Subject: Transformational Communications Architecture (TCA) 15 Aug 2003 Draft version

Purpose: To provide a description of the TCA within the context of the global information grid (GIG) and the implications for removing communications as an operational constraint through 2020.

GIG

Background: The global information grid (GIG) is an adaptive entity that integrates communications systems, computers and information management resources into an intelligent system-of-systems. Each component of the GIG exchanges information with other components, enabling the entire infrastructure to adapt to user requirements and to stresses imposed on the network. This adaptability also enables the infrastructure to scale as necessary to support force structure(s) of arbitrary size, or to incorporate new processing, network and communications technologies.

TCA

The Transformational Communications Architecture (TCA) is an end-to-end architecture that will enable the GIG and traverses the four segment domains of the DoD-IC-NASA communications infrastructure. The **terminal segment** is composed of end-users, ground stations, as well as space and airborne ISR terminals. The **space segment** is composed of two interoperable satellite constellation rings (which can and probably will operate in other topologies than ring, e.g. mesh connectivity) and NASA as an edge service with compatible space and ground hardware. One of these two rings is for the Department of Defense (DoD) and another for the Intelligence Community (IC) backbone/relay. The **terrestrial infrastructure segment** includes interfaces to other DoD networks, teleports, NASA and National special purpose networks, and commercial systems and selected ground systems RF communications ground stations for uplink and downlink, and connection to the global information grid – bandwidth expansion (GIG-BE). Lastly, the **network operations & management segment** is the portion of the TCA that connects, where deemed appropriate, the ground networks of DoD, IC, and NASA managed by each entity and supports peering across these separately procured enclave systems so that resource sharing and fault tolerance can be supported in a system-of-systems sense.

Discussion: For the **Transformational Space Segment**, the DoD assets are made up of a 5-ball satellite GEO constellation and a 3-ball satellite constellation in a Highly Inclined Orbit (HIO) at a geosynchronous altitude and inclination.

The DoD ring 5-ball Transformational Satellite (***TSAT***) GEO constellation is fully cross-linked and provides EHF, X-band (TBD), Ka-band, and laser services and supports military tactical, strategic, and Airborne Intelligence, Surveillance, and Reconnaissance (AISR) users. Additionally, the TSAT constellation of the DoD ring supports Communications on the Move (COTM) to as small as 1 ft terminals. TSAT will provide a dynamic adaptation of data rates in response to jamming or weather conditions. In addition, this architecture offers a lot more robustness due to the cross-link capability and increased bandwidth capacity. The TSAT vehicles of the DoD ring support RF data rates up to 45 Mbps, and laser communication user data rates into the 10-100's Gbps range. The constellation supports 3-5 laser single access simultaneous users, with multiple access laser heads on flights 3-5. The TSAT has an RF cross-link to complete the AEHF constellation.

Satellite Constellation

The DoD ring 3-ball HIO satellite constellation is called the Advanced Polar System (***APS***). This part of the DoD ring supports strategic and national users in the polar region and they are hardened to support the strategic mission. These satellites have EHF payloads and use laser cross-links for the connection into the TSAT.

The ***IC ring*** is a 4-6-satellite constellation that is fully cross-linked between IC assets and with the DoD ring and provides RF and laser services to support high data rate IC and DoD users. The IC ring constellation supports 4-6 single access laser communication users into the 10-100's Gbps range and will fully support all legacy RF users.

The ***TSAT*** offers an enormous increase in total bandwidth capacity beyond current capability with loaded capacity of ~2 Gbps of RF per vehicle as compared to ~250 Mbps for AEHF; WGS offers similar capacities, but provides an unprotected service to a larger terminal population. The DoD and IC rings are interoperable and able to cross-link between the two rings, which will be driven by policy and ongoing operations. This is not the normal operation, and due to the potential impacts to their missions, approval and coordination between NRO and DoD is required. Also, these satellites will be able to connect to existing and planned ***AEHF***, ***Interim Polar***, Mobile User Objective System (***MUOS***), and Wideband Gapfiller Satellites (***WGS***) through ground teleports.

Space Segment

NASA is considering the acquisition of ***TDRSS-C*** with four platforms to replace their current constellation of TDRSS spacecraft beginning in about 2012 to continue their S-band, Ka-band, and Ku-band service. Because of their continuing participation in TCA, they will be considering DoD/IC technology leverage points and co-developed standards, as well as the points of interoperability in space and on the ground with the rest of the architecture. In every sense of the words, NASA TDRSS-C will work to be Independent and Interoperable with the TCA.

The FY04 President's Budget (FY04-09) includes funding for: **Air Force** – AEHF satellites 1-3, Wideband Gapfiller Satellites 1-5, TSAT satellites 1-4 and long lead procurement for TSAT-5, APS satellites 1-3; **NRO** – incremental funding for portions of up to 4 satellites; **NASA** – TDRSS-C satellites 1-4; **Navy** – MUOS satellites.

Terminal Segment

The **terminal segment** provides users with access to space Command, Control, Computer, Communications and Intelligence, Surveillance and Reconnaissance (C4ISR) products and services. It performs the RF handling, waveform communications processing, and network and security protocols associated with MILSATCOM services. Interfaces with the space segment will be defined with a series of interface control documents (ICDs) tailored to the categories of service and frequency band of operation. Standardized interfaces to user base-band equipment will become the entry point for user applications and equipment to attach to the TCA. This segment will consist of a combination of currently programmed terminals and proposed upgrades. Some terminals will require modifications to implement standardized network and security protocols to take full advantage of TCA interoperability and connectivity. The fielded terminal population will increase due primarily to the Army's Objective Force and Airborne ISR. The military services are also moving toward multi-band and smaller aperture terminals to help integrate SATCOM into weapons platforms with little impact on the overall structure and to reduce airlift requirements by decreasing the need for multiple communications assets dedicated to single frequency bands.

Terrestrial Infrastructure Segment

The **terrestrial infrastructure segment** interfaces TCA and other terrestrial networks; specifically it allows connectivity between the space segment and CONUS networks. IC and DoD gateway terminals will receive high capacity downlinks from relay and DoD protected satellites respectively. These gateways will connect via a standard optical interface and terrestrial fiber tails to the terrestrial GIG, NASA Information Systems Network (NISN), and other terrestrial high-speed networks. Teleports will provide connectivity among MILSATCOM satellites not otherwise connected by cross-links and to select commercial satellite systems. These teleports also will be connected via a standard optical interface and fiber tails to the terrestrial GIG.

Network Operations & Management Segment

User **network operations and management** will provide the monitoring and control of gateway terminals, teleports and communications payloads that are working as network resources (IP routers on TSAT). Network management responsibilities and operations are distributed among high-level service providers implemented separately within the DoD, IC and NASA communities. Each community performs system-wide satellite control and network management from support centers with worldwide TCA responsibility. The network operations will be connected to the terrestrial networks associated with each community for nominal transmission of Tracking, Telemetry, and Control (TT&C) via gateway terminals and select in-band control terminals. The hierarchical network management construct has: (1) a policy layer with DoD, IC, and NASA participation, (2) a layer of tiered operations management centers (**OMCs**) which have "peering" between DoD, IC and NASA enclaves, and (3) an execution layer with tiered Satellite Operations Centers (***SOCs***) and Network Operations Centers (**NOCs**) which have standardized procedures to peer into each other's domains and to request/allow service to/from another enclave's resources. The network security architecture uses High Assurance Internet Protocol Encryption (HAIPE) devices, firewalls, web services, very broadband fiber and RF networks (space and ground), and a tiered network management/operations architecture that will recognize the formation of operational "domains" or "enclaves" which can be isolated or connected. Such a structure will allow "independent" management of DOD, IC, and NASA missions as well as "integrated" or "consolidated" management, potentially provided by STRATCOM or Presidential Directive.

TCA Advantages:

TCA Advantages

1. Greater Inter-networking and Interoperability - TCA allows a much greater number of users to freely and quickly interact with the full implementation of the Internet Protocol (IP) on DoD platforms. The Pre-TCA configuration was based on limited IP networks between X-band, EHF, and Ka-band users. TCA will expand this to X-band, Ka-band, EHF, and laser communication users. TCA also provides inter-satellite links between AEHF and TSAT to support the AEHF FOC with a mix of three AEHF and the first TSAT platform. TCA transport interoperability features can enable future DoD, IC, and NASA information sharing, collaboration, and data fusion within the information architecture level.

2. High Protected Data Rates – TCA provides AEHF levels of anti-jam protection to more smaller users at higher data rates. The 80-inch EHF nulling multi-beam antennas will provide significantly greater capacity with very focused nulling beams to allow users to operate geographically closer to sources of jamming. In the pre-TCA architecture, many users with requirements for protected services were satisfied by systems that did not offer protection. The increases in EHF capacity allow these users to migrate to protected services. TSAT allows a significant reduction in user terminal size with the capability to transmit at least 12 Mbps and receive at least 1 Mbps of data to a protected user with a one-foot antenna. Margin management has the potential to increase these rates substantially. This reduction in user terminal antenna size provides a new Communications-On-the-Move (COTM) capability for more maneuverable and lethal forces. The pre-TCA baseline was limited to a maximum rate of 8 Mbps for even the largest terminals (64 Kbps uplink and 6 Mbps downlink for a 1 foot terminal).

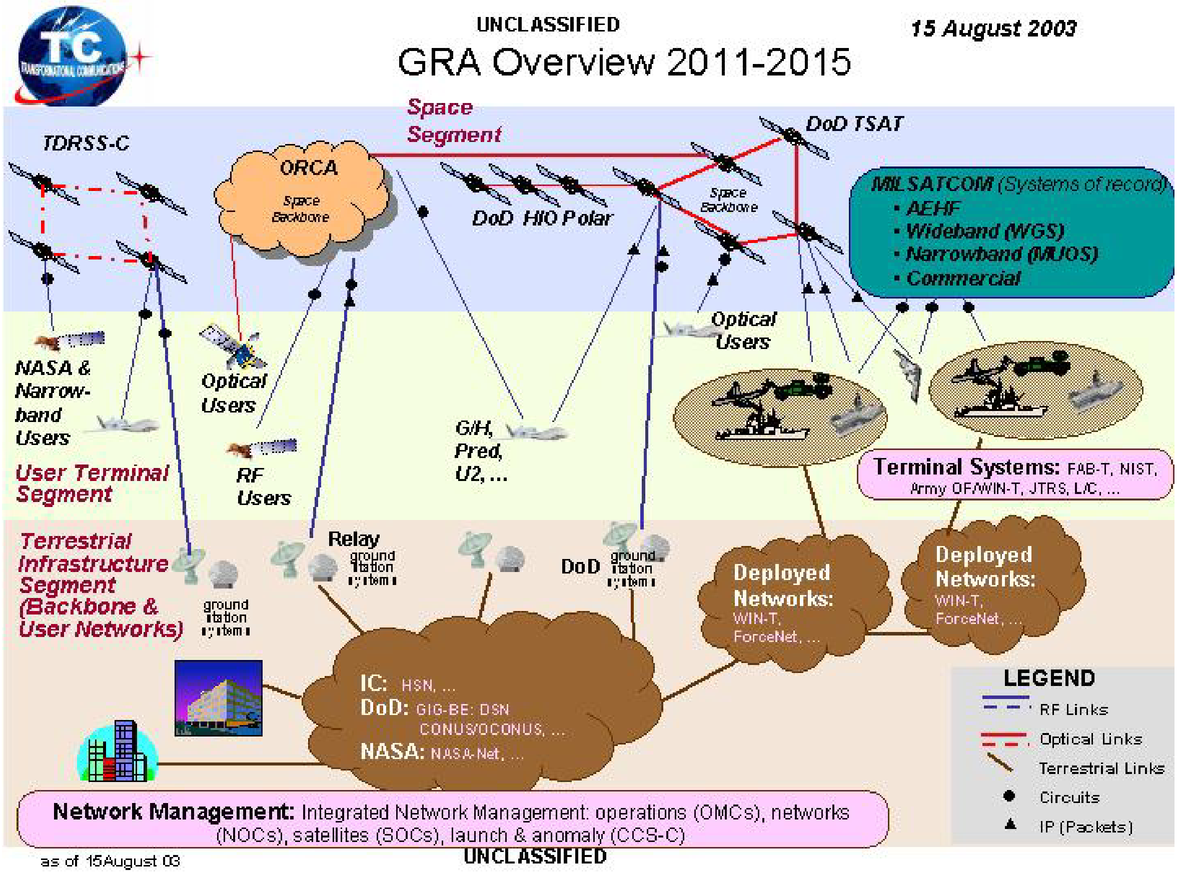
3. Greater Redundancy/ Interoperability – Under TCA, the two interoperable DoD and IC rings provide a high-level of redundancy for AISR platforms and dissemination of data. Both rings will provide these functions, so they can easily support the other constellation if a failure occurs on either.

4. Quicker Data Access Searches – Under TCA, the space and terrestrial network for DoD users will use the same IP network protocols. Therefore, data access and application tools will be easier to develop and use within the top-level information architecture, which rides on the TCA transport architecture.

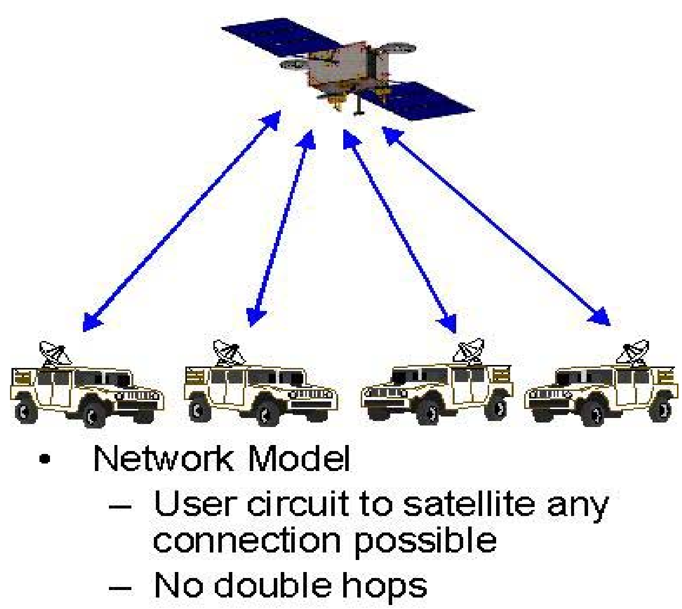
5. Larger Numbers of User Terminals – TCA will be driving the cost of terminals down by implementing IP and by implementing fully software programmable terminals for DoD users. It's expected that it will be more cost effective to buy a larger quantity of fewer terminal families, which will provide communications to lower echelon of warfighters.

6. More Perceptive and Persistent ISR – Both spaceborne and airborne ISR for DoD and the IC can be operated in a more around the clock fashion because TCA resources will have more capacity and accesses to support the backhaul of data from these platforms to analysis centers. New sensor missions can be enabled which would not be possible with current relay systems due to the increased data volumes.

7. New Ways to Support Manned Spaceflight and Scientific Data Collection and Dissemination – Due to the interconnected nature of the architecture, the possibility is enabled to support near-real time critical manned Spaceflight operations and new paths for routing scientific mission data in space and on the ground beyond the bounds of the very capable TDRSS-C satellites and associated NISN ground infrastructure.



TCA Operational View



Improved TSAT Connectivity