High-Speed Data System Performance and Error Statistics at 4800 bps

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A survey was conducted from March through June of 1971 to study the performance of the Ground Communications Facility upgraded High-Speed Data System. Operational and other user traffic was used as the basis for the tabulated results. This article describes the conditions under which the data were gathered and draws some conclusions based upon analysis of those data.

I. Introduction

The implementation of the upgraded High-Speed Data System (see Refs. 1 and 2), which introduced a number of new features into the transmission of data, also posed a number of questions. The questions involved the effect that user's operational data would have on total performance, on system reliability and on the occurrence of errors. This article attempts to develop some answers to these questions, using information gathered from real-time operational use of the system, as opposed to extracting measurement data from "controlled" tests. There are clearly a number of pitfalls in using a real-time approach as opposed to controlled tests; however, it is also evident that a more realistic set of conclusions can be drawn.

An explanation of the constraints, problems, and solutions and a tabulation of the actual statistics is developed in the following paragraphs. Wherever possible, any assumptions that were used will be indicated so that a progressive approach to the final results can be properly appreciated. This progressive technique was used for many reasons, among them being the time span involved (from early March 1971 to mid-June 1971), the varied types of activity during that time span, and the need to modify the meaning of observations resulting from the buildup in experience with the system.

The nature of the High-Speed Data System design, with its associated monitoring capability, led to the first limitation of this survey in which only traffic from the DSIF to the SFOF would be used for statistical analysis. The next bound was to use only DSSs 12, 14, 41, 51, 62, and 71 since these stations were engaged in the heaviest activity for both development and flight project support. Finally, all available data would be used to determine the performance of the system, permitting exclusions of data only where evidence could be found that the tabulated counts were erroneous.

II. Sources of Information, Method of Collection, and Analysis

The High-Speed Data System terminal equipment at JPL contains hardware items which provide the means to keep accurate records of the relevant monitored parameters. These data are fed to the GCF Communications Processor (CP) to drive a display for real-time technical control. Simultaneously, the CP maintains a log of this information and builds a summary for printout. Among the number counts contained in these summaries, four were selected as the prime source of statistical data:

(1) Count 1: Total number of data blocks received from a station during a scheduled operational activity.

(2) Count 2: Total number of data blocks received with transmission errors.

(3) Count 3: Total number of data blocks received in an out-of-sync condition.

(4) Count 4: Total time in seconds during which a loss of carrier signal was observed. Each second currently represents the loss of 4 data blocks.

The second source of information was the GCF Technical Controller's log and the Comm Chief's log. These were used to pinpoint anomalies that could adversely bias the summary counts mentioned above. Furthermore, these logs enabled the user of the system/station to be identified for further comparison and evaluation.

The printout of these summaries from the CP was provided on a weekly basis, each weekly report containing entries against each station on a per day basis. With these initial data, the logs were then scrutinized to uncover those periods which were clearly not of any value statistically, such as troubleshooting activities, procedural tests, associated difficulties, etc.

Lastly, there were periods during which the author made personal observations and notes of significant events to be used as a guide in establishing explanations for the later analyses.

These then were the major sources of data; others could be sought out and used on an "as-needed" basis.

The analysis itself was to take the form of an efficiency rating expressed in percent, and developed by summing together all data blocks either lost or received with errors as deficient blocks. Thus,

$$\text{Efficiency, \%} = \frac{\text{Count 1} - [\text{Count 2} + \text{Count 3} + 4\,(\text{Count 4})]}{\text{Count 1}} \times 100\,.$$

It is therefore apparent that a figure of data block transfer efficiency will be the outcome. This method was used rather than a bit error rate since a data block received with errors contained an unknown number of bit errors, and it was virtually impossible to determine the number of bit errors in blocks received in an out-of-sync condition. It also should be evident that the efficiency rating thus established cannot be related to bit error rates without considerably more fine-grained statistical data.

III. Constraints, Problems, and Solutions

Certain constraints have already been indicated—namely that only data streams incoming to the SFOF were being monitored efficiently enough for adequate statistical data and that only specific stations would be used. Of further significant importance is the constraint of limited observational data, not only within the SFOF itself, but also at strategic points along each transmission path which, if available, might lead to the further deletion of erroneous number counts. Experience with this and other data transmission systems, however, leads to the conclusion that certain of these types of discrepancies tend to cancel one another out and can fairly safely be ignored.

The first problem to be faced was how to forecast or predict the results during the early stages of the survey and from them determine what additional information would need to be secured. The answer was readily available since, during the latter part of 1970 and into the first few weeks of 1971, acceptance tests (see Ref. 3) had been conducted in which similar statistics had been gathered. The unknown factor now being introduced was the addition of the user to the system. Such users would inevitably be involved in tests and development activities which of themselves would introduce degraded overall performance from a purely statistical point of view. Yet it could logically be expected that as more use was made of the transmission capability, then a number of performance improvements should be apparent. For instance, procedures would be updated, software deficiencies would be exposed and rectified, hardware in the serial data streams would be modified as required to counter incompatibilities in overall network system designs, and interfaces between the various data sources and the processors in the SFOF would become "cleaner" and therefore more efficient as their weaknesses were found by the necessary tests.

As far as the purely communications portion of the end-to-end transmission of data was concerned, a great effort was made to provide the most efficient technical control and operational use procedures as possible. Extensive training and practice was given to all operators and careful coordination was established with the other agencies who would be involved in use of the high-speed capability.

This leads to the second problem. In using logs and other verbal reports, the reliability of the information contained therein, as it affected the results, was of concern. If taken at face value, then much valuable data could be erroneously deleted or, equally possibly, erroneous data could be inadvertently included. The solution became a matter of judgment and intuition, supported by questioning log entries whenever doubt existed. A substantial gain was made by this method since operations personnel subsequently improved the quality of such entries. To support this reporting activity, a secondary monitoring technique was introduced to deliver limited counts at a shorter sample rate than the daily printout available from the CP.

Yet another problem involved finding a method to feed back the early returns from the survey to the proper agencies, either users or communications operations, so that the indicated inefficiency could be corrected. It was found advantageous to make the user immediately aware, principally by verbal report, of suspected problems. It was also fairly straightforward to correct the activities of communications operations personnel when it was evident that errors either of judgement or of understanding were occurring and thereby causing a loss of efficiency.

Finally, there was the problem of the analysis itself and the results it would be expected to give. Of what value would this survey be, if the end result remained obscure and unintelligible? Thus, the efficiency equation expressed earlier was felt to represent in the simplest terms the sum total of all the data that were gathered.

IV. Tabulated Results and Observations

To make clear the magnitude of the data, some overall totals are given. During this survey, 20,807,024 data blocks were received at the SFOF. (Each data block contains 1200 bits.) This is equivalent to 60 days continuous operation at 4800 bps. A total of 230 separate station operational periods were scrutinized to provide additional background information and eliminate erroneous data.

Table 1 shows the tabulated results over the 13-week period of the survey. First, it is necessary to establish some reasonable standard against which the number counts and efficiency ratings can be judged. To do this we must make some assumptions: the first is that as time passes and experience is gained then human error is reduced to a negligible amount; the second is that software and hardware do not make random errors, therefore will either perform flawlessly or not at all. The next assumptions concern the transmission circuits alone, where it is expected that bit errors will occur in bursts at random, that each burst will create an average of 15 error bits and that such bursts will impact only 1 data block at a time.

Extensive tests on the circuits alone have produced evidence that the average long term bit error rate is 4 bit errors in every 10^5 bits transmitted. From the above assumptions it is clear that 15 bit errors require the transmission of $15/4 \times 10^5$ bits, which in turn equates to 312.5 data blocks of 1200 bits each. Thus, 1 data block will be "lost" in every 312.5 blocks transmitted, which gives an efficiency rating of 99.68% as the long term network average. This could also be viewed as the theoretical upper limit of network performance efficiency. The percentage figures in the right hand column of Table 1 should be compared with this limit.

It is now possible to make several interesting observations. First, it would be logical to expect a steady improvement in overall average efficiency for reasons which have already been given, and certainly the statistics bear this out. The reader is invited to extract the weekly figures for any particular station and observe the variations in performance that occurred. It is somewhat difficult to explain these variations in simple terms, since such a wide variety of activity was occurring. Among the more important events, it is significant to note that during the weeks before the first *Mariner* Mars 1971 launch (May 8), the efficiency climbed to a peak. The inference is that tests and practice performed both by the DSN and the *Mariner* Mars Project with high-speed data had substantially improved the quantity of error-free and loss-free data arriving at the SFOF. The ensuing two- or three-week period reflects the return to test and development activity following the loss of the spacecraft. Again, as *Mariner IX* launch occurred (May 31), a noticeable upsurge was seen, to the extent that in the last week of recorded activity a figure of 99.46% was achieved. This is only slightly below the theoretical limit established earlier, and would indicate that the network as a whole is (or was) operating at just about peak efficiency.

There are clearly a mass of other trends and variations that can be developed and studied from the tabulated data. It is not the purpose of this article to try to consider all of them, since this would require an intimate knowledge of all activities at all locations at all times.

V. Conclusions

The first conclusion is that this survey can be considered an appetizer for what is yet to occur. Second, given good operating procedures, adequate training, and practice, operations personnel can provide the expected complement to a well-designed system. Third, all operations improve as important events approach and occur. Fourth, since the actual measured performance approached the theoretical limit, then the assumptions that were used to arrive at that limit are reasonably accurate.

References

1. McClure, J. P., "Ground Communications Facility Functional Design for 1971–1972," in *The Deep Space Network,* Space Programs Summary 37-66, Vol. II, pp. 99–102. Jet Propulsion Laboratory, Pasadena, Calif., Nov. 30, 1970.
2. Nightingale, D., "High-Speed System Design Mark IIIA," in *The Deep Space Network,* Space Programs Summary 37-66, Vol. II, pp. 103–105. Jet Propulsion Laboratory, Pasadena, Calif., Nov. 30, 1970.
3. Nightingale, D., and McClure, J. P., "Ground Communications Facility System Tests," in *The Deep Space Network Progress Report,* Technical Report 32-1526, Vol. III, pp. 190–192. Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1971.

Table 1. Tabulated error statistics

Week ending	DSS	Data blocks received (Count 1)	Data block errors (Count 2)	Data blocks out of sync (Count 3)	Carrier off time (Count 4)	Efficiency, %	Overall average efficiency, %
Mar 13	12	229199	2923	801	1220	96.25	—
	14	38937	3	1	26	99.72	—
	41	168105	2846	1143	2	97.63	—
	51	225822	3076	739	611	97.23	—
	62	150658	279	634	1114	97.44	—
	71	273121	237	7630	1	97.12	—
	—	—	—	—	—	—	97.03
Mar 20	12	349945	4487	225	217	98.41	—
	14	179457	2276	1517	227	97.37	—
	41	596976	10552	8083	1332	95.99	—
	51	421239	3347	6162	913	96.88	—
	62	77897	780	1033	0	97.67	—
	71	x	x	x	x	x	—
	—	—	—	—	—	—	96.97
Mar 27	12	203530	1420	16466	559	90.11	—
	14	426558	3836	3278	899	97.49	—
	41	325740	1749	8307	35	96.87	—
	51	133716	258	2620	0	97.85	—
	62	327446	1551	3294	0	98.53	—
	71	x	x	x	x	x	—
	—	—	—	—	—	—	96.56
Apr 3	12	221110	1670	21	51	99.14	—
	14	296246	1487	10983	41	96.19	—
	41	257261	1433	3712	0	98.00	—
	51	430757	16429	1952	84	95.66	—
	62	258357	6373	311	498	96.64	—
	71	138882	139	3628	30	97.29	—
	—	—	—	—	—	—	96.81
Apr 10	12	487590	2553	26	303	99.23	—
	14	286038	2325	2446	1038	96.88	—
	41	319415	4796	584	158	98.27	—
	51	104505	439	5039	40	94.76	—
	62	103127	3264	6	0	96.83	—
	71	x	x	x	x	x	—
	—	—	—	—	—	—	98.04
Apr 17	12	594281	1526	438	588	99.57	—
	14	268374	776	3832	836	97.03	—
	41	851391	4463	5710	765	98.45	—
	51	607231	7751	11951	0	96.75	—
	62	402153	1029	10445	0	97.14	—
	71	143268	545	4020	0	96.82	—
	—	—	—	—	—	—	98.86
Apr 25	12	273866	1036	223	524	98.77	—
	14	246426	44	6	186	99.68	—
	41	103851	614	1495	12	97.92	—
	51	403043	3617	78	95	98.99	—
	62	215700	501	42	4	99.74	—
	71	140112	122	6	0	99.91	—
	—	—	—	—	—	—	99.17

Table 1 (contd)

Week ending	DSS	Data blocks received (Count 1)	Data block errors (Count 2)	Data blocks out of sync (Count 3)	Carrier off time (Count 4)	Efficiency, %	Overall average efficiency, %
May 2	12	207099	1158	68	741	97.98	—
	14	338607	162	442	116	99.68	—
	41	496186	2981	3598	507	98.26	—
	51	379374	1084	677	19	99.51	—
	62	195007	262	32	180	99.48	—
	71	107690	183	10	10	99.78	—
	—	—	—	—	—	—	99.02
May 8	12	101259	475	3	0	99.53	—
	14	x	x	x	x	x	—
	41	27780	94	3	0	99.65	—
	51	106946	297	639	0	99.12	—
	62	97181	1114	1187	15	97.57	—
	71	298579	934	41	0	99.68	—
	—	—	—	—	—	—	99.23
May 15	12	167127	186	462	140	99.28	—
	14	85311	91	2	25	99.77	—
	41	134103	493	2873	0	97.49	—
	51	204408	609	77	0	99.66	—
	62	94208	87	4	0	99.90	—
	71	79942	212	11	13	99.66	—
	—	—	—	—	—	—	99.24
May 21	12	x	x	x	x	x	—
	14	69426	92	1801	0	97.27	—
	41	112010	973	818	0	98.40	—
	51	106115	432	267	0	99.34	—
	62	85637	1284	1835	0	96.36	—
	71	117708	368	30	0	99.66	—
	—	—	—	—	—	—	98.39
May 30	12	25978	8	0	0	99.97	—
	14	82592	1827	2018	249	94.14	—
	41	13367	7	0	0	99.95	—
	51	195828	160	2415	1	98.68	—
	62	152594	242	18	29	99.75	—
	71	352146	570	3841	0	98.75	—
	—	—	—	—	—	—	98.51
Jun 6	12	1012827	127	7	65	99.96	—
	14	541496	2497	5	187	99.40	—
	41	1379902	3230	3736	142	99.45	—
	51	1353699	4762	8639	2	99.01	—
	62	123872	170	223	0	99.68	—
	71	214585	264	27	0	99.86	—
	—	—	—	—	—	—	99.46