Availability of the DSN Telemetry Data System and Its Major Elements, Including the TWM Assemblies

R. Stevens
Telecommunications and Data Acquisition Office

The DSN Discrepancy Report System records all outages of DSN Data Systems that occur during mission support operations. The recorded outages of the Telemetry Data System for 1981 through 1983 were tabulated and analyzed. The analysis developed availability characteristics of the Telemetry Data System and several of its major elements, including, in particular, the Traveling Wave Maser (TWM) Assemblies. The principal objective of the work was to provide a comparison of availability characteristics of the TWM Assemblies with those of other DSN subsystems and assemblies.

For the three-year period, the Availability of the Telemetry Data System is 99.03%, and its Mean Time to Restore Service is 0.9 hours; the Availability of the TWM Assemblies is 99.83%, and their Mean Time to Restore Service is 2.5 hours.

I. Introduction and Summary

This article presents Mean Time Between Failures (MTBF), Mean Time to Restore Service (MTTRS), and Availability data of the Telemetry Data System and certain of its critical elements, including the Traveling Wave Maser (TWM) Assemblies. The results are based on analysis of Telemetry Data System outages recorded in the DSN Discrepancy Reports for 1981, 1982, and 1983.

The purpose of the article is to support a comprehensive study of TWM Assembly reliability. That study is reported in Ref. 1.

Table 1 contains the most significant results of the analysis.

More than 100,000 station support hours are represented in the data of the table. The Antenna + Pointing Subsystems and the TWM Assembly are the two leading equipment contributors to Telemetry Data System outage time.

The most significant problem with the TWMs is their time-to-restore-service characteristics. Table 1 shows a relatively very long MTTRS (2.5 hours) for the TWMs. The results of a detailed analysis of the 1982 and 1983 DR Monthly Reports are more descriptive of the problem. That sample covers approximately 60K station hours. In that sample, there is a total of 22 times during the two years when telemetry was unavailable for most or all of a pass. Ten of those times were caused by TWM unavailability. The TWM Assembly is currently by far the worst offender in causing long telemetry outages.

Averaged over the last three years, the performance of the Telemetry Data System meets the future MK IVA Availability requirements; it does not meet the future MK IVA service restoration requirements.

The time trajectory of the Telemetry Data System Availability and the related outage hours for 10,000 station support hours are shown in Fig. 1. Station support hours represented by the points of Fig. 1 are: 1981 – 50K hours, 1982 – 30K hours, 1983 – 30K hours. As an example, the planned Voyager Uranus encounter operations require approximately 10,000 individual station support hours. Thus, if the 1986 MK IVA performance is no better than the 1981 - 83 MK III performance, about 100 hours of Uranus encounter telemetry will be lost or significantly degraded by DSN Telemetry Data System outages.

II. Discussion of Analysis

A. Data Source

The raw data were taken from the monthly DSN Discrepancy Report (DR) System. During spacecraft mission support, any interruption in a DSN Data System service is documented by a DR. The DR identifies the faulty DSN Data System and its faulty subsystem and assembly. The DR also gives the duration of service outage.

Data were taken from available monthly DRs for 1982-83 and from the DR data archives for 1981. The 1981 through 1983 period includes support of the Voyager 2 Saturn encounter and subsequent S/C testing and preparations for the 1986 Uranus encounter. The majority of other support was of S/C in extended mission cruise. Overall, the period must be characterized as much less demanding on DSN mission support than what lies ahead after mid-1985.

The prime objective of this study is to compare operability characteristics of TWMs with operability characteristics of other subsystems or assemblies. That objective was met by tabulating and analyzing the outages of the Telemetry Data System. The Telemetry Data System includes the TWM Assembly and other major subsystems and assemblies.

B. Results of Analysis

The summary tabulation of the DR data and its analysis are in Table 2. Footnotes below the table explain the entries.

Failures in the five Telemetry Data System elements that were analyzed, items 2-6 of Table 2, caused 80% of the total telemetry outage time during the three-year period (excluding that caused by RFI). The remaining 20% of the outage time was caused by failures in several other subsystems/assemblies, the effects of adverse weather and procedural errors. No detail analysis of their individual contributions was done.[1]

Figure 2 is a plot of the Table 2 MTBF and MTTRS data for the Telemetry Data System and the five of its system elements. Data for the individual years and for the entire period are plotted. Contours of constant availability are shown. MTBF/MTTRS time-trajectories that move to higher availabilities are generally good, and, conversely, those that move to lower ones are generally not good.

C. Discussion of TWM MTBF and MTTRS

The TWMs occupy a lonely position on Fig. 1. They have a relatively high MTBF, but also a high MTTRS. Actually, the 2.5 hour MTTRS shown is the average of a number of brief outages when backup systems restore service quickly and a number of very long outages when backup is not available and the failed maser has to be fixed.

That characteristic is further illustrated in Fig. 3 by plots of the percentage of telemetry function outage events (ordinate) for which service was restored in less than the indicated time (abscissa). Figure 2 shows the character of the Telemetry Data System and three of its major elements: the Antenna + Pointing Subsystems, the TWM Assembly, and the Telemetry Subsystem. The relatively very high percentage of long outages of the TWMs is evident.

Incidentally, Fig. 2 shows that the median time to restore Telemetry Data System service is approximately 10 minutes. It also shows that 10% of the outages are of 2 hours or more duration.

D. Outages from RFI

Telemetry outages from RFI were considerable, but they did not impact high priority mission support. During the three-year period, RFI caused 251 Telemetry System outages totaling 141 hours – 8 hours in 1981, 23 hours in 1982, 110 hours in 1983 (cf. Table 2).

Detailed analysis of the 1982 and 1983 DRs showed the following: Only missions in extended phase were affected

[1]The weather effects were analyzed for 1982 and 1983. The outages were: Total – 25.2 hrs; from wind – 19.4 hrs; from rain – 3.0 hrs (all X-band S/N degradation); from snow and ice – 2.8 hrs.

(Pioneers 10, 11, 12); there were no X-band outages; essentially all RFI was from external sources (only 17 minutes were identified as station internal); approximately 80% of the events were predicted in advance.

III. Availability, MTBF, and MTTRS: MK IVA Future Requirements vs Current Performance

A. Requirements

The DSN has two basic mission support regimes: mission critical phase and mission cruise phase. An example of the former is Voyager 2 Uranus encounter; an example of the latter is Pioneer 10 extra-solar-system cruise.

The Availability and MTTRS requirements for the MK IVA Telemetry Data System recognize the two support regimes.[2] The basic requirements are:

Spacecraft support regime	Tele. funct. avail.	Tele. funct. restore time
Critical activity	99.0%	30 mins max; 15 mins mean
Normal (cruise) activity	96.0%	30 mins max; 15 mins mean

The requirements recognize that, realistically, performance may be impacted by critical system elements that sometimes cannot be restored to service in less than 30 minutes. Those are elements having inherently long repair times and lacking ready redundancy. The recognized inclusion of any such elements requires justification on a cost vs performance basis during the system design phase.

B. Discussion of Requirements

1. **Cruise support.** The Availability requirement of 96% is probably as high as can be justified. Actually, the dominant factor in the support availability is the limited station tracking time that can be allocated to cruise missions. For the lower priority missions, that results in an average network support availability vs their SIRD requirements of about 50–80%. Providing a Data System Availability greater than the 96% specified would scarcely be felt by those users. Also, informal studies by the TDA Mission Support Office have shown that, usually, the economical approach to providing a significant percentage increase in availability is via more station facilities, rather than via increased system functional availability.

[2]Deep Space Network System Requirements, MK IVA Telemetry System (1984 through 1986), JPL document 832-16 (preliminary), March 15, 1982. (Internal)

Regarding restoration time – except for emergencies and scheduled special events support – the acquisition of cruise mission data is basically not time critical. Probably the requirement shown is more rigorous than need be, although it is a commendable goal for a smoothly operating network.

2. **Critical support.** The Availability requirement of 99% appears realistic. It has a historical foundation with deep space missions, because it appears that that is about what has been provided in the recent past. The figure applies to a single stream, and, in an arrayed configuration of N independent antennas, the Availability implicitly is approximately 0.99^N. For example, the availability of the full capability of a three-antenna array would be approximately 97%. Because the array configurations are applied to the most critical support activities, this suggests that a more ambitious Availability goal may be appropriate in the future.

The Time-To-Restore-Service requirement appears appropriate from a mission support perspective. However, it will be very difficult to meet. If it is met, and the present MTBF is maintained, the single antenna system Availability will be approximately 99.7%.

C. Discussion of Performance

The analysis did not differentiate between critical and cruise S/C support periods. During the time covered by the analysis, the majority of the support was for cruise phase missions.

The average Telemetry Data System Availability determined for the three-year period is 99.0%. That meets the stated MK IVA requirement for critical support.

The average MTTRS determined is 0.9 hours. The 1982–1983 data show a significant number of long outages: e.g., 10% of the outages are greater than 2 hours. These service restoration characteristics are far off of the MK IVA mark.

D. Discussion of the Findings

The leverage on improving the Availability and service restoration performance of the Telemetry Data System is with the Antenna + Pointing Subsystems and the TWM Assemblies. They cause 31% and 18%, respectively, of the total system outage time. The TWMs cause almost half of the system outages longer than 6 hours.

If the MTTRS of the TWMs were improved to the average of the other Telemetry Data System elements examined (0.8 hrs), the System MTTRS would be reduced from 0.9 to 0.8 hours, and its Availability would be increased from 99.0% to 99.2%. Achieving that TWM MTTRS will require full redundancy and exceptionally vigilant maintenance and use procedures.

The current MTBF of the TWMs is very good, relative to other station equipment. It is believed to be practical to double it. Achieving that is especially important for critical event support when TWM redundancy is not available.

Finally, the large antennas and the ability to point them correctly are in a special category. An outage of the antenna causes an outage of all DSN Data Systems that are in use for mission support, not only Telemetry. The subsystems that provide the function are large and complex, have mechanical and structural elements that are time consuming to replace or repair, and full and effective redundancy is very expensive. Nonetheless, their contribution to system outage is prominent, and any improvement that could be made in their availability characteristics would produce a significant improvement in the Telemetry Data System Availability. That is probably also true for the Availability of the other DSN Data Systems.

Reference

1. Stevens, R., and C. P. Wiggins, A Study of DSN Traveling Wave Maser Reliability, *The Telecommunications and Data Acquisition Progress Report 42-78,* Jet Propulsion Laboratory, Pasadena, California, August 15, 1984.

Table 1. Analysis of Telemetry Data System outages

Syst/SS/assy	No. of outages	Outage hours	MTBF (hrs)	MTTRS (hrs)	Availability[a] %
Tele Data Syst	1182	1044	90	0.9	99.03
Antenna + Pointing SSs	354	322	300	0.9	99.70
TWM Assy	75	186	1420	2.5	99.83

[a]Availability = MTBF/(MTBF+MTTRS)

Table 2. Summary of telemetry outage events and resulting MTBFs, MTTRSs, and Availabilities[a]

	Syst/Subsyst/Assy	Time period	Number of outage events[b]	Total outage (hours)	Station hours	MTBF (hours)[c]	MTTRS (hours)[d]	Availability for telemetry (%)[e]
1.	Telemetry Data System (without RFI outages)	1981	500	414	47,700	95	0.83	99.13
		1982	362	294	30,100	83	0.81	99.03
		1983	320	336	29,000	91	1.05	98.86
		All Years	1182	1044	106,800	90	0.88	99.03
2.	Antenna + Pointing SSs	1981	138	107	"	346	0.78	99.78
		1982	129	109	"	233	0.84	99.64
		1983	87	106	"	334	1.22	99.64
		All Years	354	322	"	302	0.91	99.70
3.	TWM Assy	1981	29	65	"	1645	2.24	99.86
		1982	20	55	"	1500	2.75	99.82
		1983	26	66	"	1120	2.54	99.77
		All Years	75	186	"	1424	2.48	99.83
4.	Receiver SS	1981	80	77	"	596	0.96	99.84
		1982	52	29	"	578	0.56	99.90
		1983	58	59	"	501	1.02	99.80
		All Years	190	165	"	562	0.87	99.85
5.	Telemetry SS	1981	66	58	"	723	0.88	99.88
		1982	36	42	"	835	1.17	99.86
		1983	47	13	"	618	0.28	99.95
		All Years	149	113	"	717	0.76	99.89
6.	Facility SS	1981	32	20	"	1491	0.63	99.96
		1982	14	14	"	2210	1.00	99.95
		1983	18	9	"	1610	0.50	99.97
		All Years	64	43	"	1669	0.67	99.96
7a.	Telemetry Data System (with RFI outages)	1981	516	422	"	92	0.82	99.12
		1982	413	317	"	73	0.77	98.96
		1983	504	446	"	58	0.88	98.51
		All Years	1433	1185	"	75	0.83	98.91
7b.	RFI Outages	1981	16	8	"	2981	0.50	99.98
		1982	51	23	"	589	0.45	99.92
		1983	184	110	"	158	0.60	99.62
		All Years	251	141	"	425	0.56	99.87

[a] From DSN DRs for 1981–83. Data from 35 monthly DR reports are included in Table 2 – the September 1982 report was not available.

[b] Only DRs that caused a recorded outage of the Telemetry Data System are included in the tabulation. The outages are recorded to the closest minute, so outages less than 1/2 minute are uncounted. For example, during 1982–83, there was a total of 46 DRs against the TWM Assy that resulted in telemetry outages – those 46 were included in the count. Also, there was a total of 16 Telemetry System DRs against the TWM Assy that did not cause recorded outages – those 16 were not included in the count.

[c] The MTBFs shown are calculated as the number of station tracking hours divided by the number of telemetry outage events for the period considered. That approach implicitly assumes that station hours=telemetry hours, which is not quite true. For example, a small amount of VLBI for mission support does not provide simultaneous telemetry. That results in telemetry hours less than station hours. Conversely, some telemetry is dual channel, which results in telemetry hours greater than station hours. The assumption was used for simplicity; it probably doesn't bias the MTBFs by more than a few percent.

[d] The MTTRSs shown are calculated as the total outage time divided by the number of recorded outages for a period.

[e] The Telemetry Data System Availabilities are calculated as the MTBF divided by the sum of the MTBF plus the MTTRS.

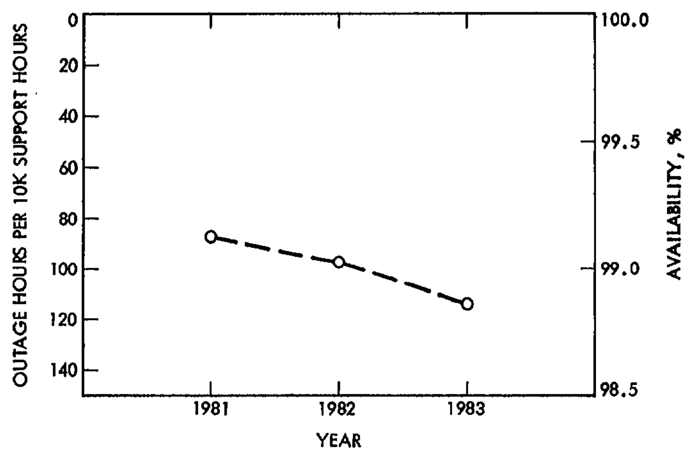

Fig. 1. Availability and outage hours per 10K support hours for DSN Telemetry Data System

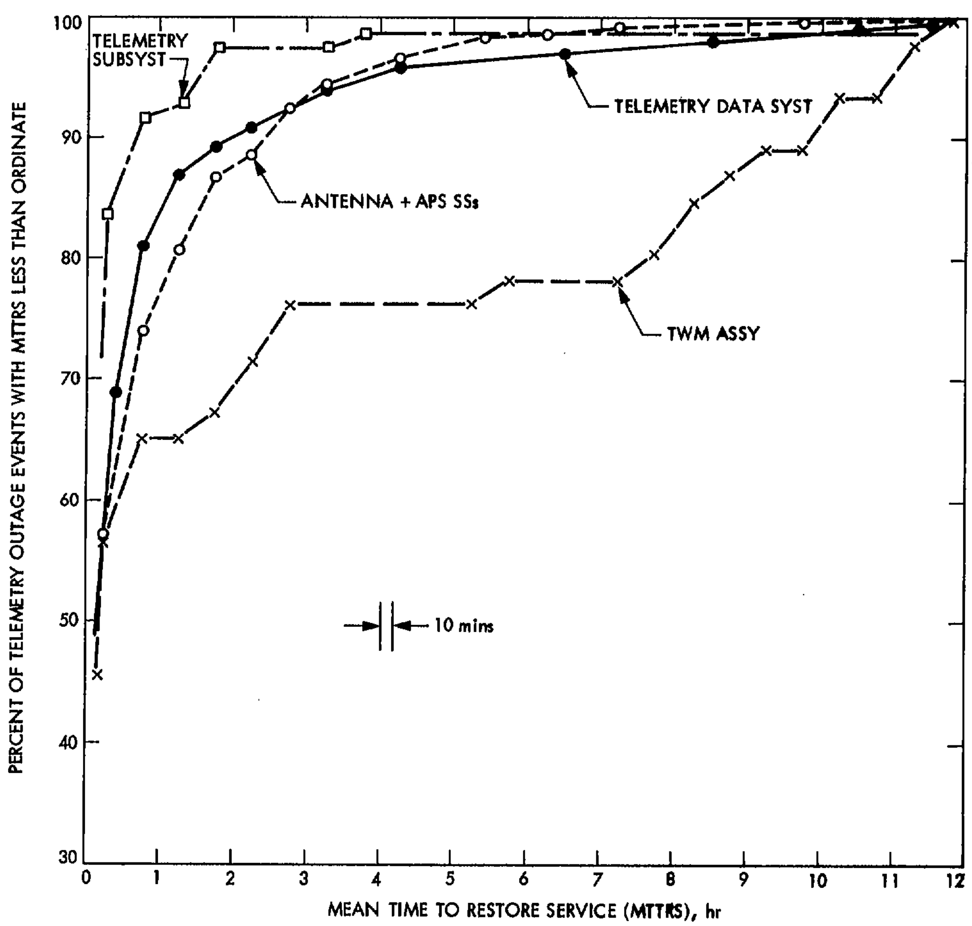

Fig. 2. Mean Time Between Failures, Mean Time to Restore Service, and Availability for DSN Telemetry Data System and its major elements

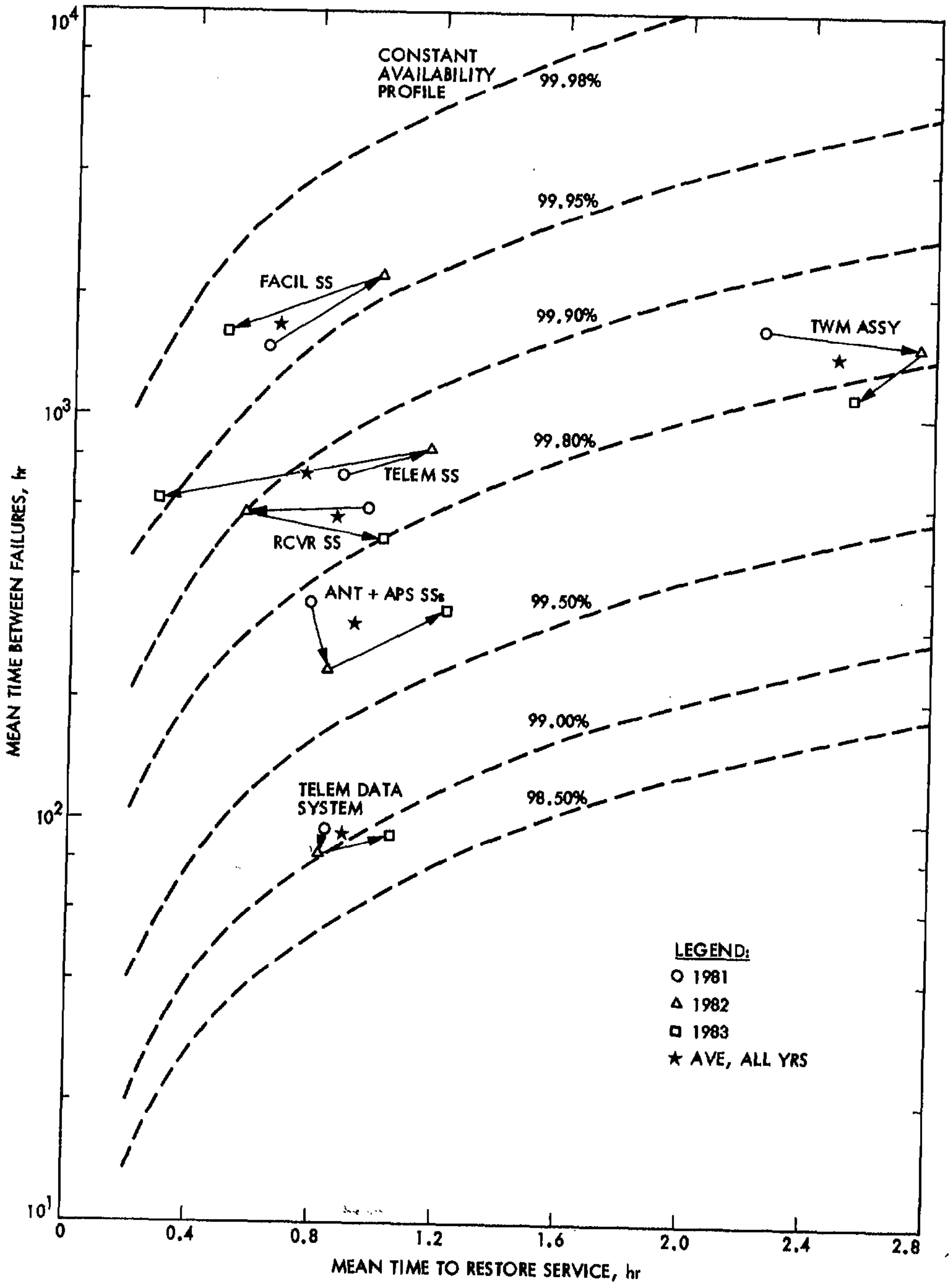

Fig. 3. Percent of telemetry system outage events with Mean Time to Restore Service less than a given time