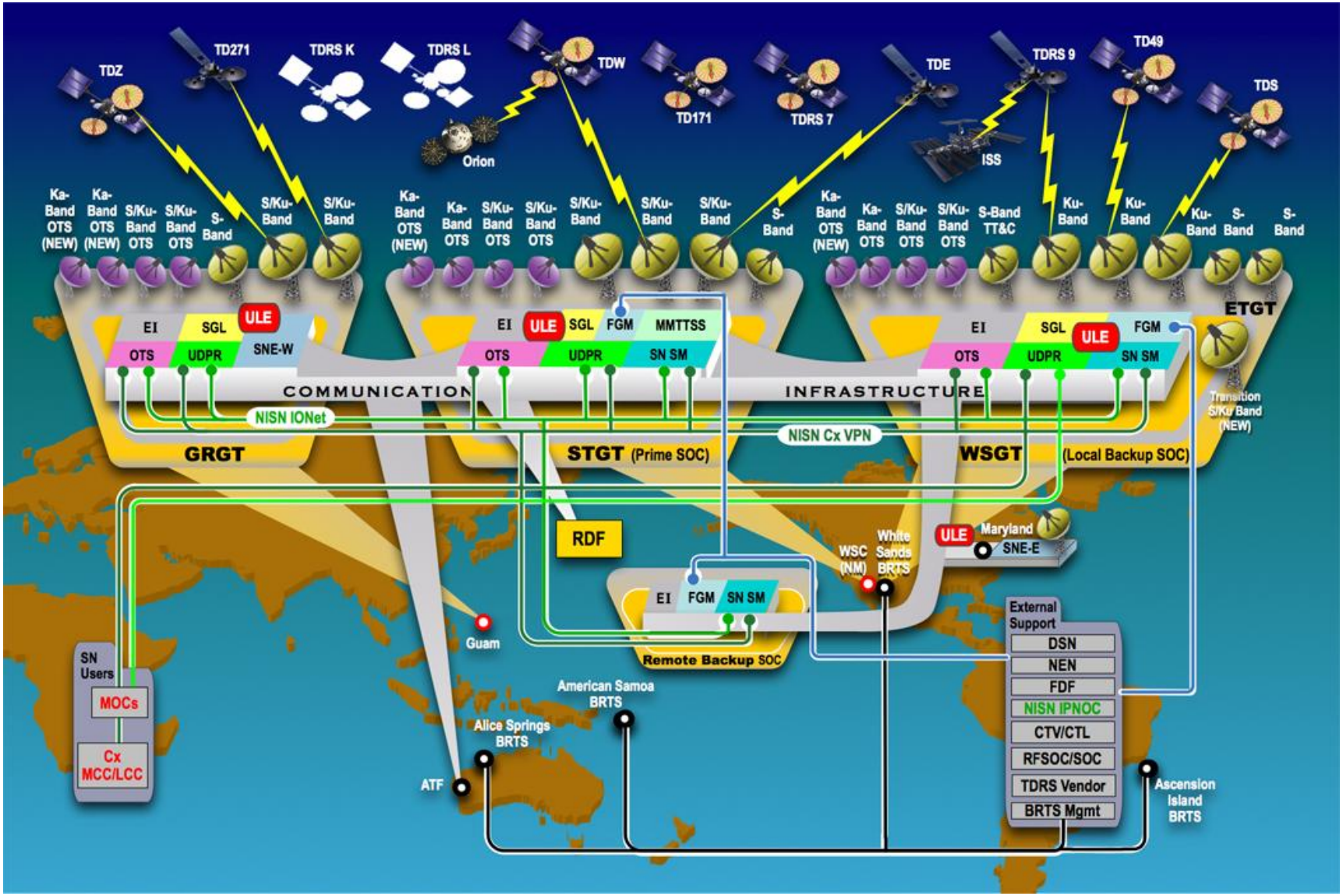
SGSS DoDAF SV-1



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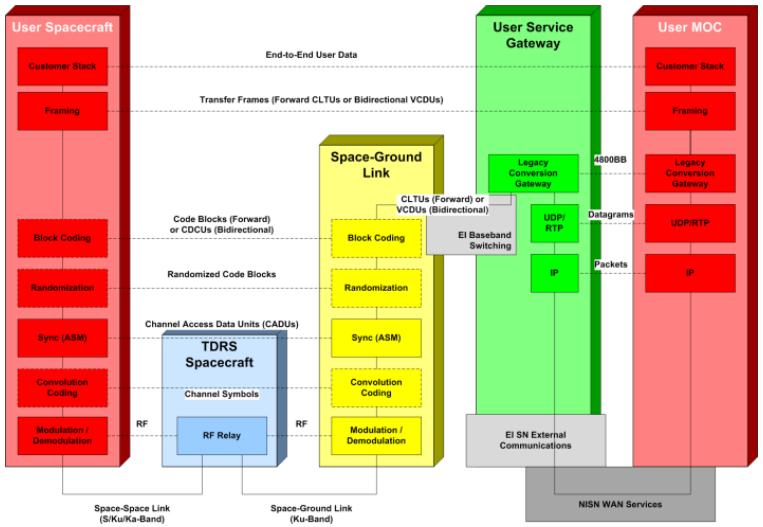
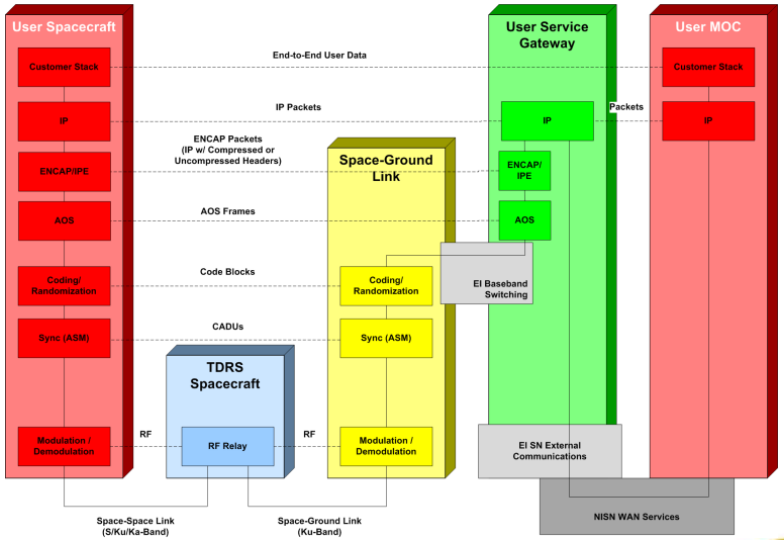
RASDS Supplementation

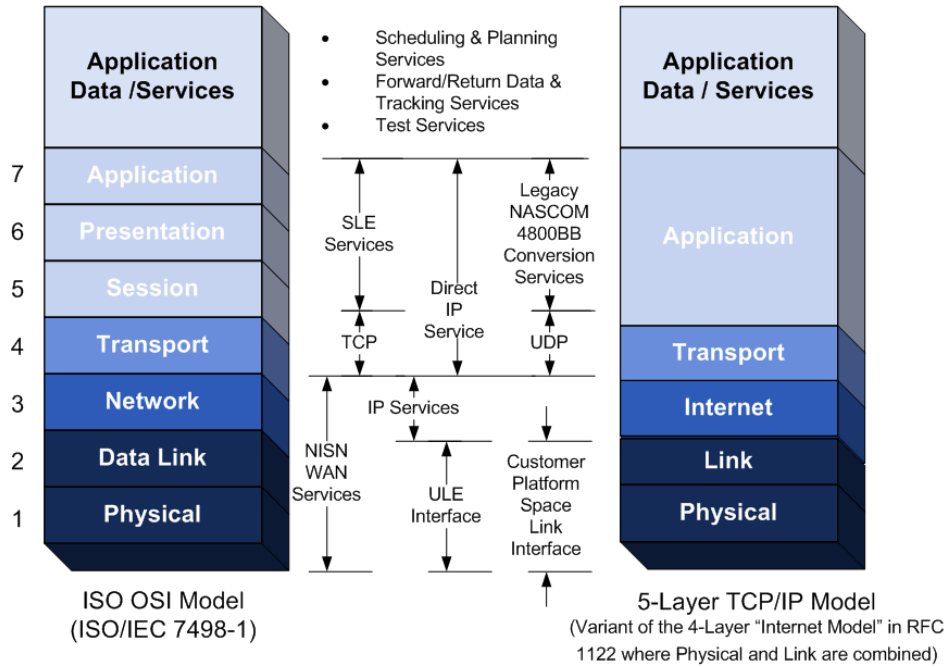
- The RASDS Communications Viewpoint represents protocol stacks and the data flows through them more clearly than standard DoDAF 1.5 views typically do
- Due to the many protocols needed for different SN user services, we chose to create these views in order to describe the division of protocol implementation across elements and find the protocols needed to interface between elements

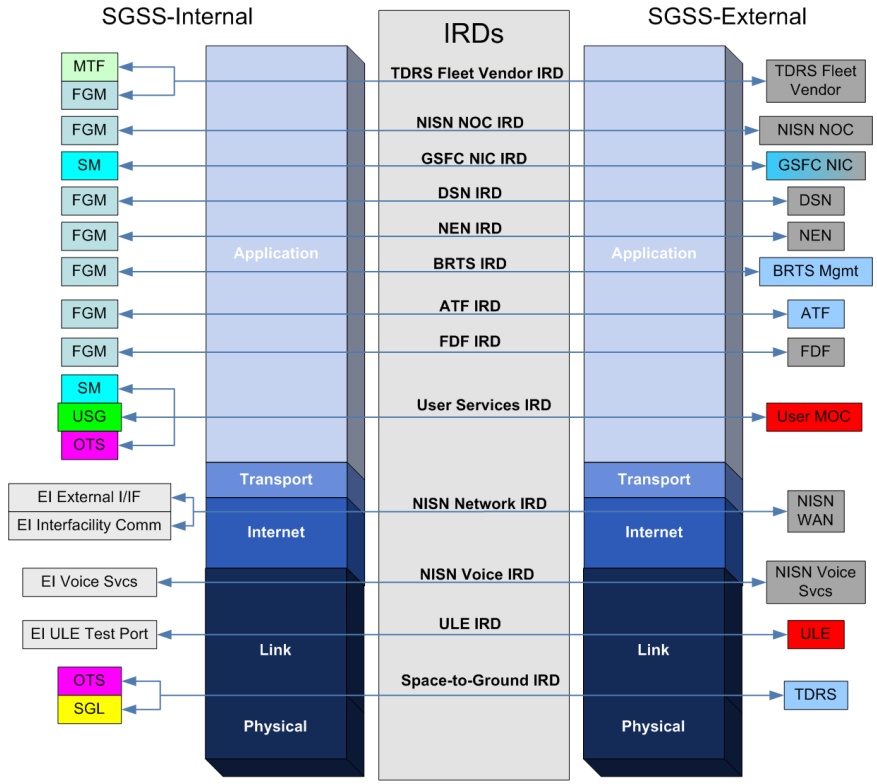




Interface Roadmaps

- "Interface Roadmap" views were also added in order to show the different layers where various elements require interface specifications and where IRD documents would need to be written towards





Conclusions

- **The complexity of the SGSS project required architecture techniques in order to perform early systems engineering activities, prior to contract award**
  - Even though this architecture was not intended to be built or used by the contractor, it was essential in understanding the system needs and structuring of the SRD
  - The architecture solidified overall context and scope, and was used to document decisions about inter-element relationships, element functionalities, and element physical deployment assumptions needed for estimation of costs and schedule
- **DoDAF 1.5 provided useful guidance and several essential views, but we also employed a number of other techniques:**
  - Our enhanced graphical AV-1 is a strong tool in establishing scope and context
  - Additional RASDS Communications Viewpoint diagrams were used to enhance the architecture because of its heavy communications/networking content
  - Aligning interfaces along protocol stack diagrams aids in determining the needed levels of protocol detail in each IRD