DSIF Operations Support of *Mariner* Mars 1971

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This article is an abbreviated description of DSIF Operations activities in preparation for, and up to and including, Mariner Mars 1971 launches H and I. New DSIF hardware is covered briefly, with rather more detailed coverage of the DSIF training, testing, operational documentation and performance aspects of the preparations.

I. Introduction

A direct result of the application of knowledge and experience accumulated by the DSIF during preparations for the now considerable number of past lunar and deep space missions has been the development of a logical standard pattern and sequence of events.

Basically, the major events in readying the DSIF for a mission are:

(1) Evaluation of new mission spacecraft parameters and possible requirements for new DSIF hardware (HW) and software (SW).

(2) Design, prototype fabrication and checkout of necessary additional new HW.

(3) Design of new SW.

(4) Procurement of production models of HW including spares, documentation, etc.

(5) Generation of engineering (mission independent) training program, initially for DSIF instructors, then DSS personnel.

(6) Generation of operations (mission dependent) training plan (DSN Test Plan, Vol. VI).

(7) Generation of operations (mission dependent) procedures (DSN Operations Plan, Vol. VII).

(8) Acceptance testing of SW programs.

(9) Implementation of any necessary mission independent DSS personnel training.

(10) Implementation of mission-dependent DSS personnel operational training (if possible with live spacecraft).

(11) Installation of HW at DSSs (per DSN Operations Plan, Vol. VI, DSIF Configuration Document).

(12) Delivery of SW to DSSs and implementation of HW and SW integration tests at DSSs (DSN Test Plan, Vol. VI).

(13) Implementation of DSS on-site training.

(14) Starting DSIF operational verification tests (OVTs).

(15) Supporting DSN system tests.

(16) Finalizing DSIF OVTs.

(17) Supporting DSN OVTs.

(18) Supporting MOS, OVTs and ORTs.

(19) Supporting launch and tracking.

Mariner Mars 1971 (MM-71) preparations followed this outline as closely as possible, but slippages in delivery of HW, SW, documentation, and in particular, loss of SFOF support, seriously restricted the early DSIF training, making numerous tradeoffs necessary.

II. New DSIF Hardware (HW) for MM-71 Era

The MM-71 mission design called for increased capabilities at the DSSs, the main requirements being to process four spacecraft subcarriers (one engineering and one science from each of two spacecraft) simultaneously, science up to 2 kbits/s at the 26-m stations, and 16.2 kbits/s at DSS 14, higher command activity, and repetitive occultation experiments.

These added requirements plus the continuing state-of-the-art improvements resulted in the following new equipment being installed prior to MM-71 launch:

(1) Open-loop receivers and peripheral equipment (at DSSs 14, 41, and 62).

(2) Additional SDAs (total of four at 12, 41, 62 and six at DSS 14).

(3) Command modulator assemblies (CMAs).

(4) New TCP HSDL buffers (for use with 4800 bps modems).

(5) Dual high-density digital recorders (DSSs 14, 71, and CTA 21).

(6) Dual low-density digital recorders (DSSs 12, 41, and 62).

(7) Symbol sync assemblies (SSAs).

(8) Block decoder assemblies (BDAs).

(9) Simulation conversion assemblies (SCAs).

(10) DSIF monitor system, Phase 1 (HW and SW).

(11) Updated station monitor console (SMC).

(12) Updated timing system (FTS II).

(13) Dual Block III masers.

The foregoing equipments were installed and, with the exception of the open-loop receivers, operational before launch. The open-loop receivers will be operational at the end of June 1971.

The various DSIF mission-independent software programs and the mission-dependent MM-71 software are described in "DSIF *Mariner* '71 Operational Program" by R. Chafin. Also the DSIF/S/C compatibility activities associated with MM-71 preparations are not covered in the article.

III. DSIF Training

A. Mission-Independent Training

Formal training for two engineers from each DSS was carried out during August 1970. This covered detailed theory of operation, calibration, maintenance and general operation of most of the equipments listed in Subsection II. After completion of the course the engineers returned to their respective stations with training packages and proceeded to instruct the station personnel on the operation and maintenance of the equipment in their respective areas of concern.

At this time the new equipment was delivered and installation started at the prime MM-71 stations.

B. Mission-Dependent Training

The mission dependent training took place at JPL and GDSCC during November and early December 1970. The trainees were: One Operations supervisor, one senior RF operator and two senior digital instrumentation operators from each of the MM-71 prime stations, i.e., DSSs 12, 14, 41, 51, 62, 71 and MSFN ACN, plus the DSIF elements of the DSN OCT, i.e., five assistant DSIF chiefs and five station controllers. Approximately six engineers from the DSIF Operations section also took part in the training to varying degrees.

1. Program objectives. The purpose of this training was to:

(1) Train operators in the use of MM-71 software and the recently updated hardware under realistic operational conditions.

(2) Familiarize operators with MM-71 spacecraft RF parameters.

(3) Check, verify and finalize MM-71 operational procedures with teams of DSS operators.

(4) Develop and exercise any special procedures required to work around spacecraft non-standard performance or spacecraft/DSIF design incompatibilities.

(6) Ensure immediate recognition and isolation of any inadvertent simulation-induced problems during DSIF/DSN/MOS tests.

(7) Familiarize members of the DSN operations organization, including the OCT, with pertinent aspects of the above.

2. Description of training program. The training covered by this section is outlined in Sections II, III and IV of Document 610-88, "DSN Test and Training Plan for *Mariner*-71 Project," Vol. VII of *DSIF Operations Test Procedures*. In general, the training consisted of lectures, classroom instruction, review of procedures, hands-on equipment familiarization, practice of procedures, observation, and tours of facilities.

A list of the speakers of the lecture portion of the program is contained in Table 1, which also lists their subjects. The classroom instruction, for operators only, consisted of familiarization with the SCA and TCP software programs, and was integrated with "hands-on" training on the computers. This phase was conducted at the Goldstone Network Training Support Facility and the DSS 12 control room, and lasted four days.

While the operators were at GDSCC, the supervisors were reviewing MM-71 documents. These were:

(1) 610-82, DSIF stations configuration

(2) 610-83, DSIF operating procedures

(3) 610-88, DSIF test and training plan

Tours of the Spacecraft Assembly Facility (SAF) and the Space Flight Operations Facility (SFOF) were conducted by G. Wade Earle and L. William Pellman, respectively.

Three days were utilized in performing station countdowns on the Multiple Mission Telemetry and Command Subsystems at DSS 12.

The final 12 days of training were conducted at the CTA 21. Both a live MM-71 spacecraft and the Simulation Center in the SFOF were used as data sources. The trainees operated station equipment in accordance with MM-71 Operating Procedures and DSIF Standard Operating Procedures and daily sequence of events. This phase was conducted on a team, or crew, basis; teams not involved in counting down the station or "tracking" periods observed activities at CTA 21 or in the SFOF.

3. Lecture series presentation. The series of lectures listed in Table 1 were presented at JPL, Pasadena. Lectures 1 through 13 were delivered at Von Karman Auditorium and were attended by all trainees. Lectures 14 through 15 were given at various locations in Buildings 126 and 230 and were attended by the Operations Supervisors only. Visual aids, namely slides, were used extensively.

4. Goldstone presentation. On Nov. 5, 1970 operator trainees attended classroom instruction on the SCA and TCP Software Programs. Each student received approximately three and one half hours on each program.

On Nov. 6 through Nov. 8, the following on-site training was held in the control room at DSS 12.

SCA. All individuals received 4 h of group training on the SCA mnemonic inputs. Eight hours were spent using the SCA as a data source for the TCP, with the students configuring the SCA, RCVR, SDAs, SSAs, BDAs and CMAs, as if in an actual countdown.

TCP. All individuals received 12 h training on the TCP/CMA software covering the telemetry and command portions of the program.

The major problem area was in the command portion of the software. The software and documentation was incorrect and certain interrupt patches were omitted.

For the Station Countdown 11 to 13 November 1970, all operator trainees plus the operation supervisor of the stations participated in the countdown tests. The group from each station had the opportunity to do each countdown twice for a total of 6 h actual hands-on practice. Included in the training was two hours theory on Y factor techniques.

SMC/CRT. The participating students were given an introduction to the CC-30 display system by video tape. Then a brief explanation was given as to how the monitor program will interface with the SMC/CRT, followed by a demonstration program from the DIS. In addition, convergence of the CC-30 color TV display was taught by hands-on training. The summary was presented by video tape.

5. CTA 21 presentation. Training was conducted at CTA 21 from Nov. 16 through Dec. 2, 1970 in three phases using equipment configurations as follows:

Nov. 16 through 21	CTA 21/Spacecraft at SAF/SFOF.
Nov. 23 through 25	CTA 21/Simcen/Spacecraft at SAF/SFOF OPS Control.
Nov. 30 through Dec. 2	CTA 21/Simcen/SFOF OPS Control; CTA 21/Simcen.

A final critique covering DSIF operator training for MM-71 was held on Dec. 3, 1970.

A typical sequence of events was used from Nov. 16 through Nov. 30. Minor modifications were made from time to time to facilitate changes in configuration. This sequence simulated a normal spacecraft pass with the following nominal schedule of activities:

0800–1100 PST	Station countdown
1100–1700 PST	Tracking
1700–1800 PST	Daily critique

As a result of the daily critiques, training activities during Dec. 1 and 2 concentrated on hands-on operation of the SCA only. Each team was allotted 2 h to operate the SCA in the stand-alone mode and as a data router in the Simcen long-loop mode. The trainees returned to their respective DSSs the second week in December 1970 and using the training packages provided, initiated the DSS on-site training programs. Two weeks were allocated to on-site training and the DSIF operational verification tests started on Jan. 1, 1970.

IV. DSIF Testing

Table 2 summarizes the number of operational tests supported by the various stations.

V. Operational Documentation

The main changes in the documentation for MM-71 were in the DSN Operations Plan, Vols. VII and VIII. Volume VII was subjected to a major revision which resulted in the basic document containing only DSIF MM-71 procedures for use on a day-by-day basis. This is supplemented by ten appendices covering rarely (or once only) used procedures e.g., MSFN ACN commanding, launch procedures etc. The second part of the document (addendum) is composed entirely of useful background information, e.g., spacecraft RF, Command, subsystem descriptions and parameters, etc.

The DSN Operations Plan, Vol. VIII basic content followed the MM-69 philosophy to a greater degree by containing only limited samples of launch predicts, and went into great detail on the initial acquisition study. The various documents were published as shown in Table 3.

VI. Operational Performance of New Equipment

The new equipment has performed very satisfactorily under operational conditions during OVTs, both launches, one trajectory correction maneuver and approximately 4 wk of tracking.

The main exception was the operation of the command system. In the early training and testing numerous command alarms and aborts were experienced. These were gradually eliminated by modifications (patches) to the DSIF TCP and SFOF 360/75 software programs and eventually reissues of both programs. However, approximately 6 wk prior to launch it became apparent that a "bit verify" alarm/abort problem still existed. This triggered an intensive 24-h/day trouble shooting exercise at GSDCC, CTA 21, and some of the overseas stations. The problem was isolated to a noise problem inherent in the TCP/CMA basic hardware design. A modification was hastily fabricated and personnel rushed to the prime MM-71 stations where it was installed and soak tests carried out prior to the ORT.

During the extensive soak tests a specific version of the bit verify abort problem (abort on first bit of first command in block) was observed on a random/periodic basis. This was isolated to a software induced hardware (timing) problem where an erroneous bit verify abort could occur because of the phase relationship between the DSS 1 PPS timing and the CMA CMD modulation frequency (random) coupled with the cumulative effect of the phase difference (periodic). A software program "fix" was generated. However, due to the lack of time to carry out extended checks on the fix before launch it was decided that any unknown side effect of the fix would be a greater risk than the known possibility of an erroneous command abort, and the fix was not incorporated for launch and midcourse. Both launches and the "I" midcourse correction were supported without any command problems.

After the midcourse correction a spacecraft CC&S update was carried out involving transmission of approximately 450 ground commands. These commands were planned to be sent continuously on 30-s centers, and in the early part of the exercise a total of 5-bit verify aborts occurred. These were noted as occurring approximately every 21 min, and simple arithmetic quickly tied this to the nominal subcarrier frequency over spacecraft actual frequency, which gives 1 1/1277, giving a coincident periodicity of 21 min, 17 sec. The commands were then continued with a break of 2 min every 20 min, thus avoiding the problem.

Phase four of the DSIF TCP operational program will incorporate a permanent fix for this problem together with other refinements.

Table 1. Lecture presentations

Lecture number	Speaker	Topic
1	R. K. Mallis	Introduction and Section 337 Organization
2	R. T. Hayes	Mission Operations
3	J. H. Duxbury	Spacecraft Systems
4	D. M. Scaff	Spacecraft Radio Subsystem
5	W. H. Chitty	Spacecraft Command Subsystem
6	C. E. Geuy	Spacecraft Telemetry Subsystems
7	I. L. Emig	Operator Training Schedule
8	J. R. Buckley	Station Countdown Philosophy
9	R. C. Chernoff	DSN/DSIF Monitor System
10	H. C. Thorman	SFOF Simulation Center
11	E. Garcia	Simulation Conversion Assembly
12	D. L. Gordon	DSN Operations Control Team
13	R. L. Chafin	DSIF Software Program Support
14	D. Nightingale	Introduction to Upgraded High Speed Data System
15	R. W. Burt	System COE Functions
16	R. B. Miller	SFOF Tracking System
17	W. H. Higa	Time Synchronization Systems
18	J. G. Leflang	Block III Masers
19	C. P. Wiggins	DSS Transmitters

Lectures 14 through 19 were attended by supervisors only.

Table 2. Operational tests

Tests	Station							
	ACN	12	14	41	51	62	71	Total
DSIF OVTs	4	13	12	12	11	10	4	66
MOS Launch I/cruise H	3	3		7	7	3	7	30
MOS Trajectory correction		1		5	5	1		12
MOS Trajectory correction 67-h test		—	—	—	—	—		
MOS Trajectory correction 85-h test		—	—	—	—	—		
MOS ORT	—	—	—	—	—	—	—	
DSN combined systems tests		6	1	3	3	3	2	18

Table 3. DSIF documentation

DSN Operations plan for MM-71			
Volume	**Title**	**Document number**	**Date**
Vol. VI	*DSIF Station Configuration*	610-82	10/9/70
		610-82; Rev. A	4/23/71
Vol. VII	*DSIF Operations Procedures*	610-83	11/1/70
		610-83; Rev. A	2/15/71
		610-83; Ad. 1	3/30/71
Vol. VIII	*DSIF Preflight Nominal Predictions*	610-84	4/20/71
DSN Test/Training Plan			
Vol. VI	*DSIF Engineering Test Procedures*		10/30/70
Vol. VII	*DSIF OPS Test Procedures*		8/15/70