Economic Evaluation of DSS 13 Unattended Operations Demonstration

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This article presents the goals and data collection requirements to be used for the economic and performance evaluation indices and life-cycle cost parameters for the upcoming operations demonstration of an automated Deep Space Station run unattended and controlled remotely from JPL. These evaluation indices will compare the remote operation of telemetry at DSS 13 with the cost and performance of a comparable manned operation at DSS 11. A description is presented of the data that needs to be collected, how the data will be analyzed, and what can and cannot be learned from this operations demonstration.

I. Introduction

In the last decade there has been an increasing emphasis on improving the cost effectiveness of DSN use of NASA resources for tracking and data acquisition. To this end, the DSN has been introducing automation into the stations to reduce manpower and to improve network productivity. For example, the crew size at DSS 12 has gone from 15 people in 1967 to 3 in 1977. The change in crew size is shown below for the last decade:

Year	DSS 12 Crew Size
1967	15
1972	8
1975	4
1977	3

The next step in this process is to attempt to run a completely automated station, i.e., unattended and controlled remotely from JPL in Pasadena. Accordingly, during the last half of 1978, an unattended operations demonstration test will be performed at DSS 13.

There are three objectives of this demonstration. First, to see if unattended remote operation can be accomplished. Second, to collect operations data from which an evaluation of unattended operation can be performed, and third to provide a single point, remote, unattended control of DSS 13 to accomplish Voyager spacecraft telemetry reception and transmission to the Network Operations Control Center (NOCC) via DSS 12 during the DSS 12 downtime for S/X upgrade from a 26-meter to a 34-meter antenna.

This article will be concerned with the second objective, namely, what data do we collect, how do we analyze the data,

and what can and cannot be learned from this demonstration test.

The overall objective will be to compare the unattended remote operation for telemetry at DSS 13 with the cost and performance of a comparable operation at DSS 11. This comparison will hopefully give us valuable insight into the advantages and disadvantages of automated, remote operation compared to our present method of operation.

In Section II, the detailed goals are outlined for the test. Also the indices and figures of merit used for comparing DSS 13 performance with DSS 11 are introduced. In Section III, the data requirements from DSS 13 and DSS 11 are outlined. In Section IV, some of the limitations on extrapolation of the test results are explored. Finally, in Section V we summarize the salient features of the report.

II. Goals for Unattended Operations Demonstration

A. Background

One of the primary DSN program goals of the demonstration is to collect an operations data base from which the values of life cycle cost (LCC) parameters can be computed. However, in the original program goal these LCC parameters were not defined. The major purpose of this report is to summarize our work on developing these parameters so that the DSN program goal can be reached.

B. Comparison Indices

Described below are eight comparison indices that we will use to evaluate the cost and performance of telemetry activities at DSS 13 and DSS 11. The comparison is limited to the unattended remote operation of telemetry at DSS 13 with a comparable operation at DSS 11.

The first two comparison indices are efficiency and productivity. These indices are to be determined for both DSS 13 and DSS 11 in telemetry mode. These indices are referenced in Tables 1 and 3.

I-A (1) Efficiency ratio $= \dfrac{\text{EUH/unit time}}{\text{SOH/unit time}}$

where

SOH = station operating hours, those hours when a station is required to be available to conduct DSN activities. (SOH are usually set at 40, 80, 120, 160, or 168 hours per week.)

EUH = end user hours, those station operating hours where spacecraft data, test, or training information is obtained for the end user.

I-A (2) Productivity ratio $= \dfrac{\text{EUH/unit time}}{\text{M\&O MH/unit time}}$

where

MH = manhours

M&O MH = the sum of the manhours spent on operations, corrective maintenance, preventive maintenance and training.

The next three indices are to be used for comparing the maintenance and operations costs at each station per end user hour. There is a separate index for operations and another index for maintenance because it is expected that unattended operation will lower operating manpower costs, but may increase maintenance costs because of the extra equipment required.

I-A (3) End user's hourly M&O cost $= \dfrac{\text{M\&O cost \$/unit time}}{\text{EUH/unit time}}$.

I-A (4) End user's hourly operations cost $= \dfrac{\text{Operations cost \$/unit time}}{\text{EUH/unit time}}$.

I-A (5) End user's hourly maintenance cost $= \dfrac{\text{Maintenance cost \$/unit time}}{\text{EUH/unit time}}$.

The next three indices are to be used for comparing maintenance and operations costs at DSS 13 and DSS 11 per station operating hour.

I-A (6) Station hourly M&O cost $= \dfrac{\text{M\&O cost \$/unit time}}{\text{SOH/unit time}}$.

I-A (7) Station hourly operations cost $= \dfrac{\text{Operations cost \$/unit time}}{\text{SOH/unit time}}$.

I-A (8) Station hourly maintenance cost $= \dfrac{\text{Maintenance cost \$/unit time}}{\text{SOH/unit time}}$.

C. Automated vs Nonautomated Station Ratios

In addition to the previous eight comparison indices, we have developed eleven ratios to compare automated with

nonautomated station operation. The first ratio compares operating manhours per station operating hour.

I-B (1) Operating MH ratio $= \dfrac{\text{operations MH/SOH(A)}}{\text{operations MH/SOH(NA)}}$

where

A = automated station (DSS 13)

NA = Nonautomated station (DSS 11 or 12).

The next four comparison ratios, given below, are designed to compare corrective maintenance at DSS 13 with that at DSS 11. Corrective maintenance is divided into two categories, according to whether station downtime is or is not a consequence of the necessity for maintenance action. Also corrective maintenance is compared per unit time, e.g., week, month, year, and per station operating hour.

I-B (2) Corrective (DT) MMH ratio (1) =

$$\frac{\text{corrective (DT)MMH/unit time (A)}}{\text{corrective (DT)MMH/unit time (NA)}}$$

where

MMH = maintenance manhours

DT means that downtime resulted from the necessity for maintenance action.

I-B (3) Corrective ($\overline{\text{DT}}$) MMH ratio (1) =

$$\frac{\text{corrective } (\overline{\text{DT}}) \text{ MMH/unit time (A)}}{\text{corrective } (\overline{\text{DT}}) \text{ MMH/unit time (NA)}}$$

where

$\overline{\text{DT}}$ means that no downtime was necessary

I-B (4) Corrective (DT) MMH ratio (2) =

$$\frac{\text{corrective (DT) MMH/SOH (A)}}{\text{corrective (DT) MMH/SOH (NA)}}.$$

I-B (5) Corrective ($\overline{\text{DT}}$) MMH ratio (2) =

$$\frac{\text{corrective } (\overline{\text{DT}}) \text{ MMH/SOH (A)}}{\text{corrective } (\overline{\text{DT}}) \text{ MMH/SOH (NA)}}.$$

Automation is expected to reduce pre- and postcalibration time per track. The following efficiency ratio will show this potential improvement if it occurs.

I-B (6) Pre- and postcal efficiency ratio =

$$\frac{\text{pre- and postcal SOH/track (A)}}{\text{pre- and postcal SOH/track (NA)}}.$$

Another very significant variable is downtime hours, i.e., time during which the end user suffers a loss of data as a result of human error or equipment failure. At the present time, it is not clear whether we will have more or less downtime with automation. With an automated station, human operating errors should be reduced, but reaction time to repair equipment may be increased. The following ratio will give us an indication of the downtime associated with automated and nonautomated equipment in this test.

I-B (7) Downtime ratio $= \dfrac{\text{downtime hours/SOH (A)}}{\text{downtime hours/SOH (NA)}}$.

The following four cost ratios will be important life cycle cost parameters.

I-B (8) Operations cost ratio $= \dfrac{\text{operations cost/SOH (A)}}{\text{operations cost/SOH (NA)}}$.

I-B (9) Corrective MC ratio =

$$\frac{\text{corrective MC/unit time (A)}}{\text{corrective MC/unit time (NA)}}$$

where

MC = maintenance cost.

I-B (10) M&O cost ratio (1) $= \dfrac{\text{M\&O cost/unit time (A)}}{\text{M\&O cost/unit time (NA)}}$.

I-B (11) M&O cost ratio (2) $= \dfrac{\text{M\&O cost/SOH (A)}}{\text{M\&O cost/SOH (NA)}}$.

All of the above 8 indices and 11 ratios are summarized in Table 1.

D. Other Goals:

In addition to the previously described quantitative goals, there are several very important qualitative goals. These are:

II- (1) To determine advantages and disadvantages of operating in an unattended mode.

II- (2) To list some trouble areas that may require design or operating changes or that may provide inputs to a future automated station design.

II- (3) To try to determine the change in effectiveness of unattended operation due to learning and how rapid this change is likely to progress.

II- (4) To determine the difference in quality of the telemetry received by DSS 13 in unattended operation and that received by DSS 11 or DSS 12 in attended operation.

II- (5) To try to determine the effect on the availability of the telemetry reception system at DSS 13 of adding control equipment.

III. Data Required to Achieve Goals

Twenty-five data types, listed in Table 2, must be collected to achieve the above goals.

Data categories 1-11 are variables appearing in the comparison indices discussed in Section II. Data types 12 and 15 will permit direct comparisons of the quantity and quality of telemetry data received.

For the extra equipment required in DSS 13 to do unattended operation, it is important to have adequate data to evaluate failure rates, mean-time-to-repair, and man-hours needed for repairs. This information must be compiled separately from the corresponding data for the conventional equipment. This accounts for data categories 16–19. Comparison of the results with DSS 11 is provided for by data category 25.

The remaining data types, 20–24, correspond directly with the goals for qualitative evaluation discussed in Subsection IID.

IV. Limitations

The limitations on the conclusions to be drawn from the demonstration are principally caused by the following factors:

(1) DSS 13 is not a standard DSN station, nor are its personnel or hours of operation comparable.

(2) The method of automation used in the demonstration, adding control equipment to existing subsystems, is different from the integration of operating and control equipment that would actually be used to implement unattended operation in the DSN.

(3) The cost to design and implement integrated operating and control equipment from demonstration data cannot be estimated.

(4) Some effects of automation (e.g., on wear or reliability of subsystems) may not show up at all in the demonstration period, or may be masked by normal statistical fluctuations.

(5) Sometimes it will be impossible to distinguish if downtime was caused by standard subsystems, or control equipment added for unattended operation, or the interface between the standard subsystems and the new control equipment.

(6) Segregating an "equivalent" system at DSS 11 to compare with DSS 13 and allocating operators time to that equivalent system will be difficult and may introduce significant variances in the results.

(7) The results from this demonstration test are limited to the effectiveness of unattended operation for the telemetry mode of operation only.

V. Summary

To permit evaluation of the unattended operation demonstration at DSS 13, a data base will be constructed during this demonstration test. The types of data included are those needed to calculate selected indices of performance and costs, using as a basis of comparison the telemetry operations of DSS 11 during the same period.

Additionally, subjective impressions will be recorded during the demonstration in an effort to gain insight into the problems and potential benefits of unattended operation.

Although there are significant limitations upon the extrapolation of the data base to project the costs and benefits of DSN automation, we can expect to learn a great deal from the demonstration.

Table 1. Summary – Indices

	X DSS 13	Y DSS 11 or 12	Ratio X/Y
Index: I-A			
1. Efficiency ratio = $\frac{\text{EUH/unit time}}{\text{SOH/unit time}}$			
2. Productivity ratio = $\frac{\text{EUH/unit time}}{\text{M\&O MH/unit time}}$			
3. End user's hourly M&O cost = $\frac{\text{M\&O cost \$/unit time}}{\text{EUH/unit time}}$			
4. End user's hourly OC = $\frac{\text{OC \$/unit time}}{\text{EUH/unit time}}$			
5. End user's hourly MC = $\frac{\text{MC \$/unit time}}{\text{EUH/unit time}}$			
6. Station hourly M&O cost = $\frac{\text{M\&O cost \$/unit time}}{\text{SOH/unit time}}$			
7. Station hourly OC = $\frac{\text{OC \$/unit time}}{\text{SOH/unit time}}$			
8 Station hourly MC = $\frac{\text{MC \$/unit time}}{\text{SOH/unit time}}$			
Index: I-B			
1. Operations MH/SOH			
2. Corrective (DT) MMH/unit time			
3. Corrective ($\overline{DT}$) MMH/unit time			
4. Corrective (DT) MMH/SOH			
5. Corrective ($\overline{DT}$) MMH/SOH			
6. Pre- and postcal SOH/track			
7. Downtime hours/SOH			
8. Operations cost/SOH			
9. Corrective MC/unit time			
10. M&O cost/unit time			
11. M&O cost/SOH			

Table 2. Data required to achieve overall goals of DSS 13 unattended test demonstration

I. Data required from DSS 13 and DSS 11 or DSS 12 in telemetry mode:

1. End user hours.
2. Station operating hours.
3. Operations manhours.
4. Preventive maintenance manhours.
5. Corrective (DT) maintenance manhours.
6. Corrective ($\overline{DT}$) maintenance manhours.
7. Pre- and postcal station operating hours/track.
8. Downtime hours during operation.
9. Training manhours.
10. Cost per operating manhour.
11. Cost per maintenance manhour.
12. Quality of telemetry data received.
13. Cost of materials used to operate equipment.
14. Cost of materials used to maintain equipment.
15. Hours of telemetry data received, arranged by spacecraft.

II. Additional data required from DSS 13:

16. Corrective maintenance manhours for automated equipment.
17. Corrective maintenance manhours for automating equipment.
18. Failure history and time to repair for automated equipment.
19. Failure history and time to repair for automating equipment.
20. An evaluation of the differences in ease of operation between unattended and attended operations. This information should come from all personnel associated with the operation of DSS 13.
21. A record of all unusual occurrences at DSS 13 whose cause cannot be immediately ascertained, presumably because of remote control.
22. A list of advantages and disadvantages of operating in an unattended mode as they become apparent to operating and supervisory personnel.
23. A list of trouble areas that may be due to the design of an automating piece of equipment or its interface with the equipment it controls.
24. A periodic evaluation of the changes in effectiveness of unattended operation due to learning as the test progresses.

III. Additional data required from DSS 11 or DSS 12:

25. Failure history and time to repair for equipment used for telemetry.

Definitions:

Station operating hours denotes the number of hours that a station is required to be available to conduct DSN activities (usually set at 40, 80, 120, 160, or 168 hours per week).

End user hours denotes the number of station operating hours in which spacecraft data, test, or training information is obtained for the end user.

DT means that downtime resulted from the necessity for maintenance action.

$\overline{DT}$ means no downtime was necessary.

Table 3. Data requirements to achieve each specific goal of DSS 13 unattended test demonstration

Goal indices	Data requirement indices
I-A1	I1, I2
A2	I1, I3, I4, I5, I6, I9
A3	I1, I3, I4, I5, I6, I9, I10, I11, I13, I14
A4	I1, I3, I9, I10, I13
A5	I1, I4, I5, I6, I11, I14
A6	I2, I3, I4, I5, I6, I9, I10, I11, I13, I14
A7	I2, I3, I9, I10, I13
A8	I2, I4, I5, I6, I11, I14
B1	I2, I3
B2	I5
B3	I6
B4	I2, I5
B5	I2, I6
B6	I7
B7	I2, I8
B8	I2, I3, I10
B9	I5, I6, I11
B10	I3, I4, I5, I6, I9, I10, I11, I13, I14
B11	I2, I3, I4, I5, I6, I9, I10, I11, I13, I14
II-1	II 20, 22
2	II 23
3	II 24
4	I 12
5	II 16, II 17, II 18, II 19, III 25