MSFN/DSN Integration Program for the DSS 11 26-m Antenna Prototype Station

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A plan was proposed in mid-1971 wherein unique Deep Space Network (DSN) equipment would be installed in the 26-m antenna Manned Space Flight Network (MSFN) operations control room and integrated to function with pre-existing MSFN equipment. This effort was initiated at the Pioneer Deep Space Station (DSS 11) site in November 1970 and shortly thereafter at the two overseas sites. This plan allows the 26-m antenna DSN tracking capability to exist at these sites while the 64-m antenna is in the process of being built and integrated into the original 26-m antenna DSN control room.

The details of the integration efforts at the DSS 11 prototype station are outlined, and significant accomplishments and milestones are indicated. The equipment layout in the operations control room is illustrated and the unique operational and electrical interfaces between the DSN equipment and the MSFN equipment are described.

During the period from 1966 through mid-1971 the *Apollo* mission to the moon has been supported by a three-site dual-station S-band 26-m tracking network. Each site consisted of a 26-m X-Y antenna operated by the Goddard Space Flight Center and a 26-m HA-dec antenna shared with the Jet Propulsion Laboratory but utilizing a completely separate control room for *Apollo* manned missions.

With the approval of the construction of the two overseas 64-m DSN antennas to be built by the Jet Propulsion Laboratory and dedicated to the DSN, it was realized that the need for additional control room facilities and equipment would add a considerable financial burden to the stringent budget. This is a consequence of the requirement for simultaneous operation of the 26-m system and the 64-m system at the 64-m antenna sites. As a consequence, a plan was proposed in mid-1970 wherein the unique DSN equipment would be installed in the 26-m MSFN operations control room and integrated to function with the preexisting MSFN equipment where this equipment is similar to the DSN equipment. This effort was initiated at the DSS 11 site in November 1970 and shortly thereafter at the two overseas sites, DSS 42 and DSS 61. This plan has the added dividends of allowing the DSN to have 26-m antenna tracking capability at these sites while the 64-m overseas antennas are being constructed and are being interfaced with new equipment in the original 26-m antenna DSN control room and furnishing the original 26-m DSN receiver to the 64-m antenna stations.

The *Apollo* wing 26-m joint MSFN/DSN sites, which include DSS 11, DSS 42, and DSS 61, operate with three categories of equipment as follows: (a) DSN and MSFN common equipment, (b) MSFN equipment equivalent to DSN equipment and (c) unique MSFN equipment.

The shared-equipment includes the 26-m cassegrain antenna and feed, the servo hydraulics and antenna drive system, the dual S-band masers, preamplifiers and control racks, the dual 20 kW S-band transmitter power amplifiers, control racks and power supplies (one of which is used in the DSN configuration), the site primary power and the 30-m collimation tower. Refer to Fig. 1 for a typical *Apollo* wing operations room layout.

The DSN equipment that has been replaced with equivalent MSFN equipment includes the servo electronics, the antenna pointing subsystem (APS) replaced with the antenna position programmer (APP), the tracking data handling subsystem (TDH) replaced with the tracking data processor (TDP), the frequency and timing subsystem (FTS) supplemented by the timing system (TMG), and the analog instrumentation system (AIS) recording replaced with the MSFN recording system and the S-band receiver-exciter subsystem (RCV) replaced by a dual S-band receiver-exciter system. In addition, the MSFN communications room teletype interfaces and control have been replaced by the DSN communications room equipment. However, the MSFN high speed data (HSD), the wing-to-prime site microwave link facilities, and the 112A MSFN station intercommunications system will be maintained in a separate MSFN communications room.

The unique MSFN equipments, located in the *Apollo* wing, include the verification receiver, the subcarrier oscillators (SCOs) housed in the collimation control rack, the incoming and outgoing data patching and multiplexing racks to interface with the wing-to-prime site microwave link. The MSFN collimation tower transponders and related equipment in the control room rack, the 1218 Univac computer for processing predicts which will be replaced by the DSN antenna pointing subsystem (APS), a Loran receiver for timing purposes and the wing-to-prime site microwave link and high-speed data (HSD) equipment referenced above.

The concept applied to the MSFN-DSN integration program is that of using the existing equivalent MSFN equipment wherever possible, with particular emphasis on the MSFN receiver-exciter, and establishing DSN functions and interfaces in the simplest manner possible. The resulting effort shall not degrade either the *Apollo* station performance or the DSN station performance; however, certain operational procedures and functions may be simplified or deleted where they do not directly affect the quality of the data to be acquired.

The integrated stations will perform all the *Apollo* requirements with the original MSFN equipment, with the exception of the DSN antenna pointing subsystem (APS) and the DSN simulation conversion assembly (SCA) units which will process antenna-pointing predict information in place of the 1218 Univac computer. A minor concession to the integrated configuration is the elimination of the seldom used on-line processing of the 29-point predict message and electrically driving the APP and the antenna directly from the computer. The processing of a drive tape and reloading it in the APP unit electrically or mechanically in the torn-tape mode is required in the integrated station (Fig. 2).

The DSN operation of the integrated stations will function very similarly to that of a normal MM'71 backup station. The first wing receiver will be interfaced with the subcarrier demodulator assembly (SDA) and command modulator assembly (CMA) units via new distribution amplifiers and a new exciter modulation mode-select unit in the exciter modulator system, respectively. The DSN loop bandwidth will be electrically selected when the DSN VCOs are installed. The *Apollo*-peculiar wide-band modifications will be installed in the second wing receiver in May 1971 and will not affect the DSN receiver configuration or performance. Two channels of telemetry will be provided by the SDAs, the symbol synchronizer assemblies (SSAs) and the dual telemetry and command processor (TCP). Two channels of command will be provided by two CMAs. A single 20-kW S-band transmitter will be available for DSN transmissions. The frequency and timing signals will be provided by the DSN frequency and timing subsystem (FTS). The exception will be the 5-MHz signals required by the SDAs which must be coherent with the receiver and will be provided by the MSFN timing subsystem.

The DSN FTS clock and the MSFN TMG clock will be compared and the DSN clock will be updated to provide the required 50 μs tracking tolerance. The DIS function at the integrated station will be provided by the 7-rack DIS-I which will provide monitor data to SFOF via HSD lines; however, station observation of monitor data will require a backfeed mode from the SFOF wherein data is processed at the SFOF and fed to the station via the HSD line. The tracking data sent to SFOF in the DSN mode will originate in the MSFN TDP unit.

The HSD line output of the TDP will be sent to the SCA HSD receive-register for processing and changing into the DSN format by the SCA and APS computer. This processed data will then be transmitted from a HSD coupler in the APS to the SFOF via DSN HSD lines. The only teletype backup available will be the output of the TDP in MSFN format which is acceptable to DSN. The APS antenna pointing options will be reduced due to the computing load placed upon the 8-K word memory and software of the XDS-910; however, no compromise in data acquisition quality is expected. The 29-point DSN acquisition message may be received at the APS on either the HSD line or via teletype and the related "torn-tape" mode. The APS will be capable of producing an off-line drive tape from the 29-point acquisition message. This tape may then be used to drive the antenna by loading it into the APP unit and driving with one point per ten seconds.

The alternative mode is also available wherein the 29-point acquisition message may be processed by the APS and the result stored for subsequent electrical readout to the APP at a one-point-per-second rate. This "direct electrical drive" mode will, however, have to be interrupted in the event of being compelled to receive and process a new acquisition message from either the HSD input or the teletype torn-tape input. The previously cut drive tape must then be relied upon for antenna pointing, or auto-track or aided-track substituted, when this situation is presented during antenna pointing operations. The planetary mode and the injection-conditions mode will not be available due to the lack of APS/XDS-910 computer capacity.

In addition to the above integrated station features, the teletype functions of the DSN and MSFN communications rooms have been combined in the DSN communications room. Administrative traffic on GSFC collectives will be routed at the source through JPL NASCOM circuits. The special predict-message circuit and the prime-to-wing teletype circuit will be available on the station communications control group (SCCG) in the DSN communications room.

The program implementation began at the prototype DSS 11 station in November 1970. The period of time, prior to *Apollo 14* operations in mid-January 1971, was confined to moving the MSFN equipment to a more space-efficient location and moving the DSN microwave and transmitter racks into the new control room. In addition, the DSN recording racks, analog racks, the telemetry and command data handling subsystem (TCD), the patch-rack, a single SDA, SSA, and CMA rack, and the Alpha portion of the TCP telemetry processor, complete with a half patch-rack and a half communications buffer rack, were moved into the new integrated control room. Following the conclusion of the *Apollo 14* operations, the FTS-I and DIS-I (digital instrumentation system used for recording and displaying station parameters) systems were moved in place and were subsequently upgraded and tested in the new station configuration. The DSN modules and modifications to the first MSFN receiver were installed with JPL and GSFC participating at the site. The original MSFN communications room was enlarged and the two data multiplexing racks, used to interface the sending and receiving of inter-site microwave information with the receiver and exciter, were removed from the control room to the MSFN communications room. In addition, a new DSN rack was installed to house the additional television equipment required when the surveillance TV and antenna fence alarm system was integrated into the MSFN servo system. The DSN system monitor console (SMC) was reduced to three half-height racks and installed in the control room. It is presently being repackaged to house the DIS TV alarm display, the CMA status panel, the new tactical intercommunications station and other necessary station monitor indicators. Later, the three APS racks and the two racks of SCA equipment were installed and tested. The layout of the completed DSS 11 integrated station control room is shown in Fig. 3.

All presently installed DSN subsystems have been tested and are operating nominally. The system interface tests have begun and are expected to be completed after the arrival of the TCP Beta racks, the second SDA, SSA and CMA racks, and the receiver test rack which will replace the present RCV/1929 test rack. This event will be followed by DSN antenna-pointing software, tracking data software and monitor software testing with Ground Communication Facility (GCF) and Space Flight Operations Facility (SFOF) participation. The new APP-APS and the new APS-SCA-TDP hardware interfaces will be implemented at DSS 11 starting in May 1971. The APP-APS hardware interface for antenna pointing will be completed by the end of June 1971, in time for demonstration purposes during the *Apollo 15* mission. However, the hardware and software implementation of the DSN APS-SCA-TDP tracking data system will not be completed until the end of August 1971.

Concurrent with the implementation program, an *Apollo* operator training program is being conducted at DSS 11 during the month of April and half of May. This effort will provide *Apollo* mission operator certification in antenna servo, receiver-exciter, ranging, timing, tracking data processor (TDP), antenna position programmer (APP), 1218 Univac computer (used for *Apollo 15* only), 112A intercommunications system, teletype, 205 and 203 high-speed data modems, and documentation procedures. In addition to the 4 to 6 wk of classroom instruction in the above subjects, several weeks will be scheduled for hands-on training and simulations. Finally, an aircraft simulation fly-by will be scheduled for the first week of June as a final exercise before mission readiness testing.

The two overseas stations, DSSs 42 and 61, are presently undergoing integration installation and testing patterned after the prototype effort at DSS 11. These stations will be available to support the *Apollo 15* mission in July in the original MSFN configuration using the 1218 Univac computer. All three stations will be available to support *Pioneer F* and other DSN missions after September 15, 1971.

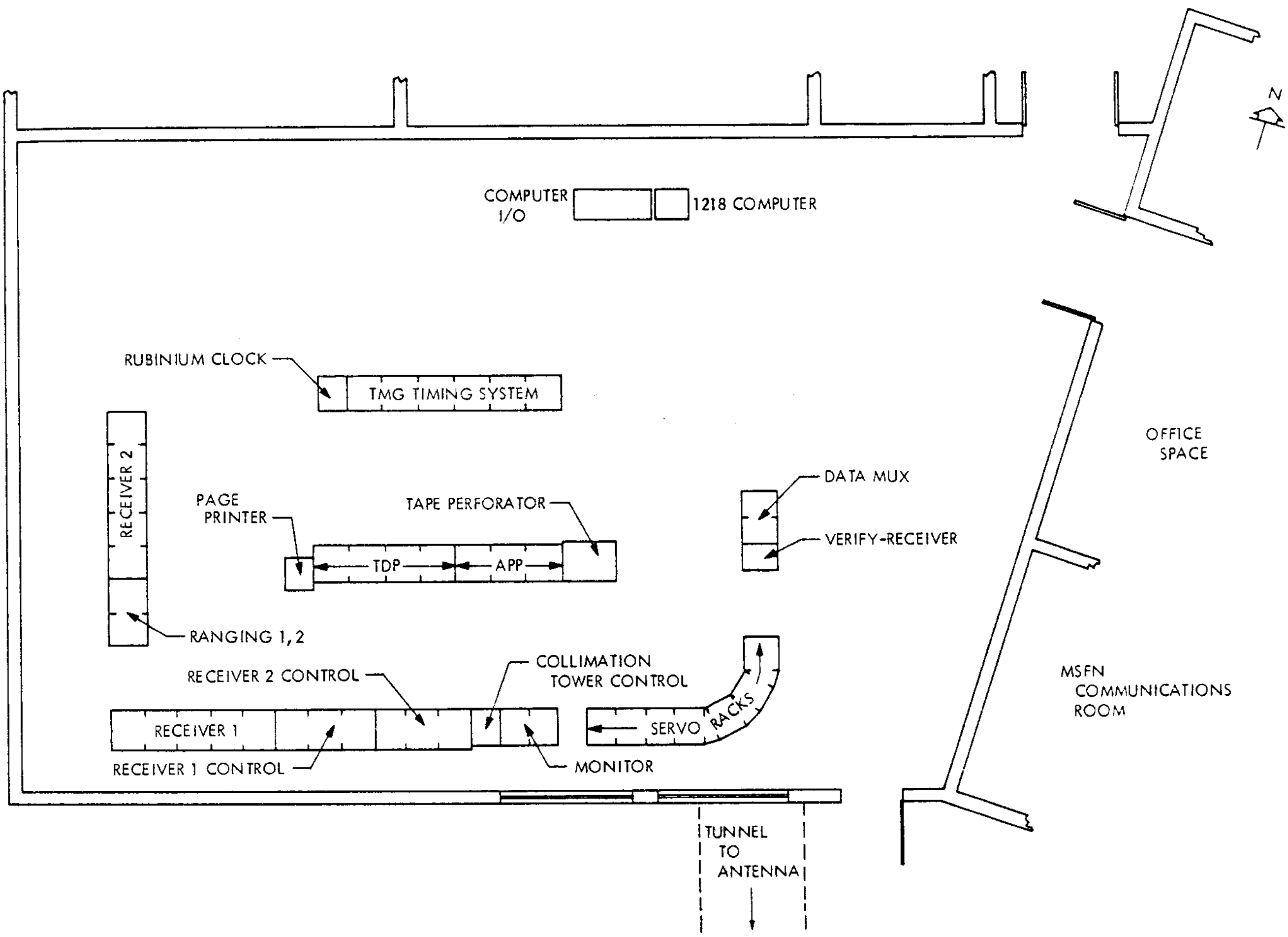

Fig. 1. MSFN/DSS 11 control room

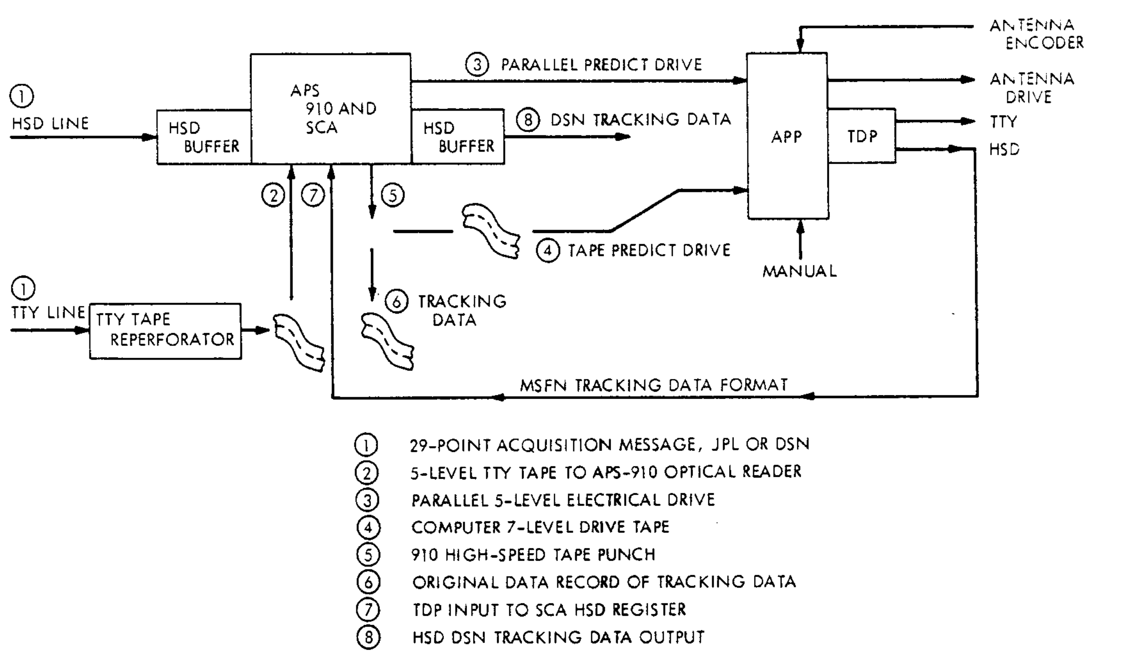

Fig. 2. Integrated MSFN/DSN configuration

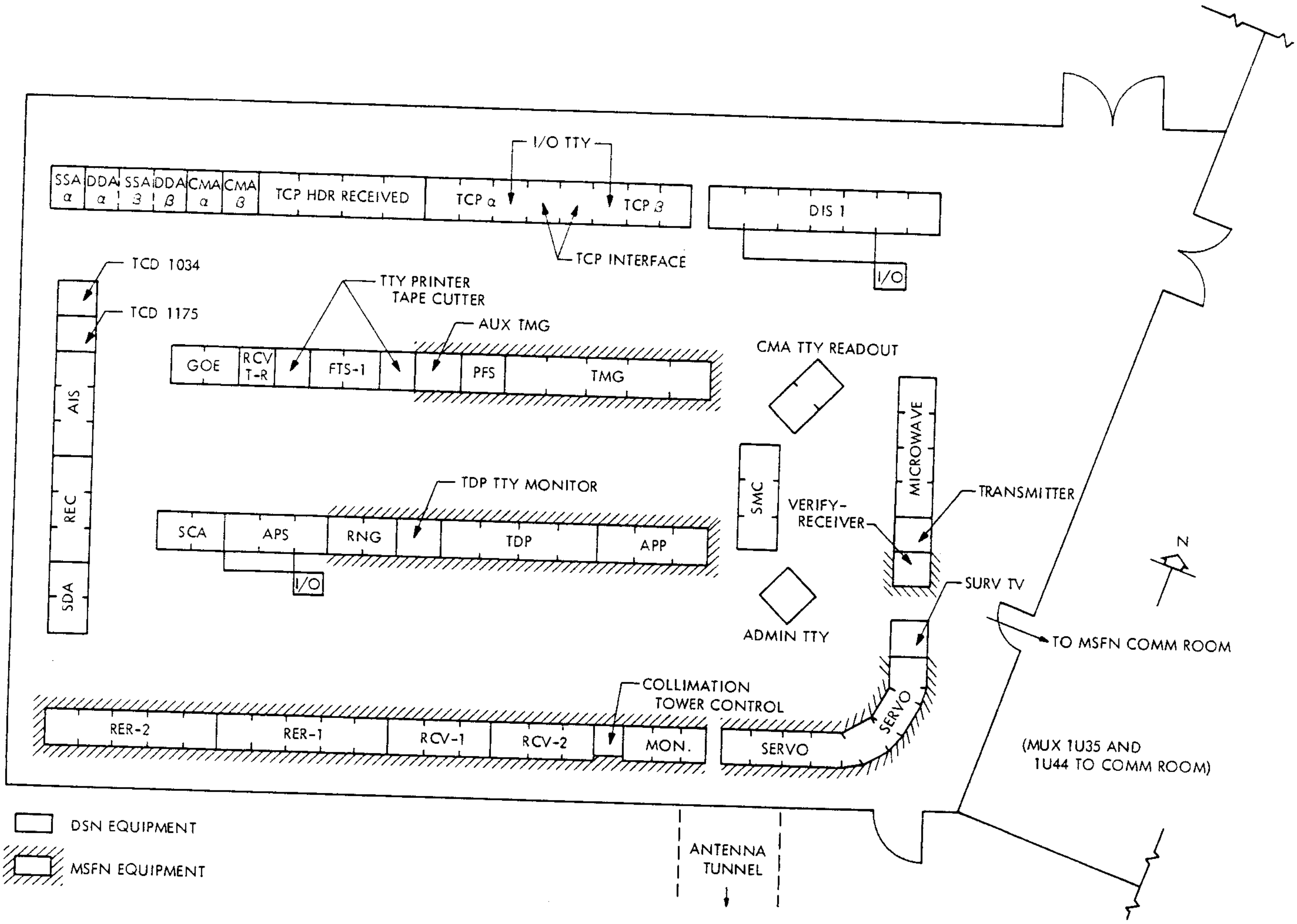

Fig. 3. DSS 11 integrated with MSFN