Operations Analysis of Intermediate Data Record Production in the Viking Era

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As a final step in the operations analysis of Intermediate Data Record (IDR) production capability, dynamic system simulation models have been constructed and executed within the context of the General Purpose Simulation System (GPSS) applications program on the Univac 1108 system. The dynamic models simulate all activity in the DSN ground systems which contributes to data flow characteristics and ultimate throughput times for the IDRs.

Two basic model versions have been constructed, representing alternative configurations at the merge processor: Model A simulates 4 tape-drive units at the merge processor; Model B simulates 8 tape-drive units. It has been confirmed subsequently that the 8 tape-drive configuration will be implemented. Both basic models were "driven," in dynamic simulation runs, by the same "worst case" mission support profile, representing the heaviest possible support requirement during the Viking encounter and planetary experiment period.

Quantitative specification for system parameters, flow logic, and support profiles has been derived from internal JPL documents. Much of the essential specification for dynamic models was immediately at hand as a consequence of earlier "static" analysis studies.

A 4 tape-drive configuration was found to meet a 24-hour throughput time requirement for IDRs. However, the simulated facilities are heavily loaded by the "worst case" profile; therefore, significant deviations from assumed facility availability or operational capabilities may have a critical effect upon performance to the requirement.

With an 8 tape-drive configuration, the Merge Processor easily meets the throughput time requirement. The simulated facilities show no severe utilization

stress, and the configuration provides sufficient input/output capability that recall operations are not delayed on-queue waiting for Merge Processor facility availability (not the case for the 4 tape-drive configuration).

I. Introduction

This article reports the principal results of an operations analysis task which has culminated in the development and application of computer-based dynamic simulation models of data flow in the DSN systems essential to the production of Intermediate Data Records (IDRs). The immediate motivation has been to determine whether specific systems configurations possess sufficient capability to produce IDRs within 24 hours of end-of-pass during heavy demand periods on the network, such as that anticipated during Viking encounter and planetary experiment.

The effort is the logical extension of a series of operational capabilities studies; it has been carried out in the period from March 1 to June 30, 1975, resulting in the completion of working, programmed simulation models of mission data flow from deep space station (DSS) site to IDR production.

The impetus for analyzing the operational capabilities to produce IDRs was provided by a network commitment to provide engineering and science IDRs within 24 hours from the end of the associated station tracking and data acquisition pass. This performance requirement originally arose as a defined requirement of the Viking project. It was subsequently reflected as a general DSN performance requirement in the DSN Operations Control Center Requirements.

Because of anticipated heavy support demands upon the Network during the Viking era, there was concern in the Network Operations organization that such a performance requirement might not be met uniformly using the planned facility configurations. In response to these concerns, several "static" time-line studies were performed. These studies showed that, under ideal conditions and in a "worst case" network loading period, the planned configuration with 4 tape-drive units at the Merge Processor appeared to be adequate to meet the requirement. However, the time-line approach was essentially deterministic in structure and could not admit random events, such as equipment failure or operations variability, just from a practical standpoint. As a result, the bounds on feasible system and operations characteristics which would permit the requirement to be met remained uncertain. The logical continuation of the operational performance

analysis was to construct relatively detailed dynamic models to simulate operations, using a digital computer. This approach makes accessible results that reflect a broader, more complete representation of the system characteristics which will affect performance, including the pertinent random events.

The extended dynamic simulation analysis has been performed using the General Purpose Simulation System (GPSS) program on the 1108 system. This choice was made on the basis of accessibility of the 1108 systems programs and availability of GPSS modeling expertise in the Network Operations organization.

The results of this approach to operations analysis for a complex system operation have the further distinction of demonstrating both the effectiveness and utility of this technique as applied to network operations analysis.

II. Objective

The principal objective of this operations analysis effort has been to develop an effective tool capable of providing the information necessary to determine whether or not designed network control configurations, along with their specified functional design, will meet established requirements. The general criteria for effectiveness which have been followed in this effort are:

(1) The models and analytic methods used should be valid representations of the operating systems and their functional design; further, the representations should be visible such that validity may be assessed.

(2) The analytic models should permit the incorporation of realistic system specification and assumptions, insofar as these are known or can be estimated at any time.

(3) Analysis should be able to respond to engineering and management needs for quantitative evaluation of system design.

(4) Access to results from fully developed analysis models should be timely (a few days) and economical.

(5) The output results of analytic models must be readily interpreted into usual system engineering

descriptive parameters, such as throughput times, element availability, and facility utilization.

III. Operations Analysis Approach

In order to meet the objective, it was decided to use the General Purpose Simulation System (GPSS) application program as the central tool in the operations analysis. The reasons for this choice include:

(1) GPSS is a developed, available user applications program.

(2) Extensive past experience with GPSS is available in the system support group.

(3) GPSS, in its organization and design, is directly suited to the detailed analysis of traffic-flow systems having discrete traffic units.

(4) Use of a powerful and versatile montecarlo system allows effective automation of operations analysis, minimizing the amount of analytic modeling requiring other methods.

Because the Network systems, the data records production, and the systems functional design and specification were at a fairly advanced state, it was anticipated that the requisite specification for quantitative modeling, at a useful level of detail, would be available, thereby shortening that part of the simulation model task which is generally the most consuming of resources; this hope was happily confirmed.

GPSS, in its structure, permits modular development of the elements which will ultimately comprise a model. This feature was used to advantage to develop the various elements which constitute a final model of the overall data records production processes. Furthermore, care has been taken to preserve modularity in the end-product simulation models, thereby increasing model structure generality such that variations in specification or modification of configuration or functional design can be incorporated into production analysis models relatively quickly.

The remaining sections of this report describe the configurations and functional design of the system, the details of model assumptions and specification, and the quantitative results yielded by these simulation models.

IV. Requirements of the Analysis Approach

Because development of the system models themselves "simulates" the design and implementation of a function-

ing system, the requirements which the analyst must meet are the following:

(1) System block diagram. This provides a general "map" of traffic flow from initiation to destination, as well as a general indication of the boundaries of functional independence within the overall system (the "blocks").

(2) Description and diagrams of the functional logic of each element of the system. This must be provided to the level of detail which is comparable with system status and interactions which have a significant effect upon the observable measures of traffic flow.

(3) System and functional element specification. This includes primarily the quantitative specification of processes and events which affect traffic flow, such as traffic density, element capacities, reliability statistics, process times, and priorities.

(4) Description of the system dynamic "drivers." A profile of the input dynamic flow, including description of all associated parameters which distinguish traffic types in significant ways in the functional operation.

These requirements have been met sufficiently to produce the operating models described here. The sources for these requirements are the documents mentioned at the beginning of the memorandum.

Because of these relatively demanding requirements, the initiation of system simulation efforts early in the functional design process often is useful in identifying areas where design details are poorly understood, require more specific attention, or where conflicts and ambiguities exist.

V. Brief Description of the System

Figure 1 depicts graphically the data record flow system, from input to output, which is the subject of the analysis models. The modules of the computer simulation models correspond with the major elements of the system, shown as blocks in the diagram. The basic unit of traffic considered is the data block, so that the dynamic units "flowing" in the simulation models provide for events and model bookkeeping at the data block level (although each dynamic entity during simulation generally represents a collection of data blocks, the objective being economy of required computing without sacrifice of mode validity or flexibility). The first level of distinction among data flow types, introduced at the input, is the triple specification:

mission, deep space station source, and high-speed or wideband type.

VI. Brief Description of the Models

There is currently available for analysis purposes one basic model of the data flow and data records production in the Network for the Viking era. Two versions of this model exist and have been used to generate numerical results: one version provides for 4 tape-drive units at the Merge Processor (Model A); the other provides for 8 tape-drive units (Model B), a network configuration design which arose while Model A was being developed.

The simulation models are modular in structure, with logic modules and their associated assumptions and attributes as, follows:

(1) *DSS Module.* Routes real-time data pass representatives to the Comm Log Processor module, and creates a digital original data record representative for records bookkeeping and later coordination with recall activity. Assumes existence of a single-thread, serial facility which is not interrupted by ancillary activity (such as recall) during real-time pass activity. Any particular complement of DSSs, providing mission support during a time-span of interest, may be represented in the models.

(2) *Comm Log Processor Module.* Provides two basic model functions: network data log (NDL) coordination and bookkeeping, and generation of gap statistics to be associated with each data stream representative. This module is subdivided into three submodules which provide the necessary logical structure: .

    (a) High-Speed (HS) Data NDL Module. Generates NDL representatives and performs the bookkeeping which assigns to each representative a unique identifier and the number of passes associated with it. The current models assume NDLs are recorded according to a fixed schedule which is coordinated with pass support.

    (b) High-Speed Data Module. Associates with each high-speed data stream representative the identifiers of the NDLs which are active during the pass period, and the gap statistics generated for each particular pass.

    (c) Wideband Data Module. Associates with each wideband (WB) data stream representative the number of NDL tapes generated during the pass, and gap statistics for the data stream.

(3) *Network Data Log Transfer Logic.* Provides for direct transfer of NDLs to the Merge Processor, except in the case of Real-Time Monitor outage during production, in which case NDLs are first captured to fill-in the RTM outage, and then transferred to the Merge Processor. Allowance for RTM needs so far affects only the HS data streams in the models, since the precise effect on WB streams was unknown to the author. Wideband logs are therefore transferred directly to the Merge Processor at the end-of-pass.

(4) *Gap Edit and Recall Request Module.* Receives the data stream representatives after the pass, for both wideband and high-speed data. Simulates any additional time required for Gap Lists to be turned over from the monitor (there is currently no active module for monitor subsystems, since it is assumed that monitor does not impinge directly on the data records throughput except in the two ways mentioned). Simulates the process time required to generate edited gap lists and data recall requests. Priority is then assigned the data stream representatives to give data recall activity priority over intermediate data record (IDR) merge processing in competition for facilities at the Merge Processor. The data stream representatives become "recall request" representatives as they pass into the Merge Processor job sequencing chain at this point. A Gap Editor Availability module is associated with the Gap Edit module to represent intervals during each simulated day when the edit operator is not available, and edit jobs which become active or are waiting at these times are further delayed until the edit operator resumes activity.

(5) *Merge Processor Module.* Provides for the logical control and simulation of recall data tape production and data merge for IDR production. In order to accomplish these functions, the module is partitioned into several logical units:

    (a) Recall Chain. Receives any entering recall task which must wait for available facilities. Strict control of task sequencing is maintained by use of a "chain" entity. Recall tasks have priority over merge tasks. Within the recall class, the order is first-in first-out.

    (b) IDR Chain. Receives merge tasks which must wait for facilities. Ordering within the merge class is first-in first-out.

    (c) Three additional chain entities, NDL, Merge, and Temp, provide ordering and flow control for

HS NDL representative transactions at the Merge Processor.

(d) Tape-drive unit facilities represent "single-thread" operation of the tape drives in both models. Jobs awaiting facility availability on the Recall or IDR chains will wait until sufficient tape-drive facilities are available before proceeding to execute task simulation at the Merge Processor.

(6) *Reliability/Availability Modules.* In addition to the Gap Editor availability module, there are also present in the current models reliability simulation modules for Real-Time Monitor (insofar as the flow of NDLs is affected), Merge Processor, and Merge Processor Tape-Drive Units.

VII. Description of the Dynamic Drivers

The discrete dynamic entities in GPSS models are referred to as "transactions." Transactions, which simulate the traffic units in a dynamic traffic-flow simulation, may be assigned and carry with them various parametric values of significance to the particular model. In this model, three classes of transactions are generated as the dynamic system drivers:

(1) Data pass representative transactions.

(2) HS data NDL transactions.

(3) Drivers for the various unreliability/availability modules.

VIII. Data Pass Representatives

The models are designed to allow for an arbitrary number of DSS-mission-data type generators. The current models incorporate 14 distinct "data pass" representatives of this type. The module which generates these dynamic entities associates with them:

(1) Pass start time.

(2) Pass duration.

(3) DSS identifier.

(4) Project identifier.

(5) Data type identifier (high speed or wideband).

(6) Data rate for telemetry stream represented.

Each pass generator may initiate passes according to a predetermined and specified view period profile. In the current versions, a simple, fixed view period profile is assumed wherein each pass for a particular stream has a fixed duration and successive passes begin 24 hours after the beginning of the next preceding pass, for the whole interval simulated. All these simplifying assumptions may be relaxed in order to incorporate more realistic view period profiles, if there are cases in which these parameters have a significant effect upon the outcome. Table 1 summarizes the complement of telemetry data streams represented in the current models. The simulator clock unit is *minute.*

The profile models are designed to represent a "worst case" support load during Viking encounter. Time can be simulated continuously in any model run up to 90 days. Driver profiles may be constructed to simulate support schedules and data profiles which change over time.

IX. High-Speed Data Network Data Log Representatives

The production of wideband data network data logs (NDLs) at the Comm Log Processor appears to be heavily dependent upon each WB data pass, since, otherwise, none are produced. Therefore, it is not necessary to simulate a separate NDL entity flow; all necessary information can be carried along by each WB data pass transaction. High-speed data NDLs, on the other hand, may be produced successively according to a schedule which is not dominated by any single data pass consideration; because of this essential "pass-independence," the HS NDLs must be represented as separate model entities. The NDL module generates a sequence of contiguous NDLs according to a specified schedule. The NDLs and the HS data passes which should be associated with them (i.e., passes which are actively yielding HS data during the recording time of the NDL) are mutually coordinated in the model by cross-indexing the NDL identifiers to associated data pass transactions.

Beginning at model "epoch," the HS NDLs have record times of 7, 9, and 8 hours, in succession, a sequence which is periodic throughout model runs. Since data passes and HS NDL cycles are periodic with periods of 24 hours, the NDL cycle has been chosen to yield a convenient recording schedule. Figure 2 shows graphically the association between HS NDLs and telemetry stream data passes recorded on them.

The HS NDLs pass from active "recording" status to:

(1) Merge Processor to await IDR production for each of the data streams associated, or

(2) The "Real-Time Monitor (RTM)–System Performance Record (SPR) fill-in" model if an RTM outage

has occurred during the active time of the NDL, then to (1).

X. Drivers for Unavailability Modules

Each reliability or availability module in the models generates its own independent dynamic event driver. The event driver controls failure event initiation (or other facility unavailability) for its particular associated system element. It also controls the associated down-time for each of these events. Both the intervals between outage and outage duration are sampled according to analyst-specified distributions. Table 2 summarizes the various down-time and unavailability events associated with the current models.

XI. General Model Assumptions and Model Specification

A. General Assumptions and Model Features

(1) Telemetry data streams, including post-pass recall, are simulated according to the system-driver time table and rates given in Table 1. These streams and their interactions with the functional systems are the most directly related to the throughput times for IDR production. Monitor, command, and metric data streams are not specifically simulated as distinct dynamic entities, but are maintained as a cumulative traffic composite in order to be accounted for in the production of HS data IDRs.

(2) Recall play-back begins after the real-time pass (reference documents indicate that this is a valid assumption).

(3) Recall tape production has priority over IDR merge processing.

(4) For each data pass, the merge process may begin only when all associated NDLs and the Recall Data tape are available at the Merge Processor job sequence chains.

(5) Each of the distinct data passes represented is associated one-to-one with production of a separate IDR.

B. Model Specification

(1) Input data specification for the data passes has been described above.

(2) Gap simulation for wideband data streams (all).

    (a) Time between gaps: Poisson distributed with mean 1 gap/414 seconds.

(b) Gap length: Poisson distributed with mean 10 wideband data blocks (WBDB)/gap.

Result will be: expected number of gaps in 12 hours = 104; expected number of blocks lost = 1040, each 12-hour pass.

(3) Gap simulation for high-speed data streams (all).

    (a) Time between gaps: Poisson, with mean 1 gap/800 seconds.

    (b) Gap length (in high-speed data blocks HSDB): Poisson, with mean 2 HSDB/gap, Result: expected number of gaps in 12 hours = 54; expected number of blocks lost = 108, each 12-hour pass. These statistical parameters for HS data are hypothetical. For the 11 data streams included, these statistics yield a weighted average 0.75% recoverable data loss over all streams (99.25% of HSDB received at Comm Log Processor in real-time, ignoring nonrecoverable losses). The data quality statistics for the simulation are summarized in Table 3.

(4) Numbers of data blocks recorded per Digital Original Data Record (DODR):

    (a) High-speed DODR: 85140 HSDB

    (b) Wideband DODR: 54750 WBDB

(5) SPR "outages" (Model is not based on quantitative data, since none are available; the only statement in the reference documents claims that outage is a "fairly infrequent event"):

    (a) Time to failure: Poisson, with mean 360 hours (15 days).

    (b) Times to recover: Uniform on [13, 17] minutes (average: 15 minutes).

(6) Gap list edit time. Computed as the sum of:

    (a) 0.2 minutes per gap.

    (b) "Variability" factor, uniformly distributed on [0, 0.05 × (number of gaps)]; with mean 0.025 × (number of gaps) minutes.

    (c) Typical values for edit times: for 50 gaps, 11.25 minutes; for 100 gaps, 22.5 minutes.

(7) Time to recall data from DSS (assuming facilities at both ends are acquired and ready):

    (a) 15 ± 5 minutes "set-up" time (uniform on [10, 20]).

    (b) 8 minutes read time per DODR.

    (c) 2.4 minutes rewind time per DODR.

(d) 2 ± 1 minute "tape handling" time per DODR (uniform on [1, 3]).

Table 4 contains average recall times for all characteristic data streams.

(8) Wideband data pass merge process time:

(a) Number NDLs per pass: (number WBDB)/ 79660.

(b) Read time per NDL: 7.27 min.

(c) Rewind time per NDL: 2.4 min.

(d) Tape handling time: 2. min.

(e) Write time. Assumes 11616 Logical Data Records (LDRs) per IDR tape (11616 × 5 WBDB/ LDR = 58080 WBDB/IDR tape). Write rate: 0.0356 sec/LDR, 6.9 min/IDR.

Typical merge process times which result:

DSS 14: 334 minutes (5 hours 34 minutes).

DSS 43 and 63: 225 minutes (3 hours 45 minutes).

(9) High-speed data pass merge process time:

(a) Read time per NDL: 7.27 min.

(b) Rewind time per NDL: 2.4 min.

(c) Tape handling time: 2 min.

These factors are applied to the number of NDLs on which the HS data for the particular pass are written; (a) and (b) should apply to the actual (fractional) number, and (c) applies to the integral number of tapes represented. In the case of HS NDLs, HS data pass terminations generally do not coincide with the end of the last NDL written upon. For the model, it was found that an average (over all data passes) fraction of NDL not read (after pass termination) is about 0.125 of the total NDL time. Therefore, a compensating factor has been incorporated into the general formula used to compute HS merge times, so that (a) and (b) become 0.94 × 7.27 min and 0.94 × 2.4 min, respectively.

(d) Write time: 0.02315 sec × number (LDRs).

(e) Rewind: 2.4 min × number (IDRs).

(f) Tape handling: 3 min × number (LDRs) where:

Number (LDRs) = (total HSDBs)/5

Number (IDRs) = (total HSDBs)/93430.

Some typical HSD merge process times which result are:

DSS 11: 32 min.

DSS 12: 28.4 min.

DSS 14(A): 33 min.

In case Network Operations Control Center (NOCC) were required to verify the computer compatibility of written IDR tapes, it is assumed that verification would be performed at the Merge Processor as a sequential part of the IDR production operation. The verification process model assumed by the analyst is: read IDR tapes, rewind IDR tapes. A separate simulation model version was created which includes the verification process, the additional process times having been specified as follows:

(10) Wideband IDR verification:

(a) Read-to-verify: 0.03565 sec per LDR.

(b) Rewind: 2.4 min per IDR tape.

(c) Tape handling: 3 min per IDR tape.

Verify times computed by these formulas are:

DSS 14: 140 min.

DSS 43 and 63: 94 min.

(11) High-speed IDR verification:

(a) Read-to-verify: 0.02315 sec per LDR.

(b) Rewind: 2.4 min per IDR (or fraction).

(c) Tape handling: 2 min per IDR tape.

(12) Job sequence policy at Merge Processor:

(a) Recall tape processing has priority over merge processing; i.e., if there are any recall jobs waiting on the job chain, they will always take precedence over merge processing.

(b) Within the two priority classes, jobs are sequenced according to oldest waiting job first.

The performance at the Merge Processor, compared with facility utilization and requirement to produce IDRs within 24 hours from end-of-pass, is essentially dependent upon the job sequencing policy. Nearly any quantifiable policy could be implemented as a policy model.

As of this writing, no attempt has been made to incorporate modified sequencing policies into the model runs.

XII. Simulation Results

Simulation runs have been made with both basic versions of the Automatic Total Recall System/IDR models, i.e., Model A having 4 tape-drive units, and Model

B, having 8 tape-drive units. These simulation runs have simulated 3 and 10 days support to IDR production, using the mission profile defined in a previous section. These results are tabulated in Tables 5 and 6. Other cases have been simulated, especially cases which include variable mission data profiles. These data are not included here, however, since they would not add anything significant to this summary.

Model output data in Table 5 show that the Merge Processor with 4 tape-drive units available for input/output (I/O) operations can perform within the network requirement for finished IDRs within 24 hours of end-of-pass. Obviously these results are qualified by the validity of the assumptions used (and described in a previous section). Model output statistics show the tape-drive utilization factors to be relatively high, the implication being that, in order to perform to requirement, it is necessary that a very tight control be maintained on the job sequencing schedule for 24 hours each day that such a support level is required. Furthermore, the reader is reminded that, although the model support profile may be a realistic "worst case," other model features to which throughput time is quite sensitive may be lenient; e.g., no consideration for possible wait on communications link outages, etc. These features are easily modified in the models, should there be data available to indicate that further analysis would be of some value. Therefore, it is hoped that the reader may give serious consideration to the validity of the model parametric specification.

Table 6 shows that a Merge Processor facility with 8 tape-drive units handles the load of the support profile rather easily (although model output "bookkeeping" statistics indicate that all eight units would be in use on occasion, if the job-sequencing policy were to process jobs as soon as they enter the facility, and I/O units are available).

A significant feature of the 8 tape-drive version is that it permits two simultaneous, independent merge process jobs to be done, with margin to handle one or two recall jobs. The 4 tape-drive version is strictly limited to "single-thread" merge processing.

A further analytic result which may be of some operational significance is that, on the 8 tape-drive version, no recall job waits on queue for I/O facilities, whereas, on the 4 tape-drive version, as many as three recall jobs may wait on queue at some time before I/O facilities are available for acquiring recalled data.

With the further requirement for IDR compatibility verification imposed upon the Merge Processor, under the quantitative assumptions made for verification processing times, the 4 tape-drive unit Merge Processor is no longer able to perform adequately to the 24-hour throughput requirement. The results are summarized in Table 7. Furthermore, additional model statistical output shows that I/O facilities used for merge processing (as well as recall) have a joint utilization factor over 0.92, a situation which indicates that the process is unstable and that, therefore, throughput becomes worse with increasing time.

The 8 tape-drive Merge Processor, with the additional burden of verification of IDR tapes, still meets the 24-hour requirement without difficulty; furthermore, the process remains quite stable. The throughput time statistics for 10 days simulated passes are displayed in Table 8.

Within the limitations of the initial model assumptions which have been adopted for this study and demonstration, it may be concluded that:

(1) Without the burden of IDR verification, the 4 tape-drive configuration Merge Processor would likely perform within the 24-hour throughput bound.

(2) With verification as an additional requirement, the 4 tape-drive-equipped processor is not capable of meeting requirements adequately.

(3) The 8 tape-drive configuration will meet the throughput requirement under all conditions considered thus far.

Table 1. Specification of model DSS data streams

DSS[a]	Data stream supported	Telemetry data rate, blocks/min	Data type (HS or WB)	Additional data rate (MON, TRK, CMD), (blocks/min)	Initial pass epoch[b]	Pass duration, min	Time between passes, min
DSS 11	Viking Orbiter (VO) Engr	12	HS	59	0	720	1440
DSS 12	Pioneer (PIO)	20	HS	17	1110	660	1440
DSS 14(W)	VO Sci	900	WB	0	0	720	1440
DSS 14(A)	VO Engr	24	HS	59	0	720	1440
DSS 14(B)	Viking Lander (VL) Sci + Engr	67	HS	14	30	180	1440
DSS 42	VO Engr	12	HS	59	450	720	1440
DSS 43(W)	VO Sci	600	WB	0	450	720	1440
DSS 43(H)	VO Engr	12	HS	59	450	720	1440
DSS 44	PIO	20	HS	17	270	360	1440
DSS 61	VO Engr	12	HS	59	990	690	1440
DSS 62	PIO	20	HS	17	540	660	1440
DSS 63(W)	VO Sci	600	WB	0	990	690	1440
DSS 63(A)	VO Engr	24	HS	59	990	690	1440
DSS 63(B)	VL Sci & Engr	67	HS	14	30	180	1440

[a](W) is designator for wideband data channel; (A), (B), and (H) are designators for high-speed data channels.

[b]Relative to simulated clock time, in minutes.

Table 2. Time table of events which compete for facility availability

Model facility	Event	Mean time to event	Mean duration, min	Model facility availability
Real-Time	Monitor outage	15 days		
Monitor	Downtime (at outage)		15	0.9993
Gap Edit Operator	Edit Operator "out"	4 hours	20	0.923
Merge Processor	Processor failure	10 days	20	0.9986
Tape-drive units (for 4 units)	Drive unit failure (each unit)	40 days	15	0.999 (facility)
(for 8 units)		80 days (each unit)	15	0.999 (facility)

Table 3. High-speed data loss during real-time operations (recoverable science and engineering telemetry)[a]

DSS[b]	Pass duration, min	Telemetry data rate, blocks/min	Total telemetry data blocks per pass	Blocks lost (avg) (recoverable)	Comm quality ratio
DSS 11	720	12	8640	108	0.9875
DSS 12	660	20	13200	99	0.9925
DSS 14(A)	720	24	17280	108	0.9938
DSS 14(B)	180	67	12060	27	0.9978
DSS 42	720	12	8640	108	0.9875
DSS 43(H)	720	12	8640	108	0.9875
DSS 44	360	20	7200	54	0.9925
DSS 61	690	12	8280	104	0.9875
DSS 62	660	20	13200	99	0.9925
DSS 63(A)	690	24	16560	104	0.9938
DSS 63(B)	180	67	12060	27	0.9978

[a]Weighted average data quality over all HS streams: 0.9925.

[b](A), (B), and (H) are designators for high-speed data channels.

Table 4. Expected recall times for high-speed and wideband data streams

DSS[a]	Number DODRs	Data type	Expected recall time, min
11, 12, 14 (A), 14 (B), 42, 43 (H), 61, 62, 63 (A), 63 (B)	1 (for all HS passes)	HS	25.9
14 (W)	12	WB	167.8
43 (W)	8	WB	116.2
63 (W)			

[a](A), (B), and (H) are designators for high-speed channels; (W) is designator for wideband data channel.

Table 5. Throughput time statistics to completed IDR: Model "A" (4 tape-drive units at Merge Processor) 3- and 10-day pass support simulated

DSS[a]	Number of passes[b]		Mean throughput time, hours		Standard deviation, hours	
	3 days	10 days	3 days	10 days	3 days	10 days
DSS 11	3	10	11.00	10.3	0	1.73
DSS 12	3	10	5.00	6.4	1.41	1.63
DSS 14 (W)	3	10	9.67	10.0	0.47	0.77
DSS 14 (A)	3	10	12.67	10.9	1.70	2.47
DSS 14 (B)	3	10	5.00	6.6	0	1.56
DSS 42	3	10	8.67	9.0	0.47	0.45
DSS 43 (W)	3	10	7.67	7.9	0.47	0.30
DSS 43 (H)	3	10	9.00	9.0	0	0.45
DSS 44	3	10	12.00	11.0	0	2.00
DSS 61	3	10	6.00	7.3	1.41	1.62
DSS 62	3	10	8.67	9.0	0.47	0.63
DSS 63 (W)	3	10	8.67	7.7	1.25	1.35
DSS 63 (A)	3	10	5.67	7.1	0.94	1.37
DSS 63 (B)	3	10	4.33	6.5	0.47	1.69

[a](A), (B), and (H) are designators for high-speed data channels; (W) is designator for wideband data channel.

[b]Profile generator starts, at time 0, on a "blank" system; at the end of three and ten days, respectively, the pass profile generator is "turned off" and the simulated systems complete tasks remaining without additional loading.

Table 6. Throughput time statistics to completed IDR: Model "B" (8 tape-drive units at Merge Processor) 3- and 10-day pass support simulated

DSS[a]	Number of passes[b]		Mean throughput time, hours		Standard deviation, hours	
	3 days	10 days	3 days	10 days	3 days	10 days
DSS 11	3	10	6.00	5.7	0	0.90
DSS 12	3	10	4.00	4.0	0	0
DSS 14 (W)	3	10	9.67	9.8	0.47	0.40
DSS 14 (A)	3	10	6.00	5.6	0	1.20
DSS 14 (B)	3	10	4.67	4.6	0.47	0.49
DSS 42	3	10	6.33	6.2	0.47	0.40
DSS 43 (W)	3	10	7.00	7.0	0	0
DSS 43 (H)	3	10	6.00	6.0	0	0
DSS 44	3	10	7.00	6.5	0	1.50
DSS 61	3	10	5.00	4.9	0	0.30
DSS 62	3	10	6.00	6.0	0	0
DSS 63 (W)	3	10	7.00	6.9	0	0.30
DSS 63 (A)	3	10	4.67	5.0	0.47	0
DSS 63 (B)	3	10	4.33	4.6	0.47	0.49

[a]See footnote a, Table 5.

[b]See footnote b, Table 5.

Table 7. Throughput time statistics for IDR: Model "A" with verification processing 10-day support simulated

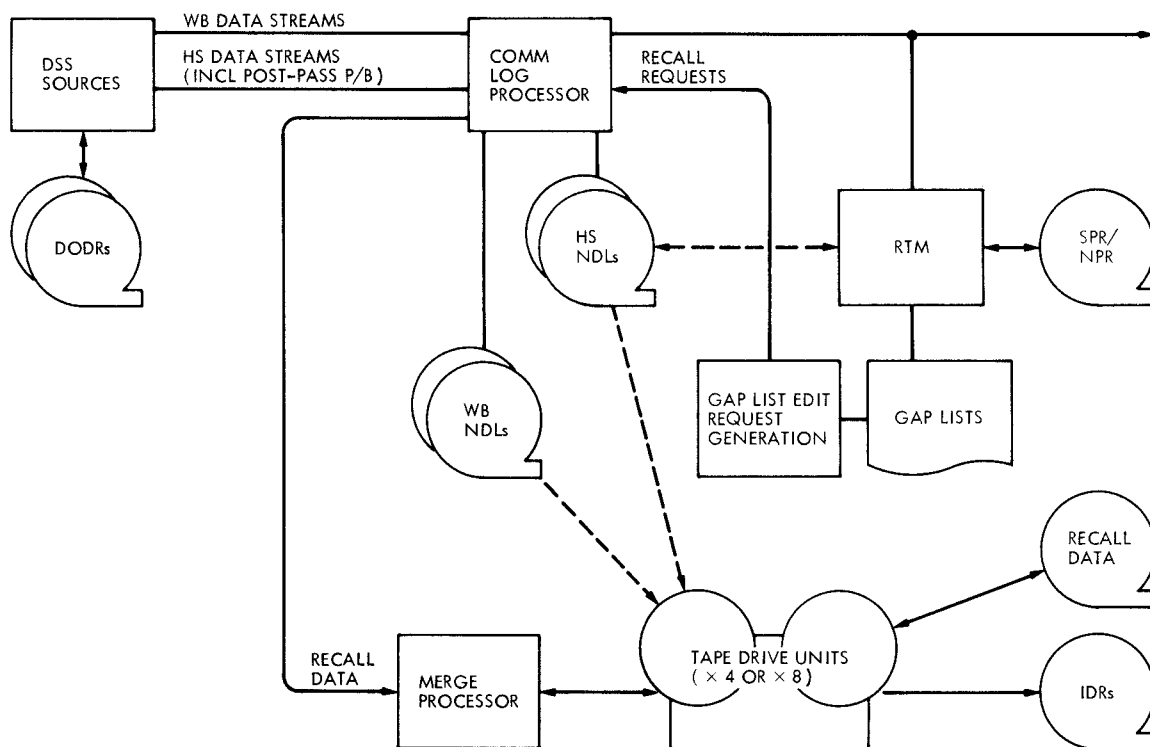| DSS[a]	Number of IDRs[b] completed	Mean throughput time, hours	Standard deviation, hours	Range of throughput times, hours
DSS 11	10	12.20	3.89	6–18
DSS 12	9	15.44	4.19	10–21
DSS 14 (W)	10	19.20	3.99	12–25
DSS 14 (A)	10	12.40	3.53	7–17
DSS 14 (B)	10	11.10	3.48	5–16
DSS 42	10	14.60	4.80	7–23
DSS 43 (W)	10	18.50	3.75	12–23
DSS 43 (H)	10	15.10	5.01	8–24
DSS 44	10	12.50	3.59	7–17
DSS 61	10	14.70	4.67	8–22
DSS 62	10	18.20	3.92	13–24
DSS 63 (W)	9	16.78	3.85	9–21
DSS 63 (A)	9	14.44	4.79	8–22
DSS 63 (B)	10	11.10	3.70	4–16

[a]See footnote a, Table 5.

[b]See footnote b, Table 5.

Table 8. Throughput time statistics for IDR: Model "B" with verification 10-day pass support simulated

DSS[a]	Number of IDRs[b] completed	Mean throughput time, hours	Standard deviation, hours	Range of throughput times, hours
DSS 11	10	5.9	1.04	3–7
DSS 12	10	4.9	0.30	4–5
DSS 14 (W)	10	12.1	0.30	12–13
DSS 14 (A)	10	6.3	1.49	2–7
DSS 14 (B)	10	4.8	0.40	4–5
DSS 42	10	6.5	0.50	6–7
DSS 43 (W)	10	8.7	0.46	8–9
DSS 43 (H)	10	6.5	0.50	6–7
DSS 44	10	6.6	1.20	3–7
DSS 61	10	5.3	0.64	4–6
DSS 62	10	6.8	0.40	6–7
DSS 63 (W)	10	8.5	0.50	8–9
DSS 63 (A)	10	5.5	0.50	5–6
DSS 63 (B)	10	4.7	0.46	4–5

[a]See footnote a, Table 5.

[b]See footnote b, Table 5.

Fig. 1. Network data records block diagram

END-OF-PASS   (ALL DSS/DATA STREAM PASSES)

LAG TIME; 10-min AVERAGE

GAP EDIT TIME
        AVERAGE: $0.225 \times$ (NUMBER OF GAPS) min

LAG TIME; 5-min AVERAGE

RECALL TIME
        AVERAGE: $13 + 1.5 \times$ (NUMBER DODR TAPES) $+ 11.4$
                  $\times$ (FRACTIONAL NUMBER DODRs) min

LAG TIME; 10-min AVERAGE

AND ← NDL AND FACILITY AVAILABILITY

MERGE TIME
        AVERAGE: { HS: $11.0 \times$ (NUMBER NDLs) $+ 0.000135$ (HSDB) $+ 3$ min
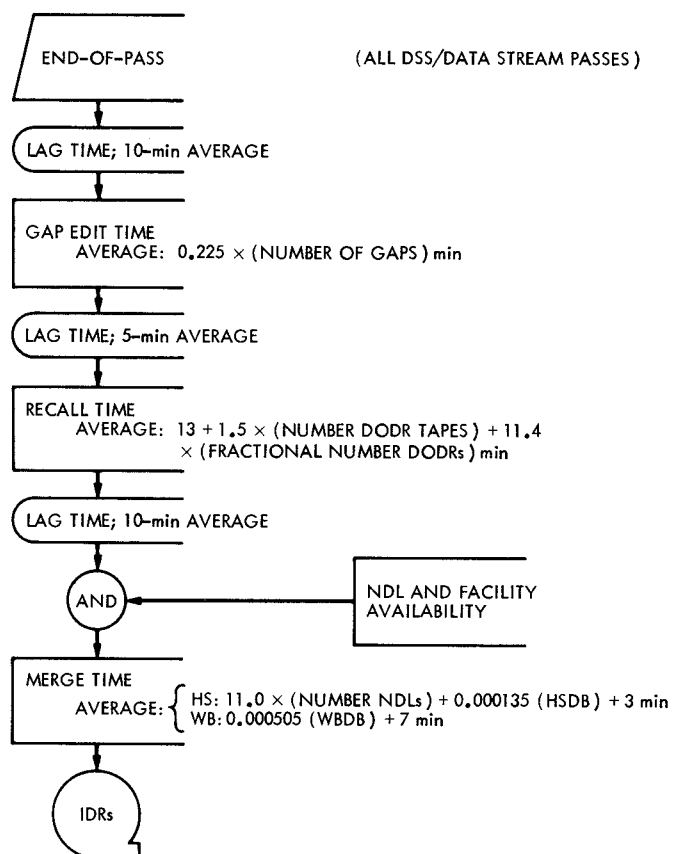   WB: 0.000505 (WBDB) $+ 7$ min
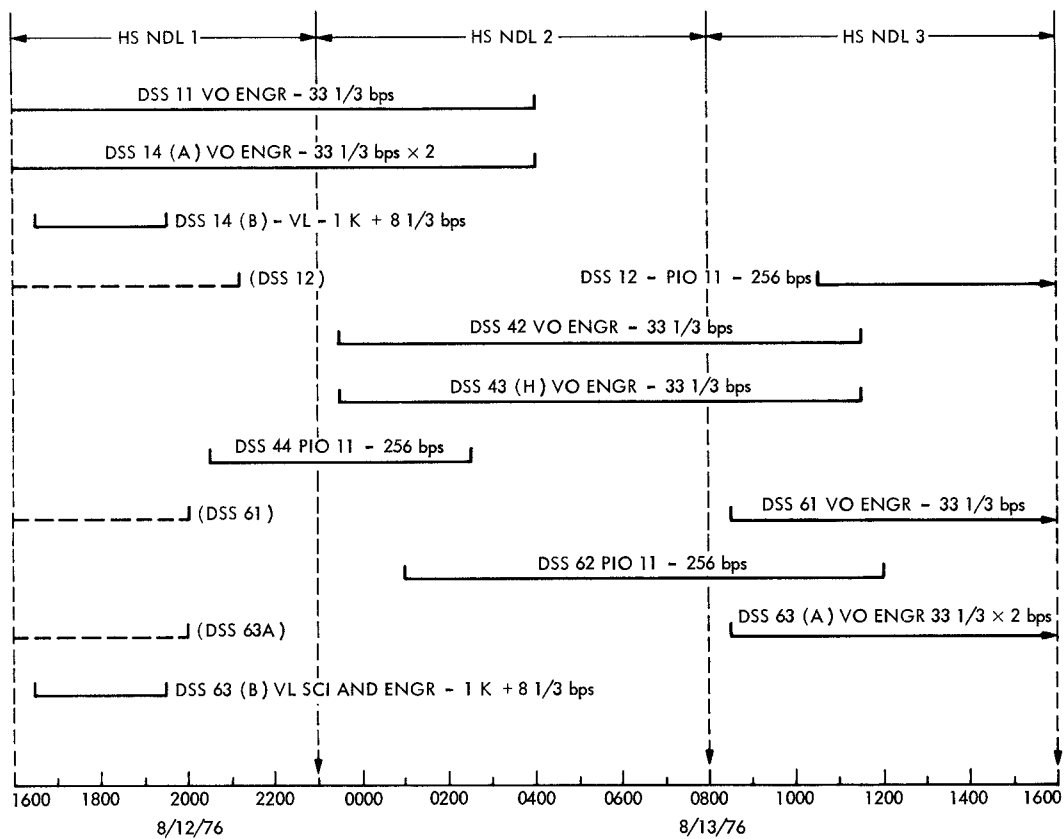
IDRs

Fig. 2. Flow sequence to IDR production

Fig. 3. High-speed data passes and high-speed data NDL (telemetry data)