Apr 1st, 8:00 AM

GSFC Network Operations with Tracking and Data Relay Satellites

Robert Spearing
Deputy Project Manager, Ground Segment, TDRSS Project Office, NASA Goddard Space Flight Center, Greenbelt, Maryland

David E. Perreten
Operations Manager, TDRSS Project, NASA Goddard Space Flight Center, Greenbelt, Maryland

Follow this and additional works at: https://commons.erau.edu/space-congress-proceedings

EMBRY-RIDDLE
Aeronautical University™
SCHOLARLY COMMONS

Mr. Robert Spearing
Deputy Project Manager, Ground Segment
TDRSS Project Office
NASA Goddard Space Flight Center
Greenbelt, Maryland

Mr. David E. Perreten
Operations Manager, TDRSS Project
NASA Goddard Space Flight Center
Greenbelt, Maryland

ABSTRACT

Since the first flights into space, the Goddard
Space Flight Center has been providing various
levels of support to Users of its data acquis-
ition network. The Tracking and Data Relay Sat-
ellite System (TDRSS) Network (TN) has been dev-
eloped as part of an evolving network program
to continue to meet the increased communications
and orbit determination needs of Users with ad-
vanced spacecraft in near-earth orbits. The ex-
tensive changes to the various network elements
are nearing completion of their implementation,
integration and test phases in preparation for
the series of Tracking Data Relay Satellite
(TDRS) launches beginning in early 1983. The
final phase of integration requires extensive
post-flight testing of the TDRS's with opera-
tional network elements before the TN can be
declared operational for full Users support.

The TDRSS Network is unique from past network
development concepts in that it comprises a com-
bination of commerical and government elements
integrated into a highly automated end-to-end
system. The commercial portion, a series of
satellites in geostationary orbit monitored
and controlled by a central ground terminal is
intended to replace NASA's present geographic-
ally distributed ground terminals. The NASA
portion comprises a series of elements that pro-
vide unique services and support to monitor and
control the entire network under a mission sup-
port type contract. An overview of this system
that is planned to fulfill the Users scientific
requirements in the 80's and into the 90's is
presented.

INTRODUCTION

The conversion of the Goddard Space Flight Track-
ing and Data Acquisition network from a dis-
tributed control, semi-automated, receive/rec-
ord with buffered playback system to a central-
ized control, automated throughput system is
being completed. The new system will provide
more efficient and economical support to its
Users, increased data gathering capabilities,
more flexible scheduling, an elementary level
of conflict analysis and a selectable set of
services.

Presently, User spacecraft are monitored and
controlled through a network of ground sta-
tions. However, the network is capable of pro-
viding support during only a small fraction of
the orbital period, the distribution of sta-
tions being optimized and dependent upon access-
ability and availability to NASA. Also, some
stations can monitor and control only up to
two spacecraft at a time.

A series of studies initiated in the late 60's
indicated that present network limitations
could be removed through a new network composed
of geostationary satellites controlled from a
central ground station. Such a near earth or-
biting network could provide coverage for al-
most the entire orbital period of a User space-
craft, could have the capability of supporting
a number of spacecraft simultaneously and could
have a high level of reliability and availabil-
ity. Other studies addressed such areas as
throughput data handling techniques, remote
controlled operations of the TDRSS, orbit de-
terminations/accuracies from geostationary
platforms and state-of-the-art systems reliabil-
ity over extended periods of time (up to 10
years). The culmination of this period of def-
inition resulted in a competitive fixed price
contract awarded to the Space Communications
Company (SPACECOM) for the design, development,
operation and maintenance of the TDRSS in Dec-
ember, 1976. Another major effort was the task-
ing of Computer Sciences Corporation, a NASA
support contractor, for the design, development
and implementation of the Network Control Cen-
ter Data System (NCCDS) to provide end-to-end
scheduling, control, status and monitoring
functions for the TDRSS Network. Finally, new
high data rate data handling communications
interfaces were identified to be provided by
the NASA Communications Division (NASCOM).

The SPACECOM (commercial) portion is composed of the orbiting satellites, 2 operating and 1 on-orbit spare (space segment), plus the single ground terminal located at White Sands, New Mexico (ground segment). SPACECOM will be providing TDRSS telecommunications services to NASA and the appropriate scheduling, control and status interfaces. SPACECOM, as the prime contractor for TDRSS, is supported by two contractors, TRW and the Harris Corporation.

CSC as a support contractor to NASA at GSFC, is responsible for providing the entire NCCDS, both software and hardware, for the Network Control Center (NCC) located on the Goddard Space Flight Center, Greenbelt, Maryland. Because of the lack of adequate physical facilities and space availability within existing buildings, the NCC is contained within new construction, completed in 1981.

The NASA Communications Network (NASCOM) has been upgraded to presently handle up to 1.544 Mbps by Ford Aerospace Corporation with commercial DOMSAT terminals provided by American Satellite Corporation. This basic communications capability is to provide prime and backup services between the SPACECOM, NASA/GSFC and NASA/JSC facilities. Figure 1 represents a simplified block diagram of the TDRSS Network (TN).

Evolution of the TDRSS Network (TN)

The tracking and acquisition of data gathered by Users in space and returned to earth is the primary mission of NASA/GSFC Networks, including the capability to transmit commands to User spacecraft.

Early system concepts to provide these functions centered on satisfying User requirements based upon type of missions supported, namely scientific versus manned flight. Since space exploration began with unmanned, unsophisticated missions, a NASA network evolved which concentrated on these type missions utilizing state-of-the-art technology, e.g., passive tracking acquisition techniques, receive/record data handling, scheduling/administrative message interfaces via teletype and voice interfaces for control, status and monitoring. Data tapes were mailed to users of other data reduction facilities. This network is characterized by its predominantly manual mode of operation. By 1971 this network was upgraded with new systems to become more compatible with the manned space flight network prior to their merger in 1971 into the unified Spaceflight Tracking and Data Network (STDN).

The dawning of manned space flight levied a completely different set of requirements and new concepts on the NASA networks. So it was, that a totally new and dedicated network was developed to support very stringent mission

and data requirements to support Mercury, Gemini, Apollo and Skylab spaceflights. Initially, selected remote stations included spacecraft and booster control consoles as backups to NASA/JSC Mission Control, Houston, Texas. These were later removed, once system and network reliability were proven. Lunar missions required much longer data acquisition and tracking periods (hours versus minutes) than the unmanned missions, coordinated handovers from one station to another for continuous contact, required increased data/handling/storage requirements, significant increases in system reliability and the need for a level of redundancy in mission critical elements. Use of higher frequencies and new data types, increased numbers of data channels, alternate downlink modes, imposing spacecraft checkout, command and control requirements, the implementation of computers both in the spacecraft and ground stations and real-time data pre-processing were significant evolutionary changes provided by the manned flight network.

The combined network could be characterized as semi-automated utilizing high-speed (2.4-9.6 Kbps) data interfaces to recieve spacecraft commands and control data, to transmit command verifications and blocked/formatted telemetry data. On-site recorded data could be temporarily stored for delayed playback.

The continued evolution of spacecraft sophistication, that is, primarily higher data rates, need to accummulate data on-board during uncovered parts of orbits (necessitating even high dump playbacks), the need for increased coverage and the data bottlenecks at remote stations required a new concept for tracking and data acquisition and handling.

Figure 2 is the concept that evolved during the 70's, centered around geostationary orbiting, data transfer (repeater) platforms. Proper placement of these platforms at 35,680 km (22,300 miles) would provide 100% coverage for near earth orbiting Users above a 1200 km (745 miles) zone of exclusion, up to 85% coverage below this orbit. The significant cost savings of this new concept arise from the need for only one (1) ground station which provides TDRS control and housekeeping and "bent pipe" data throughput to Users or other data storage/handling facilities. The other significant advantage developed is the capability for increased simultaneous User support (from 2-24 Users). Other concepts which have solidified to increase system reliability are ground systems redundancy, an orbiting spare satellite, totally automated ground systems operation with failover capability. Because of increased coverage and throughput, there is no on-site data storage, playback or preprocessing. K-band links from TDRS to the ground station at White Sands, New Mexico,

provide optimum connectivity.

A proof-of-concept experiment involving the Application Technology Satellite 6 (ATS-6) and Nimbus-6 spacecraft was successfully conducted in the mid-70's. The test of a forward link demonstrated that the earth-orbiting Nimbus-6 could be commanded from a ground station via the ATS-6 earth-synchronous satellite. Data generated on-board the Nimbus-6 was transmitted to the ATS-6 and relayed by ATS-6 to the ground, proving the return link capability. Finally, range and range-rate measurements of the Nimbus-6 through the ATS-6 determined the relative distance and velocity of the two spacecraft. These measurements were then compared, found to agree with similar direct measurements made by the ground station.

Other network functions have undergone similar evolutionary changes from manual, to computer-aided to automated transitions. One such area is that of acquisition and tracking data handling. From manual positioning of broad beam antennas to manual data entry of azimuth/elevation data at remote-control consoles to torn tape programmed drive systems with manual override. Today, inter-range vectors (IIRV's) are transmitted directly over low speed data lines into Tracking Data Processors which perform the conversions, drive the antennas to the acquisition point and across the station envelope. Tracking data initially was transmitted via low speed teletype services and with the implementation of the Tracking Data Processor is now being transmitted over high speed data lines.

NASA Network Control Center functions and operations will likewise undergo significant change to support the TN. Initially basic functions were to coordinate network resources to assure availability to support in accordance with manually scheduled operations. Also, station status maintenance was manual with the aid of lighted wall displays and computer-aided console display functions.

Results of pre-pass preparation activities as well as scheduled pass (event) sequences were monitored via voice communication capabilities. The control center also provided fault isolation coordination and the provision of network engineering support back-up to on-site (station) resources if needed. This coordination was performed through Operations Controller personnel using centralized station operation facilities and consoles.

TDRSS Network (TN) Capabilities-Space Segment

The TDRSS Network is being designed to provide sufficient performance margins, operational flexibility and a high reliability factor for supporting projected space shuttles, attached shuttle payloads and free-flying spacecraft

during the 1980's and into the early 1990's. These factors were implemented in the TDRS design such that no signal processing is performed on-board the satellites other than frequency conversions. In a true sense, they act as pure repeaters or relays between the User Spacecraft and Ground Terminal facilities. Sufficient redundancy has been designed into the TDRS, in power, thermal, control, antenna and electronic systems to support projected 10 year end-of-life cycle system requirements.

The TDRSS has two (2) basic top level functions to perform: 1) to provide for the health and welfare of the satellite itself, 2) to provide three primary capabilities for its customers. Only the capabilities provided for customers will be discussed further and how these capabilities (services) are provided through the entire set of ground elements. Figure 3 is a simplified functional block diagram depicting the TDRSS ground segment components.

Forward Link Services (User Spacecraft Commands)

The White Sands Ground Terminal (WSGT) accepts User command data received through the NASA Communications Network (NASCOM), will add tracking data requirements if scheduled and transmits these to the specified spacecraft. These commands will initiate, terminate certain spacecraft functions or can be used to transmit on-board computer functions. For Shuttle, Shuttle payloads, these commands are originated from Lyndon B. Johnson Space Center (JSC) or for free-flyers directly from User facilities or the Goddard Space Flight Center (GSFC).

Tracking Services (User Spacecraft Position)

The TDRSS provides precise location of orbiting User spacecraft by measuring range (distance) and range rate (velocity) with respect to the known position of the TDRS. Doppler data measurements are also provided for one-way or two-way tracking data. All of these measurements are transmitted to the Orbiting Spacecraft Computational Facility (OSCF) at GSFC for data extraction as well as being provided to the Users. To insure TDRS position location to an accuracy sufficient to determine User positions accurately, a Bilateral and Range Tracking System (BRTS) network has been established. This dispersed network of remote-controlled, fully automatic stations are unmanned and are controlled/monitored from the OSCF.

Return Link Services (User Spacecraft Telemetry Data)

As a result of Forward Link activity or from automatic on-board systems, each User may transmit collected data, housekeeping and/or scientific, directly through the TN to User facilities. This data is not disturbed in any way but for formatting for transmission

through the NASCOM facilities or other domestic networks.

Services

To provide for user operational flexibility as mentioned earlier, the three basic capabilities (services) discussed above are further structured into various types of services. For the Forward (command) and Return (Telemetry) Link services, either Multiple Access (S-Band) or Single Access (S, K-band) services are available to support the large amounts of data being gathered and to provide simultaneous service to multiple spacecraft. There is redundancy available through alternate channels. The tracking services are also available in a variety of types - to provide tracking flexibility. These are identified as normal support (Multiple-Access, Single-Access/S-Band, Single-Access/K-Band), Cross Support (Multiple-Access Forward and Single-Access/S-band Return) using one TDRS and Hybrid Support (Multiple-Access or Single-Access/S-band Forward and Multiple-Access or Single-Access/S-Band Return) using two TDRS's.

A final service that will be made available to all Users is a Simulations service, which will allow Users the flexibility of utilizing the TDRSS to simulate a set of User spacecraft characteristics and before actual flight,validate a Users capability to send and accept commands that transmit and receive telemetry to a user facility.

With the handling of these larger amounts of data from numerous Users, there is the high risk of mutual interference and jamming. Using Pseudorandom Noise (PN) coding techniques applied to all data streams for transmission and reception, immunity to equipment jamming, security from interception and mutual interference are provided. Encoding and decoding are accomplished at the White Sands Ground Terminal for every User scheduled.

Single Access (S, K-Band) Services

For Single-Access, (SA) services, each TDRS has two (2) dual-feed S-Band/K-Band deployable parabolic antennas. These antennas are 5 meter (16 foot) dishes attached on two (2) axes that can move horizontally and vertically to follow earth orbiting spacecraft and those in highly elliptical orbits up to approximately synchronous altitudes. This SA service provides the high bit rate services for Users but because of pointing constraints, only one User at a time can utilize a given antenna/feed combination. Users having both S, K-Band antennas may utilize one antenna to provide both types of services depending upon service availability.

Multiple Access (S-Band) Services

Where single access services are limited to one User each, multiple-access (MA) services allow up to 20 Users to use this service simultaneously for return services and time-sharing of the forward MA links, (one per TDRS). This service is provided by a multi-element S-band phased array of helical radiators directed toward the center of the Earth. Parallel processing of data and beam forming are accomplished at the ground terminal.

Simulations Services (S, K-Band)

Simulations Services are provided by spacecraft simulators at the ground terminal. A TDRS is directed to the ground terminal S, K-Band simulations antennas, then to equipments that are set up to simulate the user spacecraft. Commands transmitted to the TDRS are directed to the ground Sim antenna then to the User for verification. A User may then transmit telemetry data through the spacecraft simulators up to a TDRS for return to Earth via normal User channels to complete end-to-end validations.

TDRSS Network (TN) Capabilities-Ground Segment

As the TDRSS development progressed, significant changes were being made to the ground segment portion of the TN. To interface the large amount of data to be relayed through the TDRSS, to utilize the operational flexibility designed into TDRSS and to optimize resource allocation required new operational concepts for the various associated ground based elements that comprise the end-to-end NASA/GSFC TN to be developed. Each of these elements will be discussed below beginning with the data gathering, control and monitoring functions of the ground portion of the TDRSS.

White Sands Ground Terminal - SPACECOM

The TDRSS Ground Terminal is a fully automated system with fully redundant ADP capabilities. It is centrally controlled and monitored from an on-site operational control center (TOCC). The TOCC continuously monitors the health and safety of the orbiting TDRS's, transmits required commands that reconfigure on-board equipment modes, maintains attitude control/ station keeping functions and provides the interface with the TDRSS Network Control Center (NCC) at NASA/GSFC, Greenbelt, Maryland. Ground terminal equipment is automatically configured in response to service assignment requests received from the NCC. These requests are automatically acknowledged with subsequent acceptance/rejection dependent upon services requested and resource availability. Provisions are made to store up to 24 hours of scheduled service requests and automatic failover to assure high availability. Manual back up capability with reduced response is also avail-

if required.

White Sands Ground Terminal - NASA

The communications interface between the TDRSS and the NASA Communications Network (NASCOM) is provided by the NGT. This portion of the White Sands Ground Terminal provides the switching interfaces for high and low data rates, monitoring status keeping of User data channels, and both emergency outage data recording and limited high data rate buffering for Users. The Fault Isolation and Monitoring System (FIMS) provides User data channel service monitoring and status functions to the NCC. The NGT selects interface configurations from high speed data messages received from the NCC or verbally, in emergencies. The interface switching system selects the proper channels to connect User data channels to NASCOM for distribution to User facilities at GSFC or other centers.

NASA Communications Network - NASCOM

A significant renovation has occurred to the NASCOM in the form of a major system upgrade, to provide 1.5 Mbps data services for the TN. This service is capable of expansion up to 12 Mbps. For TN requirements above these data rates, leased commerical services are available to 50 Mbps. NASCOM provides global, long-line operational communications support to all NASA projects. It also offers voice, video and teletype links between TN elements, to the Ground Spaceflight Tracking and Data Network (GSTDN) and to User spacecraft control centers. NASCOM has recently awarded a mission type contract for the maintenance, operations and support of the communications network. Figure 4. is a simplified block diagram of the NASCOM and NCC, depicting the major TN interfaces.

Network Control Center - NCC

The most significant change in network operational concepts has occurred with the redefinition of Network Control functions brought about by the level of automation designed into the TDRSS. As part of the function of scheduling User services, specific parameters must be designated by the Users in the form of configuration tables which are converted by the NCC into service schedules which are ultimately used by the TDRSS ground terminal to perform equipment setup functions. Remote equipment setup through the use of schedules is a major change in network philosophy. This concept allows more User flexibility in scheduling of TN resources and with the use of Mission Planning Terminals (MPT's) located at User facilities, provides interactive scheduling. Provision of these capabilities requires extensive User interfacing during the early mission planning phases and the development of User Data Base files. Additional capabilities are provided to the Users during real-time operations to perform certain specific functions such as service reconfigurations, frequency sweeps, low to high power changes, etc. During real-time operations, console operators within the NCC monitor service operations, may monitor User data, schedule emergency interfaces, isolate system faults and obtain status information from the TDRSS and NGT. It is also responsible for accounting for all services provided and testing of the network to assure User compatibility. Equipment configuration within the NCC allows for redundancy and provides for system maintenance to maximize system availability. Figure 5 depicts a functional flow chart of TN activities.

The User - TN Interface

The Users Payload Operations Control Center (POCC) provides the central point of interface to the TN via the NCC. Each POCC is generally tailored to the requirements of the space mission and may be either dedicated or may utilize the multisatellite operations control center facilities. The POCC's function to handle telemetry data, generate commands, provide voice communications interfaces with the NCC, process housekeeping and User experiment data, control User spacecraft operations and plan/analyze mission activities.

In the past, POCC personnel generally interfaced directly with remote-site operations personnel during real-time operations. This was possible because per schedule, a remote site was dedicated to Users for a fixed period or extension of time if there were no conflicts. In effect, for this schedule period, the remote site was an extension of a specific POCC.

For the TN era, POCC's will interface principally through the Mission Planning Terminals (MPT's) to the NCC. Extensive planning, coordination and testing may precede real-time operations to thoroughly exercise the User-TN interface. All operations have to be more thoroughly planned than in the past if the TN is to optimize resource utilization.

Summary

With full operations a near reality, the TN will provide services to all NASA User spacecraft in near-Earth orbits. Basically, three (3) inter-relating entities will provide for these services. First, each POCC that interfaces the User Community to the TN, the NCC that coordinates TN element resources and the TOCC which maintains and controls the TDRSS resources. The TN has evolved from a network continuously changing to meet User specific requirements to a network that is flexible to meet future needs without significant changes in Operational Concepts.

The TN will be an atuomated network with distributed processing capabilities and redundancy required to provide 24 hour, 7 day per week services to those Users capable of interfacing.

Although present operational concepts meet the presently foreseen needs of Users through the 80's and 90's, NASA has initiated studies for improved TDRS's and for system configuration changes to keep the TN current with state-of-the-art architectures and system design concepts, to meet their objective of a schedule driven, automated, real-time throughput data acquisition system.

END-TO-END TDRSS NETWORK
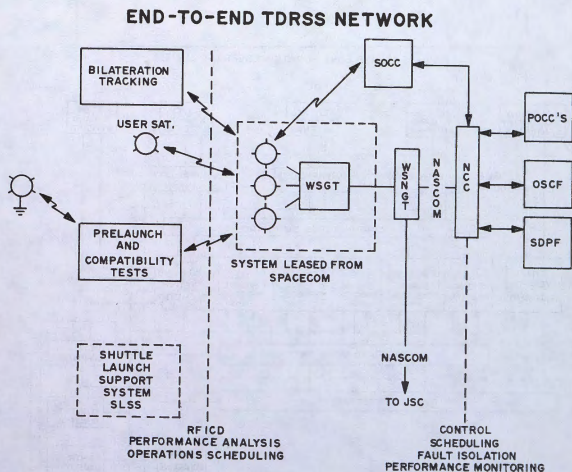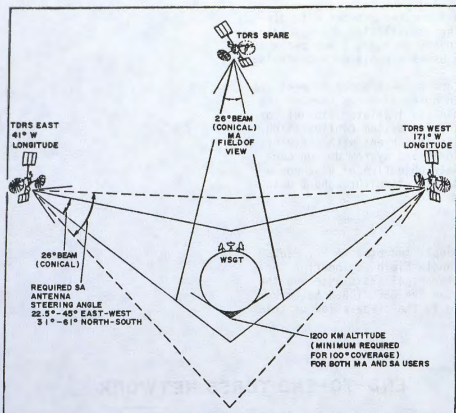

Figure I. Simplified TDRSS Network Diagram

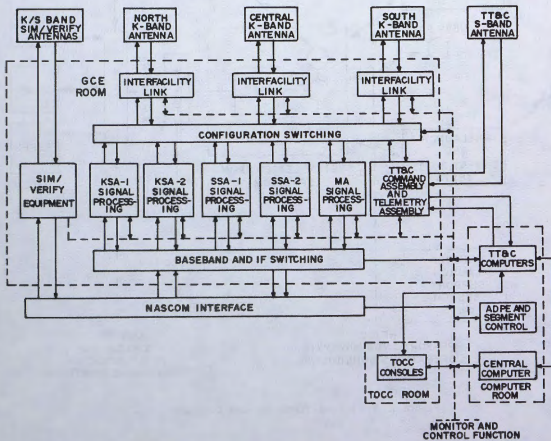Figure 2. TDRSS CONFIGURATION COVERAGE LIMIT

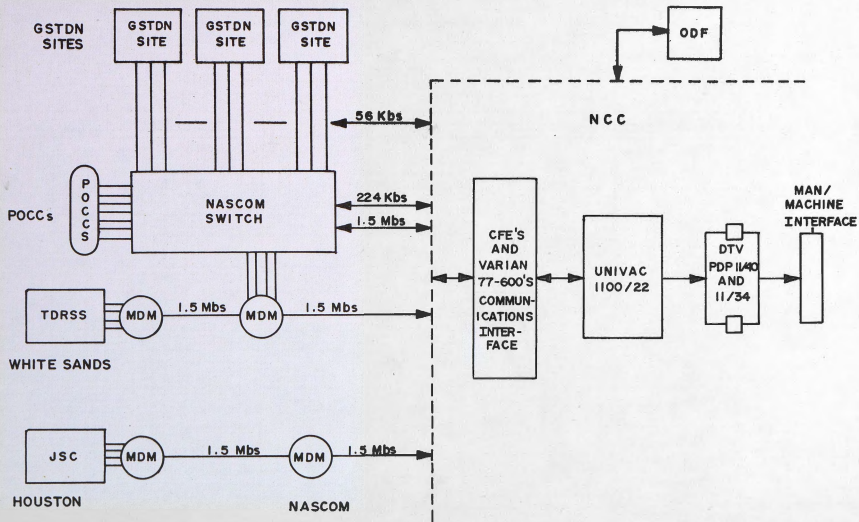Figure 3. Ground Terminal Simplified Block Diagram

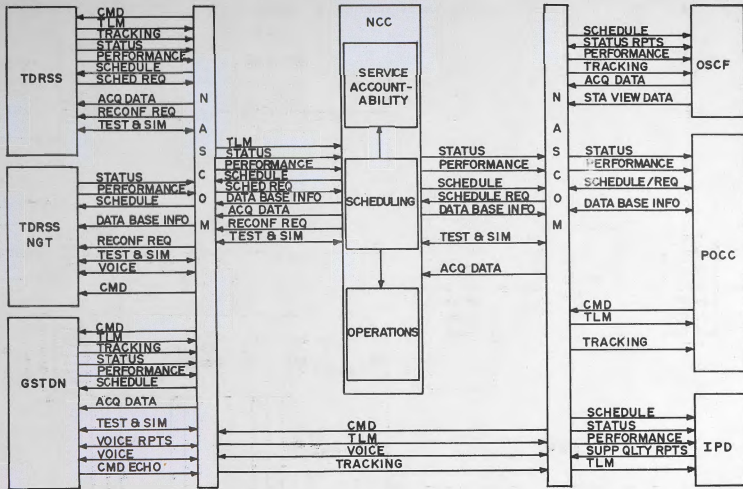# NCC/NASCOM BLOCK DIAGRAM

Figure 4. Simplified Nascom Interfaces

IC-57

TDRSS NETWORK FUNCTIONAL FLOW

Figure 5. Operations Flow Diagram