NASA's Space-Based Relay Study: Overview and Direction

Background and Motivation

NASA Goddard Space Flight Center's (GSFC) Exploration and Space Communications Division (ESC), is leading a study on behalf of the Space Communications and Navigation (SCaN) Program in order to identify future space-based relay communications and navigation architectures that will enable NASA to support missions in the mid 2020 timeframe and beyond. The current fleet configuration consists of 8 satellites and it is shown in Figure 1 (first and second TDRS generations). Recently SCaN started the deployment of the third generation of Tracking and Data Relay Satellites (TDRS) with the successful launch of TDRS-K on January 31, 2013. The remaining satellites (TDRS L and TDRS M) will be launched to replenish first generation satellites that are planned for retirement.

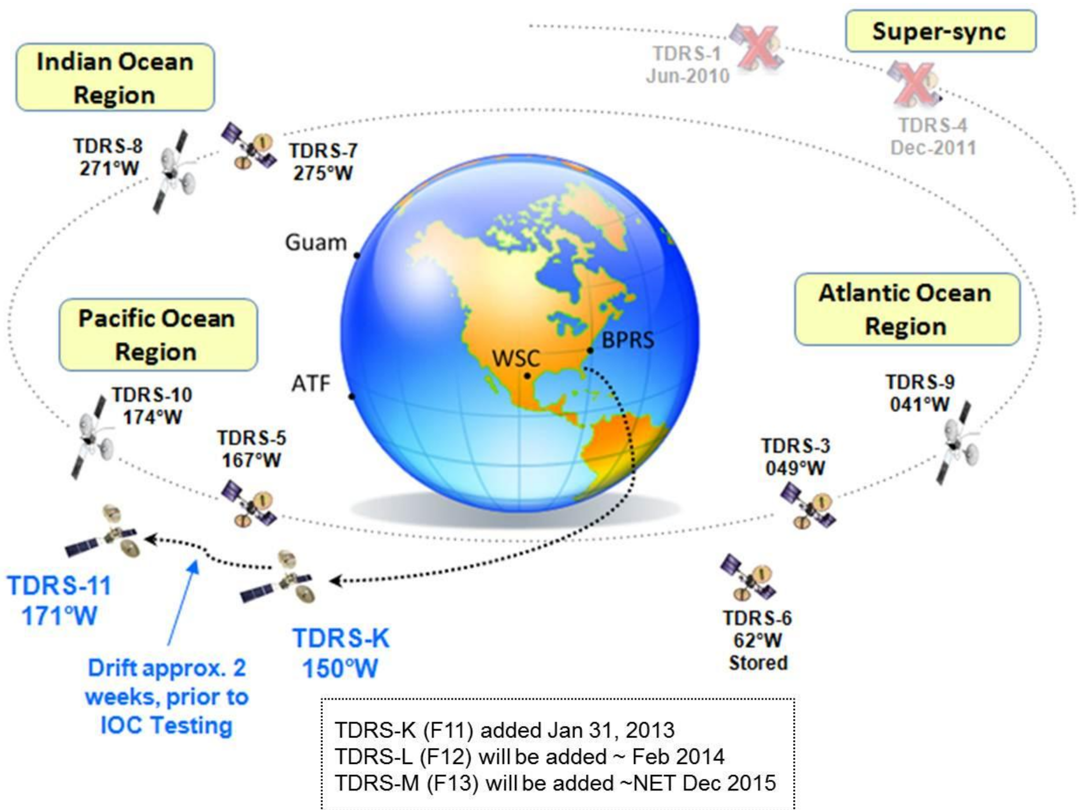

Figure 1. TDRSS Constellation in 2013

The anticipated relay configuration by the end of 2015 is shown in Figure 2. It is expected that by the end of this decade, the first generation satellites will be retired and second generation satellites will be beyond their design life as shown in Figure 3. Current projections suggest that in this timeframe the Tracking and Data Relay Satellite System (TDRSS) will have insufficient capacity to meet all anticipated mission demands.

The SCaN Program is also upgrading its ground-based networks that support the Space Network (SN), Near Earth Network (NEN) and Deep Space Network (DSN), to a more modern digital signal processing environment. The goal is to standardize communication and navigation services across the networks and provide internetwork interoperability.

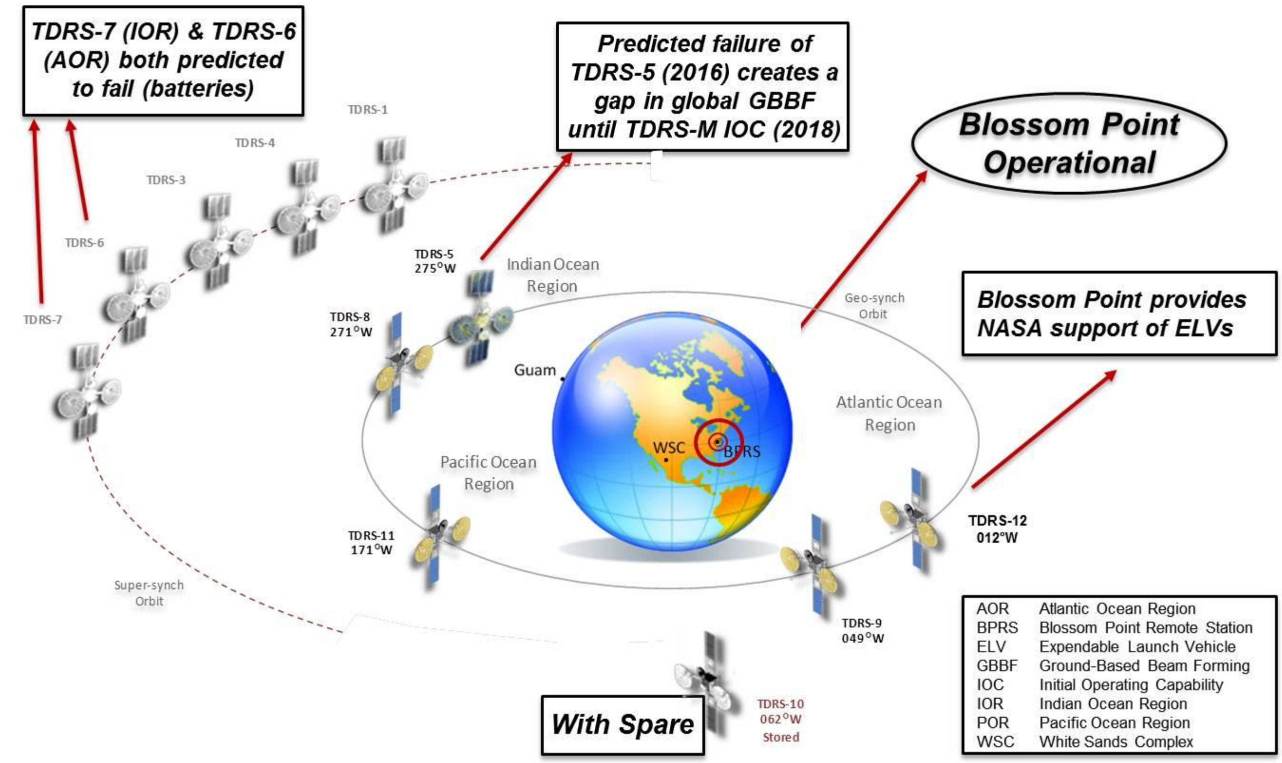

Figure 2. TDRSS Constellation at end of 2015

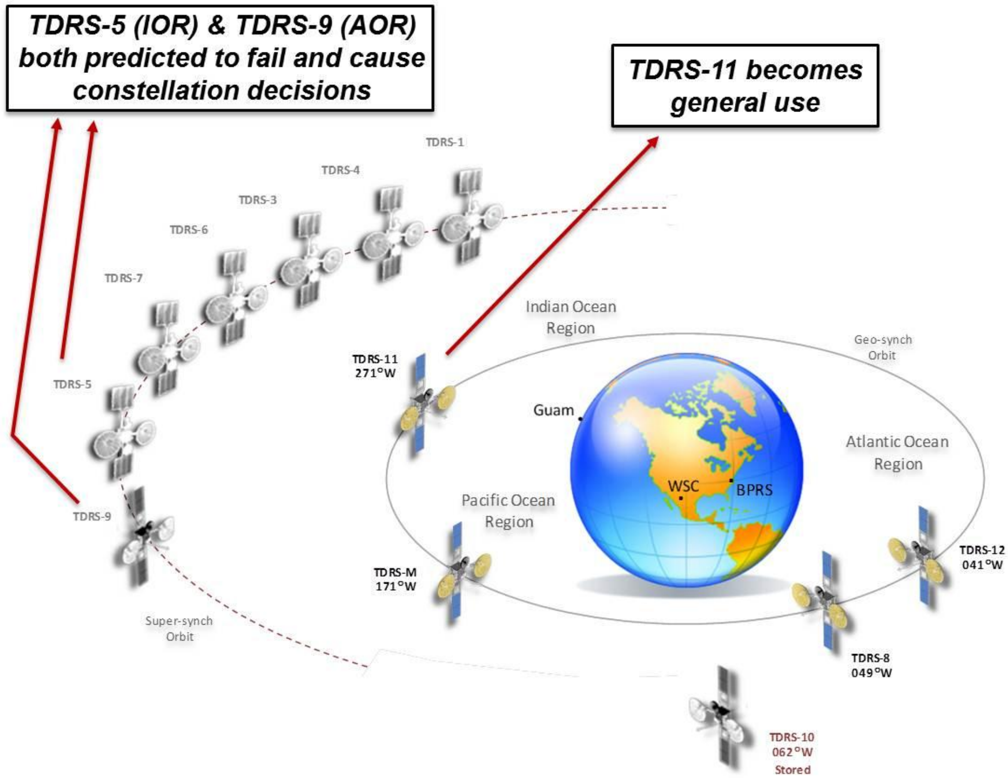

Figure 3. TDRSS Constellation by the end of 2020

The planning phase for the future Space Based Relay (SBR) architecture was recently initiated in order to ensure continuity of mission support in decades to come. This Space Based Relay Study (SBRS) is designed to leverage this lead time and begin with a “clean slate”; the SBRS is not bound by prior technical and business practice. The current architecture of large, dedicated geosynchronous satellites and associated ground systems, operating as a bent pipe relay system between customer platforms and ground facilities, was developed in the late 1970’s, and faces challenges with operational and sustainment costs. The team is charged with “thinking outside the box” – architecting broadly to reflect future capability in technology and operations; and striving for scalable, interoperable, and cost-effective solutions that will meet future user needs. The SBRS represents the opportunity to investigate the use of new technologies and methodologies to implement cost saving changes for a more fiscally sustainable architecture. In particular, interoperability with other US civil Government, commercial and international relay assets, and ability to minimize development, sustainment and operational costs, mindful of the current budgetary environment, will be an area of emphasis in the study. The objective of the year-long government-led effort is to produce a reduced set of recommended architecture options and business / programmatic approaches for further evaluation. Recommended architectures will be put forward based on being a best value across the spectrum of capability, feasibility, affordable cost, security, and flexibility to accommodate a broad range of users to include the evolving human space flight program.

SBRS in Context with the Evolution of the Space Communications and Navigation Infrastructure

The SBRS effort is being conducted as part of the broader SCaN Program charter. The Program is responsible for providing communications and navigation services to user missions located from the surface and atmosphere of the Earth to low Earth orbit and throughout the solar system. The SCaN Program provides user missions with services that may include transmitting data to and from user mission space vehicles; deriving information from transmitted signals for tracking, position determination, and timing; and measuring the radio frequency emission or reflection from celestial bodies.

In 2008, and reiterated in 2011, the “Level 0” requirements for the SCaN program include a key effort to develop a unified space communications and navigation network. The integration of the SN, NEN, and DSN is being conducted in two phases. During Phase 1 changes for the SN are focused on the replacement and upgrade of the existing SN ground segment, and the replenishment of the space-based assets with the launch of TDRS K/L/M series. Phase 2 will leverage the commonly developed hardware and software from Phase 1 to upgrade the NEN and DSN. This will result in a standardized services and interfaces environment, where users see one virtual network rather than three dissimilar networks. It is anticipated that an internally integrated architecture will lead to lower overall operations and maintenance costs. The SBRS effort represents the first step in Phase 3 of the SCaN Network implementation strategy, with an Initial Operating Capability (IOC) of the future relay architecture in the early-to-mid-2020’s. (Further information on SCaN’s Architecture Planning can be found in the SCaN Network Architecture Definition Document Volume 1: Executive Summary on the SCaN website- http://www.nasa.gov/pdf/675092main_SCaN_ADD_Executive_Summary.pdf) In this context, a number of ground rules and objectives apply for the SBRS effort:

1. The capability of the future architecture shall be driven by user needs and stakeholder interests.
2. The cost effectiveness of the future architecture shall be an integral part of its design; the right solution shall be affordable because it is designed from the outset to meet programmatic constraints and a conservative budgetary profile.
3. Operations and development costs will be balanced for a supportable, sustainable budget profile. Over the life of the architecture, modifications and enhancements shall be sustainable in a relatively flat budget environment.
4. Best value architectures will have several key attributes including: expandability to meet future requirements; interoperability with other networks; ability to transition smoothly from the current architecture; standardization of services offered; low developmental cost; and low operational cost.
5. The future architecture is not to be constrained by backward compatibility with legacy systems; however, the SBRS will assess compatibility issues and costs that arise with each reference framework chosen for further analysis.

Top Level Approach

Prior to the initiation of the SBRS, a limited industry survey was conducted where industry practitioners were interviewed to gain an understanding of the state of the art in technology, acquisition, and operations. In parallel with assessing the state of the industry, the potential user base was surveyed to better understand customer requirements and desires. The SBRS intends to reflect an assessment of both traditional and potential user groups for requirements.

The SBRS is designed to leverage NASA internal expertise from GSFC, Glenn Research Center (GRC), and the Jet Propulsion Laboratory (JPL), as well as outside senior level subject matter experts from other federal agencies and academia. A Core Team of civil servants and support contractors are the “engine” of the effort, conducting the analysis and preliminary trade studies. To supplement, accelerate, and bring fresh ideas to the effort, a blue ribbon cadre of experts from academia and other government agencies has been formed. This subject matter expert team will engage the study effort through a series of intense two-day workshops to evaluate alternatives and make recommendations for further analysis. The inclusion of external views and expertise is intended to create a more robust process, to produce a more robust set of recommendations, and to achieve maximum buy-in from stakeholders.

In parallel, the SBRS is building an architecture decision tool in conjunction with the Massachusetts Institute of Technology (MIT). This computational architecture sorting and assessment tool will allow the team to conduct trades at a higher level and with greater breadth (vice the in-depth analysis of the Core Team), looking for trends across a much larger set of options than could be analyzed individually.

As the Core Team progresses toward a report in late 2013, their results and recommendations will be bolstered through a series of industry engagements, including the release of a Request For Information (RFI) on issues related to future architectures and business models and a Request For Proposals (RFP) for follow-on Phase A formulation studies anticipated to occur in Fiscal Year 2014.

Overview of the Architecture Trade Space

The SBRS addresses three dimensions of the future architecture: user needs and service performance, technological/physical configuration, and business implementation options.

User needs and service performance evaluation will be based on the projected mission profile covering 2020-2040 as well as participation from representatives of Other Government Agencies (OGAs) to provide input on potential users and synergies between agencies. Service and performance considerations include orbital coverage, level of scheduled vs. on-demand service, latency, data rates/volumes, periodicity of services, and security requirements.

The study will also accommodate the fact that the target initial deployment period is in the mid-2020s, and technology that is currently too immature for deployment may be sufficiently advanced in the next decade to make it viable. Technologies being evaluated include optical, microwave and millimeter wave inter-satellite links, phased arrays, disruption tolerant networks, space internetworking, cognitive and adaptive protocols, and software-defined radios. These technologies can be deployed in a number of configurations, including dedicated spacecraft buses (similar to the existing TDRS), use of hosted payloads on commercial or other government satellites, clusters of small satellites with distributed capability, or combinations thereof. Architecture options will address combinations of space- and ground-based networks.

The method by which NASA acquires and operates the future architecture capability is also being evaluated. The current fiscal climate is increasingly challenging for traditional government acquisition methods. Any one or combinations of the following are being included in the evaluation: public-private partnerships, pure commercialization of services, joint ownership with OGAs, and traditional NASA dedicated / NASA owned systems.