ENHANCED METHODS FOR DETERMINING OPERATIONAL CAPABILITIES AND SUPPORT COSTS OF PROPOSED SPACE SYSTEMS

FINAL REPORT
June 1993

Prepared for

National Aeronautics and Space Administration

Langley Research Center

Under

Grant No. NAG-1-1327

Prepared by

Charles Ebeling

University of Dayton

Engineering Management and Systems Department

300 College Park

Dayton, Ohio 45469-0236

Table of Contents

List of Figures

List of Tables

Chapter I

Introduction

A. Background

This report documents the work accomplished by the University of Dayton, School of Engineering, under NASA grant NAG-1-1327 during the first two years of the research effort. Work accomplished during the first year is also documented in the report entitled "The Determination of Operational and Support Requirements and Costs during the Conceptual Design of Space Systems," dated June 18, 1992 [23].

The purpose of the grant is to provide support to NASA in predicting operational and support parameters and costs of proposed space systems. Specific research objectives include:

(1) the development of a methodology for deriving reliability and maintainability (R&M) parameters,

(2) based upon R&M estimates determine operational capability and support requirements,

(3) the identification of data sources and the establishment of an initial data base to support the methodology, and

(4) implementation of the methodology through the development of a comprehensive computer model.

B. Summary of Research Effort

The first year's research developed a methodology for deriving reliability and maintainability parameters of conceptual space vehicles and for applying these parameters in establishing manpower and spares requirements. The methodology was based upon the use of regression analysis to establish empirical relationships between aircraft performance and design specifications and corresponding mean time to failures and mean repair times. Adjustments were then made to account for the different environment in which space vehicles must operate. This methodology was applied to a large data base consisting initially of 35 military aircraft and implemented through the use of a personal computer (PC) model.

The second year focused on three major areas:

(1) enhancements to the methodology,

(2) increased scope of the model, and

(3) software improvements.

Additional work also included the transfer of all input and computed data files into an EXCEL spreadsheet format for easy access by NASA personnel. This will support future updates to the equations and parameters utilized by the model.

Enhancements to the methodology include:

(1) Performing the analysis at a lower work breakdown structure (WBS). This increased the number of subsystems addressed by the model from 16 to 33. An avionics roll-up is also performed. Additional regression analysis was performed at the lower level to develop new parametric equations.

(2) Incorporating subsystem redundancy into the reliability calculations including a more general k out of n redundancy for engine, power, and avionics subsystems.

(3) Computing subsystem and system reliabilities at key milestones during a mission. These include reliability at launch, at booster separation, at orbit insertion, at reentry, and at mission completion.

(4) Subsystem weights may be input directly or computed from a total dry weight based upon a specified weight distribution. Four different distributions corresponding to a small vehicle, a large vehicle, the shuttle, and a computed aircraft distribution may be used.

(5) The option to specify directly the MTBF's, MTTR's, abort rates, removal rates, crew sizes, and on/off subsystem manhour percentages rather than have these values computed from parametric equations.

(6) The addition of a sixth segment in the mission profile and subsystem operating hours consisting of a ground recovery and processing time. Unlike pad time, this ground operational time does not impact upon the mission reliability calculations but is considered when computing total failures and scheduled/unscheduled maintenance workload as well as vehicle turn time.

(7) The failure rate of the landing gear system was changed from operating hours to a cyclical measure (per mission).

(8) Vehicle turn time calculations now include a minimum turn time under the assumption of parallel maintenance tasks on all subsystems. Integration time and pad time are included as part of the turn time. Turn time is based upon one, two and three shift maintenance schedules.

(9) Scheduled maintenance is determined as a percent of the on-equipment unscheduled maintenance rather than as a percent of the total unscheduled maintenance.

(10) The addition of a variable representing the number of assigned crews by subsystem. This allows for parallel tasks to be accomplished in determining vehicle turn times.

The scope of the model was increased with the following:

(1) A more detailed work breakdown structure which uniquely identifies 33 subsystems.

(2) The addition of an optional (liquid) booster rocket as part of the overall system with both reliability and maintainability parameters computed.

(3) The addition of an optional external fuel tank as part of the overall system with both reliability and maintainability parameters computed.

(4) The incorporation of space shuttle mean time between failure (MTBF), mean time to repair (MTTR), removal rate, and crew size data into the analysis. The user has the option of selecting by subsystem, shuttle data, computed (aircraft) data, or direct input of data for use in the analysis.

(5) Manpower is now computed in three ways based upon aggregated (vehicle) manhours per month, subsystem manhours per month, and subsystem crew size requirements.

Software enhancements to the model include:

(1) A complete redesign of the user interface providing a menu driven navigation path rather than sequential input.

(2) The addition of an error trapping routine to prevent unnecessary aborts resulting from non-fatal input/output errors.

(3) The use of a compiled version of the computer model to increase speed and portability.

(4) Increase modularization of the code through the use of subprograms under the Quick BASIC environment. This was necessary to utilize additional core memory needed to provide more input options and handle the increased scope.

(5) The addition of a system performance summary report to provide vehicle level summary output without having to navigate through each of the detailed output reports.

(6) The addition of a weight factor to support sensitivity analysis. This factor permits a specified percent increase or decrease in weights across all subsystems.

(7) Assigning file names based upon vehicle/project names rather than inputting additional file names.

(8) Subsystem names may be changed thereby allowing for the addition of new subsystems so long as the total number of subsystems does not exceed 33.

C. Scope of Research

This follow-on effort expands the prediction of reliability and maintainability (R&M) parameters and their effect on the operations and support of space transportation vehicles to include other system components such as booster rockets and external fuel tanks. It also increases the scope of the methodology and the capabilities of the model as implemented by the software. The focus is on the failure and repair of major subsystems and their impact on vehicle reliability, turn times, maintenance manpower, and repairable spares requirements.

Chapter II documents the data utilized in this study. Chapter III outlines the general methodology for estimating R&M parameters and for relating these parameters to the logistics support and operational requirements of the proposed vehicle. Chapter IV presents the analysis and results of applying the methodology to the initial data base while Chapter V describes the implementation of the methodology through the use of a computer model. The report concludes with a discussion on validation and a summary of the research findings and results.

Chapter II.

Data Sources

The principle approach to be used in establishing R&M estimates of new space systems is based upon comparability with existing systems. In this regard, many of the subsystems defined for manned space vehicles may be favorably compared to corresponding aircraft systems. Therefore, a primary source of data to support this analysis are aircraft failure and repair data. A secondary source of data is the space shuttle obtained through data collected by Martin-Marietta Corporation [22].

A. Reliability and Maintainability Data

Data requirements consist of the following R&M data pertaining to all relevant aircraft and space shuttle subsystems.

The primary R&M data are:

(1) Mean time between maintenance (MTBM). This is defined to be the length of time in flying hours between maintenance actions on a particular subsystem or component. Only unscheduled maintenance actions are included. A distinction is made between maintenance actions and failures. Maintenance actions include inherent failures (subsystem failures), induced failures (external failure causes) and no defect found or cannot duplicate actions.

(2) Maintenance manhours per maintenance action (MH/MA). This is the primary measure of maintainability used in this study. Along with the number of maintenance actions per mission (obtained from the MTBM), it becomes the basis of the maintenance requirements.

(3) Maintenance Task Times. The length of time (usually in hours) to perform a particular task such as troubleshoot, remove and replace, perform minor maintenance, etc. This maintainability parameter is usually summarized at the subsystem or component level as the Mean Time to Repair (MTTR). In this study, aircraft task times are obtained by dividing the MH/MA by an average crew size. For the space shuttle, MTTR's are derived directly from the Martin-Marietta data.

(4) Maintenance crew sizes. The number of maintenance personnel required to perform a particular task. This number may vary depending upon the task, the particular component involved and the skill level of the personnel. An average crew size is determined by subsystem. A related variable, the number of crews, assumes each crew consists of the average crew size.

(5) Removal rates (RR). This is the percent of maintenance actions which results in a removal and replacement of a component from the aircraft. It is the basis for establishing demand rates for spare components.

(6) Abort rates (AB). This is the percent of maintenance actions which results in a ground or air abort. This rate is used to establish a critical failure rate which in turn is used to compute the mission reliability.

(7) Percent off equipment (POFF). This is the percent of the total unscheduled maintenance manhours performed on components removed from the aircraft. These hours do not delay processing the vehicle. Therefore 1-POFF, or the percent of on-aircraft work, is used in determining the vehicle turnaround time.

B. Military R&M Data Systems

(1) US Air Force data systems

Reliability and maintainability data for USAF aircraft originates with the Maintenance Data Collection (MDC) system as described in AFM 66-1. This data is collected at the base (squadron/wing) level (AFTO Form 349) and transmitted periodically to AF Material Command (AFMC). AFR 65-110 data (aircraft status reporting) reports flying hours and sorties for the same bases monthly. The D056 Product Performance System processes this data producing several R&M reports. D056 also provides data to the Maintenance and Operational Data Access System (MODAS) for on-line viewing and retrieval. AFALD Pamphlet 800-4, Aircraft Historical Reliability and Maintainability Data summarizes the worldwide R&M data at the two-digit work unit code (WUC) in 6-month intervals. Currently Volumes I through VI covering the years 1972 through 1989 have been published. Volume VII has not been published and the consolidation of the data systems into REMIS place the continued publication in jeopardy.

The current OPR for AFALDP 800-4 is ALD(AFMC)/LSR, Wright-Patterson AFB, Ohio. However, with the consolidation of AFLC and the Air Force Systems Command (AFSC) to form Air Force Material Command (AFMC), this office may be eliminated. With the eventual implementation of REMIS (Reliability and Maintainability Information System), the D056 system along with MODAS will also be eliminated. As of May 1993 MODAS is still operating under a day-to-day extension. Both REMIS and MODAS were to operate in parallel until August 3, 1992 when MODAS was to be eliminated. They are still (June 1993) operating in parallel with limited support of the MODAS system. It is not certain at this time what the final configuration and capabilities of REMIS will be.

The MODAS system (G063) is currently sponsored by AFMC(I)/ENIS, Wright-Patterson AFB, Ohio 45433. MODAS provides the user with access to various data bases through an interactive menu driven system. It is a Data Base Management System (DBMS) with some automated analytical capability. R&M information may be displayed by aircraft (MDS), WUC, level of WUC, base, and by month.

(2) US Navy

The primary source of R&M data pertaining to Navy aircraft is the Aviation 3-M Information reports. The Navy Maintenance Support Office (NAMSO), is the central data bank for Aviation 3-M data (Maintenance and Material Management system). NAMSO is part of the Naval Sea Logistics Center. Although preformatted reports are published monthly, quarterly and annually, and are available on request, a potential user may also request the development of a new report. Most reports can be obtained on either hard copy or microfiche. Magnetic tape may be obtained under a special request.

The following two R&M reports have been utilized in this research.

Report Title	Report Number
Reliability and Maintainability Summary	NAMSO 4790.A7142-01
WUC System R&M Summary	NAMSO 4790.A7142-02

The R&M Summary Report provides data similar to that available from the MODAS system. Summary statistics are reported by aircraft type at the 5-digit WUC and include mean flying hours between maintenance actions, maintenance manhours per flying hour, maintenance manhours per maintenance action, and elapsed maintenance time per maintenance action.

Of particular interest in this research is the WUC System R&M Summary. This report provides mean flying hours between maintenance actions, maintenance manhours per flying hour, maintenance manhours per maintenance action, and elapsed maintenance time per maintenance action by system level WUC (2-digit) for all appropriate aircraft.

C. Shuttle Data Source

R&M data pertaining to the Space Shuttle operations was obtained from a Martin Marietta Corporation study (NASA Contract NAS1-18230) and documented in a final report: "Space Station Definition, Design and Development, Task 18: Launch Vehicle Maintenance Analysis," November 1992 [22]. Data used in this study included maintenance actions, remove and replace actions, operating hours, MTBM's, MTTR's, and crew sizes. In general, these parameters were obtained for 21 different subsystems covering shuttle missions STS 31 through STS 49 (excluding STS 34, 46 & 47). A limited amount of data was obtained on the Titan expendable launch system and the external tank system. All data elements were aggregated by subsystem and are summarized in Appendicies B, C, and D. Overall averages computed from the Martin Marietta data provided default shuttle input values to the model.

D. Aircraft Performance and Design Specifications

In addition to R&M data, aircraft performance and design specifications (Table 1) were necessary to support the parametric analysis. A primary source of this data for military aircraft was a technical report titled "Modular Life Cycle Cost Model for Advanced Aircraft Systems Phase III," prepared by the Grumman Aerospace Corporation [15] for the Flight Dynamics Laboratory, Wright-Patterson AFB, Ohio. This report documents the data base used in developing a life cycle cost model for the proposed aircraft.

Table 1
Aircraft Design/Performance Variables[1]

VEHICLE DRY WEIGHT	VEHICLE LENGTH
WETTED AREA	VEHICLE WING SPAN
FUSELAGE VOLUME	SUBSYSTEM WEIGHTS
FUSELAGE SURFACE AREA	LANDING DISTANCE
CREW SIZE	NUMBER PASSENGERS
NUMBER ENGINES	NUMBER INTERNAL FUEL TANKS
MISSION LENGTH	OPERATING CEILING
NUMBER OF WHEELS	NUMBER ACTUATORS
NUMBER CONTROL SURFACES	MAXIMUM ELECTRICAL OUTPUT
NUMBER HYDRAULICS SYSTEMS	NUMBER AVIONICS SYSTEMS
BTU COOLING CAPACITY	AVIONICS INSTALL WEIGHT

Subsystem weights used in this study were obtained from the Design Branch of the Plans and Programs Directorate of the Wright Laboratories at Wright-Patterson AFB (WL/XPAD). Secondary data sources included all volumes of Jane's All The World's Aircraft [13], Aviation Week & Space Technology [3], and Observer's Directory of Military Aircraft [8].

E. Initial Data Base

The primary source of military R&M data is the Air Force AFM 66-1 Maintenance Data Collection (MDC) system and the Navy 3-M data system. The initial data base consisted of AF MDC data as reported in Volume V (October 1985 to September 1987) of AFALDP 800-4 and Navy data reported in the July 1990 - June 1991 R&M Summary Report. Volume VI of AFALDP 800-4 (October 1987-September 1989) and the MODAS on-line system (January 1990-December 1991) were secondary sources. AFALDP 800-4 summarizes R&M data at 6-month intervals. Four 6-month periods were averaged together in order to provide more accurate measures. The Navy data is presented by quarters. Four quarters were averaged

[1] Variable definitions of those used in the model are in Appendix E.

together also to provide for more accurate MTBM's and manhours. Table 2 lists the 37 Air Force and Navy aircraft used in the study and Table 3 identifies the 28 major aircraft subsystems which were included. These subsystems are identified by two-digit work unit codes (WUC).

Table 2
AF/NAVY Aircraft

TACTICAL	BOMBER	CARGO/TANKER	COMMAND/CONTROL /TRAINER
A-7D/E	B-1B	C-2A	E-2C
A-10A	B-52G	C-5A	E-3A
F-4C/D/E	FB-111A	C-9A	EA-6B
F-5E		KC-10A	T-38
F-14A		C130B/E/H	
F-15A/C		KC-135A	
F-16A/B		C-140A	
F-18A		C-141B	
F-106			
F-111A/D/F			

Table 3
Aircraft Subsystems
2-Digit Work Unit Codes (WUC)

WUC SYSTEM	SYSTEM NOUN
11	STRUCTURES/AIRFRAME
12	EQUIP/FURNGS/CREW COMPARTMENT
13	LANDING GEAR
14	FLIGHT CONTROLS
23	POWER PLANT SYSTEM
24	AIRBORNE AUXY PWR (APU)
41	AIR CONDITIONING/ENVIRONMENTAL CONTROL
42	ELECTRICAL POWER
44	LIGHTING SYSTEM
45	HYDRAULIC POWER
46	FUEL SYSTEMS
47	OXYGEN
49	FIRE PROTECTION/MISC UTILITIES
51	INSTRUMENTS
52	AUTO FLIGHT
55	MAL ANLY RECORDING
61	COMMUNICATIONS
62	VHF COMMUNICATIONS
63	UHF SYSTEM
64	PASS ADDRESS SYS
66	EMERG LOCT XMTR
71	NAVIGATION
72	RADAR NAVIGATION
74	FIRE CONTROL SYSTEMS (HUD)
91	EMERG EQUIP
93	DRAG CHUTE EQUIP
96	PERSONNEL EQUIP
97	EXP DEV & COMP

Chapter III

Methodology

A. Parametric Analysis

The primary objective is to develop a methodology for estimating reliability and maintainability parameters for use in life cycle costing, supportability requirements determination and the assessment of operational capabilities and constraints of proposed space vehicles. This methodology utilizes the available data sources identified in the previous chapter. The approach is based upon a comparability analysis with similar aircraft subsystems. By estimating aircraft equipment failure and repair parameters as a function of performance and design specifications, then, with suitable adjustments to account for the differences in operating environment, the R&M parameters of a conceptual space vehicle may be estimated based upon its design and operating specifications. Adjustments are also necessary to account for technological innovation over time. This chapter presents the mathematical foundation for the analysis performed on the data base and described in the following chapter.

Parametric R&M equations are derived using regression analysis. In general, let

$$Y = B_0 + B_1 X_1 + B_2 X_2 + \dots + B_k X_k \qquad (1)$$

where Y = R&M parameter of interest (e.g. MTBF or MH/MA)

and X_j = jth design or performance specification (e.g. vehicle dry weight), $j = 1, 2, \dots k$,

then

$B_0, B_1, \dots, B_k$ are the regression coefficients.

These are estimated by performing a least-squares fit of the equation against known paired values for Y and the corresponding $X_1, X_2, \dots, X_k$ obtained from the data base.

The following R&M parameters have been estimated using this approach:

MTBM - Mean Flying Hours between Maintenance Actions

MH/MA - Maintenance Manhours per Maintenance Actions

RR - Subsystem removal rate

POFF - Percent off-equipment (vehicle) manhours

CREW - Average crew size per maintenance task

AB - Abort Rates (Critical Failure Rate)

In addition to the above R&M parameters, regression equations were derived to estimate subsystem weights and design/performance variables (see Table 1) as functions of the vehicle **dry weight** and **length + wing** span. The variables in Table 1 are classified as secondary variables while the **dry weight** and **length + wing** span are classified as primary variables. Using these equations, it is possible to estimate all of the necessary R&M parameters using only a small number of primary (driver) variables. First subsystem weights are determined from the regression equations, or from a set of relative percentages of the vehicle dry weight, then the secondary variables are computed from their equations, and finally the MTBM, MH/MA and other R&M parameters are estimated from their regression equations. The latter equations will include subsystem weights and those secondary variables which were found to significantly improve upon the prediction capability. For those subsystems analyzed using shuttle data, the initial MTBM, RR, AB, MTTR, and crew values are input directly rather than computed from the parametric equations.

B. Computation of MTBM

An initial MTBM is obtained by subsystem from the derived parametric estimating equations. The MTBM is in units of operating (flying) hours between maintenance actions and reflects a subsystem operating in an aircraft (air/ground) environment.

(1) Technology Growth Factor

In order to account for increased reliability as a result of technological change over time, a growth factor was computed. First, the learning curve effect on the reliability of a subsystem over time was estimated. The learning curve accounts for engineering changes, modifications, and other reliability burn-in phenomena associated with a system maturing over time. This was accomplished by fitting an equation of the form:

$$\text{MTBM} = a\ T^{b} \tag{2}$$

where: T = cumulative calendar time or cumulative operating (flying) hours and "a" and "b" are parameters estimated using least-squares.

Next, a technology adjustment factor was found by averaging several pair-wise comparisons between aircraft developed during different technology periods but having similar missions and requirements. An MTBM for both aircraft was obtained from the data set (generally a two-year average value). The MTBM of the newer aircraft was modified using the learning curve growth rate (b) to account for the differences in age between the two systems. That is,

$$\text{Mod MTBM} = a \times (1986 - \text{Dev YR Old ACFT})^{b} \tag{3}$$

where solving Equation (2) for "a" provides:

$$a = \text{NEW ACFT MTBM}/(1986\text{-DEV YR NEW ACFT})^{b} \tag{4}$$

The baseline year for the aircraft data is 1986 and the MTBM reflects the baseline year. When applying the technology growth factor to Shuttle MTBM's, a baseline year of 1992 is used, reflecting the technology age of the Martin Marietta data. The "a" parameter defines the units (e.g. operating hours or years) while the "b" parameter describes the rate of growth.

The adjustment factor was then found by solving the compound growth rate curve:

$$\text{MOD MTBM} = \text{OLD ACFT MTBM} \times (1+\text{ADJ FAC})^{\text{AGE DIFF}} \tag{5}$$

That is,

$$\text{ADJ FAC} = [\text{MOD MTBM/OLD ACFT MTBM}]^{(1/\text{AGE DIFF})} - 1 \tag{6}$$

This factor was then used in adjusting the initial MTBM to account for technological growth in reliability between the baseline year of the data and the expected development year of the proposed system. That is

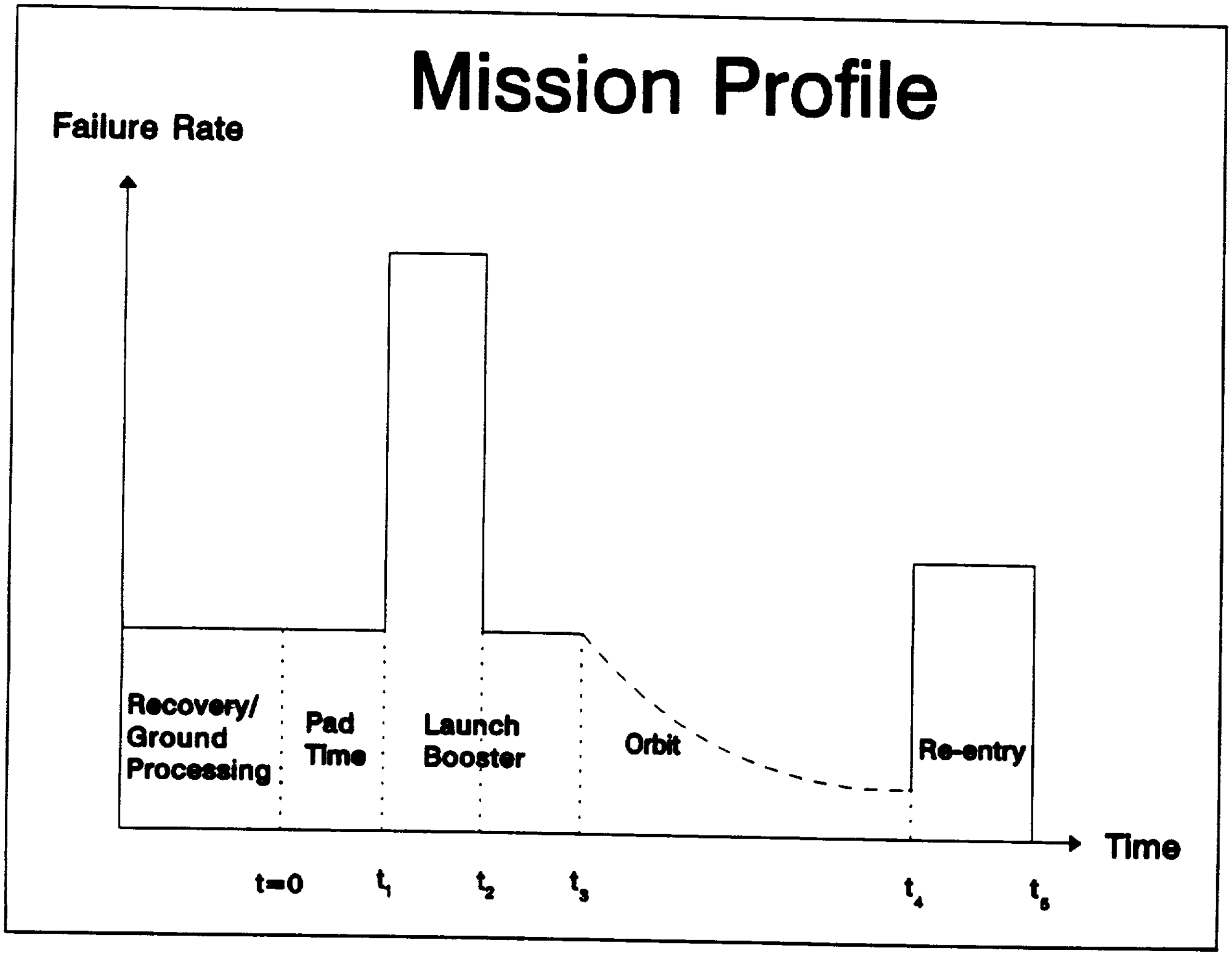
$$\text{ADJ MTBM} = \text{MTBM} \times (1+\text{ADJ FAC})^{(\text{yr}-1986)} \tag{7}$$

(2) Environmental Adjustment

A further adjustment to the MTBM was then made to account for the change in failure rates (from those of the aircraft air/ground environment) during launch and orbit. During the air (non-booster launch and re-entry phase) and ground phase, failure rates are assumed to be constant (exponential) with a MTBM based upon the ADJ MTBM defined above. However, during launch under booster rockets, the failure rate may increase dramatically as a result of the increased vibration and stresses. On the other hand, while in orbit, the failure rate is assumed to decrease over time. A Weibull failure rate function was assumed for this portion of the mission. When the MTBM is input directly from the Shuttle derived data, the space adjustment is not performed since the historical MTBM includes operating in the space environment.

For each subsystem, a mission profile curve was assumed having the following form:

Figure 1
Mission Profile



The recovery/ground processing time segment assumes a constant failure rate λ. It is utilized in computing maintenance workload, manpower, spares, and vehicle turn-times. However, it is not used in any of the reliability calculations. For reliability calculations the failure rate curve is based upon the remaining mission profile segments and may be expressed mathematically as:

$$\lambda(t) = \begin{cases} \lambda & for \quad 0 \le t < t_1 \\ \kappa \times \lambda & for \quad t_1 \le t < t_2 \\ \lambda & for \quad t_2 \le t < t_3 \\ \frac{b}{a}\left(\frac{t}{a}\right)^{b-1} & for \quad t_3 \le t < t_4 \\ \lambda & for \quad t_4 \le t < t_5 \end{cases} \tag{8}$$

where:

$$\lambda = \frac{1}{ADJ\ MTBM}$$

$$\kappa = LAUNCH\ FACTOR$$

and a, and b are the Weibull scale and shape parameters respectively, $a > 0$, $0 < b < 1$

Since, in general, a reliability function is given by

$$R(t) = e^{-\int_0^t \lambda(t)\, dt} \tag{9}$$

the reliability function may be obtained from (8) using (9):

$$R(t) = \begin{cases} e^{-\lambda t} & for \quad 0 \le t < t_1 \\ e^{-[\lambda t_1 - \kappa\lambda(t - t_1)]} & for \quad t_1 \le t < t_2 \\ e^{-\lambda[(t + t_1 - t_2) - \kappa(t_1 - t_0)]} & for \quad t_2 \le t < t_3 \\ e^{-\lambda(t_3 + t_1 - t_2) - \kappa\lambda(t_2 - t_1) + \left(\frac{t}{a}\right)^b - \left(\frac{t_3}{a}\right)^b} & for \quad t_3 \le t < t_4 \\ e^{-\lambda(t_3 + t_1 - t_2) - \kappa\lambda(t_2 - t_1) + \left(\frac{t_4}{a}\right)^b - \left(\frac{t_3}{a}\right)^b - \lambda(t - t_4)} & for \quad t_4 \le t < t_5 \end{cases} \tag{10}$$

Since the mission profile is repetitive over time, a steady-state MTBM may be computed from equation (11).

$$\text{SS MTBM} = \frac{\int_0^{t_5} R(t)\,dt}{1-R(t_5)} \tag{11}$$

The use of the Weibull failure distribution in defining R(t) requires a numerical integration to compute the MTBM from Equation (11). In the implementation of the model discussed in Chapter V, Simpson's rule was used to perform the integration.

(3) Critical MTBM

Using aircraft air and ground abort rates (AB), subsystem regression equations were derived to provide estimates of critical failure rates. A critical MTBM was then obtained from

$$\text{CRIT MTBM} = \text{SS MTBM/AB} \tag{12}$$

A vehicle MTBM is calculated from the subsystem MTBM's using:

$$\text{VEH MTBM} = 1/[1/\text{MTBM}_1 + 1/\text{MTBM}_2 + \ldots + 1/\text{MTBM}_k] \tag{13}$$

where $1/\text{MTBM}_i$ is the failure rate of the ith subsystem[2].

C. Reliability Calculations

All reliability calculations are based upon the CRIT MTBM. Letting $\lambda = \frac{1}{\text{CRIT MTBM}}$ for each subsystem, Equation (10) is used to compute a mission reliability at times t_0, t_1, t_2, t_3, t_4, and t_5. Subsystem redundancy is addressed in one of two ways. For most subsystems, reliability is obtained from:

$$R_{s_i}(t) = 1-[1-R_i(t)]^{n_i} \tag{14}$$

where $R_{si}(t)$ is computed from Equation (10) for the ith subsystem and n_i is the number of redundant subsystems of type i. For selected subsystems (engines, power, and avionics), a k-out-of-n redundancy is computed, where k_i is the minimum number of redundant subsystems (of type i) which must be operational. This calculation makes use of the binomial probability distribution and is given by:

$$R_{s_i} = \sum_{x=k_i}^{n_i} \binom{n_i}{x} R_i(t)^x \,(1-R_i(t))^{n_i-x} \tag{15}$$

[2] Certain subsystems, such as landing gear, may have failure times based upon cycles (landings) rather than operating hours. When this is the case, the MTBM is converted to mean operating hours between maintenance in order to compute the vehicle MTBM.

A vehicle reliability is computed by multiplying the subsystem redundant reliabilities (R_i)

$$R_{veh} = R_{s1} \times R_{s2} \times \ldots \times R_{sk} \tag{16}$$

D. Maintainability Estimates

The primary maintainability parameter used in this study is the maintenance manhours per maintenance action (MHMA). This parameter is estimated from the parametric regression equations for each subsystem. Then using

$$\text{TOT MA} = 1/(\text{SS MTBM}) \times \text{OPER HRS}^3 \tag{17}$$

total maintenance actions per mission is obtained and from

$$\text{TOT MANHRS} = \text{MHMA} \times \text{TOT MA} \tag{18}$$

total maintenance manhours per mission is found. Manhours are then split into on-vehicle and off-vehicle manhours using the percent off-equipment hours (POFF) obtained from regression equations:

$$\text{TOT ON-VEH MH} = (1\text{-POFF}) \times \text{TOT MANHRS} \tag{19}$$

$$\text{TOT OFF-VEH MH} = \text{POFF} \times \text{TOT MANHRS} \tag{20}$$

When using shuttle data, MHMA is not computed from the regression equations. Instead:

$$MHMA = MTTR \times CREW + \frac{POFF \times CREW \times MTTR}{1-POFF} \tag{21}$$

where MTTR is a direct input to the calculation and represents the mean time to repair on-vehicle work only.

Scheduled manhours is calculated by multiplying the total on-vehicle MH by a percentage. This percentage may be input directly to the calculation or obtained from a regression equation which estimates the scheduled manhours as a percentage of the unscheduled on-vehicle manhours.

$$SCHED\ MH = PCT \times (TOT\ ON\text{-}VEH\ MH) \tag{22}$$

[3] OPER HRS here includes the Recovery/Ground processing time.

E. Manpower Requirements

Maintenance manpower requirements are determined in three different ways. The first method is to take the total unscheduled manhours of work per month and divide this total by the number of hours per month available per technician to do direct maintenance work.

Let N = number of mission per month,

AV = available hours per month per individual

IND = percent of indirect work (work not included in the MHMA)

then,

$$NBR\ PER = \frac{TOT\ MANHRS \times N}{(1-IND)AV}\ (rounded\ up) + \frac{SCHD\ MH \times N}{(1-IND)AV}\ (rounded\ up) \tag{23}$$

The second approach uses the same methodology except it is applied by subsystem. That is total manhours represents subsystem manhours and manpower is calculated by subsystem. Since scheduled maintenance is computed only at the vehicle level and not by subsystem, it will not change.

The third approach identifies the crew size by subsystem as a minimum requirement. If the manpower computed from subsystem manhours exceed the minimum crew size requirements, then the larger number should be used. The three methods for determining manpower should provide overall bounds on the total requirement.

F. Spare Parts Requirements

In order to estimate spare parts requirements, it is necessary to distinguish between a failure resulting in a remove and (if a spare is available) replace action versus other maintenance actions such as on-aircraft troubleshoot and repair. The MODAS system identifies maintenance actions by an action taken code one of which is a removal code.

Using regression equations or an estimated Shuttle value, a removal rate (RR) per maintenance action was determined and used to obtain the mean number of demands (failures) for spares (MFAIL) per mission as follows:

$$MFAIL = RR \times (TOT\ MA) \tag{24}$$

Under the common assumption that the number of failures in a given time period follows a Poisson process, a spare parts level can now be found which will satisfy demands a specified percent of the time. This is the frequently used fill rate criterion which represents the percent of time a demand (failure) can be immediately satisfied from the on-hand stock.

Let S = spare parts level to support a given mission and
p = desired percent of time demands are satisfied (fill rate),
then find the smallest value for S such that $F(S) \geq p$ where

$$F(S) = \sum_{i=0}^{S} e^{-MFAIL}\left[\frac{MFAIL_i}{i!}\right] \tag{25}$$

F(S) is the cumulative probability of demands not exceeding the spares level (S).

G. Vehicle Turn Times

In order to determine the time required to perform maintenance on the vehicle, estimates of average crew sizes for typical on-vehicle tasks by subsystem must first be obtained. Once the average crew size has been determined from regression equations or from the data base, an average on-vehicle repair time can be obtained by

$$MTTR = (1\text{-}POFF) \times MHMA/AVG\ CREW \tag{26}$$

or input directly as in the case of the shuttle data. Average on-vehicle subsystem repair time per mission may be found from

$$MSN\ REP\ TIME = \frac{MTTR \times TOT\ MA}{NBR\ CREWS} \tag{27}$$

where NBR CREWS is the total number of crews available to perform parallel work on the subsystem. Assuming tasks, for each subsystem, are performed sequentially (a worst case), then total vehicle mission repair time is the sum of the subsystem repair times:

$$VEH\ REP\ TIME = \sum_{ALL\ SUBSYS} MSN\ REP\ TIME \tag{28}$$

Scheduled maintenance time may then be added to obtain a total vehicle maintenance task time:

$$TOT\ VEH\ TASK\ TIME = VEH\ REP\ TIME + \frac{0.98 \times SCHD\ MHRS}{AVE\ CREW\ SIZE}\ [4] \tag{29}$$

[4] Aircraft data has shown that 98 percent of the scheduled maintenance is on-aircraft maintenance.

Mission, pad, and integration time must be included in order to obtain a vehicle turn-around time. Therefore, vehicle turn-around time in working days is:

$$VEH\ TURNAROUND = \frac{MSN\ TIME + PAD + INTG}{24} + \frac{TOT\ VEH\ TASK\ TIME}{sft \times 8} \tag{30}$$

Equation (30), by including the number of shifts (shft) in the second term will provide a vehicle turnaround time based upon 1, 2, or 3 shift maintenance. Dividing the vehicle turnaround time into the number of working days per month gives an estimate of the number of missions per month per vehicle:

$$MSN/MO/VEH = \frac{WORKING\ DAYS/MO}{VEH\ TURNAROUND} \tag{31}$$

Dividing the required number of missions per month by the number of missions per month per vehicle provides an estimate of the required fleet size:

$$FLEET\ SIZE = \frac{RQD\ MSN/MO}{MSN/MO/VEH} \quad (rounded\ up) \tag{32}$$

Equation (28) implies that all subsystems will be repaired sequentially. Setting TOT VEH TASK TIME (EQ 29) equal to the maximum subsystem MSN REP TIME (or scheduled maintenance time, if larger), a minimum vehicle turnaround time assuming all work may be accomplished in parallel is obtained.

H. ET and LRB Calculations

From input parameters consisting of subsystem MTBM, OPER HRS, CRIT FAIL RT, MTTR, and CREW SIZE, subsystem reliability, scheduled and unscheduled manhours and manpower are computed. Reliability is derived from:

$$R = e^{-\frac{OPER\ HRS}{MTBM/(CRIT\ FAIL\ RT)}} \tag{33}$$

and

$$UNSCH\ MH = \frac{OPER\ HRS}{MTBM} \times MTTR \times CREW\ SIZE \tag{34}$$

$$SCHD\ MH = PCT \times UNSCH\ MH \tag{35}$$

$$MAN\ PWR = \frac{(UNSCH\ MH + SCHD\ MH) \times N}{(1 - IND) \times AU} \quad (rounded\ up) \tag{36}$$

ET/LRB system reliabilities are obtained by multiplying subsystem reliabilities while system manhours and manpower are obtained by summing corresponding subsystem values. Overall system reliabilities (VEH+ET+LRB) are computed by multiplying the results of Equation (16) by the ET reliability and the LRB reliability which is treated as a launch reliability.

Chapter IV

Analysis and Results

A. Preliminaries

Both Navy and Air Force aircraft were initially selected for deriving the parametric equations. However, Air Force subsystem data was utilized primarily in the current model because it was more comprehensive and consistent. Table 4 identifies the subsystems by military aircraft work unit code (WUC) and shows the mapping of WUC's to NASA's Work Breakdown Structure (WBS) for space vehicle subsystems and to the current Space Shuttle (STS) structure.

When a single WUC or STS Code mapped into two or more WBS codes, maintenance action rates (and therefore MTBM's) were prorated to the subsystems based upon percentages derived from the subsystem weights. The exception occurs in the propulsion system where the same aircraft equation (WUC 23) was used for the main, RCS, and OMS propulsion systems.

Table 4 WUC to WBS to STS Conversions

WBS		WUC		STS	
Wing	1.00	Airframe	11	STR (Structures)	8
Tail	2.00	Airframe	11	STR (Structures)	8
Body	3.00	Airframe	11	STR (Structures)	8
		Crew Compartment	12		
Tanks, LOX	3.10	Fuel Systems	46	MPS (Main Propulsion System)	41
Tanks, LH_2	3.20	Fuel Systems	46	MPS (Main Propulsion System)	41
IEP, Tiles	4.10			Tile	9
IEP, TCS	4.20			TCS (thermal Control System)	6
IEP, PVD	4.30			PVD (Purge, Vent & Drain)	
Landing Gear	5.00	Landing Gear	13	MEQ (Mechanisms)	51
Propulsion, Main	6.00	Propulsion Systems	23	ME/SSME (Main Engines)	41
Propulsion, RCS	7.00	Propulsion Systems	23	FRC (Forward Reaction Control)	42
Propulsion, OMS	8.00	Propulsion Systems	23	OMS	43
Power, APU	9.10	APU Power	24	APU	46
Power, Battery	9.20	Battery	66C/E/G		
Power, Fuel Cell	9.30			FCP (Fuel Cell Power)	45
Electrical	10.00	Electrical	42	EPD/OEL (Elect Power Dist)	76
		Lighting System	44		
Hydraulics/Pneu	11.00	Hydraulics/Pneu	45	HYD (Hydraulics)	58
Aero Surface Actuators	12.00	Flight Controls	14	MEQ (Mechanisms)	57
Avionics, GN&C	13.10	Autopilot	52	GNC	71
		Radio Navigation	71		
		Radar Navigation	72		
Avionics, Health Monitoring	13.20	Malfunc	55		
Avionics, Comm & Tracking	13.30	HF Comm	61	COM (Communications)	74
		VHF Comm	62		
		UHF Comm	63		
		Interphone	64		
		Emergency Comm	66		
Avionics, Display & Controls	13.40			DDC (Digital Display Control)	73
Avionics, Instrumentation System	13.50	Instruments	51	DIG (Digital Systems)	73
Avionics, Data Processing	13.60	Computers	51/52/55	Data Processing	72
Environmental Control, System	14.10	Environmental Control	41	ECL (Environmental Control)	60
Environmental Control, Life Support	14.20	Oxygen System	47	ECL (Environmental Control)	60
Personal Provisions	15.00	Misc. Utilities	49	FCS (Flight Crew Systems)	?
		Personnel Provisions	96		
Recovery & Aux, Parachutes	16.10	Drag Chute Eqpt.	93		
Recovery & Aux, Escape System	16.20	Explosive Devices	97		
		Emergency Equipment	91		
Recovery & Aux, Separation System	16.30	Explosive Devices	97	PYR (Pyrotechnics)	55
Recovery & Aux, Cross-Feed System	16.40			MEQ (Mechanisms)	56
Recovery & Aux, Docking System	16.50				
Recovery & Aux, Manipulator Systems	16.60			MEQ (Mechanisms)	53

B. Regression Analysis

Multiple linear regression procedures were used to develop each of the parametric equations. A "best fit" was defined as the simplest mathematical model having a significant F value, a large R-squared value, and a small standard error. Generally, only independent variables which were significant (based upon a t-test) were included in the final model. Several models were marginally significant but retained nevertheless. A secondary criterion for model selection was the practical test that the model would provide reasonable results over the anticipated range of independent variable values. Because of the difference between aircraft and space vehicle parameters, extrapolations outside the domain of the input data were expected. Nonlinear transformations of the independent variables were also included in the model if they significantly contributed to the prediction power of the equation. Generally these transformations consisted of squaring, taking logarithms or square roots of the variables.

An investigation of the residuals would, on occasion, identify one or more data points as outliers (two or more standard deviations from the mean). At times these outliers were deleted from the data base. This was based upon the strong possibility that the AFALDP 800-4 data was incomplete. This is particularly true for the Vol VI data which contains a warning to this effect. In processing AFM 66-1, the monthly tapes from the bases may not contain all of the failures logged for that month. On the other hand, the monthly flying hours and sorties reported through a different data system is almost always complete. The net result is an overstatement of the MTBF. This was normally the case when outliers were observed.

As a result of the new WBS, additional regression analysis was performed. The original equations are documented in Appendices J-O of the first year report [23] and the new equations are documented in Appendix A of this report.

C. Analysis of Weights and Secondary Variables

Several variables were identified as primary or "driver" variables. These include (1) vehicle dry weight in pounds, (2) the sum of the vehicle length and wing span in feet, (3) crew size, (4) number of passengers, and (5) number of main engines. Values for these independent variables were based upon references [8] and [13] and are found in Appendix G of the first year final report [23]. Using these driver variables, regression equations were derived to estimate subsystem weights and secondary variables. Table 6 displays the weight equations and Table 7 displays the secondary variable equations. As a conceptual vehicle becomes better defined, it is expected values for these variables will be obtained from the design specifications and will not need to be estimated from the "driver" variables. With the exception of Prime Power (WBS 9) and Avionics (13), there are excellent least-squares fits to the data. The number of aircraft in the data base having an APU is quite small and its weight is not as dependent with vehicle size as are other subsystems. Avionics weight is not as highly correlated with vehicle size as are the remaining subsystems. Observe that the secondary variable equations must be evaluated in a particular order since several of these equations require values derived from the previous secondary variable equations. Correlation of these equations vary from under 60 percent to over 99 percent.

Table 5 Subsystem Weight Equations[5]

WBS	SUBSYSTEM	EQUATION	R
1.00	WING	$WT = -4485026.7 + 1351022\,LOG(DRY\ WT) - 135432[LOG(DRY\ WT)]^2 + 4522.4[LOG(DRY\ WT)]^3$	.980
2.00	TAIL	$WT = -290909.9 + 91929.4\,LOG(DRY\ WT) - 9709.9[LOG(DRY\ WT)]^2 + 343.5[LOG(DRY\ WT)]^3$	.960
3.00	BODY	$WT = 3.971E08 + 1.4180E06\,LOG(DRY\ WT) - 4.047E07/\sqrt{LOG(DRY\ WT)} - 12993808.8\sqrt{LOG(DRY\ WT)}$	.986
5.00	LANDING GEAR	$WT = -49535 + 0.28256(DRY\ WT) + 6873.7\,LOG(DRY\ WT) - 160.1\sqrt{DRY\ WT}$	.989
6/7/8	ENGINES	$WT = -7141.9 + 89.1\sqrt{DRY\ WT}$	.958
9.xx	APU (PRIME PWR)	$WT = -910.4 + 100.2\,LOG(DRY\ WT) + 1.3835\sqrt{DRY\ WT}$	.785
10.00	ELECTRICAL	$WT = -757.97 + 11.22\sqrt{DRY\ WT}$	.872
11.00	HYDRAULICS	$WT = 575.3 + .02222(DRY\ WT) - 5.061\sqrt{DRY\ WT}$	.982
12.00	FLIGHT CONTROLS	$WT = -9849.51 + 0.045967(DRY\ WT) + 1364.8\,LOG(DRY\ WT) - 26.25\sqrt{DRY\ WT}$	.984
13.xx	AVIONICS	$WT = -10901.5 + 1261.5\,LOG(DRY\ WT)$	.748
14.xx	ENVIRONMENTAL	$WT = -719.2 + 5.56(LEN + WING) + 56.88\sqrt{LEN + WING}$	.904
15.00	PERSONNEL PROV	$WT = 66255.6 - 14720.4\,LOG(DRY\ WT) + 818.2(LOG(DRY\ WT))^2$	.902

[5] NOTE: LOG is the natural logarithm.

Table 6
Secondary Variable Equations

Variable	Equation	Range	R
FUSELAGE AREA	$-8833 + .0829 \times DRYWEIGHT + 1275\log(DRYWEIGHT) - 32.46\sqrt{DRYWEIGHT}$	478, ∞	.980
FUSELAGE VOLUME	$-47619 + 22144\log LEN + WING - 5743\sqrt{LEN + WING} + .4262(LEN + WING)^2$	571, ∞	.893
WETTED AREA	$486.03 + .1510(LEN + WING)^2$	486, ∞	.997
NBR WHEELS	$2.1896 + 6.6630 \times DRYWGT - 1.3872(DRYWGT)^2$	3, ∞	.912
NBR ACTUATORS	$-40.991 - .001425 \times DRYWGT + 2.0752E{-9}(DRYWGT)^2 + .007467 \times WETAREA$ $- 1.03767\sqrt{WETAREA} + .4828\sqrt{DRYWT} + 14.967\sqrt{CONTS} - .01781(CONTR)^2$	5, ∞	.978
NBR CONTROL SURFACES	$3.5887 + .000528 \times DRYWGT + .09493 \times LEN + WING - .00517 \times WETAREA$	6, ∞	.932
KVA MAX	$-214.812 + .001098 \times DRYWGT + 25.157\log(DRYWGT)$	11, ∞	.940
NBR HYDR SUBSYS	$13.48 - .5685 \times LEN\,WING + .002409 \times WETAREA + .4333\sqrt{WGT}$	8, ∞	.857
NBR FUEL TANKS	$-13.2236 + 1.85177\log(DRYWGT)$	2, 12	.569
TOT NBR AVIONICS SUBSYS	$-40.42 - 1.879 \times DRYWGT + 6.1928\log(DRYWGT)$	9, ∞	.614
NBR DIFF AVIONICS SUBSYS	$9.674 - 1.85799\log(DRYWT) + .87684 \times TOTSUBS + 1.45574\log(AVWT)$	5, ∞	.950
BTU COOLING	$-1114.5 - 12.0177 \times LEN + WING + 9.40511(LEN + WING)^2 + 230.872\sqrt{LEN + WING}$	25, ∞	.779

Because the weight equations are generated from aircraft data, they may not reflect the distribution of the subsystem weights in a space vehicle. Therefore, alternative estimators for subsystem weights are based upon NASA weight statements pertaining to two different proposed space vehicles (large and small) and the space shuttle. These weight distributions provide initial estimates only and should be revised and updated by the analyst. These percentages are then applied to the primary driver variable - vehicle dry weight to obtain the subsystem weights.

Table 7 Weight Distributions

WBS		Small Vehicle	Large Vehicle	Shuttle
Wing	1.00	9.6	8.1	10
Tail	2.00	0.4	0.3	1.7
Body	3.00	11.4	17.4	27.7
Tanks, LOX	3.10	1.8	5.4	1.5
Tanks, LH_2	3.20	1.8	11.4	1.7
IEP, Tiles	4.10	0	0	13.3
IEP, TCS	4.20	10.9	14.3	2.0
IEP, PVD	4.30	0	0.8	1.1
Landing Gear	5.00	6.4	4.3	4.0
Propulsion, Main	6.00	0	20.8	13.1
Propulsion, RCS	7.00	1.7	1.8	2.0
Propulsion, OMS	8.00	1.7	1.9	1.9
Power, APU	9.10	11.6	0	0.6
Power, Battery	9.20	1.8	0.1	0
Power, Fuel Cell	9.30	1.4	0.7	0.7
Electrical	10.00	6.3	3.5	6.5
Hydraulics/Pneu	11.00	0	0	1.2
Aero Surface Actuators	12.00	0.9	0.7	1.8
Avionics	13.10	1.6	0.3	0.6
Avionics, Health Monitoring	13.20	0.8	0	0
Avionics, Comm & Tracking	13.30	1.1	0.4	1.0
Avionics, Display & Controls	13.40	0.7	0.5	1.3
Avionics, Instrumentation System	13.50	0	0.3	0.4
Avionics, Data Processing	13.60	2.7	0.3	0.8
Environmental Control, System	14.10	3.8	1.6	1.3
Environmental Control, Life Support	14.20	4.5	0.5	2.0
Personal Provisions	15.00	7.4	0.8	1.2
Recovery & Aux, Parachutes	16.10	8.0	1.4	0
Recovery & Aux, Escape System	16.20	0.1	1.2	0
Recovery & Aux, Separation System	16.30	1.0	0.5	0.6
Recovery & Aux, Cross-Feed System	16.40	0	0.7	0
Recovery & Aux, Docking System	16.50	0.6	0	0
Recovery & Aux, Manipulator Systems	16.60	0	0	0
	TOTAL	100	100	100

D. MTBM Equations

Based upon the "driver" variables, subsystem weights, and the secondary variables, regression equations were derived to estimate MTBM. These equations are summarized in the following table with the regression analysis provided in Appendix J of the first year final report and Appendix A of this report. The estimated MTBM represents an unadjusted number and reflects aircraft reliability as captured in the data base. With the exception of Propulsion (WBS 1.6-1.8), acceptable correlations were obtained with the regression models. Aircraft engine failures were estimated exclusively from engine weight in order to utilize the equation for each Propulsion WBS and to provide a reasonable approach for extrapolating aircraft engine results to space vehicle propulsion systems. It is expected that this equation will be replaced as data on space propulsion systems becomes available. Because of the small sample size, WBS 9.20, Power, Battery, WBS 13.40, Avionics, Displays and Controls, and WBS 13.60, Avionics, Data Processing, MTBM's were estimated directly from the data rather than fitting parameters.

Table 8
MTBM Equations

WBS	SUBSYSTEM	EQUATION	Range	R
1,2,3	WING,TAIL, BODY	$15.231 + .006057(TAIL\ WT) - .137575\sqrt{TOT\ VEH\ WT} - .000723(WET\ AREA)$	1.4, ∞	.944
3.00	BODY (CREW COMP)	$3428.5 - .0142(DRY\ WT) - 423.96\,LOG(DRY\ WT) + 11.050\sqrt{DRY\ WT} + 111.57(CREW\ SIZE) - 360.72\sqrt{CREW\ SIZE} + .01865(BODY\ WT) - 4.8357\sqrt{BODY\ WT} - .25785(CREW + PASS)$	5.6, ∞	.891
3.10 3.20	TANKS, LOX LH_2	$494.8 - 54.06\,LOG(DRY\ WT) + .903\sqrt{WET\ AREA} - 50.712(\#\ ENGINES) + 16.39(\#\ FUEL\ TANKS) + 151.37\sqrt{\#\ ENGINES} - 83.12\sqrt{\#\ FUEL\ TANKS} - .0004(TANK\ WT) + .2756\sqrt{TANK\ WT}$	8.37, 84	.936
4 (.1, .2, .3)	IEP	NOT Available		
5.00	LANDING GEAR (Sorties)	$22.2723 - .00313(WET\ AREA) + .19511(LEN{+}WING) - 5.47476\sqrt{\#\ WHEELS} + .003161(LAND\ GEAR\ WT) - .5171441\sqrt{LAND\ GEAR\ WT}$	.4, 19.1	.867
6,7,8	PROPULSION[6]	$34.104 + .0009853(ENG\ WT) - .31223\sqrt{ENG\ WT}$	1.4, ∞	.509
9.10	APU (PRIME POWER)	$4996.5 - 1.9061(KVAMAX) + 46.350\sqrt{KVAMAX} - 2.735(APU\,WT) + 284.5\sqrt{APU\,WT} - LOG(APU\,WT$	14.5, ∞	.886
9.20	POWER, BATTERY	$MTBM = 3570$		
9.30	POWER, FUEL CELL	N O T Available		
10.00	ELECTRICAL	$1193 - .0755(ELECT\ WT) + 6.7588\sqrt{ELECT\ WT} - .7156(LEN + WING) - 167.2\,LOG(DRY\ WT) + 2.2308\sqrt{DRY\ WT} + 29.1\,LOG(KVA) - .00127(KVA)^2$	5.15, ∞	.955
11.00	HYDRAULICS	$396.3 - .00622(WET\ AREA) + 35.635(\#\ SUBSYS) - 779.8\sqrt{\#\ SUBSYS} + 975.6\,LOG(\#\ SUBSYS) + 8.813\sqrt{HYD\ WT} - 105.7\,LOG(HYD\ WT)$	4.7, ∞	.855
12.00	AERO SURFACES	$26.29 - 1.114\sqrt{ACTWT} + .9516(\#\ ACT) - 1.9(\#\ CONT\ SUR) + .3505(LEN + WING) - .00357(WETA$	2.8, ∞	.913

[6] Used to compute small weight engines.

13.00	AVIONICS (Roll-Up)	$-36.92 - 4.496(TOT\ SUBS) + 45.756\sqrt{TOT\ SUBS} - .1231(AVE\ WT/S) + .02360(WT\ 51/72) - 2.453\sqrt{WT\ 51/72}$	1.5, ∞	.884
13.10	AVIONICS, GN&C	$-415.17 - .000317(DRY\ WT) + .2757(LEN + WING) + .2242(AVE\ WT) - .26.744\sqrt{AVE\ WT} + 155.28\,LOG(AVE\ WT) - .3679(AVE\ WT/\#\ AVE\ SUBSYS)$	3.3, ∞	.918
13.20	AVIONICS, HEALTH MONITORING	$323.913 - 16.0757\sqrt{AVE\ WT} + 16.974(LEN + WING) + .1735(AVE\ WT) + 23.82(\#\ DIFF\ SUBSYS) - 2.305[(AVE\ WT)/(\#\ AVE\ SUBSYS)]$	4.2, ∞	.984
13.30	AVIONICS, COMM & TRACKING	$353.21 - .0338(LEN + WING) + 10.74(\#\ AVE\ SUBSYS) - 107.64\sqrt{\#\ AVE\ SUBSYS} - 7.82\,LOG(AVE\ WT)$	7.9, ∞	.927
13.40	AVIONICS, DISPLAYS & CONTROLS	MTBM=54.2		
13.50	AVIONICS, INSTRUMENTS	$330.26 + .0003821(DRY\ WT) - .451534(LEN + WING) + 137.3431(\#\ ENGINES) - 1.129(\#\ FUEL\ TANKS) - 381.666\sqrt{\#\ ENGINES}$	7, ∞	.897
13.60	AVIONICS, DATA PROCESSING	MTBM=29.13		
14.10	ENVIRONMENT	$454.4 - .000547(DRY\ WT) + .8210(LEN + WING) - 107.5\,LOG(LEN + WING)$	7.68, ∞	.840
14.20	ECS-Life Support	$6613 - 1.485(LEN + WING) - 1358.3\,LOG(DRY\ WT) + 73.58(DRY\ WT)^2 - .7259(WT/(LEN + WING))$	13.8, ∞	.720
15.00	PERSONNEL PROV	$17952.8 + .005793(DRY\ WT) + 169.96(CREW\ SIZE) - 10.136(LEN + WING) + 21.15(PERSONS) - 461.3\sqrt{PERSONS} - 1.893(SUBS\ WT) + 421.8\sqrt{SUBS\ WT} - 4054.1\,LOG(SUBS\ WT)$	46.7, ∞	.961
16.10	REC & AUX, PARACHUTES	$23030.42 + 236.89(LEN + WING) - 4657.05\sqrt{LEN + WING}$	101.1, ∞	.885
16.20	REC & AUX, ESCAPE SYS (emer equip)	$-2032.57 + 10.54\sqrt{DRY\ WT} - 23.91(LEN + WING) + .16436(AVE\ WT) - 20.27(\#\ AVE\ SUBSYS) + 352.2\sqrt{LEN + WING}$	18.9, ∞	.889
16 (.20/.30)	REC & AUX, ESCAPE SYS SEPARATION SYS (exp device)	$8962.941 + 22.477\sqrt{DRY\ WT} - .0202(DRY\ WT) - 1172.605\,LOG(DRY\ WT)$	65.9, ∞	.902
16 (.4/.5/.6)		Not Available		

The estimated MTBM is adjusted for technological change. In deriving the adjustment factor, a learning curve of the form given by Equation (2) is determined by using least-squares. These curves are summarized by subsystem in Table 9. Three separate equations were derived using historical data from the F-16B, B-1, and F-15A. Table 10 depicts the average growth rate (b parameter) for each subsystem. Only statistically significant growth rates from among the three aircraft were averaged. A separate analysis was performed for the overall aircraft.

Table 9
Learning Curve Results

WBS	SUBSYSTEM	AVE GROWTH RATE (b)
1.00	WING	.1534
2.00	TAIL	.1534
3.00	BODY	.1534
4.XX	IEP	---
5.00	LANDING GEAR	.1480
6.00-8.00	PROPULSION	.2305
9.XX	APU (PRIME POWER)	.1927
10.00	ELECTRICAL	.1333
11.00	HYDRAULICS/PNEU	.1703
12.00	ACTUATORS	.1608
13.XX	AVIONICS	.2427
14.XX	ECS	.1555
15.00	PERSONNEL PROV	.0683
16.XX	RECOVERY & AUX	.3592
	VEHICLE	.1370

Using the methodology discussed in the previous chapter, technology adjustment factors were then derived. These factors, displayed in Table 10, represent an average annual growth rate based upon a compound growth curve. One subsystem, electrical, resulted in a negative growth rate which was set equal to zero. A combined avionics growth rate of .42 appeared to be excessive and was replaced with an adjusted rate obtained by deleting the F-4E - F-16A comparison which had a 0.22 annual growth rate. The rates shown in Table 10 represent the default values used in the implementation phase. In implementation, the TPS subsystem defaulted to the structural subsystems (WBS 1.00, 2.00, 3.00) growth rates. The APU growth rate was not computed because of insufficient data. The aircraft rate is used as a default value for those subsystems not computed explicitly from the aircraft data.

Table 10
Technology Growth Rates

WBS	SUBSYSTEM	AVERAGE
1.00	WING	.08184
2.00	TAIL	.08184
3.00	BODY	.08184
4.xx	IEP	---
5.00	LANDING GEAR	.03352
6/7/8	PROPULSION	.01116
9.xx	APU (PRIME POWER)	*.0557*
10.00	ELECTRICAL	-0.02090
11.00	HYDRAULICS/PNEU	.09222
12.00	ACTUATORS	.05622
13.xx	AVIONICS	.41915 (.22)
14.xx	ECS	.00617
15.00	PERSONNEL PROV	.03571
16.xx	RECOVERY & AUX	.08358
	AVE TOTAL	.0557

Regression equations for subsystem critical failure rates were derived from MODAS obtained aircraft air/ground abort rates found in Appendix N of the first year report [23] and are displayed in Table 11. Averages were used when the number of data points were insufficient to properly fit a regression curve. Because of the processing time required to obtain the abort rates, these equations are based upon a smaller sample size consisting of 13 aircraft. Each subsystem and each aircraft data point had to be retrieved separately from the MODAS ABORT SUMMARY REPORT. In general, there is a high correlation between vehicle size as measured by DRY WEIGHT or LENGTH plus WING SPAN and abort rates.

Table 11
Critical Failure Rate Equations

WBS	Equation	Range	R
1.00 WING 2.00 TAIL 3.00 BODY	$3.1213E{-}2 + 1.956E{-}7(DRY\ WT) - 1.546E{-}4\sqrt{DRY\ WT}$	0, .02065	.802
3.00 BODY (CREW COMPARTMENT)	$.04232 + 3.8775E{-}7(DRY\ WT) - 2.5188E{-}4\sqrt{DRY\ WT}$	0, .02	.914
3.10/3.20 TANKS	Default Values		---
4.xx IEP	Default Values		---
5.00 LANDING GEAR	$-2.4321 + 5.9112E{-}3(LEN + WING) + 1.1457\,LOG(LEN + WING) - .33925\sqrt{LEN + WING}$	0, .08	.794
6.00-8.00 PROPULSION	$4.8164E{-}2 - 1.2681(LEN + WING)$	0, .048	.777
9.xx PRIME PWR (APU)	AVERAGE = .064		---
10.00 ELECTRICAL	$-39.96 + 11.09\,LOG(DRY\ WT) - 1.0178(LOG(DRY\ WT))^2 + .030908(LOG(DRY\ WT))^3$	0, .142	.833
11.00 HYDRAULICS	$5000.3 - \frac{7578.2}{\sqrt{LOG(DRY\,WT)}} - 453.6\,LOG(DRY\,WT) + 24.6(LOG(DRY\,WT))^2 - .5276(LOG(DRY\,WT))^3$	0, .1304	.970
12.00 ACTUATORS (FLIGHT CONTROLS)	$.71195 - .18814\,LOG(LEN\ WING) + 2.0988E{-}2\sqrt{LEN + WING}$	0, .08128	.956

13 AVIONICS, ROLL-UP	$5.0275E\text{-}2+2.605E\text{-}7(DRY\ WT)-2.2882E\text{-}4\sqrt{DRY\ WT}$	0, .02376	.909
13.10 AV, GN&C	Average = .01		---
13.30 AV, COMM & TRACK	Average = .011		---
13.50 AV, INSTRUMENTS	Average = .015		---
14.XX ECS	$8.2199E\text{-}2+5.007E\text{-}7(DRY\ WT)-4.0613E\text{-}4\sqrt{DRY\ WT}$	0, .05222	.888
15.00 PERSON. PROV	AVERAGE = .0185		---
16.XX REC AUX SYS	Default Values		---

E. MHMA Equations

Predicted maintenance manhours per maintenance action were obtained from regression equations using primary, secondary and subsystem weight variables. These equations are presented in Table 12.

Marginal correlations were obtained for several subsystems including electrical, and oxygen subsystems. For those subsystems average manhours per maintenance action remains somewhat constant across aircraft. However, except for landing gear and oxygen, the fitted equations were significant at the 10 percent level and therefore partly explain the variation found in this parameter. In order to separate the on and off vehicle work being performed, the percent of off-equipment (POFF) manhours was also estimated from regression equations. These equations are identified in Table 13.

Table 12
MHMA Equations

WBS	Equation	Range	R
1.00 WING 2.00 TAIL 3.00 BODY	$16.57 - .3512 \times FUS\ DENS - .7546\log(DRY\ WT)$	3.9, ∞	.6672
3.00 BODY (CREW COMPARTMENT)	$7.0855 - \frac{1.6666}{\sqrt{CREW + PASSENGERS}} + .09878 \times (CREW + PASSENGERS)$	3.2, ∞	.7414
3 (.10/.20) TANKS, LOX/LN_2	$-180.85 + .00126(DRY\ WT) + .6663(LEN+WING) - .0121(WET\ AREA) + 11.7288\,LOG(DRY\ WT)$ $-1.635\sqrt{WET\ AREA} - 20.309(\#\ FUEL\ TANKS) + 87.164\sqrt{\#\ FUEL\ TANK}$ $-.00131(MAIN+RCS+OMS\ WT) + .45(TANK\ WT)$	7, 21.34	.9600
4.xx IEP	NOT Available		---
5.00 LANDING GEAR	$-156.95 + 55.98\log(L.\ GEAR\ WT) - 6.0952\log(L.\ GEAR\ WT)^2 + .2128\,LOG(L.\ GEAR\ WT)^3$	1.9, ∞	.5243
6/7/8 PROPULSION	$52.632 + 9.12212 \times 10^{-4} \times ENG\ WGT - .3936\sqrt{ENG\ WGT}$	4.1, 21.1	.6506
9.10 POWER, APU	$-451.3954 + .09054 \times KVA\ MAX - 2.9654\sqrt{KVA\ MAX} + .26570 \times APU\ WT - 26.0995\sqrt{APU\ WT} + 150.50\,LOG(APU\ WT)$	5.2, 17.2	.8585
9.20 POWER, BATTERY	$1.907 + 6.975E{-}06(DRY\ WT)$	1.9, ∞	XXXX
9.30 POWER, FUEL CELL	NOT Available		
10.00 ELECTRICAL	$-95.161 + 20.316\log(DRY\ WT) - .9836(\log(DRY\ WT))^2$	1, ∞	.4704
10.00 ELECTRICAL-LIGHTING	$2300.0 + 474.1\,LOG(DRY\ WT) - 452.2954\,LOG(LEN + WING) - \frac{.14629 \times DRY\ WT}{LEN + WING}$ $-2769.9\sqrt{\log(DRY\ WT)} + 1788.39\sqrt{\log(LEN + WING)}$	1, ∞	.6084
11.00 HYDRAULICS	$2.4124\log(DRY\ WT) - .16307(\log(DRY\ WT))^2$	2.4, ∞	.9527
12.00 AERO SURFACES	$26.238 - 1.1067 \times ACTUATOR - 1.66585 \times CONTSUR - .00328 \times WETAREA$ $+ .0006018 \times DRY\ WT - 6.2827\log(FLTCTL\ WT) + 14.2891\sqrt{ACTUATOR}$	2.1, ∞	.7857

13.xx AVIONICS, ROLL-UP	$131.3954 + 1.0394 \times (\# \; DIF \; SUBS) - 9.0352\sqrt{\# \; TOT \; SUBS} - .0154 \times (AV \; WT) + 2.8641\sqrt{AV \; WT} - 26.19323\log(AV \; WT)$	4.6, ∞	.8016
13.10 AV, GN&C	NOT Available		
13.20 AV, HEALTH MONITOR	AVERAGE = 5.5		
13.30 AV, COMM&TRACKING	NOT Available		
13.40 AV, DISPLAY&CONT.	AVERAGE = 8.95		
13.50 AV, INSTRUMENTS	$-229.62 + .0003(DRY \; WT) + .0985(LEN + WING) + 23.4948 LOG(DRY \; WT) - .44697\sqrt{DRY \; WT} - 25.3067(\# \; ENGINES) + .17796(\# \; FUEL \; TANKS) + 74.155\sqrt{\# \; ENGINES}$	3.5, 12.6	.9000
13.60 AV, DATA PROC	$4.75 + .2446 LOG(DRY \; WT)$	4.75, ∞	.870
14.xx ECS	$.6886774\log(DRY \; WT)$	1, ∞	.9419
14.xx ECS-OXYGEN	$5.7432 + .018525\log(DRY \; WT) - .003366\sqrt{DRY \; WT}$	1, ∞	.2523
15.00 PERSONNEL PROV	$9.5132 + .03508 \times (LENTH + WING) - .000721 \times (SUBSYS \; WT) - 4.52\sqrt{CREW \; SIZE}$	2.2, ∞	.7061
16.10 REC&AUX, PARACHUTES	AVERAGE = 6.95 (DRAG CHUTE EQUIP)		
16.20 REC&AUX, ESCAPE SYS	$-1368.29 + .000704(DRY \; WT) + \frac{21064.55}{\sqrt{DRY \; WT}} + 138.37 LOG(DRY \; WT) - 1.131\sqrt{DRY \; WT}$	1.4, ∞	.666
16.30 REC&AUX, SEPARATION	AVERAGE = 4.03 (EXPLOSIVE DEVICES)		
16.50 REC&AUX, DOCKING	NOT Available		
16.60 REC&AUX, MANIPULATOR SYS	NOT Available		

Table 13
Percent Off Equipment Equations

WBS	Equation	Range	R
1/2/3 WING,TAIL,BODY	$MEDIAN = .0835$		
3.00 BODY (CREW COMPARTMENT)	$MEDIAN = .088$		
3 (.10/.20) TANKS, LOX/LN_2	$.62537 + 2.22E\text{-}05(WET\ AREA) - .0108\sqrt{WET\ AREA} - .0775\sqrt{\#\ FUEL\ TANKS} + 2.465E\text{-}05(MAIN+OMS+RCS\ WT)$	.011, .3	.951
4.XX IEP	DEFAULT VALUE		
5.00 LANDING GEAR	$.02774 - 4.07E\text{-}6 \times DRY\ WT - .00194 \times LENWING + .19316\sqrt{WHEEL} + .007156\sqrt{L.GEAR\,WT}$	.134, .54	.8146
6/7/8 PROPULSION	$1.14633 + 4.5721 \times 10^{-5} \times ENG\,WGT - .011456\sqrt{ENG\,WGT}$	.2, .725	.6551
9.10 PRIME POWER(APU)	$-109.8302 - .1645\log(DRY\ WT) + .1427 \times KVAMAX - 6.1518\sqrt{KVAMAX} + 15.751\,LOG(KVAMAX) + .066 \times APU\,WT - 5.6832\sqrt{APU\,WT} + 29.0715\,LOG(APU\,WT)$	.03, .29	.9974
9 (.20/.30) POWER, BATTERY/FUEL CELL	DEFAULT VALUE		
10.xx ELECTRICAL	$-26.5654 - .00271 \times KVAMAX + .005143 \times ELEC\,WT - .74878\sqrt{ELEC\,WT} + 6.62114\log(ELEC\,WT)$	.054, .53	.9274
10.10 ELECT, LIGHTING	$3.0610 + 1.178 \times 10^{-5} \times DRY\ WT - 1.27 \times 10^{-4} \times WETAREA - .42392\log(DRY\ WT) + .13468\sqrt{WING + LENGTH}$	.03, .47	.7817
11.00 HYDRAULICS	$.07614 - .00181(LENGTH + WING) + .001543\sqrt{DRY\ WT}$	.014, .33	.5836
12.00 AERO SURFACES	$5.512466 + .002663 \times (\#\ ACTUATOR) - .000566 \times (FLT\ CTL\ WT) - 1.193089\,LOG(FLT\ CTL\ WT) + .105556\sqrt{FLT\ CTL\ WT}$	.04, .29	.8034

13.xx AVIONICS, ROLL-UP	$7.166202 + .0209(\#\ DIFF\ SUBS) - .00128(AV\ WT) + .177379\sqrt{AV\ WT} - 1.734\,LOG(AV\ WT) + .0067\,\frac{AV\ WT}{\#\ SUBS}$	.193, .532	.8705
13.50 AV, INSTRUMENTS	$-8.734101 + 1.22E\text{-}05(DRY\ WT) + .007198(LEN+WING) + .80066\,LOG(DRY\ WT) - .02\sqrt{DRY\ WT} - 1.45834(\#\ ENGINES) + .02554(\#\ FUEL\ TANKS) + 4.19646\sqrt{\#\ ENGINES}$	.05, .44	.936
14.10 ECS	$AVERAGE = .0932$		
14.20 ECS, LIFE SUPPORT	$23.852 - .00902(LENGTH+WING) - 5.247019\,LOG(DRY\ WT) + .301(LOG(DRY\ WT))^2 - .00212\,\frac{DRY\ WT}{LENGTH+WING}$	.02, .33	.8483
15.00 PER PROVISIONS (MISC. UTILITIES)	$.198886 + 4.938\times10^{-6}\times DRY\ WT - .00205\sqrt{DRY\ WT} + 4.877\times10^{-4}\times KVAMAX$	.002, .45	.6620
15.00 PER PROV (EQPT)	$-5.46864 + .168358(LEN+WING) - .00448(WET\ AREA) + .365211(CREW+PASSEN) - 4.152794\sqrt{CREW+PASSEN} + .178\sqrt{SUB\ SYS\ WT}$	.23, .98	.9869
16.10 REC&AUX, PARACHUTE	$AVERAGE = .287$		
16.20 REC&AUX, ESCAPE SYS	$4.653976 - .457186\log(DRY\ WT) + .002421\sqrt{DRY\ WT}$	.011, .84	.6285
16 (.20/.30) REC&AUX, ESCAPE/SEPARATION	$AVERAGE = .01$		
16 (.40/.50/.60) REC&AUX	DEFAULT VALUE		

F. Scheduled Maintenance

Limited data is maintained on military aircraft pertaining to scheduled maintenance. These tasks fall into two categories: preflight/postflight inspections and periodic maintenance. For AF aircraft, total maintenance manhours expended in both areas are recorded in AFALDP 800-4. Using this data pertaining to 27 different data points, a regression analysis was performed with the results summarized in Table 14. Scheduled maintenance manhours is predicted as a percent of the unscheduled on-aircraft maintenance manhours. Once total unscheduled maintenance is computed, then the predicted percentage is applied to obtain the total scheduled maintenance.

Table 14
Scheduled Maintenance Manhours

As a percentage of UNSCHEDULED on-vehicle Maintenance Manhours:

$$\%UNSCH = 23.924 - .0545(LEN+WING) - 10.563\,LOG(LEN+WING) + 3.039\sqrt{LEN+WING}$$
$$.0215(FUS\,WT/FUS\,VOL) + 6.72e{-5}(FUSAREA)$$

(R = 0.81) (RANGE=.132, .794)

SCH MANHOURS = %SCH x UNSCH ON-VEHICLE MANHOURS

G. Removal Rates

Removal rates were based on data pertaining to six aircraft: C-5A, C-130E, C-141B, F-15D, F-111A, and T-38A. Since it was not possible to obtain adequate least-square fits for several WBS's, mean values were used. Results are depicted in Table 15.

13.xx AVIONICS, ROLL-UP	$.397347 - 4.2659E\text{-}07 \times \boldsymbol{DRY\ WT} + 2.1635E\text{-}04\sqrt{\boldsymbol{DRY\ WT}}$	.235, .726	.8705
13.10 AV, GN&C	AVERAGE = 0.4		
13.30 AV, COMM&TRACKING	AVERAGE = 0.4		
13.50 AV, INSTRUMENTS	AVERAGE = 0.51		
13.60 AV, DATA PROCESSING	$-1.3 + .14458\,LOG(DRY\ WT)$	.235, .726	.837
14.10 ECS	$.529437 - 8.913525E\text{-}5 \times ECSWT$	.168, 1	.7484
14.20 ECS, LIFE SUPPORT	$.602614 - 6.758594E\text{-}04\sqrt{DRY\ WT}$		.9309
15.00 PERSONAL PROV	*AVERAGE* = .274		
16.20 REC&AUX SYS (EMERGENCY EQUIPMENT)	$2.3489 - .35852(LEN + WING)$	0, 1	.9103
16 (.20/.30) REC&AUX, EXPL	$2.532 - .22837\,LOG(WET\ AREA)$	0, 1	.8207

42 INTENTIONALLY

H. Crew Sizes

Average (mean) crew sizes for performing unscheduled maintenance are predicted from derived regression equations. The input data for this analysis was obtained from the MODAS maintenance summary reports which provided by aircraft and by subsystem total maintenance manhours and total elapsed time. The raw data may be found in Appendix O of the first year report [23] and is summarized in Table 16. By dividing the maintenance manhours by elapsed time, an average crew size was obtained. For this analysis, crew sizes were estimated at the one digit (or higher) level. Because of the difficulty and time in extracting this data from MODAS, the data was obtained at the higher level. The resulting equations are in Table 17. No significant fit could be obtained for WUC's 2XXXX and avionics (5XXXX, 6XXXX and 7XXXX). Therefore mean values were used. Neither propulsion repair crew size nor avionics repair crew size seem to be related to aircraft size.

Table 16
Crew Size Data
(by WUC)

AIRCRAFT	1XXXX	2XXXX	4XXXX	AVIONICS	9XXXX
A7D	1.66	2.44	1.58	2.01	1.76
F111E	2.66	2.85	2.73	2.42	2.87
F4E	1.80	2.37	2.04	2.28	1.88
F15C	2.03	2.26	2.18	2.21	2.00
F16A	1.90	2.37	2.02	2.21	2.17
C130E	2.12	2.00	2.21	1.98	2.02
KC135	1.90	2.53	2.39	2.42	2.03
C141B	2.30	2.99	2.26	1.98	2.12
C5B	2.09	2.11	2.22	2.10	2.42

Table 17
Crew Size Regression Equations

WUC	WBS	EQUATION	Range	R
1XXXX	1, 2, 3, 4, 5, 12	$1.5-3.2E{-}05(WET\ AREA)$ $+9.1722E{-}03\sqrt{WET\ AREA}$	1.66,2.12	.737
2XXXX	6, 7, 8, 9	AVE = 2.43	---	---
4XXXX	10, 11, 14	$-1.48-2.833E{-}3(LEN+WING)$ $+.81466\,LOG(LEN+WING)$	1.58,2.39	.774
AVIONICS	13.xx	AVE = 2.18	---	---
9XXXX	15, 16	$1.78933+9.8722E{-}4\sqrt{DRY\ WGT}$	1.76,2.42	.759

I. Shuttle Parameters

Shuttle R&M data were obtained from the Martin-Marietta study. Subsystem MTBM's were derived from this data by summing the total number of reported subsystem maintenance actions across all 16 STS's and dividing the total into the total number of operating hours recorded against the subsystem over the same mission (see Appendix B [22]). For those subsystems identified as having cyclical failures (i.e. per mission), mission hours were used in place in operating hours in order to obtain an MTBM in units of hours per maintenance action. This was necessary for consistency with the aircraft computed MTBM's. The only exception to this was the landing gear subsystem whose failures were assumed to be cyclical for both the aircraft and the shuttle computed values. Several shuttle subsystems including structures, main propulsion system, environmental control, and mechanism map into two or more design vehicle WBS'. The overall failure rate of these subsystems was prorated to the appropriate WBS using the relative WBS weights obtained from the shuttle weight distribution. That is, letting

W = total weight of STS subsystem having a failure rate of 1/MTBM, and

W_i = weight of the ith WBS (within the STS subsystem, then

$$MTBM_i = 1/\lambda$$

where

$$\lambda = (W_i/W)/MTBM$$

The shuttle MTBM values obtained in this manner are identified in Table 18, column one.

Table 18
Shuttle Subsystem MTBMs, MTTRs, and Removal Rates

Subsystem	MTBM[7]	MTTR[8]	Removal Rate[8]
1.00 Wing Group	3.7824	14.5	.143
2.00 Tail Group	22.24941	14.5	.143
3.00 Body Group	1.365487	14.5	.143
3.10 Tanks LOX	17.728	5.47	.216
3.20 Tanks LN_2	15.64235	5.47	.216
4.10 IEP-Tiles	.129	11.46	----
4.20 IEP-TCS	3.69	20.15	.481
4.30 IEP-PVD	64.3	5.63	.391
5.00 Landing Gear	7.7721	12.12	.219
6.00 Propulsion-Main	7.02	4.02	0
7.00 Propulsion-RCS	13.06	10.19	.159
8.00 Propulsion-OMS	40.31	8.62	.303
9.10 Power-APU	7.43	4.37	----
9.20 Power-Battery	9999	0	0
9.30 Power-Fuel Cell	30.07	16.3	.261
10.00 Electrical	17.4	6.41	.088
11.00 Hydraulics/Pneumatics	5.62	3.13	----
12.00 Aero Surface Actuators	17.27139	12.12	.219
13.10 Avionics-GN&C	34.41	9.91	.392
13.20 AV-Health Monitoring	9999	0	----
13.30 Avionics-Comm&Tracking	66.22	10.88	.333
13.40 Av-Displays & Contr	34.52	13.37	.466
13.50 Avionics-Instruments	47.2	4.76	.482
13.60 Avionics-Data Processing	9999	0	0

[7] NOTE: 9999 indicates subsystem data not available for shuttle

[8] NOTE: 0 indicates subsystem data not available for shuttle

14.10 Environmental Control	24.47	9.9	.293
14.20 ECS-Life Support	9999	9.9	.293
15.00 Personnel Provision	7.2	8.3	.174
16.10 Rec & Aux-Parachutes	9999	0	0
16.20 Rec & Aux-Escape Sys	9999	0	0
16.30 Rec & Aux-Separation	11.99008	7.48	.257
16.40 Rec & Aux-Cross Feed	9999	0	0
16.50 Rec & Aux-Docking Sys	3108.85	12.12	----
16.60 Rec & Aux-Manipulator	9999	0	----

Appendix C contains the shuttle repair data. MTTR values used in this study were obtained from averaging, by subsystem, two or more MTTR's computed in the Martin-Marietta study [22] employing several methods as options one, two, and three. These averages consisted of two to five data points per STS depending upon the subsystem. Obvious outliers were eliminated. If a subsystem mapped into two or more WBS's, then each WBS would be assigned to the same MTTR. The resulting values are shown in Table 18, column 2. Appendix D contains the external tank and Titan failure data used as default values in the computer model.

Shuttle removal rates were also determined from the data set by dividing the total number of removals across all STS's by the total number of maintenance actions. Common WBS's to a single shuttle subsystem were assigned a common removal rate. These values are displayed in Table 18, column 3.

CHAPTER V

Implementation

I. Introduction

This chapter describes the PC based model for evaluating the reliability and maintainability equations derived in the previous chapter. Because of the large number of equations to be evaluated and the large number of additional calculations, the only practical way to implement the results of this research is on a computer. This PC based model is completely menu driven with all parameters computed at the subsystem (WBS) level and then rolled up to reflect overall vehicle performance.

Flying hours between maintenance actions, maintenance manhours per maintenance action, critical failure (abort) rates, percent on/off vehicle hours, removal rates, and crew sizes are estimated using the multiple regression models derived from aircraft data. Lower bounds (and in some cases upper bounds) are set if the equations predict values outside the limits of the input data. In addition to predicting failures and repair manhours, estimates of mission reliability, spares support, manpower requirements, turn times and fleet size are also made.

The computer model is design to evaluate all 33 major subsystems as defined by the NASA work breakdown structure (WBS). Upon execution of the model, the user may elect to delete any number of these subsystems from the analysis. The user may redefine any of the 33 subsystems, thus allowing the addition of new subsystems. If the user elects to redefine any of the subsystems, new input values should be specified consistent with new subsystem. The existing regression equations will no longer be appropriate.

II. Execution

The model consists of an executable MS DOS file (RAM.EXE). Upon execution, the user will be asked to supply a vehicle/project name. Unless changed by the user, this name will also serve as the input/output file name (with a .DAT extension) if the user elects to save the input parameters. The program is menu driven with the main menu (Figure 2) providing the primary options available to the user.

Normally, the user would either read in an existing input file or go to the input parameter menu in order to define the input parameters and data for use in the current study. Once the input data is finalized, the user selects the "COMPUTE R&M PARAMETERS" from the main menu and then selects the "OUTPUT REPORT MENU" in order to display the results of the computations. At any time the user may save the current values of the entire input parameter/data set under the file name shown at the bottom the main menu. This name may also

```
NASA LRC - RELIABILITY/MAINTAINABILITY MODEL

              MAIN MENU

NBR                     SELECTION

1........READ INPUT FROM A FILE
2........INPUT PARAMETER MENU
3........COMPUTE R&M PARAMETERS
4........OUTPUT REPORT MENU
5........SAVE INPUT PARAMETERS
6........SAVE OUTPUT FOR COST MODEL
7........CHANGE VEHICLE/FILE NAME
8........TERMINATE SESSION

        ENTER SELECTION?

VEHICLE/FILE NAME IS  NCC-2000

YOU ARE CURRENTLY IN THE PRECONCEPTUAL MODE
```

Figure 2 Main Menu

be changed at any time from the main menu[1]. Selected output values may also be saved. However, this option will not be completely defined until the corresponding costing model has been completed.

III. Modes of Operation

The model operates in one of three modes: PRECONCEPTUAL, WEIGHT DRIVEN, and WEIGHT/VARIABLE DRIVEN. In the preconceptual mode, the user specifies values for 6 driver variables which are used, in turn, to compute secondary variables. The user will also specify a weight distribution to be used in allocating the vehicle total dry weight (a primary variable) to the subsystems. The resulting subsystem weights along with the primary and secondary variables are then used as independent variables in evaluating the parametric R&M equations during computation.In the weight driven mode, the user must specify the actual subsystem weights to be used in the computation. In the weight/variable driven mode, the secondary variables must also be specified. The current mode of operation is displayed at the bottom of the main menu. The default mode is PRECONCEPTUAL. The user may change the mode using the primary system parameter input menu. It is possible to switch modes while defining the input data. For example, while in the **weight-driven** mode, the program will automatically update the secondary variables from the primary variables and subsystem weights. The user may the switch to the **weight/variable-driven** mode in order to change one or more

[1] The data will be saved in the default (current) directory unless the file name specifies another drive, e.g. A:TESTDATA.DAT. Subdirectories cannot be referenced in this manner.

of the secondary variables. The user should then stay in this mode for further computations in order to avoid having all the secondary variables recomputed.

IV. INPUT PARAMETERS

The input parameter menu is selected from the main menu and is shown below.

```
NASA LRC - RELIABILITY/MAINTAINABILITY MODEL NCC-2000

                 INPUT PARAMETER MENU

NBR                        SELECTION

1.......ADD/DELETE A SUBSYSTEM
2.......SELECT SHUTTLE/AIRCRAFT
3.......UPDATE/DISPLAY PRIMARY SYSTEM PARAMETERS
4.......UPDATE/DISPLAY SUBSYSTEM WEIGHTS
5.......UPDATE/DISPLAY SECONDARY VARIABLES
6.......UPDATE/DISPLAY COMPUTATIONAL FACTORS
7.......UPDATE/DISPLAY MISSION PROFILE
8.......UPDATE/DISPLAY SYSTEM OPERATING HRS
9.......UPDATE/DISPLAY REDUNDANCY CONFIGURATION
10......UPDATE/DISPLAY LRU/ET RELIABILITY DATA
11.....  UPDATE/DISPLAY SHUTTLE MTBM'S & MTTR'S
12.....  CHANGE SCHEDULED MAINTENANCE
13.....  RETURN TO MAIN MENU


        ENTER SELECTION?
```

Figure 3 Input Parameter Menu

In establishing input values as part of a new study, the user would normally begin by identifying from among the 33 subsystems, those subsystems to be used. This option will also allow the user to change a subsystem name thereby permitting new subsystems to be added as long as the total number of subsystems does not exceed 33. Through the use of the "SELECT SHUTTLE/AIRCRAFT" menu, the user may bypass the aircraft generated parametric equations and use shuttle (or user input) MTBM & MTTR values. Shuttle values should be selected if a new subsystem has been defined since the parametric equations associated with old subsystem would no longer be valid.

By selecting "UPDATE/DISPLAY PRIMARY SYSTEM PARAMETERS," the user can assign values to the 6 primary variables and the 15 system parameters (shown below with their default values). Several of the system parameter values require additional description. "Adjust shuttle MTBM - Space" determines whether the shuttle selected MTBM value will have the environmental adjustment described in Chapter III, paragraph B (2) made. Since the shuttle MTBM values already account for launch and space operations, this adjustment should not be necessary. However, if the user inputs a new MTBM, which is not based upon the space environment, then the adjustment may be necessary. "Technology year" is used to determine the number of years of reliability growth at the rate specified on a corresponding menu.

```
                    INPUT MODULE - PRIMARY & SYSTEM VARIABLES

        NBR  VARIABLE                               CURRENT VALUE

    PRIMARY DRIVER VARIABLES

         1   DRY WGT (LBS)                            10000
         2   LENGTH (FT)                              70
         2   WING SPAN (FT)                           30
         3   CREW SIZE                                2
         4   NBR PASSENGERS                           8
         5   NBR MAIN ENGINES                         3

    SYSTEM PARAMETER VALUES

         6   ADJ SHUTTLE MTBM-SPACE 0-NO 1-YES        0
         7   TECHNOLOGY YR                            1996
         8   DEFAULT ABORT RATE                       .001
         9   WIEBULL SHAPE PARAMETER                  .20
        10   LAUNCH FACTOR                            20

ENTER NBR OF VARIABLE TO BE CHANGED - 0 IF NONE?
```

Figure 4 Update/Display Primary System Parameters (Screen 1)

```
                    INPUT MODULE - PRIMARY & SYSTEM VARIABLES

    SYSTEM PARAMETER VALUES (continued)

        NBR  VARIABLE                               CURRENT VALUE

        11   AVAIL MANHRS/MONTH                       144
        12   PERCENT INDIRECT WORK                    .15
        13   SPARE FILL RATE OBJ                      .95
        14   AVG CREW SIZE-SCHD MAINT                 7
        15   PLANNED MISSIONS/MONTH                   1
     —  16   MODE INDICATOR                           0
             0-PRECONCEPTUAL
             1-WEIGHT DRIVEN
             2-WEIGHT & VARIABLE DRIVEN
        17   VEHICLE INTEGRATION TIME (HRS)           0
        18   LAUNCH PAD TIME (HRS)                    24
        19   AGGREGATE AVIONICS 0-NO/1-YES            0
        20   DEFAULT PERCENT OFF MANHRS               .2

ENTER NBR OF VARIABLE TO BE CHANGED - 0 IF NONE?
```

Figure 4 Update/Display Primary System Parameters (Screen 2)

"Default abort rate" is used for those subsystems not addressed by abort rate equations and is also used for the ET and LRB systems. The user may specify abort rates by subsystem using a subsequent menu.The "Weibull shape parameter and launch factor" are the b and k values used in Equation 10 of Chapter III. "Available manhours per month" is the total number of hours during a month an individual is available within the workplace to do both direct and indirect work. Direct work is defined as the maintenance work addressed by the model while indirect work is all other categories of work. "Spares fill rate objective" is the percent of time a spare component is available when a failure has occurred. Selecting a "yes" response for "aggregate avionics" will result in a single avionics subsystem replacing the six different avionic subsystems available.

When selecting "subsystem weights" in the preconceptual mode, a secondary input menu is obtained allowing for the selection of one of four weight distributions as shown.

```
            SELECT WEIGHT DISTRIBUTION
        1 - LARGE VEHICLE DISTR
        2 - SHUTTLE WGT DISTR
        3 - SMALL VEHICLE DISTR
        4-  AIRCRAFT WGT DISTR
        RETURN - MAINTAIN CURRENT DISTRIBUTION

SELECT DISTRIBUTION....?
```

Figure 5 Select Weight Distribution

After selecting a weight distribution, the user may modify the percents as long they continue to add to 100 percent. These percentages are then applied to the total dry weight,and a subsystem weight display screen is then observed. In the other two modes, the subsystem weight screen is displayed directly allowing the user to change any subsystem weight. The primary variable vehicle dry weight will then be updated to reflect the sum of the subsystem weights. In the weight driven and weight/variable driven modes, total vehicle dry weight cannot be specified. Instead, this variable is computed from the sum of the subsystem weights. While in the weight driven or weight/variable driven mode, all subsystem weights may be adjusted by a common factor. The effect of subsequent usages of this factor is cummulative, since the original weights are not retained. However, by multiplying by the reciprical of the product of the factors used, the original weights can be recovered. The user must record the multiplying factors, since only the last factor is retained.

The secondary variable screen cannot be updated/changed in the preconceptual and weight-driven mode. In the weight/variable driven mode, the user may change any of the variable values. This screen is shown below:

```
SECONDARY INDEP VARIABLES

     NBR        VARIABLE                     CURRENT VALUE


      1         FUSELAGE AREA                 491.2532
      2         FUSELAGE VOLUME               1185.185
      3         WETTED AREA                   1996.191
      4         NBR WHEELS                    3
      5         NBR ACTUATORS                 5
      6         NBR CONTR SURFACES            8
      7         KVA MAX                       27.87346
      8         NBR HYDR SUBSYS               8
      9         NBR FUEL TANKS (INTERNAL)     4
      10        TOT NBR AVIONICS SUBSYS       16
      11        NBR DIFF AVIONICS SUBSYS      16
      12        BTU COOLING                   86.46989

ENTER RETURN...?
```

Figure 6 Secondary Independent Variables

The following menu is obtained when selecting "UPDATE/DISPLAY COMPUTATION FACTORS. The six different screens available from this menu allows the user to display or change, by subsystem, any of these input factors. Whenever a critical failure rate, removal rate, crew size, or percent off-equipment is updated by the user, a flag is set to ensure those values are no longer computed by the model. The user, however, may overide this condition when a computation is performed (see Figure 12). The MTBM/MTTR calibration screens allow the user to make subsystem changes to the unadjusted MTBM and MTTR by multiplying subsystem values by a common factor. This is particularly useful, for example in performing sensitivity analyses where the reliability and maintainability are systematically changed.

```
COMPUTATIONAL FACTORS MENU                                   NCC-2000

NBR                          SELECTION

1.........TECHNOLOGY GROWTH FACTOR
2.........CRITICAL FAILURE (Z) RATES
3.........SUBSYSTEM REMOVAL RATES
4.........MTBM/MTTR CALIBRATION
5.........CREW SIZES
6.........PERCENT OFF-EQUIP
7.........RETURN TO INPUT MENU




          ENTER SELECTION?
```

Figure 7 Update/Display Computational Factors Menu

The screens "UPDATE/DISPLAY MISSION PROFILE" and "UPDATE/DISPLAY SYSTEM OPERATING HRS" work together to define the subsystem operating hours. The user may set up a generic mission profile based upon Figure 1 in Chapter III by updating the following screen:

```
                         MISSION PROFILE

                                                  TIME IN HOURS
       NBR

        1         GROUND RECOVERY/PROCESSING TIME      10

        2         PAD TIME                              2

   LAUNCH TIME AT T=0
        3         POWERED PHASE COMPLETION TIME        .14
        4         ORBIT INSERTION TIME                  1
        5         ORBIT COMPLETION TIME                71
        6         REENTRY TIME                         72

ENTER NUMBER TO BE CHANGED OR 0 IF NONE?
DO YOU WISH TO UPDATE SUBSYS OPERATING TIMES-Y/N?
```

Figure 8 Update/Display Mission Profile

Beginning at launch time (t=0), times are cummulative. Pad time may include integration time
and represent system operating hour times leading to a launch. The ground/recovery/processing
time, on the other hand, accounts for subsystem operating hours which will not directly impact
on the launch reliability. This screen may then be used to update the subsystem operating hours
screen. At this point the user may then change selected subsystem operating hour profiles.
Since the landing gear subsystem has failures per mission (on reentry), no update of this
subsystem is possible. The main engines operate only in the ground and launch phases therefore
the other phases will normally show zero values.

SUBSYSTEM OPERATING TIMES
TOTAL MISSION TIME 72 HRS MAX PAD TIME 2 HRS

NBR	SUBSYSTEM	RECOU TIME	PAD TIME	BOOST TIME	RE TIME TO-ORBIT	ORBIT TIME	REENTRY TIME
1	1.00 WING GROUP	10	2	.14	.86	70	1
2	2.00 TAIL GROUP	10	2	.14	.86	70	1
3	3.00 BODY GROUP	10	2	.14	.86	70	1
4	3.10 TANKS-LOX	10	2	.14	.86	70	1
5	3.20 TANKS-LH2	10	2	.14	.86	70	1
7	4.20 IEP-TCS	10	2	.14	.86	70	1
8	4.30 IEP-PVD	10	2	.14	.86	70	1
9	5.00 LANDING GEAR	0	0	0	0	0	1
10	6.00 PROPULSION-MAIN	10	2	.14	.86	0	1
11	7.00 PROPULSION-RCS	10	2	.14	.86	70	0
12	8.00 PROPULSION-OMS	10	2	.14	.86	70	1
14	9.20 POWER-BATTERY	10	2	.14	.86	70	1
15	9.30 POWER-FUEL CELL	10	2	.14	.86	70	1
16	10.00 ELECTRICAL	10	2	.14	.86	70	1

ENTER NBR OF SUBSYSTEM TO BE CHANGED - 0 IF NONE?

Figure 9 Update/Display System Operating Hours (Screen 1)

The "subsystem redundancy" configuration may be displayed and updated. Any number
of parallel subsystems may be indicated on this screen, however, the default value is a single
subsystem. For the power, engine, and avionic subsystems, a more general k-out-of-n
redundancy may be specified. The minimum number of subsystems required for operation
cannot exceed the number of redundant systems.

The user has the option of including either a liquid rocket booster (LRB) or an external
fuel tank (ET) system or both in the analysis. These two input screens will display default
values for the MTBM, MTTR, CRIT FAIL RT, CREW SIZE,and OPER HRS. These may be
updated and then an R&M computation is performed by subsystem and rolled up to the system
level. In addition, to the output displayed on these screens, system level output will be reflected
on the summary performance report.

If these screens are not selected following initialization of the model, neither an LRB or
ET will be included in the summary report. If these screens are selected and the user desires

SUBSYSTEM OPERATING TIMES

TOTAL MISSION TIME 72 HRS MAX PAD TIME 2 HRS

NBR	SUBSYSTEM	RECOV TIME	PAD TIME	BOOST TIME	RE TIME TO-ORBIT	ORBIT TIME	REENTRY TIME
18	12.00 AERO SURF ACTUATORS	10	2	.14	.86	70	1
19	13.10 AVIONICS-GN&C	10	2	.14	.86	70	1
21	13.30 AVIONICS-COMM & TRACK	10	2	.14	.86	70	1
22	13.40 AV-DISPLAYS & CONTR	10	2	.14	.86	70	1
23	13.50 AVIONICS-INSTRUMENTS	10	2	.14	.86	70	1
24	13.60 AVIONICS-DATA PROC	10	2	.14	.86	70	1
25	14.10 ENVIRONMENTAL CONTROL	10	2	.14	.86	70	1
26	14.20 ECS-LIFE SUPPORT	10	2	.14	.86	70	1
27	15.00 PERSONNEL PROVISIONS	10	2	.14	.86	70	1
28	16.10 REC & AUX-PARACHUTES	10	2	.14	.86	70	1
29	16.20 REC & AUX-ESCAPE SYS	10	2	.14	.86	70	1
30	16.30 REC&AUX-SEPARATION	10	2	.14	.86	70	1
31	16.40 REC&AUX-CROSS FEED	10	2	.14	.86	70	1

ENTER NBR OF SUBSYSTEM TO BE CHANGED -- 0 IF NONE?

Figure 9 Update/Display System Operating Hours (Screen 2)

SUBSYSTEM REDUNDANCY

NBR	WBS	NBR REDUNDANT SUBSYS	MIN NBR RQD
19	13.10 AVIONICS-GN&C	1	1
21	13.30 AVIONICS-COMM & TRACK	1	1
22	13.40 AV-DISPLAYS & CONTR	1	1
23	13.50 AVIONICS-INSTRUMENTS	1	1
24	13.60 AVIONICS-DATA PROC	1	1
25	14.10 ENVIRONMENTAL CONTROL	1	
26	14.20 ECS-LIFE SUPPORT	1	
27	15.00 PERSONNEL PROVISIONS	1	
28	16.10 REC & AUX-PARACHUTES	1	
29	16.20 REC & AUX-ESCAPE SYS	1	
30	16.30 REC&AUX-SEPARATION	1	
31	16.40 REC&AUX-CROSS FEED	1	

ENTER NBR OF SUBSYS TO BE CHANGED -- 0 IF NONE?

Figure 10 System Redundancy (Screen 2)

to subsequently delete either one or both of these systems then a reliability of one (1.00) should be assigned to the system(s) to be deleted.

EXTERNAL FUEL TANK INPUT DATA

NBR	SUBSYSTEM	MTBM	OPER HRS	CRIT FAIL RT	MTTR	CREW SIZE
1	ELECTRICAL	20.42	72	.001	13.68	4.5
2	PROP-FLUIDS	4	72	.001	18	4.5
3	RANGE SAFETY	44.77	72	.001	64.65	4.5
4	STRUCTURES	.0354	1	.001	6.83	4.5
5	THERMAL-TPS	.0219	1	.001	1.55	4.5

ENTER NUMBER FOR CHANGE?
ENTER SCHD MAINT AS % PCT OF UNSCH MAINT?

SUBSYSTEM	COMPUTED RELIABILITY	MISSION UNSCH MANHRS	SCH MANHRS	MANHR DRIVEN MANPWR
ELECTRICAL	.9964802	217.0578	0	2
PROP-FLUIDS	.982161	1458	0	12
RANGE SAFETY	.9983931	467.8713	0	4
STRUCTURES	.9721467	868.2203	0	8
THERMAL-TPS	.9553647	318.4931	0	3
OVERALL ET	.9075152	3329.643	0	29

note: set reliability=1 to eliminate subsystem
ENTER NEW RELIABILITY OR RETURN TO USE COMPUTED?

Figure 11 Update/Display LRB/ET Reliability Data

Shuttle MTBM and MTTR values may be displayed and changed by subsystem. The default values are based upon the Martin-Marietta data. However, these values may be replaced with non-shuttle values. Therefore, the user has the option of inputting his own R&M parameters obtained from data collected on other aircraft or space systems.

The final input menu selection allows the scheduled maintenance percent (as a percent of the unscheduled on-vehicle maintenance manhours) to be changed. The default value is based upon the equation in Table 14, Chapter IV.

V. Computations

When selecting the "Compute R&M Parameters" from the main menu, the following menu is obtained:

```
                    COMPUTATION SELECTION MENU



                         FACTOR                    OPTION

              1.....CRITICAL FAILURE RATES         RECOMPUTE
              2.....REMOVAL RATES                  RECOMPUTE
              3.....CREW SIZES                     RECOMPUTE
              4.....PERCENT OFF-EQUIP              RECOMPUTE
              5.....SCHD MAINT PERCENT             RECOMPUTE
              6.....CANCEL REQUEST

              RETURN.....PROCEED WITH COMPUTATION...

ENTER NUMBER TO CHANGE?
```

Figure 12 Compute R&M Parameters

The user has the option of bypassing the parametric equations which would recompute new values for the factors on the above selection menu. This option would be exercised whenever it was desired to fix these values at their current level. This would normally be the case when the user sets these values from the corresponding input screens. The primary computation involves the recalculation of the MTBM and the MHMA factors. However, if the subsystem has been identified as "SHUTTLE", then the current MTBM and MTTR values from the shuttle input screens are utilized in the R&M analysis and the parametric equations are ignored. The remaining calculations are performed in accordance with the discussion in Chapter III. Anytime the user changes an input parameter, the full effect of this change on the output can only be guaranteed if a recomputation is performed. Remember, weights and secondary variables will be recomputed in the preconceptual mode and secondary variables recomputed in the weight driven mode.

VI. Output Reports

The output selection menu identifies six different output reports. Each report is displayed on the screen and consists of two or more pages (screens). Printed copy of the reports is obtained by doing a PRINT-SCREEN or CONTROL-PRINT-SCREEN (for continuous printing) to a parallel port printer. An example of each report is presented below followed by definitions of the column headings.

```
NASA LRC - RELIABILITY/MAINTAINABILITY MODEL NCC-2000

              OUTPUT REPORT MENU

NBR                     SELECTION

1........RELIABILITY REPORT
2........MAINTAINABILITY REPORT
3........MANPOWER REQUIREMENTS
4........SPARES REQUIREMENTS
5........VEHICLE TURN TIME REPORT
6........SYSTEM PERFORMANCE SUMMARY
7........RETURN TO MAIN MENU




       ENTER SELECTION?
```

Figure 13 Output Report Menu

A. Reliability Report - page 1

RELIABILITY REPORT - page 1

VEHICLE IS NCC-2000 DATE: 06-14-1993 TIME: 03:19:31

WBS	CALIBRATED MTBM	TECH ADJ	SPACE ADJ
1.00 WING GROUP	22.23744	48.90546	245.4911
2.00 TAIL GROUP	600.4108	1320.447	7124.969
3.00 BODY GROUP	7.5456	16.59459	71.80904
3.10 TANKS-LOX	26.04	26.04	122.3636
3.20 TANKS-LH2	12.33474	12.33474	49.21217
4.20 IEP-TCS	3.69	5.057495	5.057495
4.30 IEP-PVD	64.3	80.12924	80.12924
5.00 LANDING GEAR MSN'S/FAILURE	16.68816	23.00935	23.00936
6.00 PROPULSION-MAIN	21.90945	24.44236	10.39035
7.00 PROPULSION-RCS	30.00832	33.56677	162.0272
8.00 PROPULSION-OMS	29.98339	33.4497	162.1972
9.20 POWER-BATTERY	3570	6156.125	33290.07
9.30 POWER-FUEL CELL	30.07	37.39289	37.39289
10.00 ELECTRICAL	5.15	5.15	12.77312
12.00 AERO SURF ACTUATORS	34.45455	59.41359	302.2043

RELIABILITY REPORT - page 1

VEHICLE IS NCC-2000 DATE: 06-04-1993 TIME: 14:00:14

WBS	CALIBRATED MTBM	TECH ADJ	SPACE ADJ
13.10 AVIONICS-GN&C	93.06721	679.8217	3658.518
13.30 AVIONICS-COMM & TRACK	50.45774	368.5752	1974.401
13.40 AV-DISPLAYS & CONTR	34.52	76.47335	76.47335
13.50 AVIONICS-INSTRUMENTS	35.37601	258.4080	1370.348
13.60 AVIONICS-DATA PROC	29.13	212.7839	1131.514
AVIONICS ROLLUP	8.100076	30.71465	64.65986
14.10 ENVIRONMENTAL CONTROL	35.876	38.1634	187.5782
14.20 ECS-LIFE SUPPORT	123.4479	131.3188	690.8561
15.00 PERSONNEL PROVISIONS	1946.233	2771.995	14979.45
16.10 REC & AUX-PARACHUTES	140.9023	330.511	1760.451
16.20 REC & AUX-ESCAPE SYS	17.76364	39.42907	194.3972
16.30 REC&AUX-SEPARATION	709.0712	1573.09	8496.371
16.40 REC&AUX-CROSS FEED	9999	13755.31	13755.31
VEHICLE	.0002664	1.135153	1.037986

Figure 14 Reliability Report - page 1

CALIBRATED MTBM: The initial mean time between maintenance actions computed from the regression equations or in the case of "SHUTTLE" read in directly. Time is measured in flying hours except for the landing gear system which is measured in missions (or sorties). This value is then multiplied by the MTBM calibration factor (default is a factor of one).

TECH ADJ: The calibrated MTBM multiplied by the technology growth factor (Eq. 7).

SPACE ADJ: The technology adjusted MTBM recomputed to account for the increase in failure rates during launch and the decrease in failure rates while in orbit. "SHUTTLE"MTBM's do not have the space adjustment unless requested by the user (Eq. 11).

B. Reliability Report - page 2

RELIABILITY REPORT - page 2

VEHICLE IS NCC-2000 DATE: 06-04-1993 TIME: 14:00:22

WBS	CRITICAL FAIL RATE	CRITICAL MTBM	SUBSYS NON-REDUNDANT MSN REL
1.00 WING GROUP	.017713	13859.37	.9990137
2.00 TAIL GROUP	.017713	402245.2	.999966
3.00 BODY GROUP	1.017161E-02	3951.717	.9965453
3.10 TANKS-LOX	.001	122363.6	.9990082
3.20 TANKS-LH2	.001	49212.17	.9997221
4.20 IEP-TCS	.001	5057.495	.9972996
4.30 IEP-PVD	.001	88129.23	.9998448
5.00 LANDING GEAR	4.266332E-02	541.1992	.998154
6.00 PROPULSION-MAIN	.035404	293.0434	.9808700
7.00 PROPULSION-RCS	.035404	4588.75	.9970242
8.00 PROPULSION-OMS	.035404	4570.996	.9970127
9.20 POWER-BATTERY	.001	3.329087E+07	.9999996
9.30 POWER-FUEL CELL	.001	37392.09	.9996343
10.00 ELECTRICAL	8.822889E-03	1447.725	.9985982
12.00 AERO SURF ACTUATORS	.0554238	5452.608	.9974951

RELIABILITY REPORT - page 2

VEHICLE IS NCC-2000 DATE: 06-04-1993 TIME: 14:00:31

WBS	CRITICAL FAIL RATE	CRITICAL MTBM	SUBSYS NON-REDUNDANT MSN REL
13.10 AVIONICS-GN&C	.01	365851.8	.9999626
13.30 AVIONICS-COMM & TRACK	.011	179491	.9999238
13.40 AV-DISPLAYS & CONTR	.02376	3218.575	.9957601
13.50 AVIONICS-INSTRUMENTS	.015	91089.00	.9998512
13.60 AVIONICS-DATA PROC	.02376	47622.64	.9997129
AVIONICS ROLLUP	.016704 AVG	2849.96	.995213
14.10 ENVIRONMENTAL CONTROL	.0465942	4025.705	.9966088
14.20 ECS-LIFE SUPPORT	.0465942	14027.08	.9990701
15.00 PERSONNEL PROVISIONS	.0185	809700.1	.9999831
16.10 REC & AUX-PARACHUTES	.001	1768451	.9999923
16.20 REC & AUX-ESCAPE SYS	.001	194397.2	.9999297
16.30 REC&AUX-SEPARATION	.001	8496371	.9999984
16.40 REC&AUX-CROSS FEED	.001	1.375531E+07	.999999
VEHICLE		127.6009	.9451603

Figure 15 Reliability Report - page 2

CRITICAL FAIL RATE: The percent of maintenance actions resulting in a ground or mission abort. This value is either computed from regression equations or input directly by the user.

CRITICAL MTBM: The mean time between critical maintenance actions computed from the space adjusted MTBM and the critical failure rate (Eq. 12).

SUBSYS NON-REDUNDANT MSN REL: The probability the subsystem/mission will be completed without a critical failure assuming no subsystem redundancy is present (primary system operates).

C. Reliability Report - page 3

RELIABILITY REPORT (REDUNDANCY) - page 3
DATE: 06-04-1993 TIME: 14:00:41
VEHICLE IS NCC-2000

WBS	LAUNCH TIME	END OF POWER FLT	ORBIT INSERTION
1.00 WING GROUP	.9998557	.9996537	.9995917
2.00 TAIL GROUP	.9999951	.9999881	.9999859
3.00 BODY GROUP	.999494	.9987861	.9985687
3.10 TANKS-LOX	.9999837	.9999608	.9999537
3.20 TANKS-LH2	.9999593	.9999025	.999885
4.20 IEP-TCS	.9996846	.9998514	.9988815
4.30 IEP-PUD	.9999773	.9999455	.9999358
5.00 LANDING GEAR	1	1	1
6.00 PROPULSION-MAIN	.9931983	.9837536	.9808708
7.00 PROPULSION-RCS	.9995642	.9989545	.9987673
8.00 PROPULSION-OMS	.9995626	.9989504	.9987625
9.20 POWER-BATTERY	.9999999	.9999999	.9999998
9.30 POWER-FUEL CELL	.9999465	.9998717	.9998407
10.00 ELECTRICAL	.9986195	.9966899	.996098
12.00 AERO SURF ACTUATORS	.9996333	.9991201	.9989625

ENTER RETURN..?

RELIABILITY REPORT (REDUNDANCY) - page 3
DATE: 06-04-1993 TIME: 14:00:51
VEHICLE IS NCC-2000

WBS	LAUNCH TIME	END OF POWER FLT	ORBIT INSERTION
13.10 AVIONICS-GN&C	.9999945	.9999869	.9999845
13.30 AVIONICS-COMM & TRACK	.9999889	.9999732	.9999685
13.40 AV-DISPLAYS & CONTR	.9993788	.9985098	.998243
13.50 AVIONICS-INSTRUMENTS	.9999782	.9999478	.9999384
13.60 AVIONICS-DATA PROC	.999958	.9998992	.9998811
AVIONICS ROLLUP	.9992984	.9983172	.9980159
14.10 ENVIRONMENTAL CONTROL	.9995033	.9988084	.9985951
14.20 ECS-LIFE SUPPORT	.9998651	.9996763	.9996184
15.00 PERSONNEL PROVISIONS	.9999976	.9999941	.999993
16.10 REC & AUX-PARACHUTES	.9999989	.9999973	.9999968
16.20 REC & AUX-ESCAPE SYS	.9999897	.9999753	.9999709
16.30 REC&AUX-SEPARATION	.9999998	.9999995	.9999993
16.40 REC&AUX-CROSS FEED	.9999999	.9999996	.9999996
VEHICLE	.988093	.9716612	.9666694

Figure 16 Reliability Report - page 3

LAUNCH TIME: Reliability at launch time. Probability of no nonredundant critical failures during prelaunch (pad and integration time). Based upon the subsystem redundancy established by the user (Eq. 10).

END OF POWER FLT: Reliability at the end of the main engine (and possibly booster rocket) burn time. Probability of no nonredundant critical failures up to this time. Based upon the subsystem redundancy established by the user (Eq. 10).

ORBIT INSERTION: Reliability of achieving orbit. Probability of no nonredundant critical failures up to this time. Based upon the subsystem redundancy established by the user (Eq. 10).

D. Reliability Report - page 4

RELIABILITY REPORT (REDUNDANCY) - page 4

VEHICLE IS NCC-2000 DATE: 06-04-1993 TIME: 14:01:01

WBS	REENTRY	MISSION COMPLETION
1.00 WING GROUP	.9990858	.9990137
2.00 TAIL GROUP	.9999685	.999966
3.00 BODY GROUP	.9967975	.9965453
3.10 TANKS-LOX	.9998964	.9998882
3.20 TANKS-LH2	.9997424	.9997221
4.20 IEP-TCS	.9974968	.9972996
4.30 IEP-PVD	.9990562	.9998448
5.00 LANDING GEAR	1	.998154
6.00 PROPULSION-MAIN	.9808700	.9808700
7.00 PROPULSION-RCS	.9972415	.9970242
8.00 PROPULSION-OMS	.9972308	.9970127
9.20 POWER-BATTERY	.9999996	.9999996
9.30 POWER-FUEL CELL	.9996611	.9996343
10.00 ELECTRICAL	.9912827	.9905982
12.00 AERO SURF ACTUATORS	.997678	.9974951

RELIABILITY REPORT (REDUNDANCY) - page 4

VEHICLE IS NCC-2000 DATE: 06-04-1993 TIME: 14:01:14

WBS	REENTRY	MISSION COMPLETION
13.10 AVIONICS-GN&C	.9999654	.9999626
13.30 AVIONICS-COMM & TRACK	.9999294	.9999238
13.40 AV-DISPLAYS & CONTR	.9960695	.9957601
13.50 AVIONICS-INSTRUMENTS	.9998621	.9998512
13.60 AVIONICS-DATA PROC	.9997339	.9997129
AVIONICS ROLLUP	.9955623	.995213
14.10 ENVIRONMENTAL CONTROL	.9968563	.9966088
14.20 ECS-LIFE SUPPORT	.9991454	.9990781
15.00 PERSONNEL PROVISIONS	.9999843	.9999831
16.10 REC & AUX-PARACHUTES	.9999928	.9999923
16.20 REC & AUX-ESCAPE SYS	.9999348	.9999297
16.30 REC&AUX-SEPARATION	.9999985	.9999984
16.40 REC&AUX-CROSS FEED	.9999991	.999999
VEHICLE	.9493515	.9451603

Figure 17 Reliability Report - page 4

REENTRY: Reliability at the end of the orbit phase of the mission prior to reentry time. Based upon the subsystem redundancy established by the user (Eq. 10). Probability of no nonredundant critical failures up to this time. Based upon the subsystem redundancy established by the user (Eq. 10).

MISSION COMPLETION: Reliability at the end of the mission with successful landing and recovery. Probability of no nonredundant critical failures throughout the mission. Based upon the subsystem redundancy established by the user (Eq. 10).

E. Maintainability Report - page 1

MAINTAINABILTY REPORT-page 1
DATE: 06-04-1993 TIME: 14:01:42
VEHICLE IS NCC-2000

WBS	MAINT ACTIONS/MSN	TOT MANHR/MA	AVG MANHRS/MSN
1.00 WING GROUP	.3421713	9.190797	3.144827
2.00 TAIL GROUP	1.178952E-02	9.190797	.1083551
3.00 BODY GROUP	1.169769	10.80217	12.63605
3.10 TANKS-LOX	.6864787	17.52957	12.03360
3.20 TANKS-LH2	1.706895	17.52957	29.92114
4.20 IEP-TCS	16.60901	113.3438	1882.528
4.30 IEP-PVD	.9531456	31.66875	30.18493
5.00 LANDING GEAR	.04331	5.865088	.2540169
6.00 PROPULSION-MAIN	1.250198	21.1	26.37918
7.00 PROPULSION-RCS	.5158843	21.1	10.88516
8.00 PROPULSION-OMS	.5178881	21.1	10.92744
9.20 POWER-BATTERY	2.523215E-03	1.97675	4.987764E-03
9.30 POWER-FUEL CELL	2.246416	91.68749	205.9683
10.00 ELECTRICAL	6.576311	4.751681	31.24853
12.00 AERO SURF ACTUATORS	.2779577	6.149928	1.70942

MAINTAINABILTY REPORT-page 1
DATE: 06-04-1993 TIME: 14:01:51
VEHICLE IS NCC-2000

WBS	MAINT ACTIONS/MSN	TOT MANHR/MA	AVG MANHRS/MSN
13.10 AVIONICS-GN&C	2.296012E-02	9.386148	.215507
13.30 AVIONICS-COMM & TRACK	4.254455E-02	9.386148	.3993294
13.40 AV-DISPLAYS & CONTR	1.098422	79.23214	87.03031
13.50 AVIONICS-INSTRUMENTS	6.094251E-02	8.160083	.4972959
13.60 AVIONICS-DATA PROC	7.423683E-02	7.002049	.5198693
AVIONICS ROLLUP	1.299106	22.63347 (AVG)	88.66232
14.10 ENVIRONMENTAL CONTROL	.4478132	6.342953	2.840458
14.20 ECS-LIFE SUPPORT	.1215883	5.577246	.6781278
15.00 PERSONNEL PROVISIONS	5.607682E-03	6.571245	3.684945E-02
16.10 REC & AUX-PARACHUTES	.0474992	6.95	.3301194
16.20 REC & AUX-ESCAPE SYS	.4321049	7.380109	3.188981
16.30 REC&AUX-SEPARATION	9.886574E-03	4.03	.0398429
16.40 REC&AUX-CROSS FEED	6.106732E-03	0	0
TOTALS	35.27940	19.74094 (AVG)	2353.711

Figure 18 Maintainability Report - page 1

MAINT ACTIONS/MSN: The number of maintenance actions per mission based upon the space adjusted MTBM and the subsystem operating hours. Includes maintenance actions incurred during recover/ground processing time as well as mission time (Eq. 17).

TOT MANHR/MA: The average number of on and off vehicle manhours expended per maintenance action. Computed from regression equations or in the case of "SHUTTLE" computed from the MTTR and crew size values.

AVG MANHRS/MSN: The average maintenance manhours expended mission. The maintenance actions per mission multiplied by the average manhours per maintenance action (Eq. 18).

F. Maintainability Report - page 2

MAINTAINABILTY REPORT - page 2
DATE: 06-04-1993 TIME: 14:02:00

VEHICLE IS NCC-2000

WBS	ON-VEH MH	OFF-VEH MH	PERCENT ON-VEH
1.00 WING GROUP	2.002234	.2625931	.9165
2.00 TAIL GROUP	9.930748E-02	9.047653E-03	.9165
3.00 BODY GROUP	11.55251	1.003541	.91425
3.10 TANKS-LOX	9.626943	2.406736	.8
3.20 TANKS-LH2	23.93691	5.904228	.8
4.20 IEP-TCS	1506.022	376.5056	.8
4.30 IEP-PVD	24.14795	6.036906	.8
5.00 LANDING GEAR	.1039101	7.010607E-02	.7240071
6.00 PROPULSION-MAIN	7.413773	10.96541	.2810464
7.00 PROPULSION-RCS	2.993418	7.09174	.275
8.00 PROPULSION-OMS	3.005045	7.922393	.275
9.20 POWER-BATTERY	4.987764E-03	0	1
9.30 POWER-FUEL CELL	164.7746	41.19365	.8
10.00 ELECTRICAL	24.66077	6.507758	.7091010
12.00 AERO SURF ACTUATORS	1.213688	.4957317	.71

MAINTAINABILTY REPORT - page 2
DATE: 06-04-1993 TIME: 14:02:09

VEHICLE IS NCC-2000

WBS	ON-VEH MH	OFF-VEH MH	PERCENT ON-VEH
13.10 AVIONICS-GN&C	.1000573	.1146498	.468
13.30 AVIONICS-COMM & TRACK	.1060062	.2124433	.468
13.40 AV-DISPLAYS & CONTR	40.73019	46.30013	.468
13.50 AVIONICS-INSTRUMENTS	.2784857	.2188182	.56
13.60 AVIONICS-DATA PROC	.2432988	.2765704	.468
AVIONICS ROLLUP	41.53971	47.1226	.4064 (AVG)
14.10 ENVIRONMENTAL CONTROL	2.575727	.2647307	.9068
14.20 ECS-LIFE SUPPORT	.6645652	1.356256E-02	.98
15.00 PERSONNEL PROVISIONS	3.156425E-02	5.285205E-03	.856573
16.10 REC & AUX-PARACHUTES	.2353752	9.474428E-02	.713
16.20 REC & AUX-ESCAPE SYS	2.000465	1.188516	.6523918
16.30 REC&AUX-SEPARATION	3.944447E-02	3.98429E-04	.99
16.40 REC&AUX-CROSS FEED	0	0	.8
UNSCHEDULED	1029.605	524.0253	.7006019 (AVG)
SCHEDULED	1040.519	21.23508	
TOTAL	2070.204	545.2604	

Figure 19 Maintanability Report - page 2

ON-VEH MH: The average on-vehicle maintenance manhours performed per mission. Obtained by multiplying the average manhours per mission by one minus the percent of off-vehicle work (Eq. 19).

OFF-VEH MH: The average off-vehicle maintenance manhours performed per mission. Obtained by multiplying the average manhours per mission by the percent off-vehicle work (Eq. 20).

PERCENT ON-VEH: One minus the percent of off-vehicle work. The percent of off-vehicle work is computed from regression equations or input directly by the user.

G. Manpower Report

MANPOWER REPORT

VEHICLE IS NCC-2000 DATE: 06-14-1993 TIME: 00:37:56

WBS		MANHRS/MSN	MANHRS/MO	PERSONNEL BASED UPON MANHRS	PERSONNEL BASED UPON MIN CREW
1.00	WING GROUP	3.144827	3.144827	1	1.845915
2.00	TAIL GROUP	.1003551	.1003551	0	1.845915
3.00	BODY GROUP	12.63605	12.63605	1	1.845915
3.10	TANKS-LOX	12.03368	12.03368	1	1.845915
3.20	TANKS-LH2	29.92114	29.92114	1	1.845915
4.20	IEP-TCS	1506.022	1506.022	13	4.5
4.30	IEP-PVD	24.14795	24.14795	1	4.5
5.00	LANDING GEAR	.2540169	.2540169	1	1.845915
6.00	PROPULSION-MAIN	26.37910	26.37910	1	2.43
7.00	PROPULSION-RCS	10.88516	10.88516	1	2.43
8.00	PROPULSION-OMS	10.92744	10.92744	1	2.43
9.20	POWER-BATTERY	4.987764E-03	4.987764E-03	0	2.43
9.30	POWER-FUEL CELL	164.7746	164.7746	2	4.5
10.00	ELECTRICAL	31.24853	31.24853	1	1.98833
12.00	AERO SURF ACTUATORS	1.70942	1.70942	1	1.845915

MANPOWER REPORT

VEHICLE IS NCC-2000 DATE: 06-14-1993 TIME: 00:38:10

WBS		MANHRS/MSN	MANHRS/MO	PERSONNEL BASED UPON MANHRS	PERSONNEL BASED UPON MIN CREW
13.10	AVIONICS-GN&C	.2375416	.2375416	1	2.18
13.30	AVIONICS-COMM & TRACK	.3087689	.3087689	1	2.18
13.40	AV-DISPLAYS & CONTR	66.08655	66.08655	1	4.5
13.50	AVIONICS-INSTRUMENTS	.4972959	.4972959	1	2.18
13.60	AVIONICS-DATA PROC	.5198693	.5198693	1	2.18
	AVIONICS ROLLUP	67.65002	67.65002	5	13.22
14.10	ENVIRONMENTAL CONTROL	2.840458	2.840458	1	1.98833
14.20	ECS-LIFE SUPPORT	.6781278	.6781278	1	1.98833
15.00	PERSONNEL PROVISIONS	3.684945E-02	3.684945E-02	0	1.938175
16.10	REC & AUX-PARACHUTES	.3301194	.3301194	1	1.88802
16.20	REC & AUX-ESCAPE SYS	3.108981	3.108981	1	1.88802
16.30	REC&AUX-SEPARATION	.0398429	.0398429	0	1.88802
16.40	REC&AUX-CROSS FEED	0	0	0	4.5
	UNSCHEDULED	1908.962	1908.962	35	68
	SCHEDULED	870.6879	870.6879	8	7
	TOTAL	2779.65	2779.65	43	75

Figure 20 Manpower Report

MANHRS/MSN: Average maintenance manhours per mission computed as described in the maintainability report.

MANHRS/MO: The average maintenance manhours per month. The average maintenance manhours per mission multiplied by the required number of missions per month.

PERSONNEL BASED UPON MANHRS: The number of maintenance personnel required to support the subsystem average manhours per month requirement. Computed using a monthly manhour availability and the percent of indirect work factor (Eq. 23).

PERSONNEL BASED UPON MIN CREW: The average crew size for the subsystem computed from regression equations or input directly by the user.

H. Spares Report

SUBSYSTEM SPARES REPORT

VEHICLE IS NCC-2000 DATE: 06-14-1993 TIME: 00:38:43

NOTE: Failures are assumed to be Poisson

WBS		REMOVAL RATE/MA	MEAN DEMAND PER MISSION	SPARES RQMT	EFFECTIVE FILL RATE
1.00	WING GROUP	.1923022	.0658003	1	.9979278
2.00	TAIL GROUP	.1923022	2.267152E-03	0	.9977354
3.00	BODY GROUP	.2229133	.2607571	1	.971373
3.10	TANKS-LOX	.2758	.1093308	1	.9841864
3.20	TANKS-LH2	.2758	.4707616	2	.9877322
4.20	IEP-TCS	.481	7.900936	13	.9661459
4.30	IEP-PVD	.391	.3726799	2	.9934593
5.00	LANDING GEAR	.22	.0095282	0	.990517
6.00	PROPULSION-MAIN	.5076662	.6346833	2	.9733199
7.00	PROPULSION-RCS	.5877307	.303281	1	.9623496
8.00	PROPULSION-OMS	.5060163	.3039052	1	.9621918
9.20	POWER-BATTERY	.273	6.000376E-04	0	.9993114
9.30	POWER-FUEL CELL	.261	.5063146	2	.978215
10.00	ELECTRICAL	.5007281	3.292944	7	.9804421
12.00	AERO SURF ACTUATORS	.30593	.1072722	1	.9946417

ENTER RETURN...?

SUBSYSTEM SPARES REPORT

VEHICLE IS NCC-2000 DATE: 06-14-1993 TIME: 00:38:57

NOTE: Failures are assumed to be Poisson

WBS		REMOVAL RATE/MA	MEAN DEMAND PER MISSION	SPARES RQMT	EFFECTIVE FILL RATE
13.10	AVIONICS-GN&C	.4	1.715592E-02	0	.9829984
13.30	AVIONICS-COMM & TRACK	.4	2.230015E-02	0	.9779466
13.40	AV-DISPLAYS & CONTR	.466	.5118646	2	.9846967
13.50	AVIONICS-INSTRUMENTS	.51	3.100068E-02	0	.9693974
13.60	AVIONICS-DATA PROC	.4147191	3.078743E-02	0	.9696817
	AVIONICS ROLLUP	.4381438 (AVG)	.6131887	2	.9769425 (AVG)
14.10	ENVIRONMENTAL CONTROL	.5151376	.2306854	1	.977151
14.20	ECS-LIFE SUPPORT	.53582	6.585216E-02	1	.9979737
15.00	PERSONNEL PROVISIONS	.274	1.536505E-03	0	.9984647
16.10	REC & AUX-PARACHUTES	0	0	0	1
16.20	REC & AUX-ESCAPE SYS	.7472359	.3228843	1	.9578444
16.30	REC&AUX-SEPARATION	.7966173	7.875816E-03	0	.9921551
16.40	REC&AUX-CROSS FEED	0	0	0	1
	TOTALS	.3056563 (AVG)	15.83029	39	

ENTER RETURN...?

Figure 21 Subsystem Spares Report

REMOVAL RATE/MA: The percent of maintenance actions which results in a component removal. The assumption is made that a component removal will generate a demand for a replacement (spare) component. The rate is computed from regression equations or input directly by the user.

MEAN DEMAND PER MISSION: The average number of removals (demands for spare components) per mission. Computed by multiplying the removal rate times the average number of maintenance actions per mission (see Maintainability report). This becomes the mean (number of demands) of the Poisson probability distrbution (Eq. 24).

SPARES REQUIREMENT: The expected number of spare components required per mission in order to achieve a specified fill rate. Fill rate is the percent of time a demand for a component is filled (Eq. 25).

EFFECTIVE FILL RATE: The actual fill rate achieved by the spares requirement. Differs from the fill rate goal as a result of the spares requirement having integer values.

I. Vehicle Turn Time Report - page 1

VEHICLE TURN TIME REPORT - page 1
VEHICLE IS NCC-2000 DATE: 06-14-1993 TIME: 00:39:21

WBS	ON-VEHICLE MTTR (HRS)	TOT MAIN ACT	NBR CREWS ASSIGNED	AVG SUBSYS REPAIR TIME PER MSN
1.00 WING GROUP	4.563245	.3421713	1	1.561412
2.00 TAIL GROUP	4.563245	1.178952E-02	1	5.379849E-02
3.00 BODY GROUP	5.350129	1.169769	1	6.258416
3.10 TANKS-LOX	7.597129	.6864787	1	5.215267
3.20 TANKS-LH2	7.597129	1.706895	1	12.9675
4.20 IEP-RCS	[illegible]	[illegible]	1	[illegible]
4.30 IEP-PVD	5.63	.9531456	1	5.36621
5.00 LANDING GEAR	2.300411	.04331	1	9.963083E-02
6.00 PROPULSION-MAIN	2.440362	1.250198	1	3.050936
7.00 PROPULSION-RCS	2.38786	.5158843	1	1.231859
8.00 PROPULSION-OMS	2.38786	.5178881	1	1.236644
9.20 POWER-BATTERY	.8134773	2.523215E-03	1	2.052578E-03
9.30 POWER-FUEL CELL	16.3	2.246416	1	36.61658
10.00 ELECTRICAL	1.885975	6.576311	1	12.40276
12.00 AERO SURF ACTUATORS	2.365465	.2779577	1	.6574992

VEHICLE TURN TIME REPORT - page 1
VEHICLE IS NCC-2000 DATE: 06-14-1993 TIME: 00:39:49

WBS	ON-VEHICLE MTTR (HRS)	TOT MAIN ACT	NBR CREWS ASSIGNED	AVG SUBSYS REPAIR TIME PER MSN
13.10 AVIONICS-GN&C	1.929176	4.208979E-02	1	8.274195E-02
13.30 AVIONICS-COMM & TRACK	1.929176	5.575037E-02	1	.1075523
13.40 AV-DISPLAYS & CONTR	13.37	1.098422	1	14.6859
13.50 AVIONICS-INSTRUMENTS	2.096160	6.094251E-02	1	.1277457
13.60 AVIONICS-DATA PROC	2.439275	7.423683E-02	1	.1810841
AVIONICS ROLLUP	AVG 4.352759	1.332241	5	15.18502 TOT
14.10 ENVIRONMENTAL CONTROL	2.892775	.4470132	1	1.295423
14.20 ECS-LIFE SUPPORT	2.740891	.1215883	1	.3342329
15.00 PERSONNEL PROVISIONS	2.904151	5.607682E-03	1	1.628555E-02
16.10 REC & AUX-PARACHUTES	2.624628	.0474992	1	.1246677
16.20 REC & AUX-ESCAPE SYS	2.550144	.4321049	1	1.10193
16.30 REC&AUX-SEPARATION	2.113166	9.886574E-03	1	2.089198E-02
16.40 REC&AUX-CROSS FEED	0	6.186732E-03	1	0

AVG CREW SIZE 2.497357 AVG TASK TIME 4.509994 439.4707 (TOTAL)

Figure 22 Vehicle Turn Time Report - page 1

ON-VEHICLE MTTR (HRS): The on-vehicle mean time to repair measured in hours. Represents the average on-vehicle unscheduled repair time per maintenance action for a subsystem. Computed by dividing the manhours per maintenance action by the average crew size and multiplying by one minus the percent of off-vehicle work. In the case of the "SHUTTLE," input directly by the user (Eq. 26).

TOT MAINT ACT: The average number of maintenance actions per mission (see maintainability report).

NBR CREWS ASSIGNED: The number of maintenance crews (each equal to average crew size) available to perform parallel subsystem maintenance tasks on the vehicle.

AVG SUBSYS REPAIR TIME PER MSN: The average on-vehicle subsystem unscheduled maintenance time per mission. Computed by multiplying the on-vehicle MTTR by the average number of maintenance actions per mission and dividing by the number of crews assigned (Eq. 27).

The maximum average subsystem repair time will be highlighted, since it represents a minimum processing time.

J. Vehicle Turn Time Report - page 2

```
                        VEHICLE TURN TIME REPORT - page 2
VEHICLE IS NCC-2000               DATE: 06-14-1993          TIME: 00:40:20

    CATEGORY                                         MIN TURN TIMES

    SCHD MAINT MSN TASK TIME                             121.8963 HRS
    UNSCHEDULED MAINTENANCE TIME                         334.6716 HRS
    INTEGRATION TIME                                     0 HRS
    LAUNCH PAD TIME                                      24 HRS
    MISSION TIME -INC GRND PWR TIME                      74 HRS
    TOT VEHICLE TURNAROUND TIME                          432.6716 TOTAL HRS
ONE SHIFT/DAY MAINTENANCE
    TOT VEHICLE TURNAROUND TIME                          47.91729 DAYS
    AVG MISSIONS/MONTH/VEHICLE                           .4382552
    COMPUTED FLEET SIZE                                  3
TWO SHIFTS/DAY MAINTENANCE
    TOT VEHICLE TURNAROUND TIME                          25.50031 DAYS
    AVG MISSIONS/MONTH/VEHICLE                           .8235193
    COMPUTED FLEET SIZE                                  2

NOTE:  assumes parallel unsch/schd maint tasks, 9 hr shifts, and 21 work days a
 month

ENTER RETURN    ?
```

Figure 23 Vehicle Turn Time Report - page 2

MIN TURN TIMES: Minimum vehicle turn time by category. Assumes all subsystem unscheduled maintenance work may be accomplished in parallel. Total vehicle turnaround time in hours includes the sum of the maximum subsystem unscheduled maintenance time or scheduled maintenance time (whichever is larger), integration time, launch pad time, and mission time. Turnaround time in days is based upon one or two shift maintenance operation.

K. Vehicle Turn Time Report - page 3

VEHICLE TURN TIME REPORT - page 3

VEHICLE IS NCC-2000 DATE: 06-14-1993 TIME: 00:40:45

CATEGORY	MAX TURN TIMES
SCHD MAINT MSN TASK TIME	121.8963 HRS
UNSCHED MAINT TIME	439.4707 HRS
INTEGRATION TIME	0 HRS
LAUNCH PAD TIME	24 HRS
MISSION TIME -INC GRND TIME	74 HRS
TOT VEHICLE TURNAROUND TIME	659.367 TOTAL HRS
ONE SHIFT/DAY MAINTENANCE	
TOT VEHICLE TURNAROUND TIME	76.2542 DAYS
AVG MISSIONS/MONTH/VEHICLE	.2753946
COMPUTED FLEET SIZE	4
TWO SHIFTS/DAY MAINTENANCE	
TOT VEHICLE TURNAROUND TIME	38.16877 DAYS
AVG MISSIONS/MONTH/VEHICLE	.550188
COMPUTED FLEET SIZE	2

NOTE: assumes sequential tasks, 8 hr shifts, and 21 work days a month

[illegible] ?

Figure 24 Vehicle Turn Time Report - page 3

MAX TURN TIMES: Maximum vehicle turn time by category. Assumes all subsystem unscheduled maintenance work is accomplished sequentially. Total vehicle turnaround time in hours includes the sum of all subsystem unscheduled maintenance time, scheduled maintenance time, integration time, launch pad time, and mission time. Turnaround time in days is based upon one or two shift maintenance operation.

L. Vehicle Turn Time Report - page 4

```
                        VEHICLE TURN TIME REPORT - page 4
VEHICLE IS NCC-2000               DATE: 06-14-1993          TIME: 00:40:55

    CATEGORY

THREE SHIFTS/DAY MAINTENANCE                               MIN TURN TIMES
    TOT VEHICLE TURNAROUND TIME                                18.02798 DAYS
    AVG MISSIONS/MONTH/VEHICLE                                 1.164856
    COMPUTED FLEET SIZE                                        1

THREE SHIFTS/DAY MAINTENANCE                               MAX TURN TIMES
    TOT VEHICLE TURNAROUND TIME                                26.47363 DAYS
    AVG MISSIONS/MONTH/VEHICLE                                 .7932423
    COMPUTED FLEET SIZE                                        2

    NOTE:  assumes 8 hr shifts, and 21 work days a month

ENTER RETURN ...?
```

Figure 25 Vehicle Turn Time Report - page 4

MIN/MAX TURN TIMES: Minimum and maximum vehicle turn times in days assuming three shift maintenance operation.

M. System Performance Summary - page 1

SYSTEM PERFORMANCE SUMMARY - page 1

VEHICLE IS NCC-2000 DATE: 06-04-1993 TIME: 14:04:55

RELIABILITY REPORT

CATEGORY	LAUNCH TIME	END OF POWER FLT	ORBIT INSERTION
VEHICLE	.988093	.9716612	.9666694
VEHICLE+LRB	.9453682	.9296468	.9248708
VEHICLE+LRB+ET	.857936	.8436686	.8393344

	REENTRY	MISSION COMPLETION
VEHICLE	.9493515	.9451603
VEHICLE+LRB	.9083018	.9042919
VEHICLE+LRB+ET	.8242977	.8206586

ENTER RETURN ?

Figure 26 System Performance Summary - page 1

RELIABILITY REPORT: Provides vehicle (and optionally VEH + LRB and VEH + LRB +ET) reliabilities assuming vehicle subsystem redundancies at the major mission milestone points (launch, end of power flight, orbit insertion, reentry, mission completion).

N. System Performance Report - page 2

VEHICLE IS NCC-2000 SYSTEM PERFORMANCE SUMMARY - page 2
DATE: 06-04-1993 TIME: 14:05:19

MAINTAINABILITY REPORT

CATEGORY	MAINT ACTIONS/MSN	TOT MANHR/MA	UNSCHED AVG MANHRS/MSN
VEHICLE	35.27948	19.74094 (AVG)	2353.711
EXTERNAL TANK	97.04486	34.31034	3329.643
BOOSTER	44.2023	4.5	198.9104

	ON-VEH MH	OFF-VEH MH	PERCENT ON-VEH
VEHICLE			
UNSCHED	1029.685	524.0253	
SCHEDULED	1040.519	21.23508	
TOTALS	2070.204	545.2604	.7006019 (AVG)
EXTERNAL TANK			
SCHED/UNSCHED	3329.643		
BOOSTER			
SCHED/UNSCHED	198.9104		

Figure 27 System Performance Report - page 2

MAINTAINABILITY REPORT: Provides vehicle, and optionally LRB and ET, maintainability parameters pertaining to a single mission.

O. System Performance Report - page 3

VEHICLE IS NCC-2000 SYSTEM PERFORMANCE SUMMARY - page 3

DATE: 06-04-1993 TIME: 14:05:28

MANPOWER/SPARES REPORT

SPARES-VEHICLE 39

CATEGORY	MANHR DRIVEN AGGREGATE	MANHR DRIVEN BY SUBSYS	CREW SZ BY SUBSYS	TOT CREW BY SUBSYS
VEHICLE				
UNSCH MANPWR	20	38	68	68
SCHED MANPWR	9	9	7	7
TOTAL	29	47	75	75
EXT TANK				
SCHD/UNSCH MANPWR	28	29	23	23
LRB				
SCHD/UNSCH MANPWR	2	4	18	18
TOTALS	59	80	116	116

Figure 28 System Performance Report - page 3

MANPOWER/SPARES REPORT: Shows total number of spares computed to support all vehicle subsystems. Displays manpower requirements for vehicle, ET (optional), and LRB (optional) computed in three ways:

MANHR DRIVEN AGGREGATE: Total manpower earned as a result of the total manhours of work generated in each category. Number are rounded up to the nearest integer. This method assumes complete centralization and versatility of the work force.

MANHR DRIVEN BY SUBSYS: Total manpower earned as a result of the total manhours of work generated by each subsystem. Number are rounded up to the nearest integer within each subsystem. This method assumes specialization in that each subsystem "earns" its own manpower.

CREW SIZE BY SUBSYS: Total manpower earned by assigning an average crew size to each subsystem.

TOT CREW BY SUBSYS: Total manpower earned by each subsystem by assigning an average crew size multiplied by the number of assigned crews. This number supports the minimum turn time calculations.

P. System Performance Report - page 4

VEHICLE TURN TIMES

	MIN TURN TIME	MAX TURN TIME
ONE SHIFT/DAY MAINTENANCE		
TOT VEHICLE TURNAROUND TIME	6.083333 DAYS	76.2542
AVG MISSIONS/MONTH/VEHICLE	3.452055	.2753946
COMPUTED FLEET SIZE	1	4
TWO SHIFTS/DAY MAINTENANCE		
TOT VEHICLE TURNAROUND TIME	4.583333 DAYS	38.16877
AVG MISSIONS/MONTH/VEHICLE	4.581818	.550188
COMPUTED FLEET SIZE	1	2
THREE SHIFTS/DAY MAINTENANCE		
TOT VEHICLE TURNAROUND TIME	4.083333 DAYS	26.47363
AVG MISSIONS/MONTH/VEHICLE	5.142857	.7932423
COMPUTED FLEET SIZE	1	2

Figure 29 System Performance Report - page 4

VEHICLE TURN TIMES: A summary of the minimum and maximum vehicle turn times in days is displayed for one, two and three shift maintenance. The average number of missions completed per month per vehicle and the required fleet size to support the target number of missions per month are also presented.

VI. User Options

At the conclusion of a run, the user has the option of repeating the analysis after changing one or more of the input parameters. Regardless of the mode, the primary variable screen may be displayed for update. If in mode 2 or 3, the subsystem weight screen will be available for update, and if in mode 3, the secondary variable update screen will also be available. The user may also save all of the current input data/paramerers for use at a later time.

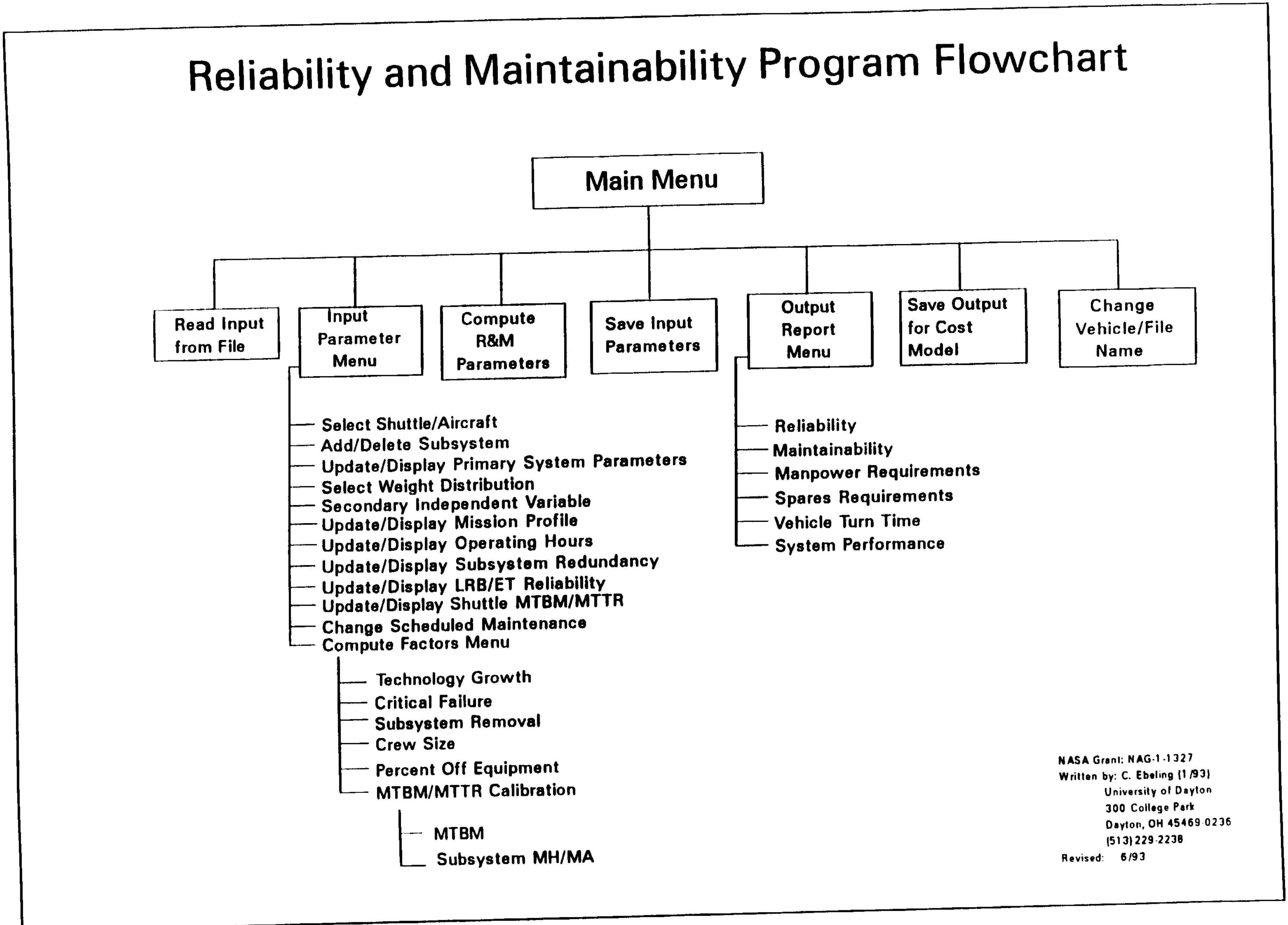


Figure 30 Reliability and Maintainability Program Flowchart

Chapter VI
Validation and Conclusion

I. Validation

Model validation was accomplished by running the computer model for different aircraft having known R&M parameters. The R&M parameters were obtained from AFALDP 800-4 Volume VI, and therefore, were not part of the input data to the model. Since the average date of the data in Volume IV is 1988, this date was used for the technology year. The space adjusted feature of the model was not utilized since it obviously does not apply to aircraft. Mission profiles reflected the average mission length of the aircraft.

Table 19 and 20 compare the predicted MTBM with the actual values for the F-16 and C-141B respectively. All three computational modes were utilized in this comparison. Two different time periods were compared in order to measure the variability in the actual data. In addition, a similar comparison is made for the F-4E (Table 21) in the preconceptual mode and the B-52G (Table 22) in the weight and variables driven mode. For the latter two comparisons, both the unadjusted and the technology adjusted MTBM's are presented. In general, it would appear that the predicted mean time between maintenance actions are in general agreement with the observed values. A further analysis was performed using the F-4E to validate the manhour per maintenance action parameters determined from the model (Table 23).

Table 19
Model Validation (MTBM) - F16

SUBSYSTEM	MODE 1	MODE 2	MODE 3	OCT 87 MAR 88	APR 88 SEP 88
STRUCTURAL	6.2	7.8	7.8	7.4	7.5
LANDING GEAR	14.0	14.2	14.2	11.4	10.1
PROPULSION	20.7	19.2	19.2	20.2	17.8
APU	22.8	37.0	50.4	23.4	21.5
ELECTRICAL	19.9	17.3	21.5	16.6	14.4
HYDRAULICS	96.8	84.9	100.3	58.7	64.8
ACTUATORS	17.4	14.1	13.3	13.7	15.2
AVIONICS	19.9	16.1	14.7	16.4	15.6
ECS	29.7	29.7	29.7	36.0	33.5
PERSON PROV	784	1539	1539	493	476
REC & AUX SYS	88.5	88.5	88.5	117	224
AIRCRAFT	1.8	1.9	1.9	1.8	1.7

Table 20
Model Validation (MTBM) - C141B

SUBSYSTEM	MODE 1	MODE 2	MODE 3	OCT 87 MAR 88	APR 88 SEP 88
STRUCTURAL	3.6	1.3	1.7	2.7	2.3
LANDING GEAR	1.5	3.6	7.8	6.8	6.3
PROPULSION	9.6	9.6	9.6	3.3	2.6
APU	147	60.7	54.1	41.5	32.0
ELECTRICAL	37.3	46.1	39.1	8.9	7.6
HYDRAULICS	5.6	5.6	5.6	15.6	14
ACTUATORS	11.1	3.1	5.0	4.9	4.5
AVIONICS	1.7	1.8	1.7	4.0	3.2
ECS	16.6	16.6	16.6	10.7	9.9
PERSON PROV	210	50.1	50.1	30.8	23.3
REC & AUX SYS	120.7	120.8	120.8	96.7	87.0
AIRCRAFT	.50	.43	.52	.57	.48

Table 21
Model Validation (MTBM) - F4E

SUBSYSTEM	MTBM	Tech Adj. MTBM	APR 88 SEP 88	APR 89 SEP 89
STRUCTURAL	2.2	2.575	1.9	2.4
LANDING GEAR	9.20	9.8	7.5	9.1
PROPULSION	17.3	17.8	14.6	13.2
ELECTRICAL	38.6	38.6	38.4	50.2
HYDRAULICS	25.2	30.1	37.3	30.2
AERO SURFACES	3.5	3.9	8.5	8.7
AVIONICS	3.0	3.7	2.4	3.19
ECS	24.9	25.2	25.7	31.7
ECS - O_2	65.2	66.0	60.8	85.9
PERSON PROV	813	8729	1349	139
AIRCRAFT	.674	.765	.700	.878

Table 22
Model Validation (MTBM) - B52G

SUBSYSTEM	MTBM	Tech Adj. MTBM	OCT 87 MAR 88	APR 88 SEP 88	OCT 88 MAR 89
STRUCTURAL	2.3	2.7	2.0	1.7	2.2
LANDING GEAR	.800	.85	.59	.59	.67
PROPULSION	11.6	11.8	4.3	3.6	4.9
APU					
ELECTRICAL	5.2	5.2	7.4	7.1	8.6
HYDRAULICS	4.7	5.6	8.1	7.0	7.8
AERO SURFACES	6.3	7.1	5.8	5.3	5.7
AVIONICS	1.5	2.2	2.7	2.5	2.9
ECS	28.1	28.5	23.2	22.3	27.1
ECS - O_2					
PERSON PROV	46.7	50.1	52.9	36.2	48.6
AIRCRAFT	.327	.378	.304	.285	.337

Table 23
Model Validation (Manhours/MA) - F4E

SUBSYSTEM	MH/MA	APR 89 SEP 89
STRUCTURAL	8.1	7.1
LANDING GEAR	9.9	7.9
PROPULSION	21.1	26.6
ELECTRICAL	7.4	12.4
HYDRAULICS	7.7	8.6
AERO SURFACES	2.1	7.7
AVIONICS	11.4	8.8
ECS	6.9	8.4
average	9.3	10.9

II. Conclusion

This report describes the data, methodology, results,and implementation of a two year research effort to develop a model for predicting R&M parameters for conceptual space transportation systems for use in determining operational capabilities and support costs. The final model incorporates both aircraft and Space Shuttle data. Considerable flexibility, on the part of the user, is provided by the implementing computer program, in allowing modification of the existing data.

The model is dynamic and should be updated as new data becomes available. It is particularly important to continue to integrate the current aircraft data base with data obtained from the Shuttle and other space systems. Subsystems unique to a space vehicle such as the TPS, propulsion systems, and docking systems require data not available from aircraft. Although this study has included these subsystems additional data obtained from other space shuttle missions is needed in order to insure a higher degree of accuracy. As the model is used over time, those features which seem to work should be retained while those which do not provide reasonable results should be replaced. The model is modularized in the sense that any regression equation may be easily replaced without affecting other areas of the model.

This research has provided an initial data base, a basic approach and a modeling structure for performing a reliability and maintainability analysis during the conceptual design activity. Based upon the validation effort, the model provides reasonable estimates (within the range of the data) and should be utilized with some degree of confidence. Data measuring the failure and repair process of space systems remains limited and the model has inherited this limitation. Nevertheless, it is empirically based and provides a rational means of obtaining support requirements and operational capabilities of space transportation systems prior to their development.

BIBLIOGRAPHY

1. *Aircraft Historical Reliability and Maintainability Data*. Vols. V & VI, J. Osmanski, ed. Air Force Acquisition Logistics Center, Pamphlet 800-4. Dayton: Department of the Air Force, 1988, 1990.

2. *Aviation 3-M Information Reports,* NAVSEALOGCEN INSTR 4790.1. Mechanicsburg: Department of the Navy, 1988.

3. *Aviation Week and Space Technology*, Vol. 134, No. 11. March 18, 1991.

4. Barnard, R. A. and T. D. Matteson. "Military Aircraft Maintenance - A New Concept." *Proceedings 1975 Annual Reliability and Maintainability Symposium* pp. 596-600. New York: Institute of Electrical and Electronic Engineers, 1975.

5. Bloomquist, C. and W. Graham. *Analysis of Spacecraft On-orbit Anomalies and Lifetimes*. For Goddard Space Flight Center Contract No. NAS 5-27279. Los Angeles: PRC Systems Service, 1983.

6. Brussell, E. R., K. R. Pope, and K. M. Tasugi. "Cost of Ownership - Industry Viewpoint: Parametric Analysis of Operating and Support Costs." *Proceedings 1975 Annual Reliability and Maintainability Symposium* pp. 217-220. New York: Institute of Electrical and Electronic Engineers, 1975.

7. Earles, D. R. "LCC - Commercial Application: Ten Years of Life Cycle Costing." *Proceedings 1975 Annual Reliability and Maintainability Symposium* pp. 74-85. New York: Institute of Electrical and Electronic Engineers, 1975.

8. Green, W. and G. Swanborough. *Observer's Directory of Military Aircraft*. New York: Arco Publishing, Inc., 1982.

9. Harmon, D. F., P. A. Pates, and D. Gregor. "Maintainability Estimating Relationships." *Proceedings 1975 Annual Reliability and Maintainability Symposium* pp. 18-25. New York: Institute of Electrical and Electronic Engineers, 1975.

10. Hecht, H. and E. Florentino. "Reliability Assessment of Spacecraft Electronics." *1987 Proceedings Annual Reliability and Maintainability Symposium* pp. 341-345. New York: Institute of Electrical and Electronic Engineers, 1987.

11. Hecht, H. and M. Hecht. *Reliability Prediction for Spacecraft*. Rome Air Development Center Final Technical Report No. 85-229, 1985.

12. Hintle, Jerry. "Number Cruncher Statistical System, Version 5.03." Kaysville, UT, September 1991.

13. *Jane's All the World's Aircraft*, J. W. R. Taylor, ed. New York: McGraw-Hill Book Company, 1971-1990.

14. Kern, G. A. and T. M. Drnas. *Operational Influences on Reliability*. For Rome Air Development Center Contract No. RADC-TR-76-366. Culver City: Hughes Aircraft Company, 1975.

15. "Modular Life Cycle Cost Model for Advanced Aircraft Systems, Phase III," Grumman Aerospace Corp., Bethpage, NY. Contract No. AFF DC-DC-TR-78-40, Vol. IV, Rev. 3, September 1986.

16. Norris, H. P. and A. R. Timmins. "Failure Rate Analysis of Goddard Space Flight Center: Spacecraft Performance During Orbital Life." *Proceedings 1976 Annual Reliability and Maintainability Symposium* pp. 120-125. New York: Institute of Electrical and Electronic Engineers, 1976.

17. Ostrofsy, B. "Development of I.L.S. Models from R and M Data." *Proceedings 1975 Annual Reliability and Maintainability Symposium* pp. 130-138. New York: Institute of Electrical and Electronic Engineers, 1975.

18. Peacore, E. J. "Reliability Developments - AWACS." *Proceedings 1975 Annual Reliability and Maintainability Symposium* pp. 383-389. New York: Institute of Electrical and Electronic Engineers, 1975.

19. *Personnel Launch System Advanced Manned Launch System (AMLS): PLS Reliability/Maintainability Analysis*, Ehrlich, Jr., C. F., ed. For Langley Research Center Contract No. NAS1-18975. Los Angeles: Rockwell International, Space Systems Division, 1990.

20. *Personnel Launch System (PLS) Advanced Manned Launch System Study (PLS/AMLS): Final Oral Review*. For Langley Research Center, Contract No. NAS1-18975. Los Angeles: Rockwell International Space Systems Division, 1990.

21. *Report on the Development of a Spacecraft Supportability Assessment Model*. Los Angeles: Rockwell International Space Systems Division, n.d.

22. "Space Station Definition, Design, and Development, Task 18, Launch Vehicle Maintenance Analysis," Martin-Marietta Corporation (NASA Contract NAS1-18230), Nov. 1992

23. "The Determination of the Operational and Support Requirements and Costs During the Conceptual Design of Space Systems," Final Report, for NASA, Langley Research Center, University of Dayton, Dayton, Ohio, June 19, 1992 (NASA Grant NAG1-1327)

24. "USAir Reliability Assurance Program Monthly Report," prepared by The Reliability and Maintenance Programs Department, Pittsburgh, PA, May 1991.

Appendix A

Regression Equations

---------------------------------Multiple Regression---------------------------------

Date/Time 04-02-1992 16:01:44
Data Base Name C:\NASA\WUC13
Description Backup of NASAMSTR created 12-20-1991

Multiple Regression Report

Dependent Variable: SBMA/3

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	22.27233	0.0000	4.77957	4.66	0.0003		
WETAREA	-.313E-02	-5.8141	.1225E-02	-2.55	0.0220	0.5132	0.5132
LEN_WING	.1951138	4.9647	.7926E-01	2.46	0.0264	0.5759	0.5710
SQRWHEEL	-5.474764	-1.0068	2.450744	-2.23	0.0411	0.5913	0.5082
WGT13	.3161E-02	6.6141	.1017E-02	3.11	0.0072	0.6141	0.3887
SQRW13	-.5171443	-5.2585	.179589	-2.88	0.0115	0.7515	0.5069

Analysis of Variance Report

Dependent Variable: SBMA

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	1185.754	1185.754		
Model	5	312.2933	62.45866	9.07	0.000
Error	15	103.2924	6.886162		
Total	20	415.5857	20.77929		

Root Mean Square Error	2.62415
Mean of Dependent Variable	7.514286
Coefficient of Variation	.3492215
R Squared	0.7515
Adjusted R Squared	0.6686

------------------------------Multiple Regression------------------------------

Date/Time 04-02-1992 16:02:04

Data Base Name C:\NASA\WUC13

Description Backup of NASAMSTR created 12-20-1991

E-2

SBMA 13

Residual Analysis

Row	Actual Y	Predicted Value	Std Err of Pred	Lower95% Mean	Upper95% Mean	Residual
1	.	.	.	.	.	.
2	.	.	.	.	.	.
3	.	.	.	.	.	.
4	9.8	8.136841	1.10426	5.783982	10.4897	1.663159
5	.	.	.	.	.	.
6	11.2	11.03452	.8757989	9.168444	12.90059	.1654816
7	.7	.8156204	1.854815	-3.136453	4.767695	-.1156204
8	2.1	.	.	.	.	.
9	7.6	.	.	.	.	.
10	4	.	.	.	.	.
11	4.7	.	.	.	.	.
12	8	.	.	.	.	.
13	9.3	7.242437	1.263991	4.549238	9.935637	2.057563
14	6.6	7.242437	1.263991	4.549238	9.935637	-.6424375
15	9.8	8.159472	1.034	5.956316	10.36263	1.640529
16	19.1	12.53667	1.006971	10.3911	14.68223	6.563335
17	.	.	.	.	.	.
18	9.9	10.79619	.8922645	8.89503	12.69734	-.8961878
19	11.5	10.61185	.8753694	8.746694	12.47701	.8881474
20	9.2	11.16838	.8813574	9.290465	13.0463	-1.968383
21	7.7	10.95342	.8397433	9.164173	12.74267	-3.253423
22	.	.	.	.	.	.
23	5.4	5.292338	.9661546	3.233742	7.350934	.1076622
24	5.5	5.292338	.9661546	3.233742	7.350934	.2076621
25	4.4	5.604521	.9766815	3.523496	7.685547	-1.204521
26	1.5	3.328344	1.889837	-.6983516	7.355039	-1.828344
27	5.6	9.002648	1.403789	6.011581	11.99372	-3.402648
28	2.3	1.412753	1.336714	-1.435397	4.260903	.887247
29	.	.	.	.	.	.
30	.4	-.5535725	2.524142	-5.931789	4.824644	.9535725
31	12.8	10.41858	1.985952	6.18709	14.65007	2.381421
32	4.5	5.769247	2.335391	.7932048	10.74529	-1.269247
33	.	.	.	.	.	.
34	.	.	.	.	.	.
35	10.6	13.53501	1.283851	10.79949	16.27052	-2.935006

Durbin - Watson Statistic .8563172

------------------------------Descriptive Statistics------------------------------

Date/Time 04-02-1992 16:10:57
Data Base Name C:\NASA\WUC13
Description Backup of NASAMSTR created 12-20-1991

Detail Report

Variable: SBMA		No. observations	36
Mean - Average	6.885185	No. missing values	9
Lower 95% c.i.limit	5.170464	Sum of frequencies	27
Upper 95% c.i.limit	8.599906	Sum of observations	185.9
Adj sum of squares	488.5341	Std.error of mean	.8342167
Standard deviation	4.334717	T-value for mean=0	8.253473
Variance	18.78977	T prob level	0.0000
Coef. of variation	.6295716	Kurtosis	.8345478
ewness	.6541274	Reject if > 1.164(10%)	1.254(5%)
rmality Test Value	1.072307	Reject if > 0.153(10%)	0.168(5%)
.S. Normality Test	0.09805	b2 3.47 Kurt-Z 1.08	Pr 0.2802
√b1 0.62 Skew-Z	1.49 Pr 0.1373		
D'Agostino-Pearson Omnibus K2 Normality Test		3.4	Pr 0.1850
100-%tile (Maximum)	19.1	90-%tile	11.5
75-%tile	9.8	10-%tile	1.5
50-%tile (Median)	6.6	Range	18.7
25-%tile	4	75th-25th %tile	5.8
0-%tile (Minimum)	.4	C.L. Median(95%)	4.4, 9.8

-------------------------Line Plot / Box Plot-------------------------

.4---19.1

11 2 11 1 21 21 1 2 1 2 21 1 11 1 1

Distribution & Histogram

Variable: SBMA

Bin	Lower	Upper	Count	Prcnt	Total	Prcnt	Histogram
1	.4	2.1	4	14.8	4	14.8	:****
2	2.1	3.8	2	7.4	6	22.2	:**
3	3.8	5.500001	6	22.2	12	44.4	:******
4	5.500001	7.2	2	7.4	14	51.9	:**
5	7.2	8.9	3	11.1	17	63.0	:***
6	8.9	10.6	5	18.5	22	81.5	:*****
7	10.6	12.3	3	11.1	25	92.6	:***
8	12.3	14	1	3.7	26	96.3	:*
9	14	15.7	0	0.0	26	96.3	:
10	15.7	17.4	0	0.0	26	96.3	:
11	17.4	19.1	1	3.7	27	100.0	:*

-----------------------------Multiple Regression-----------------------------------

Date/Time 10-20-1992 14:01:58
Data Base Name C:\NASA\WUC46
Description Merge of WUC23 and WUC11 created 10-20-1992

Multiple Regression Report

Dependent Variable: MH/MA

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	-180.852	0.0000	38.63924	-4.68	0.0034		
DRY_WGT	.1262E-02	30.9126	.4440E-03	2.84	0.0295	0.2967	0.2967
LEN_WING	.6662626	22.1215	.2297492	2.90	0.0273	0.3030	0.2956
WETAREA	-.121E-01	-30.3053	.4711E-02	-2.58	0.0420	0.3075	0.3066
LN DRYWT	11.72884	3.5508	3.175972	3.69	0.0102	0.4786	0.1568
SQR WET	-1.635298	-20.3843	.4008007	-4.08	0.0065	0.4808	0.2817
#FUEL TK	-20.30872	-18.0487	7.710523	-2.63	0.0389	0.8045	0.2700
SQR FUEL	87.16432	13.7513	36.85798	2.36	0.0559	0.8091	0.2519
ENG WGT	-.131E-02	-4.5588	.5313E-03	-2.46	0.0493	0.8184	0.2611
SQRFUEWT	.4501E-01	2.2313	.1585E-01	2.84	0.0296	0.9225	0.2949

Analysis of Variance Report

Dependent Variable: MH/MA

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	2773.602	2773.602		
Model	9	187.3895	20.82106	7.94	0.010
Error	6	15.74183	2.623638		
Total	15	203.1314	13.54209		

Root Mean Square Error	1.619765
Mean of Dependent Variable	13.16625
Coefficient of Variation	.123024
R Squared	0.9225
Adjusted R Squared	0.8063

Date/Time 10-20-1992 13:51:36
Data Base Name C:\NASA\WUC46
Description Merge of WUC23 and WUC11 created 10-20-1992

Multiple Regression Report

Dependent Variable: FHBMA

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	494.8067	0.0000	90.03053	5.50	0.0001		
LN DRYWT	-54.0643	-3.0181	9.10704	-5.94	0.0000	0.4069	0.4069
SQR WET	.9030567	2.0879	.249826	3.61	0.0028	0.6570	0.1740
#ENGINES	-50.71227	-3.3161	20.68729	-2.45	0.0280	0.6585	0.0731
#FUEL TK	16.39419	2.9423	9.158145	1.79	0.0951	0.6609	0.1566
SQR ENG	151.372	3.1771	60.0151	2.52	0.0244	0.7919	0.0635
SQR FUEL	-83.11919	-2.6988	46.67542	-1.78	0.0966	0.8225	0.1896
FUELWT	-.405E-03	-2.3474	.1690E-03	-2.40	0.0312	0.8241	0.0849
FUEWT	.275638	2.4881	.1128811	2.44	0.0285	0.8767	0.1513

Analysis of Variance Report

Dependent Variable: FHBMA

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	10061.27	10061.27		
Model	8	5687.025	710.8782	12.44	0.000
Error	14	800.1287	57.15205		
Total	22	6487.155	294.8707		

Root Mean Square Error	7.559897
Mean of Dependent Variable	20.91522
Coefficient of Variation	.3614544
R Squared	0.8767
Adjusted R Squared	0.8062

Multiple Regression (Data List)
DDDDC:\NASA\WUC46DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

Row Label	Row	FHBMA	#ENGINES	#FUEL TK	ENG WGT	FUELWT
A-4E	1	.	1	2	.	5440
A-4F	2	.	1	2	.	5440
A-6E	3	.	2	6	.	15939
A-7D	4	35.68	1	7	4497	9263
A-7E	5	.	1	7	.	10037
A-10A	6	39.95	2	.	4283	10700
B-52G	7	13.95	8	.	36554	255425
FB-111A	8	8.4	2	4	.	32460
F-106A	9	13.66	1	7	.	9425
-111A	10	18.35	2	4	.	32779
F-111D	11	18.24	2	6	.	32498
F-111F	12	15.01	2	4	.	32730
F-4C	13	11.2	2	9	9968	12278
F-4D	14	13.6	2	9	9968	12278
F-4E	15	19.16	2	9	9968	12058
F-5E	16	72.14	2	3	2247	4360
F-14A	17	.	2	.	.	16447
F-15A	18	15.8	2	5	6049	11435
-15C	19	19.6	2	5	6091	13455
F-16A	20	22.05	1	7	3671	6972

Enter *DY* to continue, or ESC to quit --

Multiple Regression (Data List)
DDDDC:\NASA\WUC46DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

Row Label	Row	FHBMA	#ENGINES	#FUEL TK	ENG WGT	FUELWT
F-16B	21	16.88	1	4	.	5785
F-18A	22	.	2	8	.	10381
-130B	23	18.27	4	6	.	45240
-130E	24	14.57	4	6	16696	45240
C-130H	25	9.28	4	6	16696	45240
KC-135A	26	8.37	4	10	23386	202800
C-140A	27	19.54	4	6	3804	9425
C-141B	28	15.07	4	12	25471	153348
C-2A	29	.	2	2	.	12400
C-5A	30	9.6	4	12	39091	318500
C-9A	31	84	2	.	10535	35484
KC-10A	32	14.26	3	15	43162	356065
E-2C	33	.	2	.	.	12400
EA-6B	34	.	2	6	.	15422
T-38A	35	72.32	2	4	1767	3880
E-3A	36	24	4	.	23321	.

Enter *DY* to continue, or ESC to quit --

-------------------------Multiple Regression-------------------------

Date/Time 10-20-1992 14:06:37
Data Base Name C:\NASA\WUC46
Description Merge of WUC23 and WUC11 created 10-20-1992

Multiple Regression Report

Dependent Variable: POFF

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	.6253686	0.0000	.0856915	7.30	0.0000		
WETAREA	.2222E-04	2.3531	.4026E-05	5.52	0.0003	0.1959	0.1959
SQR WET	-.108E-01	-5.6422	.1277E-02	-8.44	0.0000	0.6359	0.3391
SQR FUEL	-.775E-01	-0.4824	.2980E-01	-2.60	0.0264	0.6610	0.0717
ENG WGT	.2465E-04	3.1619	.4844E-05	5.09	0.0005	0.9055	0.2155

Analysis of Variance Report

Dependent Variable: POFF

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
nstant	1	.2059204	.2059204		
Model	4	8.608734E-02	2.152183E-02	23.97	0.000
Error	10	8.979494E-03	8.979493E-04		
Total	14	9.506683E-02	6.790488E-03		

Root Mean Square Error	.0299658
Mean of Dependent Variable	.1171667
Coefficient of Variation	.2557537
R Squared	0.9055
Adjusted R Squared	0.8678

--------------------------------Multiple Regression--------------------------------

Date/Time 02-06-1993 10:41:57
Data Base Name B:WUC51
Description Backup of WUC51 created 03-13-1992

Multiple Regression Report

Dependent Variable: COMPMHMA

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	4.751274	0.0000	1.607476	2.96	0.2077		
LN DRYWT	.2446564	0.8705	.1383181	1.77	0.3276	0.7578	0.7578

Analysis of Variance Report

..endent Variable: COMPMHMA

..ce	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	172.5208	172.5208		
Model	1	.1913166	.1913166	3.13	0.328
Error	1	6.115011E-02	6.115011E-02		
Total	2	.2524667	.1262333		

Root Mean Square Error	.2472855
Mean of Dependent Variable	7.583334
Coefficient of Variation	3.260908E-02
..quared	0.7578
..isted R Squared	0.5156

------------------------------Multiple Regression------------------------------

Date/Time 02-06-1993 10:42:29

Data Base Name B:WUC51

Description Backup of WUC51 created 03-13-1992

Multiple Regression Report

ndent Variable: COMP-RR

pendent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	-1.306308	0.0000	1.096597	-1.19	0.4446		
LN DRYWT	.1445828	0.8374	.9436E-01	1.53	0.3681	0.7013	0.7013

Analysis of Variance Report

Dependent Variable: COMP-RR

urce	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	.4048013	.4048013		
Model	1	6.681477E-02	6.681477E-02	2.35	0.368
Error	1	.0284579	.0284579		
Total	2	9.527267E-02	4.763633E-02		

Root Mean Square Error	.1686947
Mean of Dependent Variable	.3673333
Coefficient of Variation	.4592415
Squared	0.7013
justed R Squared	0.4026

---------------------------------Multiple Regression---------------------------------

Date/Time 11-10-1992 15:43:43 13.50

Data Base Name C:\NASA\WUC51

Description Merge of WUC47 and WUC41 created 01-10-1992

Multiple Regression Report

Dependent Variable: FHBMA

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	330.2645	0.0000	44.07154	7.49	0.0000		
DRY_WGT	.3821E-03	1.5947	.1243E-03	3.08	0.0077	0.1541	0.1541
LEN_WING	-.4515341	-2.7773	.1057518	-4.27	0.0007	0.1547	0.1448
#ENGINES	137.3431	9.7251	19.57364	7.02	0.0000	0.2006	0.0204
#F''EL TK	-1.129047	-0.1804	.9482968	-1.19	0.2523	0.2006	0.0678
ENG	-381.6661	-8.6710	56.12717	-6.80	0.0000	0.8042	0.0392

Analysis of Variance Report

Dependent Variable: FHBMA

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	16949.12	16949.12		
Model	5	4368.793	873.7585	12.32	0.000
Error	15	1063.686	70.91238		
T'tal	20	5432.478	271.6239		

t Mean Square Error	8.420949
in of Dependent Variable	28.40952
Coefficient of Variation	.2964129
R Squared	0.8042
Adjusted R Squared	0.7389

--------------------------------Multiple Regression--
Date/Time 11-10-1992 15:49:21
Data Base Name C:\NASA\WUC51
Description Merge of WUC47 and WUC41 created 01-10-1992

Multiple Regression Report

t Variable: MHMA

..dent ble	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
ercept	-229.6229	0.0000	46.8811	-4.90	0.0003		
ᴅRY_WGT	.3004E-03	8.9157	.7661E-04	3.92	0.0018	0.0562	0.0562
LEN_WING	.9850E-01	3.9641	.3884E-01	2.54	0.0248	0.0862	0.0772
LN DRYWT	23.49393	8.5240	5.139039	4.57	0.0005	0.3345	0.0058
SQR WGT	-.4469718	-20.6115	.1093038	-4.09	0.0013	0.3903	0.0369
#ENGINES	-25.30666	-10.2016	5.405278	-4.68	0.0004	0.3973	0.0606
#FUEL TK	.1779641	0.2097	.1999639	0.89	0.3896	0.4751	0.0946
SQR ENG	74.15515	9.5168	15.47659	4.79	0.0004	0.8102	0.0331

Analysis of Variance Report

Dependent Variable: MHMA

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	1122.012	1122.012		
Model	7	115.8632	16.55188	7.93	0.001
Error	13	27.13493	2.087302		
ᵀotal	20	142.9981	7.149905		

ᴊot Mean Square Error	1.44475
ıean of Dependent Variable	7.309524
Coefficient of Variation	.1976531
R Squared	0.8102
Adjusted R Squared	0.7081

------------------------------Multiple Regression------------------------------

Date/Time 11-10-1992 15:57:56
Data Base Name C:\NASA\WUC51
Description Merge of WUC47 and WUC41 created 01-10-1992

Multiple Regression Report

endent Variable: %OFF EQP

ependent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	-8.734106	0.0000	1.805796	-4.84	0.0003		
DRY_WGT	.1220E-04	8.0808	.2976E-05	4.10	0.0013	0.0973	0.0973
LEN_WING	.7198E-02	6.5017	.0013865	5.19	0.0002	0.2643	0.1812
LN DRYWT	.8006607	6.1787	.2119586	3.78	0.0023	0.2769	0.1404
SQR WGT	-.200E-01	-20.4187	.4101E-02	-4.89	0.0003	0.2952	0.1297
#FNGINES	-1.458339	-14.3381	.1893535	-7.70	0.0000	0.2959	0.1844
EL TK	.2554E-01	0.6722	.6646E-02	3.84	0.0020	0.2964	0.0380
ENG	4.196465	13.2901	.5396946	7.78	0.0000	0.8755	0.1360

Analysis of Variance Report

Dependent Variable: %OFF EQP

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	1.101719	1.101719		
Model	7	.2466979	3.524257E-02	13.06	0.000
or	13	.035083	2.698693E-03		
al	20	.281781	1.408905E-02		

Root Mean Square Error	5.194894E-02
Mean of Dependent Variable	.2290476
Coefficient of Variation	.2268041
R Squared	0.8755
Adjusted R Squared	0.8085

----------------------------Descriptive Statistics------------------------------

Date/Time 11-10-1992 15:58:43

Data Base Name C:\NASA\WUC51

Description Merge of WUC47 and WUC41 created 01-10-1992

Detail Report

: FHBMA		No. observations	35
verage	29.875	No. missing values	11
95% c.i.limit	21.51493	Sum of frequencies	24
er 95% c.i.limit	38.23507	Sum of observations	717
j sum of squares	9017.125	Std.error of mean	4.041704
Standard deviation	19.80022	T-value for mean=0	7.391684
Variance	392.0489	T prob level	0.0000
Coef. of variation	.662769	Kurtosis	1.756295
Skewness	1.43154	Reject if > 1.182(10%)	1.289(5%)
Normality Test Value	1.916794	Reject if > 0.162(10%)	0.178(5%)
K.S. Normality Test	0.21529		

/b1 1.34 Skew-Z 2.77 Pr 0.0055 b2 4.17 Kurt-Z 1.67 Pr 0.0947

gostino-Pearson Omnibus K} Normality Test 10.5 Pr 0.0053

-%tile (Maximum)	85.3	90-%tile	63.5
-%tile	35.05	10-%tile	10.5
-%tile (Median)	24.85	Range	78.3
-%tile	17.4	75th-25th %tile	17.65
0-%tile (Minimum)	7	C.L. Median(95%)	17.6, 31.6

7----------------------------Line Plot / Box Plot----------------------------85.3

11 11 22 2 2 11 12 1 1 1 1 1 1 1

-------[XXXXXXXmXXXXaXXXX]----------------------------

Detail Report

Variable: MHMA		No. observations	35
Mean - Average	7.108333	No. missing values	11
Lower 95% c.i.limit	6.007533	Sum of frequencies	24
Upper 95% c.i.limit	8.209134	Sum of observations	170.6
Adj sum of squares	156.3383	Std.error of mean	.5321857
Standard deviation	2.607167	T-value for mean=0	13.35687
Variance	6.797319	T prob level	0.0000
Coef. of variation	.3667761	Kurtosis	-.7624245
Skewness	.4738535	Reject if > 1.182(10%)	1.289(5%)
ormality Test Value	0.996	Reject if > 0.162(10%)	0.178(5%)
S. Normality Test	0.15053		

i 0.44 Skew-Z 1.04 Pr 0.2965 b2 2.15 Kurt-Z -0.92 Pr 0.3571

Agostino-Pearson Omnibus K} Normality Test 1.9 Pr 0.3795

100-%tile (Maximum)	12.6	90-%tile	10
75-%tile	9.45	10-%tile	3.9
50-%tile (Median)	6.55	Range	9.1
25-%tile	5.1	75th-25th %tile	4.35
0-%tile (Minimum)	3.5	C.L. Median(95%)	5.1, 9.4

3.5--------------------------Line Plot / Box Plot----------------------------12.6

1 21 1 2 11 2 1 1 1 2 1 2 12 1 1

-----------[XXXXXXXXXXXmXXXXaXXXXXXXXXXXXXXXXXXX]-----

```
----------------------------Descriptive Statistics------------------------------
Date/Time        11-10-1992  15:58:44
Data Base Name   C:\NASA\WUC51
Description      Merge of WUC47 and WUC41 created 01-10-1992

                          Detail Report

Variable: %OFF EQP
   n - Average            .2234783        No. observations           34
    r 95% c.i.limit       .1731752        No. missing values         11
      95% c.i.limit       .2737813        Sum of frequencies         23
      n of squares        .2977217        Sum of observations        5.14
    ..d deviation         .1163306        Std.error of mean          2.425661E-02
Variance                  1.353281E-02    T-value for mean=0         9.213089
Coef. of variation        .5205454        T prob level               0.0000
Skewness                  .3490039        Kurtosis                   -.972293
Normality Test Value      0.962           Reject if >  1.190(10%)    1.303(5%)
K.S. Normality Test        0.12749        Reject if >  0.166(10%)    0.181(5%)
/b1     0.33 Skew-Z       0.76 Pr 0.4460  b2     1.98 Kurt-Z    -1.33 Pr 0.1843
D'Agostino-Pearson Omnibus K} Normality Test          2.3          Pr 0.3098
 )-%tile (Maximum)        .44             90-%tile                   .39
 ‹-%tile                  .31             10-%tile                   .08
  -%tile (Median)         .22             Range                      .39
  -%tile                  .13             75th-25th %tile            .18
 0-%tile (Minimum)        .05             C.L. Median(95%)    .15, .3
.05-------------------------Line Plot / Box Plot-----------------------------.44
1 1   1   1     2   3    2      1 2 1     1    1 1              1 1 1 1       1
     ----------[XXXXXXXXXXXXXXXXXmaXXXXXXXXXXXXXXXX]---------------
```

Multiple Regression (Data List)
DDDDC:\NASA\WUC51DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

Row Label	Row	FHBMA	MHMA	%OFF EQP	#ENGINES	#FUEL TK
A-4E	1	.	.	.	1	2
-4E	2	.	.	.	1	2
	3	.	.	.	2	6
	4	52	4.9	.15	1	7
	5	.	.	.	1	7
A	6	26.6	7.6	.23	2	.
-2G	7	8.5	5.5	.1	8	.
FB-111A	8	10.5	7.6	.31	2	4
F-106A	9	26.3	3.9	.15	1	7
F-111A	10	17.2	11.7	.23	2	4
F-111D	11	17.1	8.8	.22	2	6
F-111F	12	22.6	9.9	.3	2	4
F-4C	13	20.5	10	.39	2	9
F-4D	14	20.1	9.4	.44	2	9
F-4E	15	17.6	9.5	.4	2	9
F-[illegible]E	16	30.5	7.4	.37	2	3
A	17	.	.	.	2	.
A	18	29.1	10	.	2	5
C	19	.	12.6	.38	2	5
6A	20	63.5	5.6	.27	1	7

Enter DY to continue, or ESC to quit --

Multiple Regression (Data List)
DDDDC:\NASA\WUC51DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

Row Label	Row	FHBMA	MHMA	%OFF EQP	#ENGINES	#FUEL TK
F-16B	21	40.5	.	.15	1	4
F-18A	22	.	.	.	2	8
C-130B	23	30.4	5.1	.18	4	6
C-130E	24	38.5	5.8	.13	4	6
C-130H	25	31.6	.	.06	4	6
KC-135A	26	7	5.8	.13	4	10
C-140A	27	68.8	5.1	.08	4	6
C-141B	28	18.3	6.1	.18	4	12
C-2A	29	.	.	.	2	2
C-5A	30	11.1	7	.24	4	12
C-9A	31	85.3	4	.	2	.
KC-10A	32	.	3.5	.05	3	15
-2C	33	.	.	.	2	.
-6B	34	.	.	.	2	6
8A	35	23.4	3.8	.	2	4

Enter DY to continue, or ESC to quit --

-----------------------------Multiple Regression-----------------------------

Date/Time 12-06-1992 10:28:49

Data Base Name C:\NASA\NEWAV

Description Merge of WUC11 and AVIONICS created 12-06-1992

Multiple Regression Report

...nt Variable: FMA13.10

.pendent ..riable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	-415.1754	0.0000	215.6908	-1.92	0.0864		
DRY_WGT	-.317E-03	-1.3670	.1609E-03	-1.97	0.0807	0.2424	0.2424
LEN_WING	.2756965	1.6220	.1450606	1.90	0.0898	0.3019	0.2948
AV WGT	.2242247	12.0078	.6982E-01	3.21	0.0106	0.3873	0.2943
SQR AVWT	-26.74394	-16.9333	8.721873	-3.07	0.0134	0.7009	0.4559
LOG AVWT	155.2838	5.8640	61.00147	2.55	0.0314	0.7092	0.5825
WGT/TSUB \v(10)	-.3678954	-1.7353	.1336855	-2.75	0.0224	0.8421	0.1220

Analysis of Variance Report

Dependent Variable: FMA13.10

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	10676.06	10676.06		
Model	6	5707.769	951.2949	8.00	0.003
Error	9	1070.425	118.9362		
Total	15	6778.194	451.8796		

t Mean Square Error	10.90579
.n of Dependent Variable	25.83125
.efficient of Variation	.4221935
R Squared	0.8421
Adjusted R Squared	0.7368

-----------------------------Multiple Regression-----------------------------

Date/Time 12-06-1992 10:34:50
ata Base Name C:\NASA\NEWAV
Description Merge of WUC11 and AVIONICS created 12-06-1992

Multiple Regression Report

Variable: FMA13.30

..ent .ole	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
.rcept	353.2148	0.0000	44.79129	7.89	0.0000		
..._WING	-.338E-01	-0.2013	.1616E-01	-2.09	0.0490	0.2184	0.2184
TOTSUBS - ✓(10)	10.74257	4.0970	2.487199	4.32	0.0003	0.4834	0.4557
SQR TSUB	-107.6389	-4.5354	23.01864	-4.68	0.0001	0.8128	0.5276
LOG AVWT	-7.82352	-0.3008	2.987087	-2.62	0.0160	0.8589	0.6148

Analysis of Variance Report

)ependent Variable: FMA13.30

ource	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	20032.73	20032.73		
Model	4	6747.038	1686.76	31.95	0.000
Error	21	1108.805	52.80025		
Total	25	7855.843	314.2337		

Root Mean Square Error	7.266378
Mean of Dependent Variable	27.75769
oefficient of Variation	.2617789
R Squared	0.8589
.djusted R Squared	0.8320

-------------------------Multiple Regression-------------------------------------

e/Time 12-06-1992 11:11:27
Data Base Name C:\NASA\NEWAV
Description Merge of WUC11 and AVIONICS created 12-06-1992

Multiple Regression Report

Dependent Variable: FMA13.20

Independent able	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
ercept	323.9129	0.0000	70.95185	4.57	0.0103		
R WGT	-16.07575	-13.0657	1.545753	-10.40	0.0005	0.0816	0.0816
LEN_WING	16.97419	12.6812	1.657259	10.24	0.0005	0.4521	0.0439
AV WGT	.1735198	1.2369	.044901	3.86	0.0181	0.4619	0.0636
DIF SUBS w(11)	23.82061	0.7075	4.05572	5.87	0.0042	0.7898	0.0013
WGT/TSUB v(10)	-2.305432	-1.5513	.4791258	-4.81	0.0086	0.9690	0.0221

Analysis of Variance Report

endent Variable: FMA13.20

rce	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	511573.9	511573.9		
Model	5	293977.9	58795.58	25.03	0.004
Error	4	9394.498	2348.625		
Total	9	303372.4	33708.05		

Root Mean Square Error	48.46261
Mean of Dependent Variable	226.18
Coefficient of Variation	.2142657
R Squared	0.9690
Adjusted R Squared	0.9303

```
----------------  ----------Descriptive Statistics------------------------------
ate/Time        12-06-1992  11:23:39
ata Base Name   C:\NASA\NEWAV
escription      Merge of WUC11 and AVIONICS created 12-06-1992

                          Detail Report

Variable: FMA13.10
Mean - Average           19.99615        No. observations          36
Lower 95% c.i.limit      12.58958        No. missing values        10
 per 95% c.i.limit       27.40273        Sum of frequencies        26
   sum of squares        8407.67         Sum of observations       519.9
    ard deviation        18.33867        Std.error of mean         3.596509
      e                  336.3068        T-value for mean=0        5.559879
     f variation         .9171099        T prob level              0.0000
    ss                   1.530243        Kurtosis                  1.44858
Normality Test Value     2.417044        Reject if >  1.169(10%)   1.265(5%)
K.S. Normality Test       0.26791        Reject if >  0.156(10%)   0.171(5%)
√b1     1.44 Skew-Z      3.00 Pr 0.0027  b2    3.96 Kurt-Z     1.52 Pr 0.1293
D'Agostino-Pearson Omnibus K² Normality Test       11.3         Pr 0.0035
100-%tile (Maximum)      66.8            90-%tile                  48.2
 75-%tile                20.5            10-%tile                  4.6
  -%tile (Median)        14.1            Range                     63.5
  -%tile                 7.2             75th-25th %tile           13.3
 0-%tile (Minimum)       3.3             C.L. Median(95%)    8, 18.4
3.3---------------------------Line Plot / Box Plot----------------------------66.8
11121111  21 1212  1 1                        11  1       1
  ---[XXXXXXXmXXXXXXXa-----------------------------------                      11

                          Detail Report

Variable: FMA13.30
Mean - Average           27.12222        No. observations          36
ower 95% c.i.limit       20.12315        No. missing values        9
pper 95% c.i.limit       34.12129        Sum of frequencies        27
dj sum of squares        8139.327        Sum of observations       732.3
Standard deviation       17.69325        Std.error of mean         3.405067
Variance                 313.051         T-value for mean=0        7.965253
Coef. of variation       .6523525        T prob level              0.0000
Skewness                 1.951009        Kurtosis                  5.486146
Normality Test Value     1.821782        Reject if >  1.164(10%)   1.254(5%)
K.S. Normality Test       0.15041        Reject if >  0.153(10%)   0.168(5%)
b1     1.84 Skew-Z       3.62 Pr 0.0003  b2    7.31 Kurt-Z     3.13 Pr 0.0018
Agostino-Pearson Omnibus K² Normality Test       22.9           Pr 0.0000
0-%tile (Maximum)        90.9            90-%tile                  43.2
5-%tile                  36.7            10-%tile                  10.3
50-%tile (Median)        21.8            Range                     83
25-%tile                 13.8            75th-25th %tile           22.9
 0-%tile (Minimum)       7.9             C.L. Median(95%)    17, 35.5
7.9---------------------------Line Plot / Box Plot----------------------------90.9
1111 21  213 1  21     11 111 2  1          1
 ----[XXXXXXmXXXXaXXXXXXXX]------                                              1
```

```
---------------------------Descriptive Statistics---------------------------------
Date/Time          12-06-1992  11:23:39
¬ata Base Name C:\NASA\NEWAV
,escription     Merge of WUC11 and AVIONICS created 12-06-1992

                                  Detail Report

Variable: FMA13.20                              No. observations              30
Mean - Average            190.1867              No. missing values            15
Lower 95% c.i.limit       99.94949              Sum of frequencies            15
    r 95% c.i.limit       280.4238              Sum of observations           2852.8
    sum of squares        371891.3              Std.error of mean             42.0822
  ndard deviation         162.9836              T-value for mean=0            4.519409
/ariance                  26563.67              T prob level                  0.0005
Coef. of variation        .8569667              Kurtosis                      1.063796
Skewness                  1.306752              Reject if >   1.285(10%)      1.519(5%)
Normality Test Value      1.432155              Reject if >   0.201(10%)      0.220(5%)
K.S. Normality Test        0.18520              b2    3.37 Kurt-Z     1.07 Pr 0.2857
√b1     1.17 Skew-Z       2.19 Pr 0.0288
¬'Agostino-Pearson Omnibus K² Normality Test         5.9                  Pr 0.0519
   -%tile (Maximum)       560                   90-%tile                      503
   -%tile                 248                   10-%tile                      50.2
   -%tile (Median)        151.7                 Range                         555.8
   -%tile                 72.2                  75th-25th %tile               175.8
  0-%tile (Minimum)       4.2                   C.L. Median(95%)    72.2, 248
4.2-------------------------Line Plot / Box Plot--------------------------------560
                                                                          1       1
1     11  11 1  1     1 1   1 1    1           1
    ----[XXXXXXXXXXmXXXXaXXXXXXX]---------------------------------------

                                  Detail Report

Variable: FMA13.50                              No. observations              36
Mean - Average            27.70833              No. missing values            12
Lower 95% c.i.limit       20.91036              Sum of frequencies            24
 pper 95% c.i.limit       34.5063               Sum of observations           665
 ij sum of squares        5962.198              Std.error of mean             3.2865
 tandard deviation        16.1005               T-value for mean=0            8.430954
Variance                  259.226               T prob level                  0.0000
Coef. of variation        .5810706              Kurtosis                      1.132741
Skewness                  1.179471              Reject if >   1.182(10%)      1.289(5%)
Normality Test Value      1.499505              Reject if >   0.162(10%)      0.178(5%)
K.S. Normality Test        0.15450              b2    3.67 Kurt-Z     1.27 Pr 0.2036
√b1     1.10 Skew-Z       2.38 Pr 0.0175
)'Agostino-Pearson Omnibus K² Normality Test         7.3                  Pr 0.0264
 00-%tile (Maximum)       68.8                  90-%tile                      52
  75-%tile                35.05                 10-%tile                      10.5
  50-%tile (Median)       23.75                 Range                         61.8
  25-%tile                17.4                  75th-25th %tile               17.65
   0-%tile (Minimum)      7                     C.L. Median(95%)    17.6, 31.6
7---------------------------Line Plot / Box Plot--------------------------------68.8
                                                             1            1       1
1 1 11       31  2  111 11  1 11        111
    ---------[XXXXXXXmXXXXaXXXXXXXX]-----------------------
```

```
------------------------Descriptive Statistics--------------------------------------------
 ate/Time       02-14-1993  08:59:06
Data Base Name  C:/NASA\NEWAV
Description     Merge of WUC11 and AVIONICS created 12-06-1992

                              Detail Report

Variable: MHMA13.2                         No. observations              36
     Average                5.489474       No. missing values            17
     5% c.i.limit           4.333384       Sum of frequencies            19
     95% c.i.limit          6.645564       Sum of observations           104.3
    Sum of squares          103.5779       Std.error of mean             .5503266
   ndard deviation          2.398818       T-value for mean=0            9.974938
Variance                    5.754327       T prob level                  0.0000
Coef. of variation          .4369851       Kurtosis                      -.6502512
Skewness                    .267567        Reject if >  1.227(10%)  1.381(5%)
Normality Test Value        0.972          Reject if >  0.181(10%)  0.198(5%)
K.S. Normality Test         0.08897        b2      2.21 Kurt-Z    -0.60 Pr 0.5473
 /b1     0.25 Skew-Z        0.54 Pr 0.5894                              Pr 0.7213
  gostino-Pearson Omnibus K) Normality Test             0.7
    -%tile (Maximum)        10             90-%tile                      9.1
    -%tile                  6.8            10-%tile                      1.9
    -%tile (Median)         5.3            Range                         8.2
  2 -%tile                  3.6            75th-25th %tile               3.2
   0-%tile (Minimum)        1.8            C.L. Median(95%)    3.6, 6.8
 1.8-------------------------Line Plot / Box Plot---------------------------------10
 11         1 1     11      1  1     11          31    1      1           1     1     1
  ---------------[XXXXXXXXXXXXXXmXaXXXXXXXXXXXX]--------------------
```

NASA - WBS SUBSYSTEM ROLL-UP - WUC91/93/97

				FMA91	MHMA91			
	FLY HRS	ME91	MH91	FMA1620	MHMA162	ME93	MH93	FMA1610
A-7D	150,924	778	5,954	194.0	7.7			
A-10	442,398	1,681	9,888	263.2	5.9			
B-52G	136,040	151	338	900.9	2.2	1,241	8,939	109.6
FB-111A	40,127							
F-106A	21,836					216	753	101.1
F-111A	16,149							
F-111D	40,114							
F-111F	31,048							
F-4C	30,998	47	2,123	659.5	45.2	150	1,233	206.7
F-4D	153,424	201	716	763.3	3.6	1,137	10,883	134.9
F-4E	204,993	233	1,673	879.8	7.2	1,312	7,962	156.2
F-5E	47,034					102	442	461.1
F-15A	172,258	354	1,568	486.6	4.4			
F-15C	103,690	287	1,475	361.3	5.1			
F-16A	350,102	270	1,621	1,296.7	6.0	19	118	18,426.4
F-16B	67,002	116	110	577.6	0.9			
C-130B	88,133	291	1,919	302.9	6.6			
C-130E	514,595	1,453	8,558	354.2	5.9			
C-130H	42,802	162	917	264.2	5.7			
KC-135A	278,012	547	778	508.2	1.4			
C-140A	5,783	24	49	241.0	2.0	15	158	385.5
C-141B	572,817	5,102	23,946	112.3	4.7			
C-5A	109,290	5,774	47,653	18.9	8.3			
C-9A	40,070	81	344	494.7	4.2			
KC-10A	67,738	73	313	927.9	4.3			
T-38	460,850							
E-3A	32,693	437	1,009	74.8	2.3			

NAVY A/C

A4-E	6,345
A-4F	9,871
EA-6B	28,023
A-6E	64,096
A-7E	15,573
C-2A	12,193
E-2C	32,258
F-18A	65,846
F-14A	92,011

MHMA161	ME97	MH97	FMA97	MHMA97
	674	3,393	223.9	5.0
	1,932	8,137	229.0	4.2
-	1,894	6,378	71.8	3.4
	161	709	249.2	4.4
3.5	317	698	68.9	2.2
	110	426	146.8	3.9
	229	1,163	175.2	5.1
	156	634	199.0	4.1
8.2	233	965	133.0	4.1
9.6	714	2,331	214.9	3.3
6.1	570	2,332	359.6	4.1
4.3	273	1,069	172.3	3.9
	2,615	13,920	65.9	5.3
	660	3,473	157.1	5.3
6.2	80,874	8,797	4.3	0.1
	15,747	1,321	4.3	0.1
	173	661	509.4	3.8
	377	1,490	1,365.0	4.0
	142	497	301.4	3.5
	67	277	4,149.4	4.1
10.5	6	32	963.8	5.3
	864	3,183	663.0	3.7
	343	990	318.6	2.9
	23	30	1,742.2	1.3
	111	615	610.3	5.5
	1,483	4,951	310.8	3.3
	42	98	778.4	2.3

----------------------------Multiple Regression----------------------------

Date/Time 11-14-1992 09:46:44

Data Base Name C:\NASA\avionics

Description Backup of AVIONICS created 11-14-1992

Multiple Regression Report

ent Variable: FMA91

pendent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	-2032.573	0.0000	707.7598	-2.87	0.0140		
SQR WGT	10.54392	4.9303	1.831801	5.76	0.0001	0.0012	0.0012
LEN_WING	-23.90989	-10.0813	4.55016	-5.25	0.0002	0.2623	0.0192
AV WGT	.1643685	0.5986	.4058E-01	4.05	0.0016	0.4508	0.1066
TOTSUBS	-20.2698	-0.4460	7.750592	-2.62	0.0226	0.5578	0.0057
LEN	352.1919	5.0997	96.50173	3.65	0.0033	0.7904	0.0169

Analysis of Variance Report

Dependent Variable: FMA91

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
stant	1	3836912	3836912		
el	5	1024571	204914.1	9.05	0.001
Error	12	271653.8	22637.81		
Total	17	1296225	76248.5		

Root Mean Square Error	150.4587
Mean of Dependent Variable	461.6945
Coefficient of Variation	.3258837
Squared	0.7904
justed R Squared	0.7031

--------------------------Sum of Functions Regression--------------------------

Date/Time 11-14-1992 11:17:47
Data Base Name C:\NASA\avionics
Description Backup of AVIONICS created 11-14-1992

Estimation Summary Report

,3 X: LEN_WING
A+B*(X)+C*(SQR(X))
.r: LEN_WING

.n	Coefficient Estimate	Std. Error	T-Value	Prob(¦t¦>T)	R-Squared
	23030.41735861124	7749.835	3.0	0.0590	0.78348637
B	236.8905826810984	83.82999	2.8	0.0664	
C	-4657.051992212503	1615.197	-2.9	0.0634	

Source	df	Sum-Sqr	Mean Square	SQR(M.S.)	F-Ratio	Prob(f>F)
Model	2	85024.7	42512.35	206.1852	5.4	0.1007
Error	3	23496.27	7832.089	88.49909		
Total	5	108521	21704.19	147.3234		

```
---------------------------Descriptive Statistics-------------------------------
Date/Time        11-14-1992  11:19:35
 Base Name       C:\NASA\avionics
  ption          Backup of AVIONICS created 11-14-1992

                                  Detail Report

Variable: FMA93
Mean - Average            222.1572       No. observations          36
Lower 95% c.i.limit       89.67506       No. missing values        29
Upper 95% c.i.limit       354.6392       Sum of frequencies        7
Adj sum of squares        123301.6       Sum of observations       1555.1
 tandard deviation        143.3536       Std.error of mean         54.18258
 ariance                  20550.27       T-value for mean=0        4.100158
  f. of variation         .6452804       T prob level              0.0064
  wness                   1.096604       Kurtosis                  -.5116125
Normality Test Value      1.686499       Reject if >  1.638(10%)   2.832(5%)
K.S. Normality Test        0.25722       Reject if >  0.279(10%)   0.304(5%)
/b1    0.85 Skew-Z        0.00 Pr 1.0000 b2    2.04 Kurt-Z    0.00 Pr 1.0000
D'Agostino-Pearson Omnibus K} Normality Test          0.0          Pr 1.0000
100-%tile (Maximum)       461.1          90-%tile                  461.1
 75-%tile                 385.5          10-%tile                  101.1
 50-%tile (Median)        156.2          Range                     360
 25-%tile                 109.6          75th-25th %tile           275.9
  0-%tile (Minimum)       101.1          C.L. Median(95%)    101.1, 461.1
)1.1------------------------Line Plot / Box Plot-------------------------461.1
: 1      1     1          1
--[XXXXXXXXXmXXXXXXXXXXXXXaXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX]---------------
                                                               1            1

                                  Detail Report

Variable: MHMA93
Mean - Average            6.95           No. observations          36
 ower 95% c.i.limit       4.921705       No. missing values        28
  per 95% c.i.limit       8.978295       Sum of frequencies        8
 dj sum of squares        41.46          Sum of observations       55.6
Standard deviation        2.433692       Std.error of mean         .8604401
Variance                  5.922857       T-value for mean=0        8.077262
Coef. of variation        .3501715       T prob level              0.0001
Skewness                  6.089145E-02   Kurtosis                  -.9670676
Normality Test Value      1.05774        Reject if >  1.548(10%)   2.421(5%)
K.S. Normality Test        0.12102       Reject if >  0.264(10%)   0.288(5%)
/b1    0.05 Skew-Z        0.08 Pr 0.9344 b2    1.87 Kurt-Z   -0.60 Pr 0.5462
)'Agostino-Pearson Omnibus K} Normality Test          0.4          Pr 0.8307
100-%tile (Maximum)       10.5           90-%tile                  10.05
 75-%tile                 8.9            10-%tile                  3.5
 50-%tile (Median)        6.7            Range                     7
 25-%tile                 5.2            75th-25th %tile           3.7
  0-%tile (Minimum)       3.5            C.L. Median(95%)    3.5, 10.5
3.5-------------------------Line Plot / Box Plot--------------------------10.5
1       1                    11       1         1              1          1
------------------[XXXXXXXXXXXXXXXXmXaXXXXXXXXXXXXXXXXXXXXXX]-------------
```

-------------------------Sum of Functions Regression------------------------------

Date/Time 11-14-1992 09:55:33
Data Base Name C:\NASA\avionics
Description Backup of AVIONICS created 11-14-1992

Estimation Summary Report

Y: MHMA91 X: DRY_WGT
Model: A+B*(X)+C*(1/SQR(X))+D*(LOG(X))+E*(SQR(X))

Term	Coefficient Estimate	Std. Error	T-Value	Prob(¦t¦>T)	R-Squared
A	-1368.289417750781	720.4002	-1.9	0.0799	0.44300359
B	7.040110685144 2D-04	3.022521E-04	2.3	0.0366	
C	21064.54902338557	11823.14	1.8	0.0982	
D	138.3702358205629	71.22768	1.9	0.0740	
E	-1.130933290017751	.5290806	-2.1	0.0521	

Source	df	Sum-Sqr	Mean Square	SQR(M.S.)	F-Ratio	Prob(f>F)
Model	4	30.55962	7.639905	2.764038	2.6	0.0865
Error	13	38.42316	2.955628	1.719194		
Total	17	68.98278	4.05781	2.014401		

```
--------------------------Descriptive Statistics------------------------------
Date/Time          11-14-1992  09:56:06
Data Base Name     C:\NASA\avionics
Description        Backup of AVIONICS created 11-14-1992
                                Detail Report

Variable: FMA91                               No. observations              36
Mean - Average             441.3316           No. missing values            17
Lower 95% c.i.limit        305.1111           Sum of frequencies            19
Upper 95% c.i.limit        577.5521           Sum of observations           8385.3
Adj sum of squares         1438034            Std.error of mean             64.84425
Standard deviation         282.6495           T-value for mean=0            6.806025
Variance                   79890.75           T prob level                  0.0000
Coef. of variation         .6404471           Kurtosis                      -.8929988
Skewness                   .398535            Reject if >  1.227(10%)   1.381(5%)
Normality Test Value       0.973              Reject if >  0.181(10%)   0.198(5%)
K.S. Normality Test         0.13778           b2     2.03 Kurt-Z    -1.01 Pr 0.3132
{b1     0.37 Skew-Z        0.80 Pr 0.4247                                  Pr 0.4373
D'Agostino-Pearson Omnibus K} Normality Test     1.7
100-%tile (Maximum)        927.9              90-%tile                      890.35
 75-%tile                  659.5              10-%tile                      74.8
 50-%tile (Median)         361.3              Range                         909
 25-%tile                  241                75th-25th %tile               418.5
  0-%tile (Minimum)        18.9               C.L. Median(95%)       241, 659.5
3.9------------------------Line Plot / Box Plot-----------------------------927.9
    1  1        1    1 2  1     2         111      1      1          1       1 1 1
    --------------[XXXXXXXXXmXXXXXXaXXXXXXXXXXXXXXXXX]------------------

                                Detail Report

Variable: MHMA91                              No. observations              36
Mean - Average             4.861111           No. missing values            18
Lower 95% c.i.limit        3.859614           Sum of frequencies            18
Upper 95% c.i.limit        5.862608           Sum of observations           87.5
Adj sum of squares         68.98278           Std.error of mean             .4747988
Standard deviation         2.014401           T-value for mean=0            10.23825
Variance                   4.05781            T prob level                  0.0000
Coef. of variation         .414391            Kurtosis                      -.7874599
Skewness                   -.139055           Reject if >  1.239(10%)   1.407(5%)
Normality Test Value       0.930              Reject if >  0.185(10%)   0.203(5%)
K.S. Normality Test         0.12043           b2     2.10 Kurt-Z    -0.79 Pr 0.4282
{b1    -0.13 Skew-Z        -0.27 Pr 0.7834                                 Pr 0.7035
D'Agostino-Pearson Omnibus K} Normality Test     0.7
100-%tile (Maximum)        8.3                90-%tile                      7.45
 75-%tile                  6                  10-%tile                      2
 50-%tile (Median)         4.9                Range                         6.9
 25-%tile                  3.6                75th-25th %tile               2.4
  0-%tile (Minimum)        1.4                C.L. Median(95%)       3.6, 6
1.4------------------------Line Plot / Box Plot-----------------------------8.3
1       1 11              1      111  1    1       1 21      1       1     1     1
    -----------------[XXXXXXXXXXXXamXXXXXXXXXXX]-----------------
```

------------------------------Multiple Reg. sion-------- --------------------

Date/Time 11-14-1992 10:56:11
Data Base Name C:\NASA\avionics
Description Backup of AVIONICS created 11-14-1992

Multiple Regression Report

..ndent Variable: FMA97

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	8962.944	0.0000	1752.219	5.12	0.0001		
SQR WGT	22.47763	14.8953	3.93019	5.72	0.0000	0.4586	0.4586
DRY_WGT	-.202E-01	-8.6333	.3661E-02	-5.51	0.0000	0.4977	0.3907
LN DRYWT	-1172.605	-5.9724	225.6105	-5.20	0.0001	0.8132	0.4215

Analysis of Variance Report

..endent Variable: FMA97

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	1732662	1732662		
Model	3	607336.8	202445.6	23.21	0.000
Error	16	139536	8720.998		
..tal	19	746872.8	39309.09		

..t Mean Square Error	93.38628
..ean of Dependent Variable	294.335
Coefficient of Variation	.3172789
R Squared	0.8132
Adjusted R Squared	0.7781

```
-----------------------------Descriptive  .:istics-----------------------------
Date/Time          11-14-1992  10:45:11
 ıta Base Name C:\NASA\avionics
.escription        Backup of AVIONICS created 11-14-1992

                                    Detail Report

Variable: FMA97
Mean - Average           314.65           No. observations            36
 ...r 95% c.i.limit      207.1208         No. missing values          14
    : 95% c.i.limit      422.1792         Sum of frequencies          22
    ;um of squares       1235499          Sum of observations         6922.3
   ıdard deviation       242.5557         Std.error of mean           51.71305
 .riance                 58833.27         T-value for mean=0          6.084538
Coef. of variation       .7708746         T prob level                0.0000
Skewness                 1.394441         Kurtosis                    1.323396
Normality Test Value     2.159788         Reject if >  1.198(10%)  1.319(5%)
K.S. Normality Test       0.22078         Reject if >  0.169(10%)  0.185(5%)
√b1    1.30 Skew-Z       2.64 Pr 0.0084   b2     3.78 Kurt-Z     1.37 Pr 0.1707
 'Agostino-Pearson Omnibus K} Normality Test      8.8            Pr 0.0121
 ,0-%tile (Maximum)      963.8            90-%tile                    663
 '5-%tile                359.6            10-%tile                    70.35001
  )-%tile (Median)       226.45           Range                       897.9
  5-%tile                157.1            75th-25th %tile             202.5
  0-%tile (Minimum)      65.9             C.L. Median(95%)     157.1, 359.6
ʋ5.9------------------------Line Plot / Box Plot--------------------------963.8
21     1112  112 1   111   1              1        1     1         1          1
--------[XXXXXmXXXXXXXaXXX]--------------------------

                                    Detail Report

Variable: MHMA97
Mean - Average           4.029167         No. observations            36
Lower 95% c.i.limit      3.647138         No. missing values          12
 ᄀper 95% c.i.limit_     4.411196         Sum of frequencies          24
  j sum of squares       18.82958         Sum of observations         96.7
 :andard deviation       .904808          Std.error of mean           .1846932
 ariance                 .8186775         T-value for mean=0          21.81546
:oef. of variation       .2245646         T prob level                0.0000
Skewness                -.1546471         Kurtosis                   -.2922936
Normality Test Value     0.987            Reject if >  1.182(10%)  1.289(5%)
K.S. Normality Test       0.13547         Reject if >  0.162(10%)  0.178(5%)
√b1   -0.14 Skew-Z      -0.35 Pr 0.7283   b2     2.53 Kurt-Z    -0.14 Pr 0.8860
D'Agostino-Pearson Omnibus K} Normality Test      0.1            Pr 0.9318
!00-%tile (Maximum)      5.5              90-%tile                    5.3
 75-%tile                4.7              10-%tile                    2.9
  0-%tile (Median)       4.05             Range                       3.3
  '-%tile                3.45             75th-25th %tile             1.25
   -%tile (Minimum)      2.2              C.L. Median(95%)     3.5, 4.4
2.2------------------------Line Plot / Box Plot----------------------------5.5
1 1               1        2 1  1   1  1 2  1 4 1    1            1  1   3    1
                  -------------[XXXXXXXXXXXXamXXXXXXXXXXXXXX]--------------
```

C5-B 10/90-9/92	WUC	NOUN	ON - MH	OFF - MH	failures	removals	aborts
FLIGHT HOURS	51A**	NAV INST	9727	4800	1864	902	1
	51AA*	COMP FLGT DIR	1193	710	262	123	0
	51CC*	FUEL SAV COMP	464	482	128	63	0
ORTIES	51EB*	BARC COMP	48	0	3	0	0
	51FA*	GPWS COMP	248	346	59	33	0
	52AC*	COPM PITCH&PACS	1163	1090	217	117	0
123956	52AG*	ROLL YAW PACS	392	291	88	47	0
27240	52AN*	PITCH/PACS	1093	713	198	118	1
	52AR*	ROLL/YAW/PACS	578	475	123	68	0
	52EA*	GAAS	721	1088	190	105	0
	52JA*	PITCH AUG	555	328	137	43	0
	52JE*	YAW/LAT AUG	1576	1300	378	206	0
	52JF*	Y/L AUGMENT	1223	1233	285	163	2
	52LA*	AUTO THROTL	80	69	22	7	0
	52LB*	AUTO THROTL	56	49	15	13	0
	52NA*	STALLMTR	502	509	137	72	0
	52PA*	DIST CON SYS	638	391	120	65	1
	55ALL	A/D COMP	42	1	0	0	0
	55AV*	DIGITAL G1	164	16	38	3	0
	55AW*	MADAR (NOT R)	17	0	7	0	0
	55AX*	MADAR	25	16	3	2	0
	55C**	MADAR SUB	15863	8812	3384	1188	0
BATTERY							
	66CAC	BATTERY	127	0	32	7	0
	66EAK	BATT LOC BEACON	285	4	73	16	0
	66GAF	BATT LOC BEACON	366	4	85	23	0

C5	MH/MA	FLY HRS/MA	REMOVE/MA
computer	7.715722121	16.18647166362	0.435884043
battery	4.136842105	652.4	0.242105263

F-15A 10/90-9/92	WUC	NOUN	ON - MH	OFF - MH	failures	removals	aborts
FLIGHT HOURS	51E**	AIR DATA SYS	14486	7601	2065	1009	166
	52A**	AUTO FLT CONT	13600	6353	1898	768	128
	57***	INT GUID	7157	3124	1977	356	22
SORTIES	74K**	HUD	10199	13509	2516	1147	32
112369							
87567							

F-15E 10/90-9/92	WUC	NOUN	ON - MH	OFF - MH	failures	removals	aborts
FLIGHT HOURS	52A**	AUTO FLIGHT	814	51	134	18	7
	51E**	AIR DATA SYS	5059	1247	926	298	69
	57***	INT GUID	12441	5407	3765	962	28
SORTIES	74K**	HUD	4312	4967	1170	377	25
87477	82***	REMOTE MAP READ	7290	5738	2076	737	2
47557							

F15	MH/MA	FLY HRS/MA	REMOVE/MA
computer	7.184393869	18.564421737111	0.123131047
HUD	8.949267499	54.217580032556	0.037401575

MH/MA	FLY HRS/MA	REMOVE/MA
7.79	66.50	0.48
7.26	473.11	0.47
7.39	968.41	0.49
16.00	41318.67	0.00
10.07	2100.95	0.56
10.38	571.23	0.54
7.76	1408.59	0.53
9.12	626.04	0.60
8.56	1007.77	0.55
9.52	652.40	0.55
6.45	904.79	0.31
7.61	327.93	0.54
8.62	434.93	0.57
6.77	5634.36	0.32
7.00	8263.73	0.87
7.38	904.79	0.53
8.58	1032.97	0.54
-	-	-
4.74	3262.00	0.08
2.43	17708.00	0.00
13.67	41318.67	0.67
7.29	36.63	0.35
3.97	3873.63	0.22
3.96	1698.03	0.22
4.35	1458.31	0.27
10.70	54.42	0.49
10.51	59.20	0.40
5.20	56.84	0.18
9.42	44.66	0.46
6.46	652.81	0.13
6.81	94.47	0.32
4.74	23.23	0.26
7.93	74.77	0.32
6.28	42.14	0.36

C-141B	WUC	NOUN	ON - MH	OFF - MH	failures	removals	aborts
[illegible]0-9/92							
T	55***	MAL ANAL REC	13479	1028	3394	981	4
RS	55EC*	A1L 1903244-2	1769	5946	449	293	
	52E**	AWLS SYS	16338	41885	4165	2526	4
SORTIES	52C**	NEW AUTOPILOT	606	16	136	57	0
	52CA*	A1L 1903244-3	87	0	20	10	
	52B**	AUTOPILOT	7536	606	1890	1371	8
622141	52BA*	A1L 1903244-2	1994	16	565	422	
161958	51AAA	CADC COMP	6298	190	1554	924	3
	51BGA	COMPUTER	1081	60	296	204	1
	51EA*	FUEL SAVING	5929	5460	1581	839	2

BATTERY

	WUC	NOUN	ON - MH	OFF - MH	failures	removals	aborts
	51EBN	BATTERY BT1	28	0	12	9	0
	66ADE	BA 1387	27	0	7	2	0

c141	MH/MA	FLY HRS/MA	REMOVE/MA
computer	7.852241993	44.280498220641	0.542846975
battery	2.894736842	32744.263157895	0.578947368

TOTAL	MH/MA	FLY HRS/MA	REMOVE/MA
computer	7.598651187	29.130138884612	0.442706248
battery	4.023923445	3569.8421052632	0.272727273

MH/MA	FLY HRS/MA	REMOVE/MA
[illegible]	183.31	0.29
[illegible]8	1385.61	0.65
3.98	149.37	0.61
4.57	4574.57	0.42
4.35	31107.05	0.50
4.31	329.18	0.73
3.56	1101.13	0.75
4.18	400.35	0.59
3.85	2101.83	0.69
7.20	393.51	0.53
2.33	51845.08	0.75
3.86	88877.29	0.29

REMOVAL RATES - AVIONICS SUBSYSTEMS

	C-5A	C130E	C-141B	F15D	F111A	T38A	COMP	
51	0.453	0.414	0.445	0.51	0.726	0.494	0.51	WBS 13.50
52	0.375	0.483	0.514	0.345	0.708	0.322		
61	0.317	0.307	0.539		0.33			
62	0.275	0.327	0.388			0.235		
63	0.299	0.306	0.275	0.405	0.546	0.375		
64	0.518	0.443	0.521		0.507	0.292		
65	0.382	0.551	0.445	0.35	0.422	0.68		
66	0.309	0.557	0.322					
69		0.295	0.419		0.652			
71	0.395	0.411	0.424	0.426	0.433	0.56		
72	0.455	0.542	0.427					
AVG	0.38	0.42	0.43	0.41	0.54	0.42	0.43	
STD	0.08	0.10	0.08	0.06	0.14	0.15	0.05	
MIN	0.28	0.30	0.28	0.35	0.33	0.24	0.24	
MAX	0.52	0.56	0.54	0.51	0.73	0.68	0.73	
52/71/72	0.43	0.46	0.43	0.31	0.39	0.35	0.40	WBS 13.10
61..66	0.35	0.42	0.42	0.38	0.45	0.40	0.40	WBS 13.30

ABORTS & MAINTENANCE ACTION DATA

	F-4E	B-52G	C-5B	KC-10A	C-130E	F-16C	KC-135R	F-15C	TOT
WUC 23									
ABORTS	323	47		23		812			1,205
MA	5,921	36,181		3,926		39,635			85,663
WUC 49									
ABORTS	62	4		3	48		2		119
MA	261	1,738		570	2,732	631	1,032		6,333
WUC 91									
ABORTS	0	1		3	1	1	4		10
MA	30	500		342	741	43	267		1,923
WUC 93									
ABORTS	2	1							3
MA	276	580							856
WUC 96									
ABORTS	1				0	4	0		5
MA	15				138	72	142		367
WUC 97									
ABORTS	0	0		1	0	0	0		
MA	902	1,306		227	575	1,888	737		
WUC 24									
ABORTS				4	15	949	12	781	1,761
MA				1,057	4,514	10,828	5,235	5,854	27,488

ABORTS & MAINTENANCE ACTION DATA

RATE
0.0188
0.0052
0.0035
;136
0.0641

ABORTS PER MAINTENANCE ACTION - ROLL-UPS

	F-4D-A	F-4D-F	F-4D	B-52G-A	B-52G-F	B-52G	B-52H-A	B-52H-F
WUC42	16	217	0.07373	16	6,620	0.00242	8	6,023
WUC44	6	218	0.02752	6	2,248	0.00267	3	1,507
WBS 10	22	435	0.05057	22	8,868	0.00248	11	7,530
WUC45	23	281	0.08185	18	21,306	0.00084	2	10,481
WUC47	1	102	0.00980	4	1,719	0.00233	0	1,324
WUC51	10	388	0.02577	22	11,280	0.00195	23	9,941
WUC52	12	144	0.08333	4	1,681	0.00238	0	1,054
WUC61								
WUC62		2	0.00000	0	22	0.00000	0	3
WUC63	13	233	0.05579	1	2,428	0.00041	4	1,787
WUC64				4	2,024	0.00198	2	1,991
WUC71	6	971	0.00618	0	2,251	0.00000	0	1,720
WUC72	0	54	0.00000	0	712	0.00000	0	645
AVIONICS ROLL-UP	41	1,792	0.02288	31	20,398	0.00152	29	17,141

ABORTS PER MAINTENANCE ACTION - ROLL-UPS

KC-10A-A	KC-10A-F	KC-10	C-130A-A	C-130A-F	C-130B-A	C-130B-F	C-130B	C-130E-A
5	1,011	0.00495	14	379	58	1,397	0.04152	101
7	3,105	0.00225	0	132	6	580	0.01034	10
12	4,116	0.00292	14	511	64	1,977	0.03237	111
17	1,707	0.00996	3	348	28	2,380	0.01176	60
3	884	0.00339	0	67	2	382	0.00524	9
6	956	0.00628	1	262	12	2,063	0.00582	44
3	1,990	0.00151	1	228	12	1,802	0.00666	37
0	196	0.00000	0	43	3	421	0.00713	8
0	473	0.00000	0	30	2	255	0.00784	3
1	1,231	0.00081	3	105	10	105	0.09524	24
2	2,509	0.00080	3	226	2	1,130	0.00177	10
2	529	0.00378	2	477	5	2,244	0.00223	80
14	7,884	0.00178	10	1,371	46	8,020	0.00574	206

ABORTS PER MAINTENANCE ACTION - ROLL-UPS

C-130E-F	C-130E	C-130H-A	C-130H-F	C-130H	F-4D-A	F-4D-F	F-4D	F-4G-A	F-4G-F
6,188	0.01632	84	3,055	0.02750	206	1,164	0.17698	100	492
4,777	0.00209	6	1,884	0.00318	48	1,176	0.04082	31	456
10,965	0.01012	90	4,939	0.01822	254	2,340	0.10855	131	948
10,763	0.00557	45	4,990	0.00902	431	3,570	0.12073	233	1,309
2,215	0.00406	6	1,247	0.00481	18	732	0.02459	14	292
9,289	0.00474	12	3,016	0.00398	50	3,033	0.01649	41	1,514
7,416	0.00499	29	3,715	0.00781	134	1,449	0.09248	61	645
2,399	0.00333	4	1,938	0.00206	0	1	0.00000		
2,133	0.00141	2	1,303	0.00153	106	2,571	0.04123	48	1,730
[illegible],611	0.00665	6	2,032	0.00295	0	0		1	0
5,630	0.00151	2	2,647	0.00076	96	10,965	0.00876	24	5,681
9,270	0.00415	25	7,244	0.00345	1	787	0.00127	2	485
50,748	0.00406	80	21,895	0.00365	387	18,806	0.02058	177	10,055
				0.0071					

ABORTS PER MAINTENANCE ACTION - ROLL-UPS

F-16A-A	F-16A-F	F-16A	F-16C-A	F-16C-F		F-15A-A	F-15A-F	F-15A	F-15B-A
884	11,654	0.07585	919	10,511	0.08743	289	2,696	0.10720	42
108	5,168	0.02090	149	6,143	0.02426	95	3,236	0.02936	19
992	16,822	0.05897	1,068	16,654	0.06413	384	5,932	0.06473	61
375	4,300	0.08721	386	3,146	0.12270	560	4,293	0.13044	115
28	1,907	0.01468	51	2,712	0.01881	6	924	0.00649	3
173	5,297	0.03266	255	6,996	0.03645	196	7,108	0.02757	35
0	5	0.00000	0	9	0.00000	158	2,239	0.07057	19
26	2,368	0.01098	14	2,099	0.00667	0	2	0.00000	
134	5,557	0.02411	178	9,895	0.01799	51	6,489	0.00786	13
30	896	0.03348	42	891	0.04714	0	8	0.00000	0
12	2,301	0.00522	22	3,568	0.00617	53	6,451	0.00822	11
0	4	0.00000	1	18	0.05556	0			0
375	16,428	0.02283	512	23,476	0.02181	458	22,297	0.02054	78

ABORTS PER MAINTENANCE ACTION - ROLL-UPS

F-15B-F	F-15C-A	F-15C-F	F-15C	F-15D-A	F-15D-F	F-15E-A	F-15E-F	F-111E-A
361	279	3,251	0.08582	36	558	64	795	59
303	96	4,948	0.01940	21	750	12	976	15
64	375	8,199	0.14197	57	1,308	76	1,771	74
[illegible]41	521	4,950	0.10525	67	851	64	421	74
253	15	1,424	0.01053	2	288	3	565	2
1,760	336	7,661	0.04386	32	1,674	69	2,305	62
419	150	2,594	0.05783	19	385	162	2,053	98
								0
				0				0
1,516	40	8,506	0.00470	11	1,478	21	2,072	8
								10
1,359	63	7,636	0.00825	7	1,217	7	1,303	0
						0	185	
5,054	589	26,397	0.02231	69	4,754	259	7,918	178

ABORTS PER MAINTENANCE ACTION - ROLL-UPS

F-111E-F	F-111E	KC-135A-A	KC-135A-F	KC-135A	TOT	TOT	ABORT	
1,345	0.04387	57	8,464	0.00673	3,237	66,181	0.049	
1,136	0.01320	13	3,849	0.00338	651	43,092	0.015	
2,481	0.02983	70	12,313	0.00569	3,888	109,273	0.036	
1,822	0.04061	25	11,361	0.00220	3,047	88,920	0.034	
911	0.00220	4	2,326	0.00172	171	20,274	0.008	
2,791	0.02221	37	17,086	0.00217	1,416	94,420	0.015	
2,244	0.04367	4	6,911	0.00058	903	36,983	0.024	
308	0.00000	0	911	0.00000	0	1,219	0.000	
9	0.00000	1	207	0.00483	56	9,710	0.006	
1,120	0.00714	2	2,013	0.00099	637	51,589	0.012	
608	0.01645	7	2,326	0.00301	140	15,828	0.009	0.011
411	0.00000	0	1,301	0.00000	320	60,277	0.005	0.010
		17	10,650	0.00160	135	43,304	0.003	
7,491	0.02376	68	41,405	0.00164	3,607	313,330	0.012	
					0	0		

------------------------------Multiple Regression------------------------------

Date/Time 04-16-1993 10:05:25
Data Base Name C:\NASA\MAINT
Description Merge of WUC51 and WUC11 created 02-21-1992

Multiple Regression Report

Dependent Variable: %ON-EQ

Independent Variable	Parameter Estimate	Stndized Estimate	Standard Error	t-value (b=0)	Prob. Level	Seq. R-Sqr	Simple R-Sqr
Intercept	23.92398	0.0000	5.936497	4.03	0.0007		
LEN_WING	-.545E-01	-33.3534	.1817E-01	-3.00	0.0073	0.1383	0.1383
LOG LEN	-10.56261	-33.4358	2.899613	-3.64	0.0017	0.4397	0.2415
SQR LEN	3.039025	64.8849	.9162678	3.32	0.0036	0.5834	0.1854
FUS DENS	.0214718	0.4241	.1081E-01	1.99	0.0617	0.6115	0.0315
FUS AREA	.6716E-04	1.3912	.3991E-04	1.68	0.1087	0.6619	0.0494

Analysis of Variance Report

Dependent Variable: %ON-EQ

Source	df	Sums of Squares (Sequential)	Mean Square	F-Ratio	Prob. Level
Constant	1	5.103081	5.103081		
Model	5	.4836388	9.672775E-02	7.44	0.001
Error	19	.2470872	1.300459E-02		
Total	24	.730726	3.044692E-02		

Root Mean Square Error	.1140377
Mean of Dependent Variable	.4518
Coefficient of Variation	.2524074
R Squared	0.6619
Adjusted R Squared	0.5729

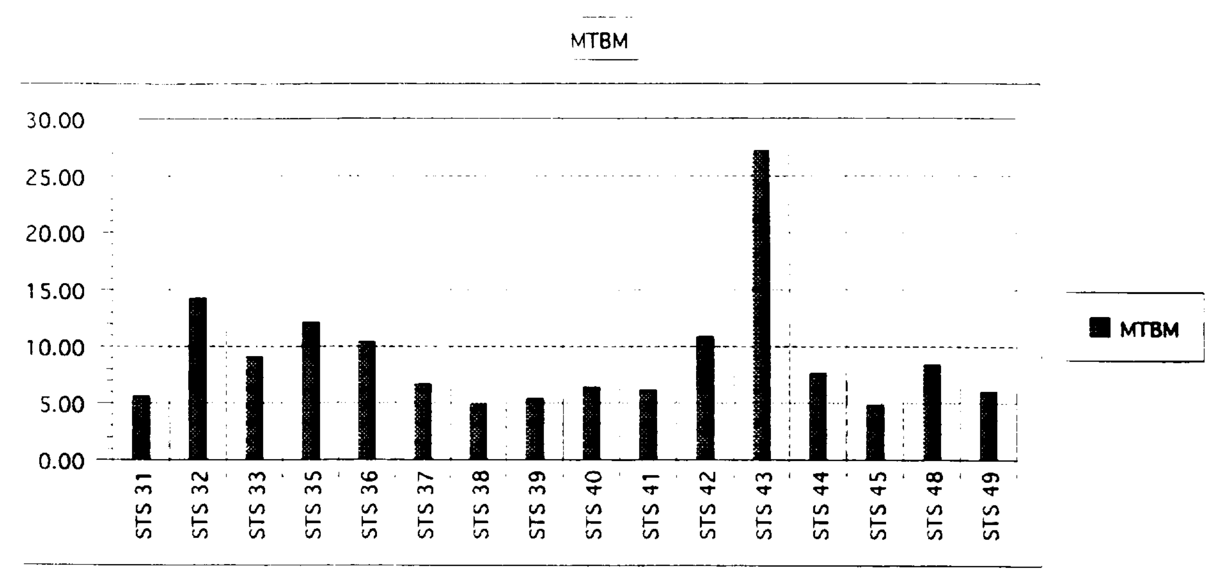
```
---------------------------Descriptive Statistics--------------------------
Date/Time          04-16-1993  10:06:11
Data Base Name  C:\NASA\MAINT
Description       Merge of WUC51 and WUC11 created 02-21-1992
                                 Detail Report

Variable: %ON-EQ                                   No. observations              35
Mean - Average              .4518                  No. missing values            10
Lower 95% c.i.limit         .3797759               Sum of frequencies            25
Upper 95% c.i.limit         .5238241               Sum of observations           11.295
Adj sum of squares          .730726                Std.error of mean             3.489809E-02
Standard deviation          .1744905               T-value for mean=0            12.94627
Variance                    3.044692E-02           T prob level                  0.0000
Coef. of variation          .3862117               Kurtosis                      -.3016444
Skewness                    .6069534               Reject if >  1.176(10%)  1.276(5%)
Normality Test Value        1.060809               Reject if >  0.159(10%)  0.174(5%)
K.S. Normality Test         0.15008                b2     2.52 Kurt-Z    -0.16 Pr 0.8696
{b1    0.57 Skew-Z          1.34 Pr 0.1794                                    Pr 0.4006
D'Agostino-Pearson Omnibus K} Normality Test            1.8
100-%tile (Maximum)         .794                   90-%tile                      .728
  75-%tile                  .523                   10-%tile                      .294
  50-%tile (Median)         .407                   Range                         .6620001
  25-%tile                  .332                   75th-25th %tile               .191
   0-%tile (Minimum)        .132                   C.L. Median(95%)      .338, .516
.132--------------------------Line Plot / Box Plot-------------------------------.794
1              1       11 112 1111  1     2  1 1   11 1                1 1 1       11
                     -----[XXXXXXXmXXXXXaXXXXXXX]-----------------------
```

Appendix B

Shuttle Failure Data

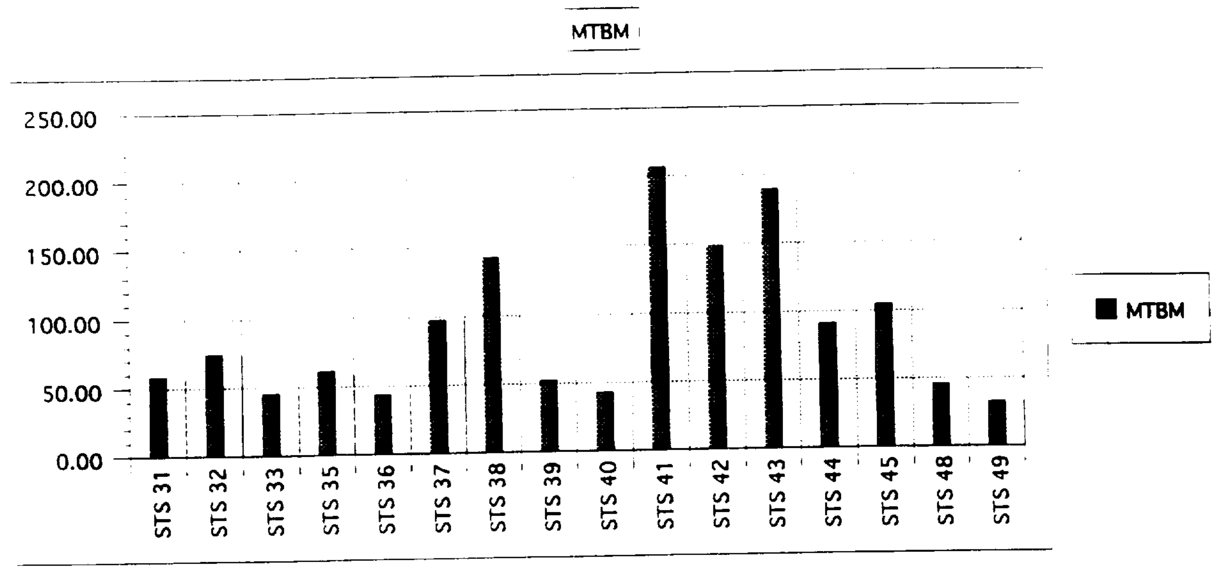
APU



OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	25	13	140	5.60
STS 32	10	4	143	14.30
STS 33	18	7	164	9.11
STS 35	28	17	341	12.18
STS 36	9	9	94	10.44
STS 37	21	10	141	6.71
STS 38	49	23	240	4.90
STS 39	28	7	151	5.39
STS 40	16	9	103	6.44
STS 41	32	19	199	6.22
STS 42	13	6	142	10.92
STS 43	5	1	136	27.20
STS 44	20	4	153	7.65
STS 45	26	8	126	4.85
STS 48	17	10	143	8.41
STS 49	42	12	253	6.02
TOTAL	359	159	2669	7.43
AVERAGE	22.44	9.94	166.81	9.15
SD	11.80	5.80	63.11	5.56
CONFIDENCE	95%			
INTERVAL				
HIGH	28.72	13.03	200.43	12.11
LOW	16.15	6.85	133.19	6.18

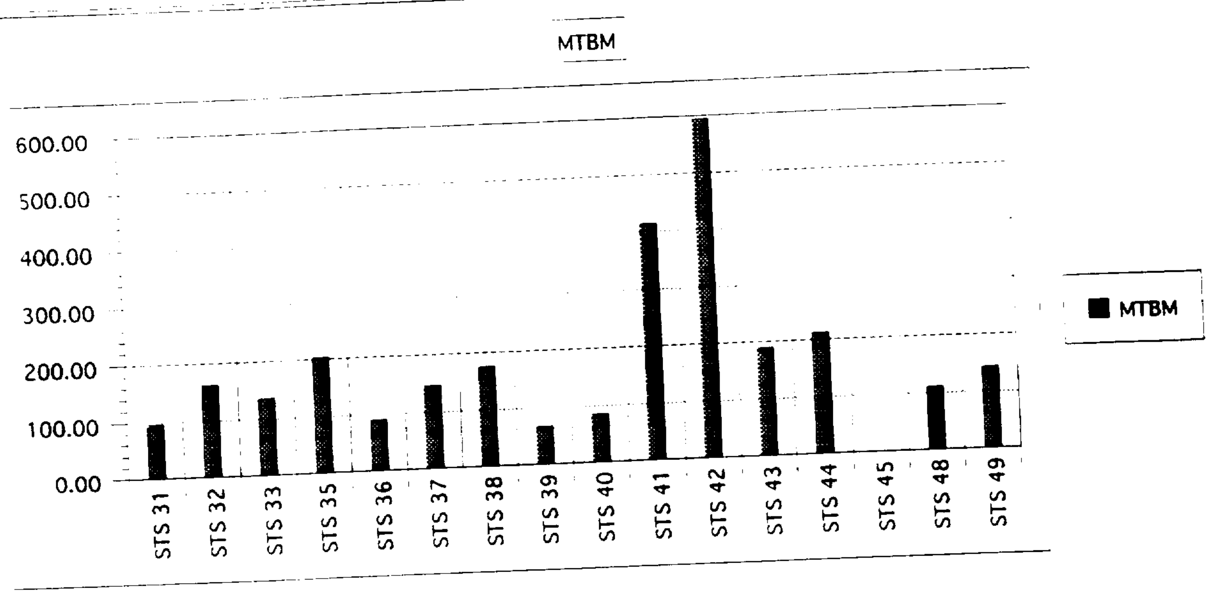
COM



OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	10	2	584	58.40
STS 32	8	5	597	74.63
STS 33	15	3	683	45.53
STS 35	23	10	1420	61.74
STS 36	9	6	393	43.67
STS 37	6	1	586	97.67
STS 38	7	0	998	142.57
STS 39	12	2	630	52.50
STS 40	10	3	430	43.00
STS 41	4	0	829	207.25
STS 42	4	0	594	148.50
STS 43	3	1	569	189.67
STS 44	7	4	639	91.29
STS 45	5	1	524	104.80
STS 48	13	8	595	45.77
STS 49	32	10	1054	32.94
TOTAL	168	56	11125	66.22
AVERAGE	10.50	3.50	695.31	89.99
SD	7.62	3.41	262.34	54.85
CONFIDENCE	95%			
INTERVAL				
HIGH	14.56	5.31	835.07	119.22
LOW	6.44	1.69	555.55	60.77

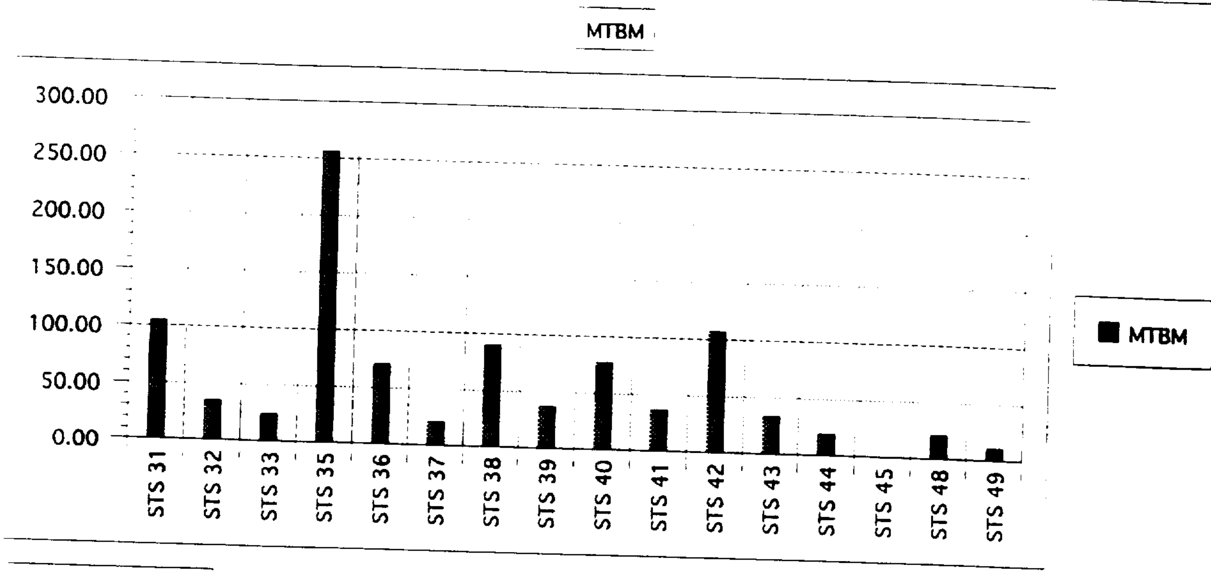
DIG



OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	18	15	1752	97.33
STS 32	11	3	1791	162.82
STS 33	15	8	2048	136.53
STS 35	21	14	4261	202.90
STS 36	13	8	1179	90.69
STS 37	12	6	1759	146.58
STS 38	17	11	2995	176.18
STS 39	28	11	1890	67.50
STS 40	15	14	1289	85.93
STS 41	6	5	2486	414.33
STS 42	3	5	1781	593.67
STS 43	9	6	1706	189.56
STS 44	9	3	1916	212.89
STS 45	9	11	1571	
STS 48	16	10	1784	111.50
STS 49	22	10	3163	143.77
TOTAL	224	140	33371	148.98
AVERAGE	14.00	8.75	2085.69	177.01
SD	6.40	3.86	787.52	142.74
CONFIDENCE	95%			
INTERVAL				
HIGH	17.41	10.80	2505.24	253.06
LOW	10.59	6.70	1666.14	100.97

DDC

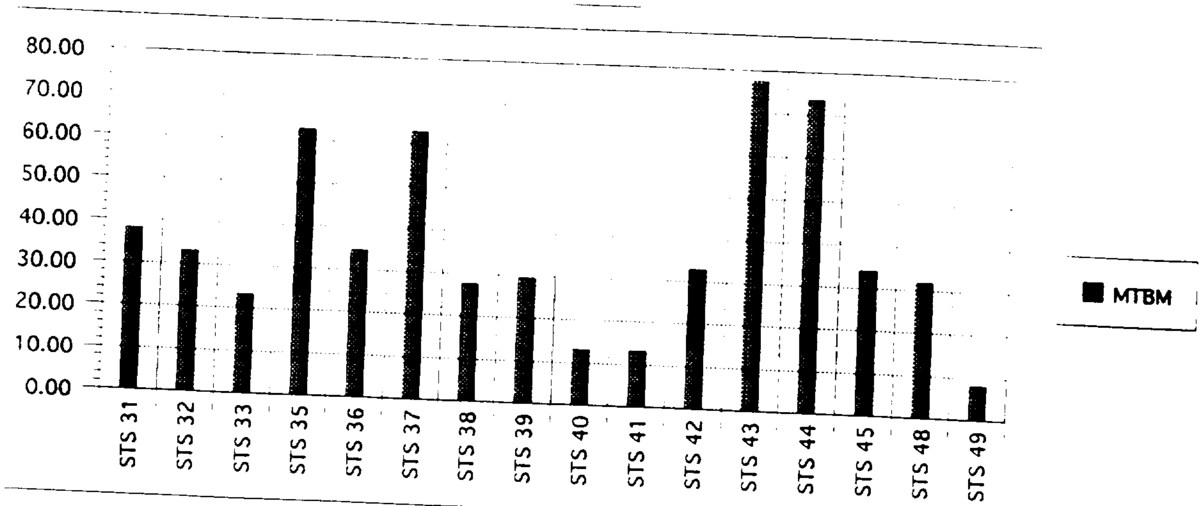


OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	1	1	105	105.00
STS 32	3	2	107	35.67
STS 33	5	3	123	24.60
STS 35	1	0	256	256.00
STS 36	1	0	71	71.00
STS 37	5	2	106	21.20
STS 38	2	0	180	90.00
STS 39	3	1	113	37.67
STS 40	1	1	77	77.00
STS 41	4	4	149	37.25
STS 42	1	2	107	107.00
STS 43	3	1	102	34.00
STS 44	6	2	115	19.17
STS 45	0	0	94	0.00
STS 48	5	4	107	21.40
STS 49	17	4	190	11.18
TOTAL	58	27	2002	34.52
AVERAGE	3.63	1.69	125.13	59.26
SD	4.01	1.45	47.38	62.26
CONFIDENCE	95%			
INTERVAL				
HIGH	5.76	2.46	150.37	92.42
LOW	1.49	0.92	99.88	26.09

ECL

MTBM

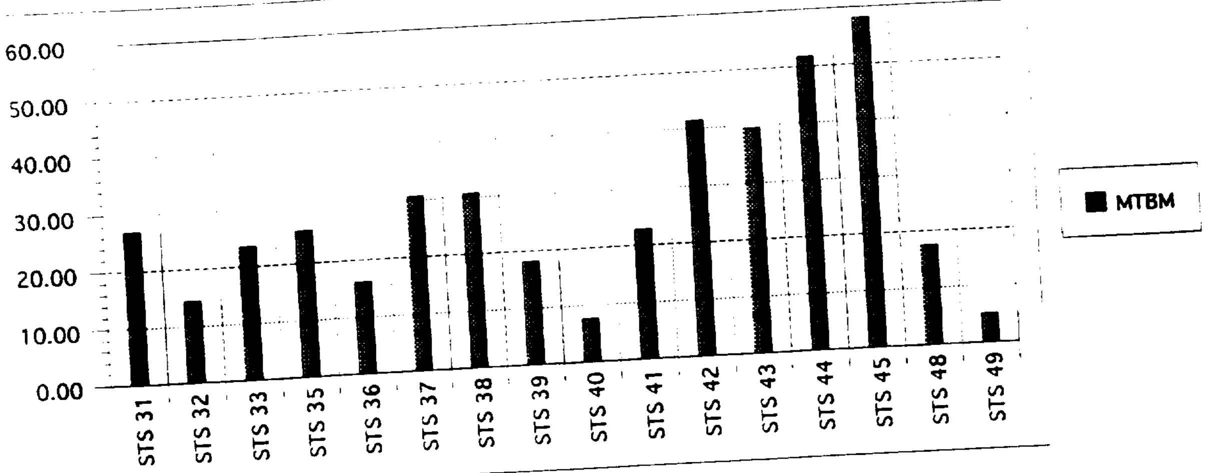


OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	23	9	876	38.09
STS 32	27	13	896	33.19
STS 33	44	14	1024	23.27
STS 35	34	18	2131	62.68
STS 36	17	3	590	34.71
STS 37	14	3	880	62.86
STS 38	54	9	1498	27.74
STS 39	32	11	945	29.53
STS 40	49	12	645	13.16
STS 41	93	22	1243	13.37
STS 42	27	8	891	33.00
STS 43	11	2	853	77.55
STS 44	13	8	958	73.69
STS 45	23	4	786	34.17
STS 48	28	6	892	31.86
STS 49	193	58	1582	8.20
TOTAL	682	200	16690	24.47
AVERAGE	42.63	12.50	1043.13	37.32
SD	44.97	13.33	393.80	21.09
CONFIDENCE INTERVAL	95%			
HIGH	66.58	19.60	1252.92	48.55
LOW	18.67	5.40	833.33	26.08

EPD/OEL

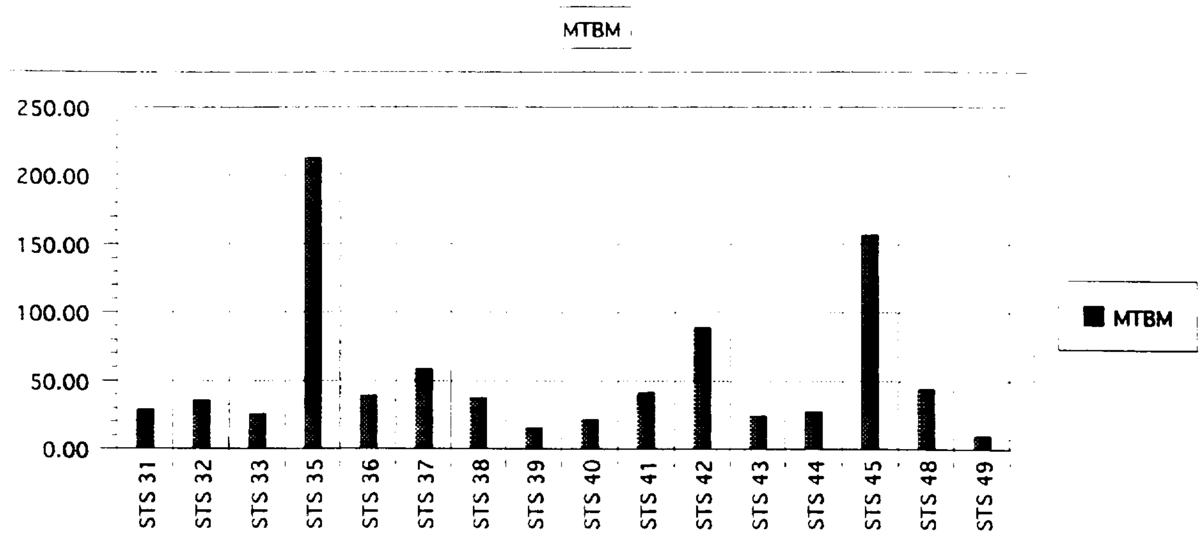
MTBM



OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	65	13	1752	26.95
STS 32	124	14	1791	14.44
STS 33	87	9	2048	23.54
STS 35	165	13	4261	25.82
STS 36	73	8	1179	16.15
STS 37	57	4	1759	30.86
STS 38	97	17	2995	30.88
STS 39	104	14	1890	18.17
STS 40	168	6	1289	7.67
STS 41	109	10	2486	22.81
STS 42	43	6	1781	41.42
STS 43	43	5	1706	39.67
STS 44	37	4	1916	51.78
STS 45	27	4	1571	58.19
STS 48	102	3	1784	17.49
STS 49	617	39	3163	5.13
TOTAL	1918	169	33371	17.40
AVERAGE	119.88	10.56	2085.69	26.94
SD	139.11	8.77	787.52	14.86
CONFIDENCE	95%			
INTERVAL				
HIGH	193.99	15.24	2505.24	34.85
LOW	45.76	5.89	1666.14	19.02

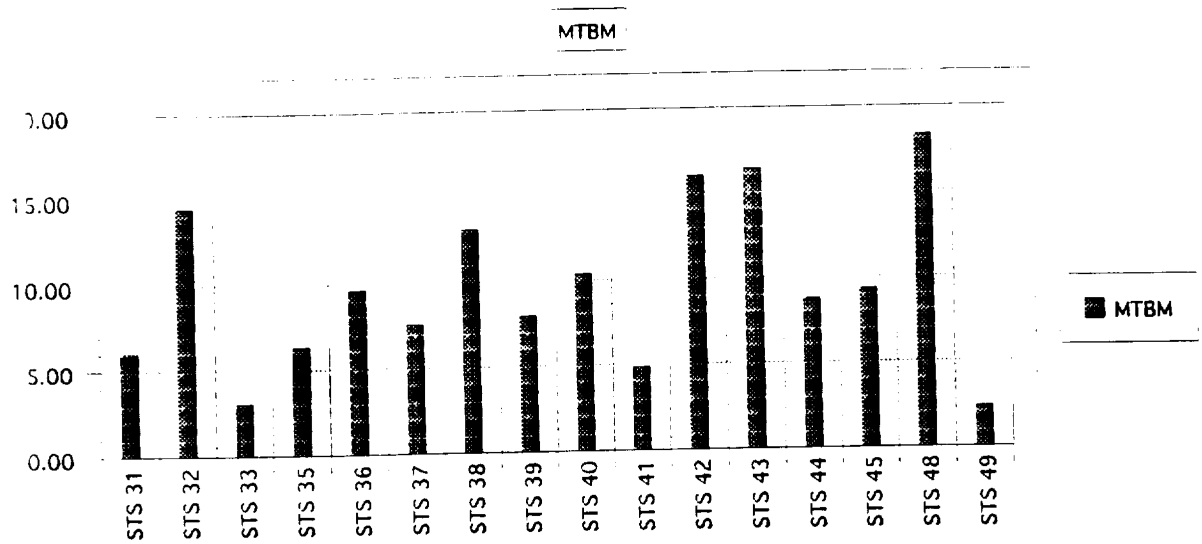
FCP



OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	6	1	175	29.17
STS 32	5	1	179	35.80
STS 33	8	2	205	25.63
STS 35	2	1	426	213.00
STS 36	3	1	118	39.33
STS 37	3	1	176	58.67
STS 38	8	3	300	37.50
STS 39	12	2	189	15.75
STS 40	6	0	129	21.50
STS 41	6	2	249	41.50
STS 42	2	2	178	89.00
STS 43	7	1	171	24.43
STS 44	7	4	192	27.43
STS 45	1	1	157	157.00
STS 48	4	1	178	44.50
STS 49	31	6	316	10.19
TOTAL	111	29	3338	30.07
AVERAGE	6.94	1.81	208.63	54.40
SD	7.01	1.47	78.75	55.16
CONFIDENCE	95%			
INTERVAL				
HIGH	10.67	2.60	250.58	83.79
LOW	3.20	1.03	166.67	25.01

FCS

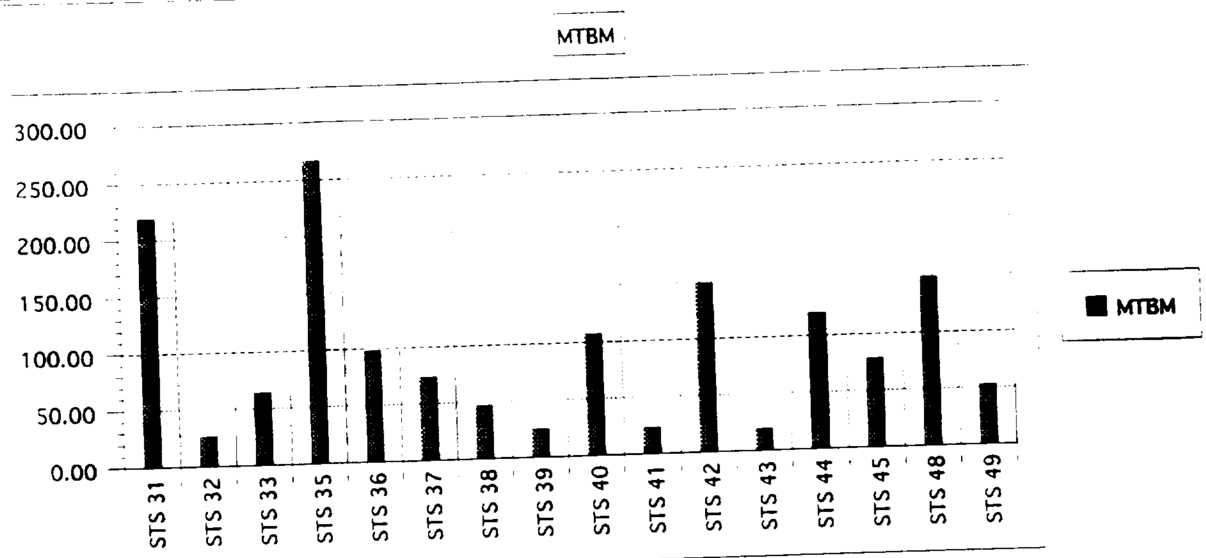


OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	20	1	121	6.05
STS 32	18	3	261	14.50
STS 33	39	7	120	3.08
STS 35	34	3	215	6.32
STS 36	11	2	106	9.64
STS 37	19	3	144	7.58
STS 38	9	2	118	13.11
STS 39	25	1	199	7.96
STS 40	21	2	218	10.38
STS 41	20	6	98	4.90
STS 42	12	1	192	16.00
STS 43	13	0	213	16.38
STS 44	19	2	167	8.79
STS 45	23	5	214	9.30
STS 48	7	0	128	18.29
STS 49	89	28	213	2.39
TOTAL	379	66	2727	7.20
AVERAGE	23.69	4.13	170.44	9.67
SD	19.37	6.67	50.92	4.81
CONFIDENCE	95%			
INTERVAL				
HIGH	34.00	7.68	197.57	12.23
LOW	13.37	0.57	143.31	7.11

›f 1 indicates one mission.

FRC

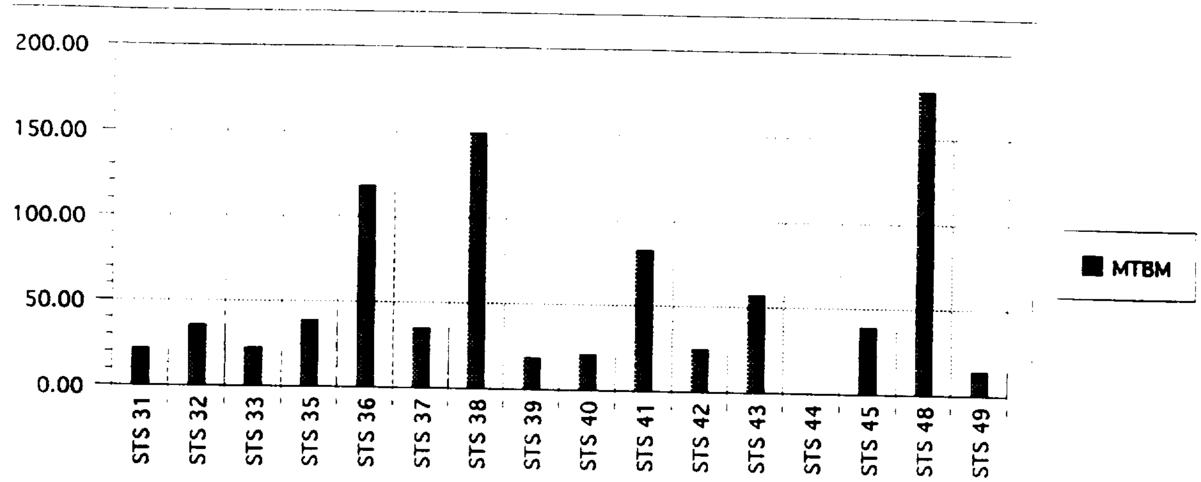


OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	2	0	438	219.00
STS 32	17	3	448	26.35
STS 33	8	0	512	64.00
STS 35	4	0	1065	266.25
STS 36	3	0	295	98.33
STS 37	6	1	440	73.33
STS 38	16	0	749	46.81
STS 39	19	0	473	24.89
STS 40	3	0	322	107.33
STS 41	27	11	622	23.04
STS 42	3	0	445	148.33
STS 43	22	7	427	19.41
STS 44	4	0	479	119.75
STS 45	5	0	393	78.60
STS 48	3	0	446	148.67
STS 49	15	3	791	52.73
TOTAL	157	25	8345	53.15
AVERAGE	9.81	1.56	521.56	94.80
SD	8.17	3.16	196.85	71.89
CONFIDENCE	95%			
INTERVAL				
HIGH	14.16	3.25	626.43	133.10
LOW	5.46	-0.12	416.69	56.50

GNC

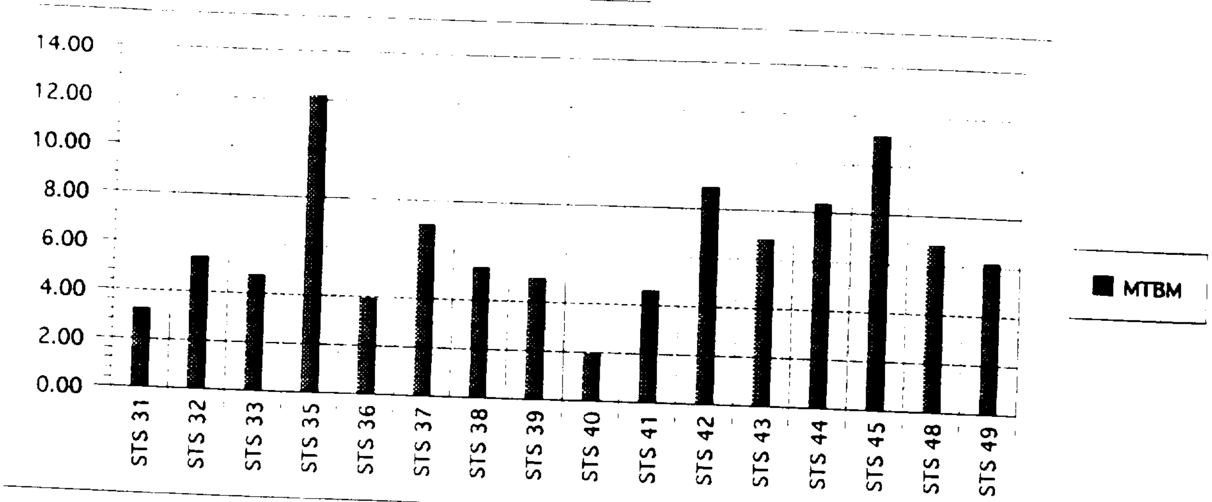
MTBM



OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	8	0	175	21.88
STS 32	5	3	179	35.80
STS 33	9	5	205	22.78
STS 35	11	5	426	38.73
STS 36	1	0	118	118.00
STS 37	5	3	176	35.20
STS 38	2	2	300	150.00
STS 39	10	5	189	18.90
STS 40	6	4	129	21.50
STS 41	3	2	249	83.00
STS 42	7	0	178	25.43
STS 43	3	1	171	57.00
STS 44	0	0	192	0.00
STS 45	4	2	157	39.25
STS 48	1	0	178	178.00
STS 49	22	6	316	14.36
TOTAL	97	38	3338	34.41
AVERAGE	6.06	2.38	208.63	53.74
SD	5.40	2.13	78.75	51.81
CONFIDENCE	95%			
INTERVAL				
HIGH	8.94	3.51	250.58	81.34
LOW	3.19	1.24	166.67	26.13

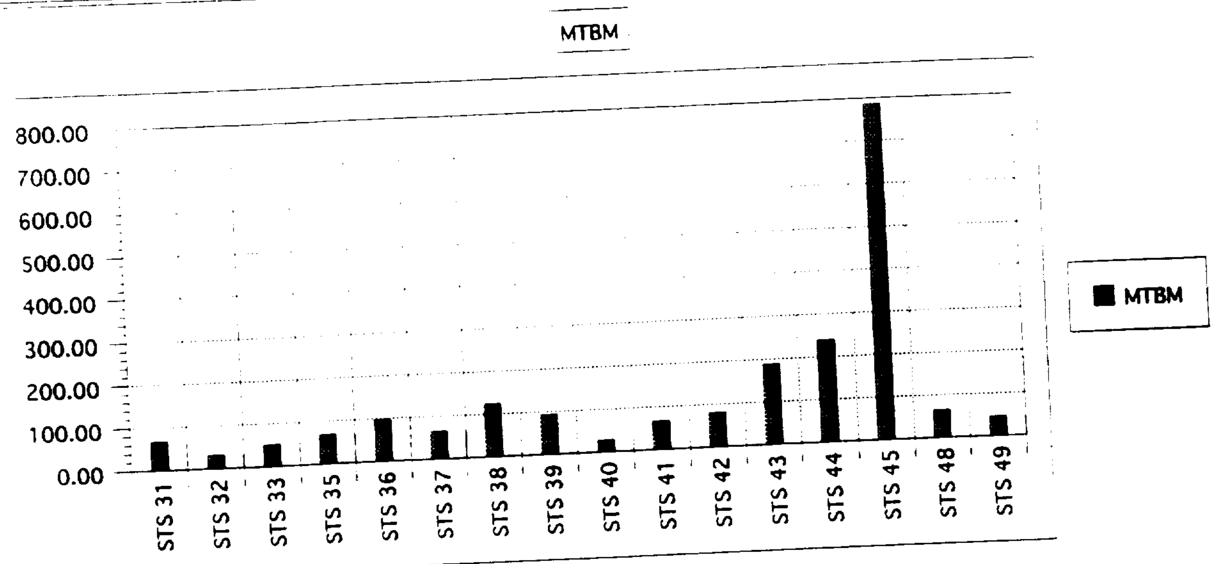
HYD



OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	54	17	175	3.24
STS 32	33	11	179	5.42
STS 33	43	7	205	4.77
STS 35	35	12	426	12.17
STS 36	30	8	118	3.93
STS 37	25	7	176	7.04
STS 38	56	26	300	5.36
STS 39	38	14	189	4.97
STS 40	67	15	129	1.93
STS 41	54	11	249	4.61
STS 42	20	8	178	8.90
STS 43	25	10	171	6.84
STS 44	23	12	192	8.35
STS 45	14	6	157	11.21
STS 48	26	5	178	6.85
STS 49	51	12	316	6.20
TOTAL	594	181	3338	5.62
AVERAGE	37.13	11.31	208.63	6.36
SD	15.41	5.16	78.75	2.75
CONFIDENCE INTERVAL	95%			
HIGH	45.34	14.06	250.58	7.83
LOW	28.91	8.56	166.67	4.90

INS

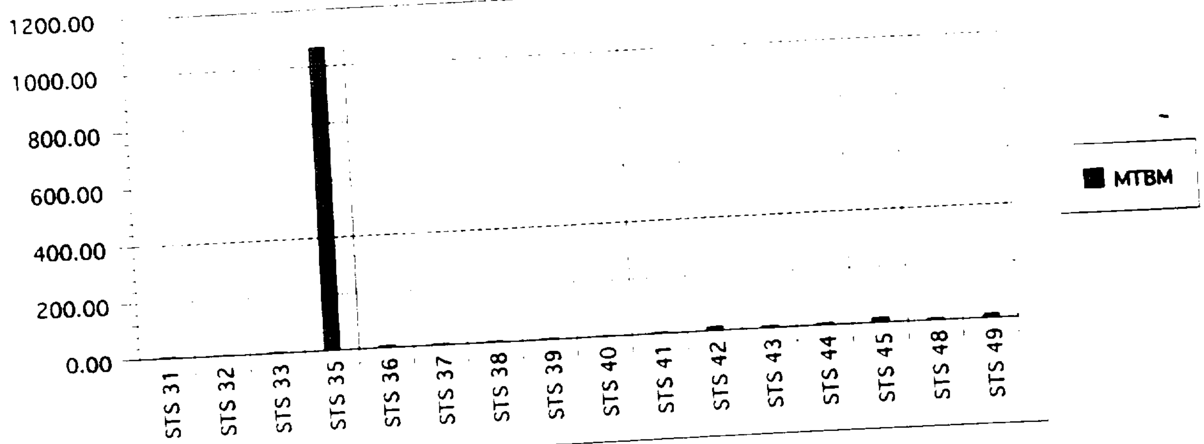


OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	26	16	1752	67.38
STS 32	55	13	1791	32.56
STS 33	40	19	2048	51.20
STS 35	61	11	4261	69.85
STS 36	12	1	1179	98.25
STS 37	27	4	1759	65.15
STS 38	24	6	2995	124.79
STS 39	20	11	1890	94.50
STS 40	45	17	1289	28.64
STS 41	37	18	2486	67.19
STS 42	22	13	1781	80.95
STS 43	9	3	1706	189.56
STS 44	8	3	1916	239.50
STS 45	2	2	1571	785.50
STS 48	27	10	1784	66.07
STS 49	68	17	3163	46.51
TOTAL	483	164	33371	69.09
AVERAGE	30.19	10.25	2085.69	131.73
SD	19.44	6.29	787.52	183.05
CONFIDENCE	95%			
INTERVAL				
HIGH	40.55	13.60	2505.24	229.24
LOW	19.83	6.90	1666.14	34.21

ME/SSME

MTBM



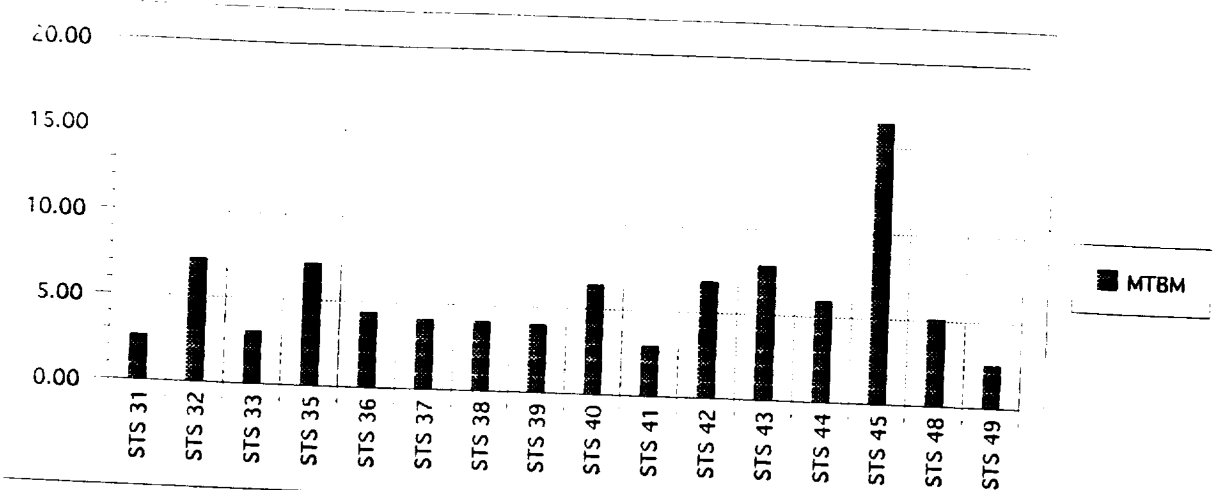
OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	89	0	438	4.92
STS 32	158	0	448	2.84
STS 33	82	0	512	6.24
STS 35	1	0	1065	1065.00
STS 36	29	0	295	10.17
STS 37	92	0	440	4.78
STS 38	166	0	749	4.51
STS 39	82	0	473	5.77
STS 40	121	0	322	2.66
STS 41	149	0	622	4.17
STS 42	27	0	445	16.48
STS 43	45	0	427	9.49
STS 44	47	0	479	10.19
STS 45	18	0	393	21.83
STS 48	42	0	446	10.62
STS 49	41	0	791	19.29
TOTAL	1189	0	8345	7.02
AVERAGE	74.31	0.00	521.56	8.93
SD	51.90	0.00	196.85	6.01
CONFIDENCE INTERVAL	95%			
HIGH	101.96	0.00	626.43	12.14
LOW	46.66	0.00	416.69	5.73

NOTE: STS 35 DATA IGNORED

MEQ

MTBM

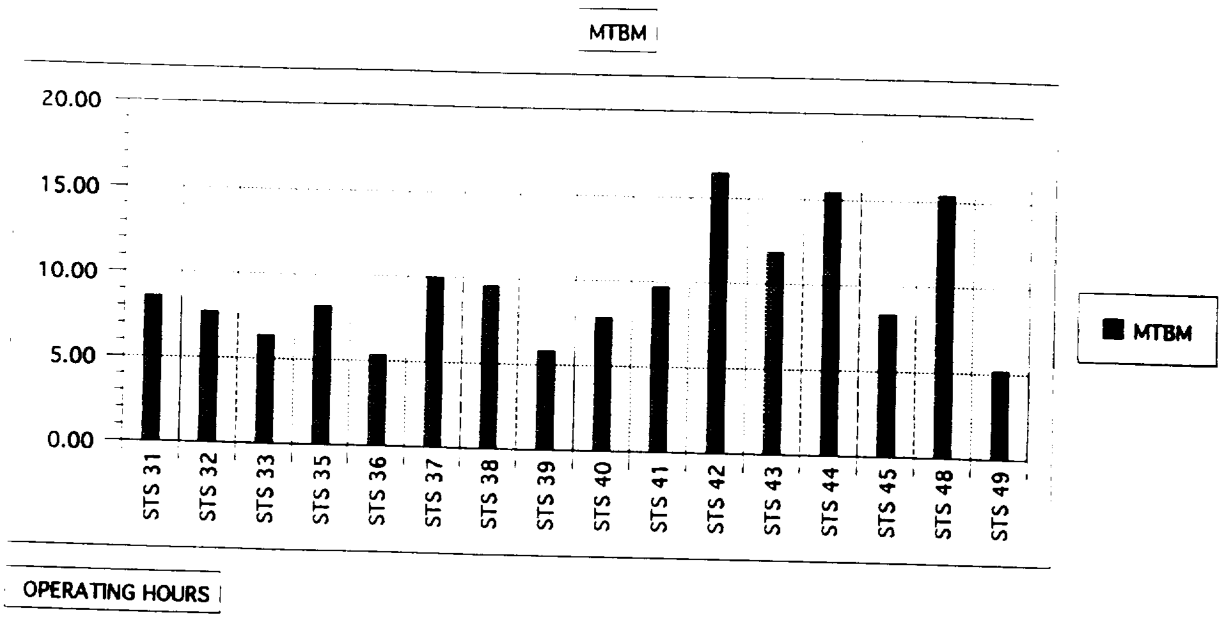


OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	46	14	121	2.63
STS 32	36	2	261	7.25
STS 33	39	9	120	3.08
STS 35	30	10	215	7.17
STS 36	24	6	106	4.42
STS 37	35	9	144	4.11
STS 38	29	4	118	4.07
STS 39	50	21	199	3.98
STS 40	34	6	218	6.41
STS 41	33	9	98	2.97
STS 42	28	6	192	6.86
STS 43	27	6	213	7.89
STS 44	28	4	167	5.96
STS 45	13	0	214	16.46
STS 48	25	5	128	5.12
STS 49	85	12	213	2.51
TOTAL	562	123	2727	4.85
AVERAGE	35.13	7.69	170.44	5.68
SD	15.91	5.06	50.92	3.38
CONFIDENCE	95%			
INTERVAL				
HIGH	43.60	10.38	197.57	7.48
LOW	26.65	4.99	143.31	3.88

hours of 1 indicates one mission.

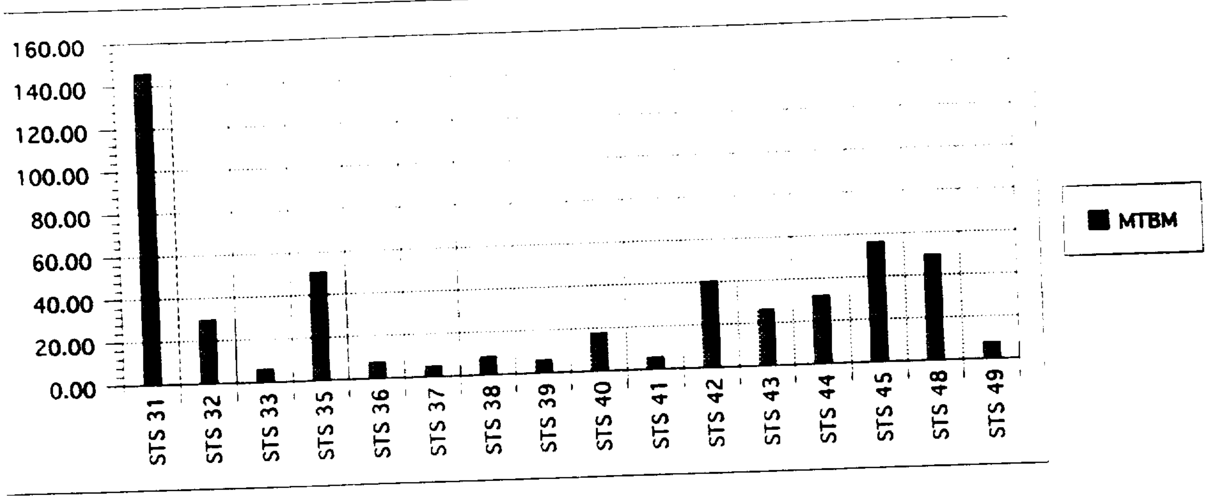
MPS



	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	51	14	438	8.59
STS 32	58	18	448	7.72
STS 33	80	36	512	6.40
STS 35	130	37	1065	8.19
STS 36	55	9	295	5.36
STS 37	44	4	440	10.00
STS 38	78	11	749	9.60
STS 39	81	18	473	5.84
STS 40	41	3	322	7.85
STS 41	64	13	622	9.72
STS 42	27	6	445	16.48
STS 43	36	5	427	11.86
STS 44	31	8	479	15.45
STS 45	47	8	393	8.36
STS 48	29	8	446	15.38
STS 49	152	19	791	5.20
TOTAL	1004	217	8345	8.31
AVERAGE	62.75	13.56	521.56	152.02
SD	35.39	10.25	196.85	3.59
CONFIDENCE	95%			
INTERVAL				
HIGH	81.60	19.02	626.43	153.93
LOW	43.90	8.10	416.69	150.11

PRECEDING PAGE BLANK NOT FILMED

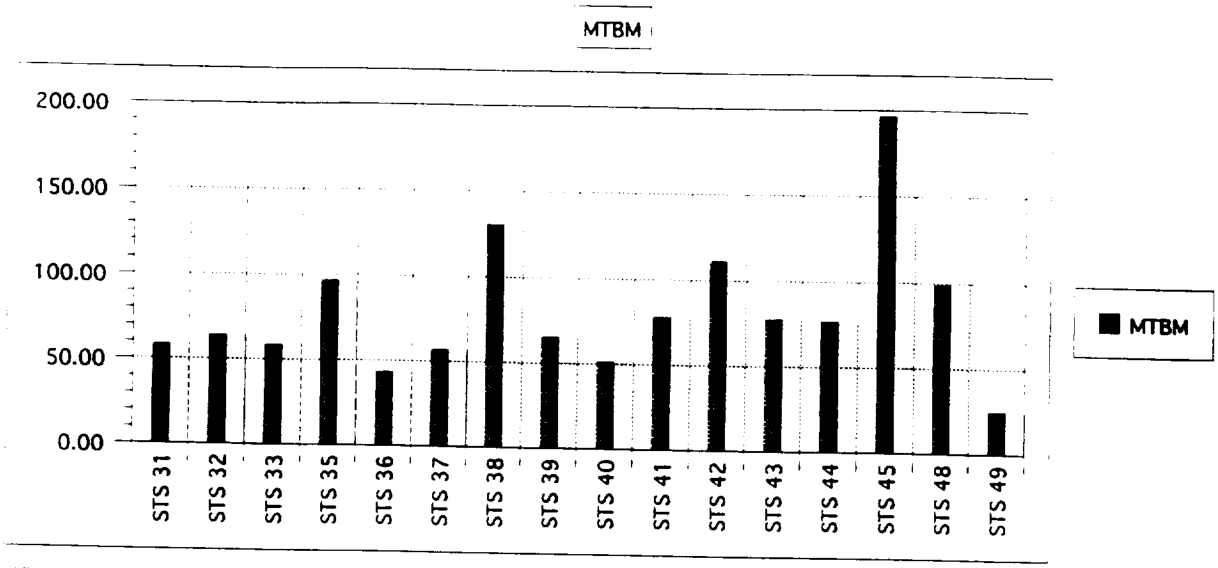
OMS



OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	3	0	438	146.00
STS 32	15	1	448	29.87
STS 33	81	47	512	6.32
STS 35	21	1	1065	50.71
STS 36	38	14	295	7.76
STS 37	85	23	440	5.18
STS 38	88	43	749	8.51
STS 39	75	12	473	6.31
STS 40	18	1	322	17.89
STS 41	106	28	622	5.87
STS 42	11	1	445	40.45
STS 43	16	3	427	26.69
STS 44	15	2	479	31.93
STS 45	7	0	393	56.14
STS 48	9	2	446	49.56
STS 49	101	31	791	7.83
TOTAL	689	209	8345	12.11
AVERAGE	43.06	13.06	521.56	31.06
SD	38.38	16.25	196.85	35.56
CONFIDENCE	95%			
INTERVAL				
HIGH	63.51	21.72	626.43	50.01
LOW	22.61	4.40	416.69	12.12

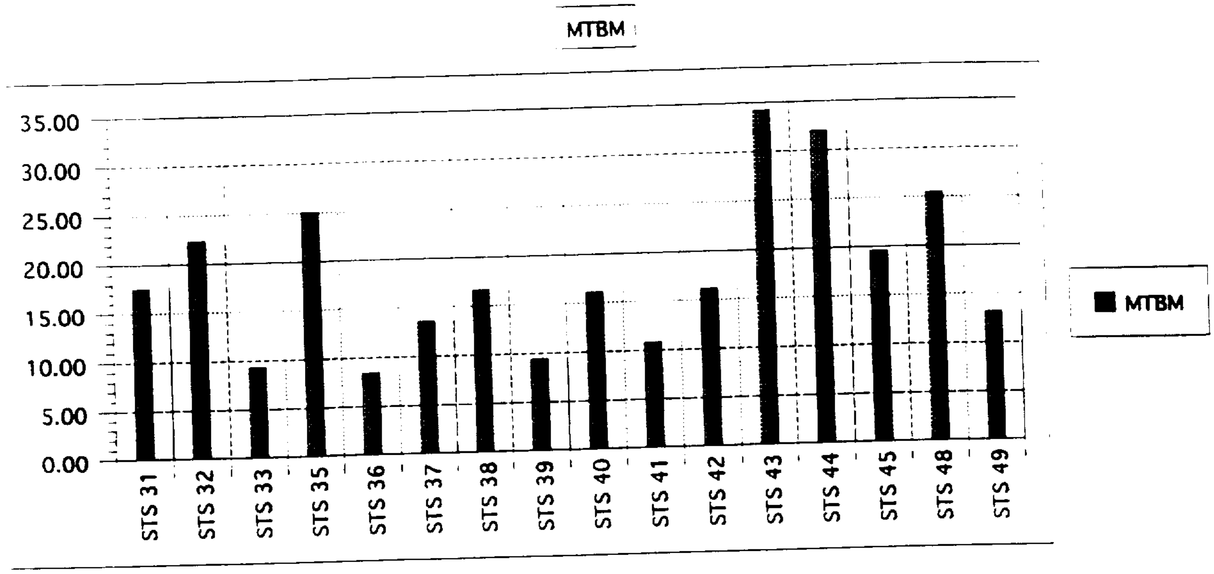
PVD



OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	30	7	1752	58.40
STS 32	28	10	1791	63.96
STS 33	35	13	2048	58.51
STS 35	44	20	4261	96.84
STS 36	27	9	1179	43.67
STS 37	31	10	1759	56.74
STS 38	23	12	2995	130.22
STS 39	29	12	1890	65.17
STS 40	25	3	1289	51.56
STS 41	32	17	2486	77.69
STS 42	16	10	1781	111.31
STS 43	22	9	1706	77.55
STS 44	25	5	1916	76.64
STS 45	8	4	1571	196.38
STS 48	18	5	1784	99.11
STS 49	126	57	3163	25.10
TOTAL	519	203	33371	64.30
AVERAGE	32.44	12.69	2085.69	80.55
SD	26.27	12.66	787.52	40.66
CONFIDENCE	95%			
INTERVAL				
HIGH	46.43	19.43	2505.24	102.22
LOW	18.44	5.94	1666.14	58.89

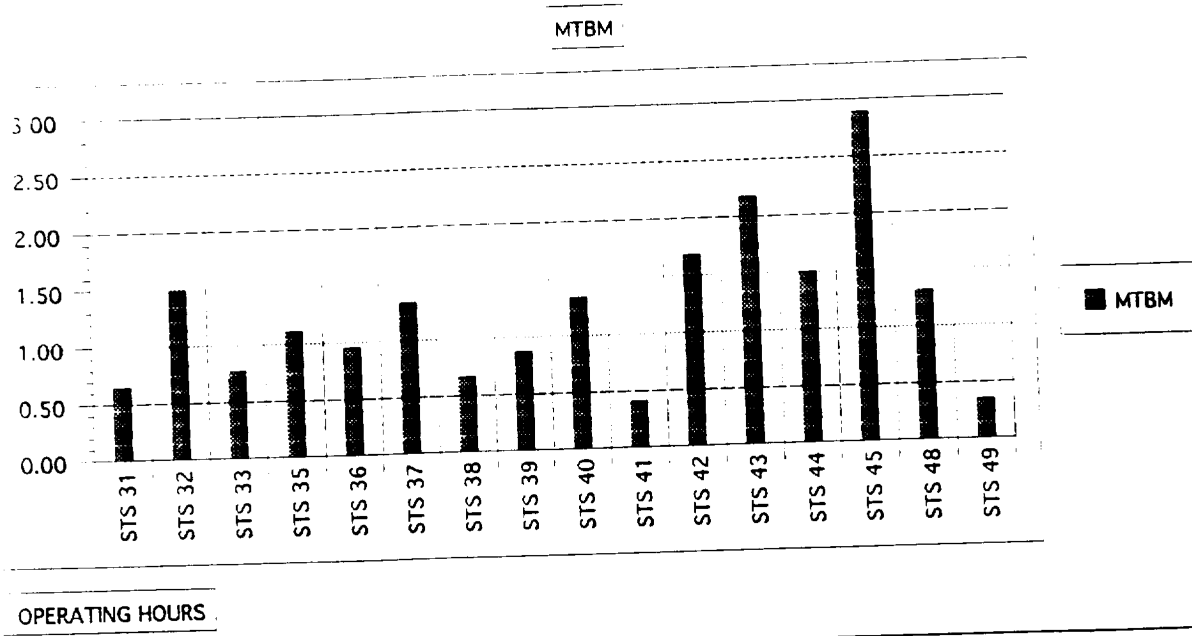
PYR



OPERATING HOURS

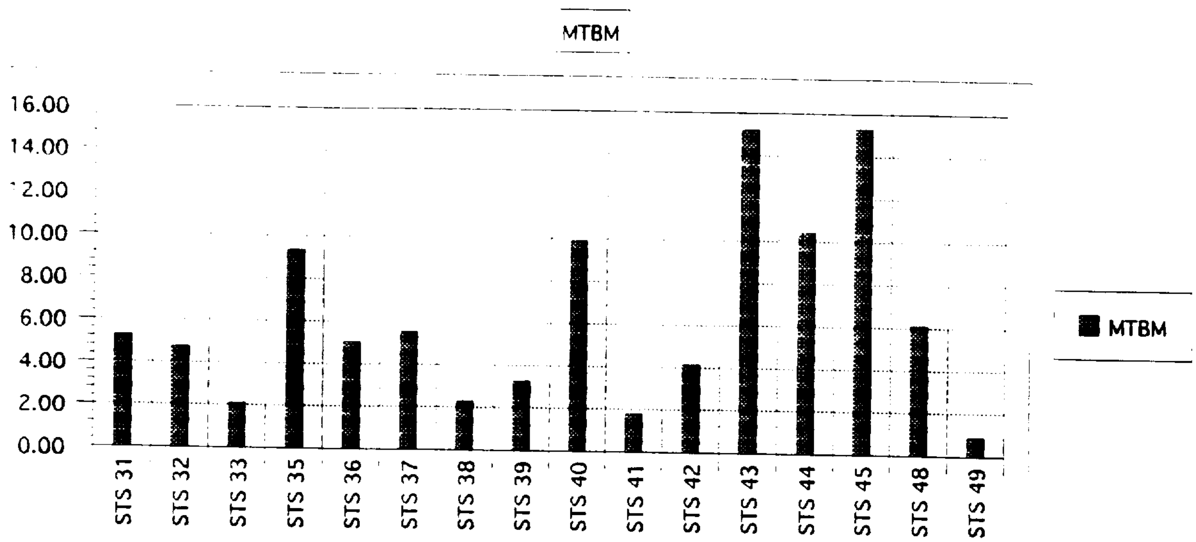
	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	10	5	175	17.50
STS 32	8	0	179	22.38
STS 33	22	1	205	9.32
STS 35	17	5	426	25.06
STS 36	14	10	118	8.43
STS 37	13	3	176	13.54
STS 38	18	5	300	16.67
STS 39	20	8	189	9.45
STS 40	8	2	129	16.13
STS 41	23	8	249	10.83
STS 42	11	1	178	16.18
STS 43	5	0	171	34.20
STS 44	6	1	192	32.00
STS 45	8	2	157	19.63
STS 48	7	0	178	25.43
STS 49	24	4	316	13.17
TOTAL	214	55	3338	15.60
AVERAGE	13.38	3.44	208.63	18.12
SD	6.47	3.16	78.75	7.87
CONFIDENCE INTERVAL	95%			
HIGH	16.82	5.12	250.58	22.31
LOW	9.93	1.75	166.67	13.93

STR



	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	188	20	121	0.64
STS 32	176	31	261	1.48
STS 33	155	15	120	0.77
STS 35	194	23	215	1.11
STS 36	111	6	106	0.95
STS 37	108	19	144	1.33
STS 38	178	15	118	0.66
STS 39	227	78	199	0.88
STS 40	162	29	218	1.35
STS 41	237	66	98	0.41
STS 42	114	7	192	1.68
STS 43	98	8	213	2.17
STS 44	111	27	167	1.50
STS 45	74	13	214	2.89
STS 48	97	6	128	1.32
STS 49	607	44	213	0.35
TOTAL	2837	407	2727	0.96
AVERAGE	177.31	25.44	170.44	1.22
SD	124.58	21.05	50.92	0.66
CONFIDENCE	95%			
INTERVAL				
HIGH	243.68	36.65	197.57	1.57
LOW	110.94	14.22	143.31	0.87

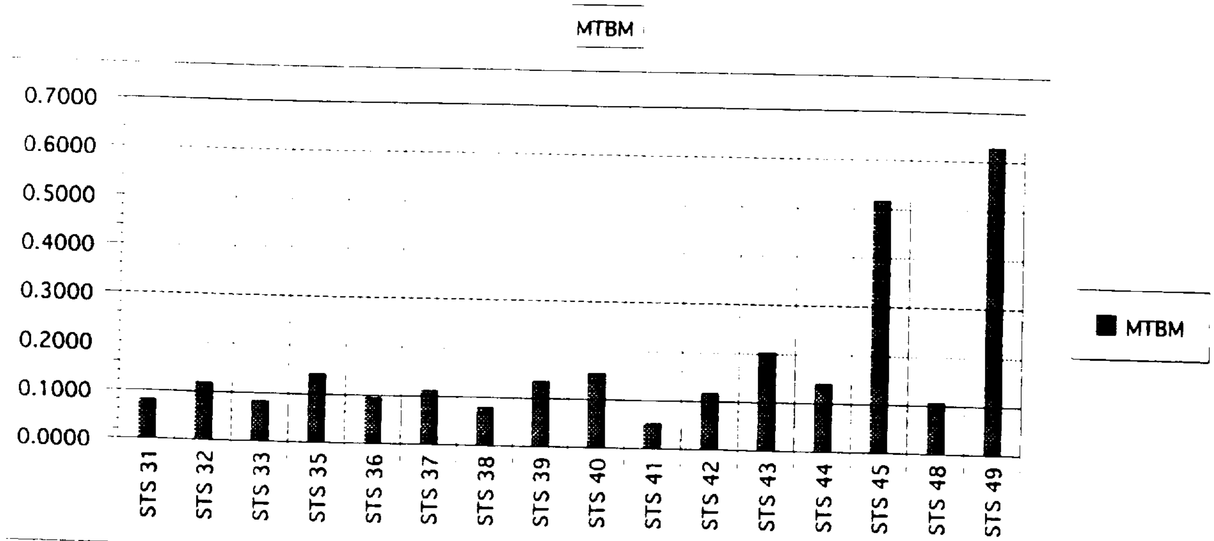
TCS



OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	23	21	121	5.26
STS 32	55	40	261	4.75
STS 33	57	34	120	2.11
STS 35	23	5	215	9.35
STS 36	21	6	106	5.05
STS 37	26	18	144	5.54
STS 38	51	47	118	2.31
STS 39	61	59	199	3.26
STS 40	22	4	218	9.91
STS 41	54	26	98	1.81
STS 42	46	29	192	4.17
STS 43	14	7	213	15.21
STS 44	16	9	167	10.44
STS 45	14	7	214	15.29
STS 48	21	7	128	6.10
STS 49	236	37	213	0.90
TOTAL	740	356	2727	3.69
AVERAGE	46.25	22.25	170.44	6.34
SD	53.45	17.28	50.92	4.49
CONFIDENCE	95%			
INTERVAL				
HIGH	74.72	31.46	197.57	8.73
LOW	17.78	13.04	143.31	3.95

TILE



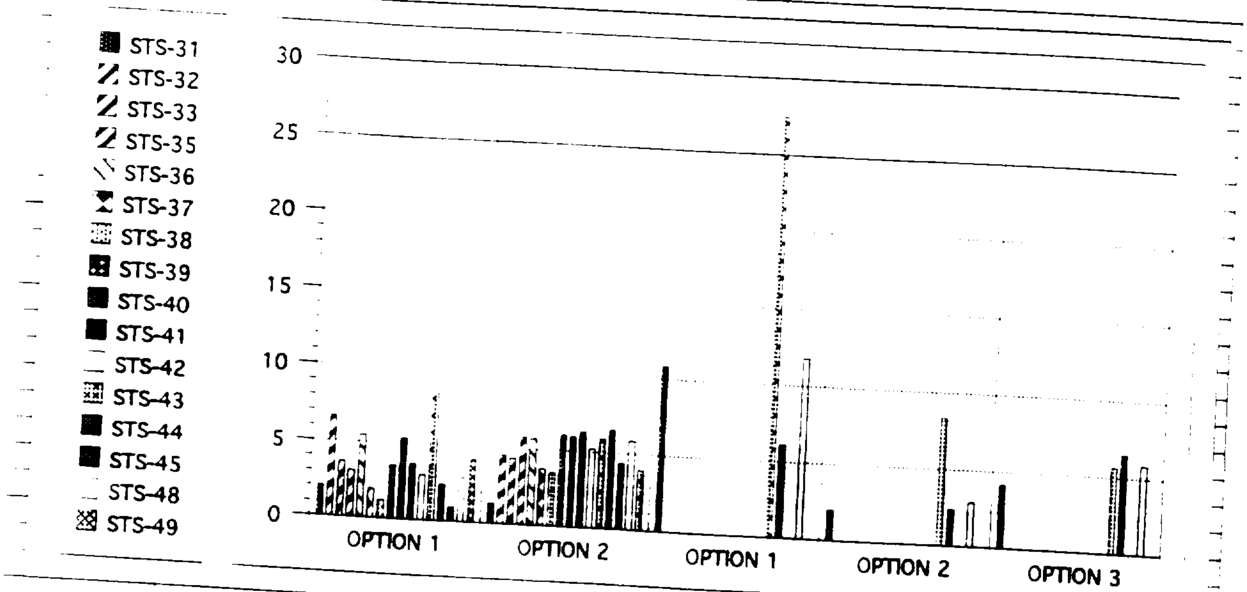
OPERATING HOURS

	#MA	# R&R	OPERATING HOURS	MTBM
STS 31	1483	93	121	0.0816
STS 32	2206	141	261	0.1183
STS 33	1433	118	120	0.0837
STS 35	1521	133	215	0.1414
STS 36	1107	76	106	0.0958
STS 37	1282	328	144	0.1123
STS 38	1500	117	118	0.0787
STS 39	1474	205	199	0.1350
STS 40	1419	372	218	0.1536
STS 41	1865	273	98	0.0525
STS 42	1646	104	192	0.1166
STS 43	1049	87	213	0.2031
STS 44	1190	106	167	0.1403
STS 45	414	45	214	0.5169
STS 48	1208	78	128	0.1060
STS 49	339	187	213	0.6283
TOTAL	21136	2463	2727	0.1290
AVERAGE	1321.00	153.94	170.44	0.1728
SD	466.68	95.11	50.92	0.1613
CONFIDENCE	95%			
INTERVAL				
HIGH	1569.62	204.61	197.57	0.2587
LOW	1072.38	103.27	143.31	0.0868
R&R/MA	0.007283			

Appendix C

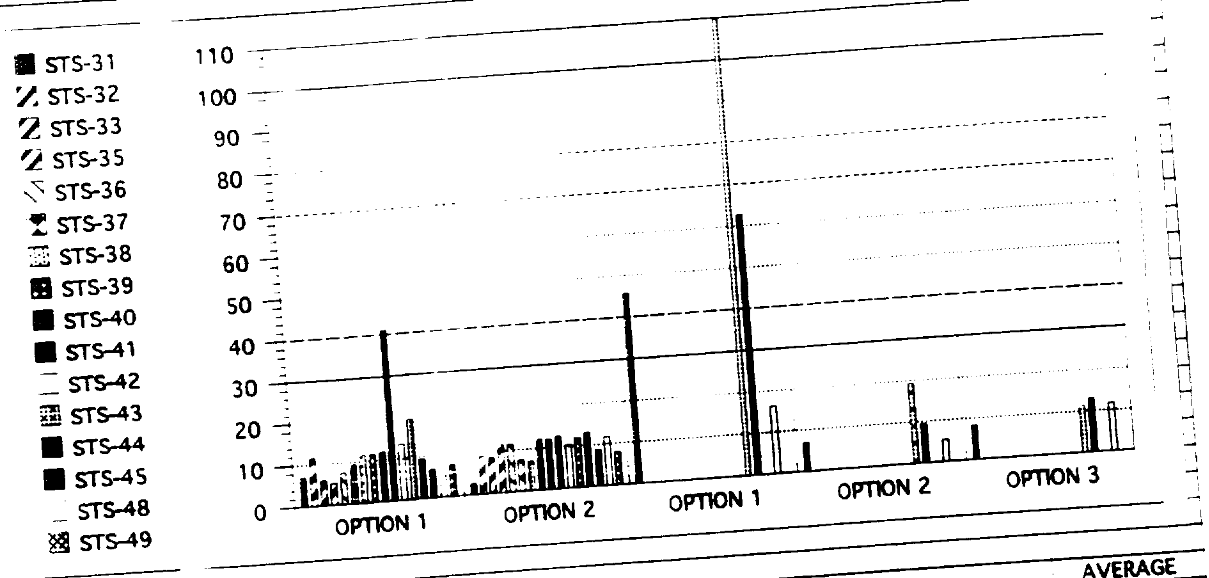
Shuttle Repair Data

APU



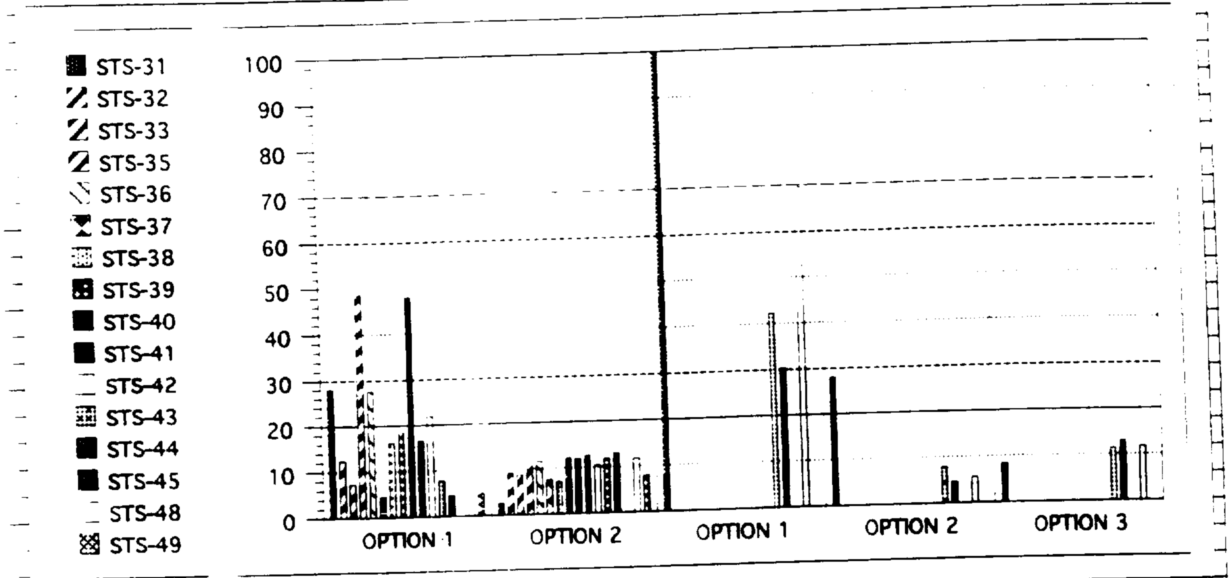
		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	33	1.99	1.34	10.85	1.99	4.18	3.09
STS-32	25	6.63	4.56				5.60
STS-33	40	3.63	4.33				3.98
STS-35	31	3.09	5.76				4.43
STS-36	31	5.45	5.72				5.59
STS-37	23	1.94	3.75				2.85
STS-38	32	1.18	3.49				2.34
STS-39	31	3.55	6.07				4.81
STS-40	25	5.34	5.96				5.65
STS-41	29	3.69	6.31				5.00
STS-42	14	2.99	5.2				4.10
STS-43	22	8.37	5.89	27.46	8.37	5.66	7.02
STS-44	16	2.4	6.51	6.14	2.4	6.51	4.46
STS-45	22	0.94	4.34				2.64
STS-48	30	2.92	5.84	11.79	2.92	5.84	4.38
STS-49	31	4.13	3.94				4.04
AVERAGE	27.19	3.64	4.94	14.06	3.92	5.55	4.37

COM



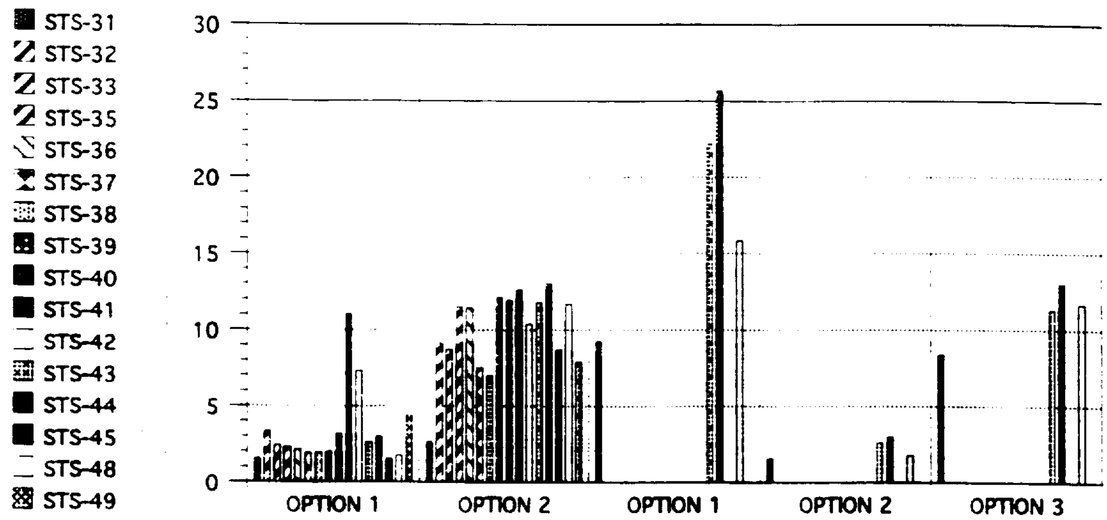
		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	26	6.94	2.67	45.67	6.94	8.35	7.65
STS-32	37	11.54	9.13				10.34
STS-33	54	6.07	8.67				7.37
STS-35	39	5.24	11.52				8.38
STS-36	31	7.58	11.45				9.52
STS-37	30	9.44	7.5				8.47
STS-38	29	11.53	6.98				9.26
STS-39	18	11.52	12.15				11.84
STS-40	48	11.9	11.93				11.92
STS-41	23	41.05	12.62				26.84
STS-42	28	13.52	10.39				11.96
STS-43	26	19.42	11.78	109.55	19.42	11.33	15.38
STS-44	28	9.56	13.01	62.73	9.56	13.01	11.29
STS-45	16	6.77	8.68				7.73
STS-48	15	5.31	11.69	16.21	5.31	11.69	8.50
STS-49	55	7.54	7.89				7.72
AVERAGE	31.44	11.56	9.88	58.54	10.31	11.10	10.88

DDC



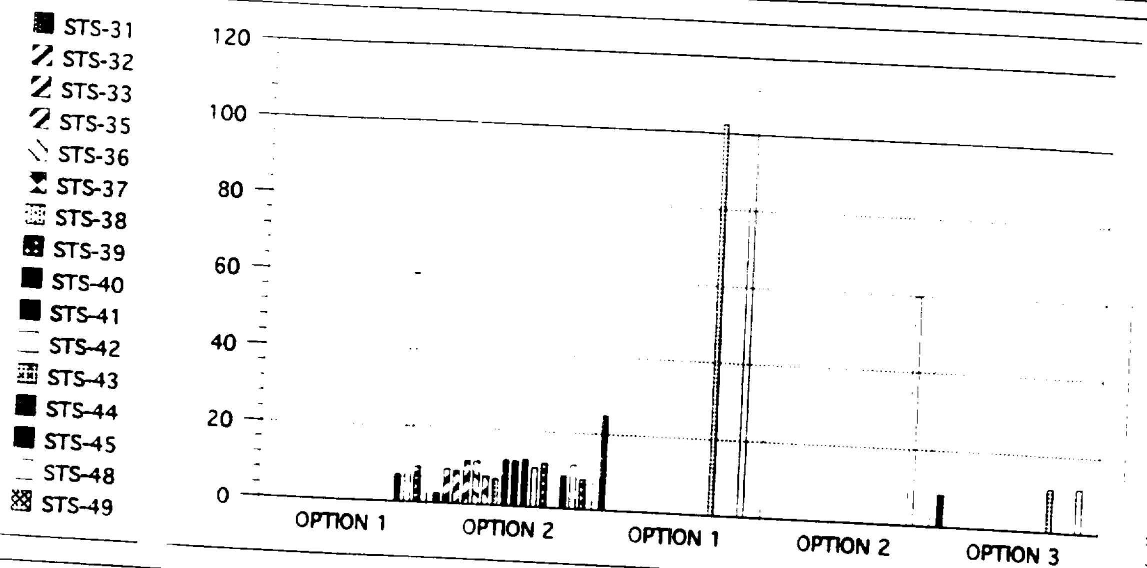
		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	6	27.98	2.67	99.83	27.98	8.35	18.17
STS-32	16	12.41	9.13				10.77
STS-33	84	7.34	8.67				8.01
STS-35	0	48.59	11.52				30.06
STS-36	13	27.53	11.45				19.49
STS-37	26	4.57	7.5				6.04
STS-38	3	16.28	6.98				11.63
STS-39	34	18.58	12.15				15.37
STS-40	32	47.99	11.93				29.96
STS-41	59	16.56	12.62				14.59
STS-42	31	21.81	10.39				16.10
STS-43	10	7.83	11.78	42.23	7.83	11.33	9.58
STS-44	12	4.5	13.01	30.3	4.5	13.01	8.76
STS-45	0	0	0				0.00
STS-48	26	5.57	11.69	69.49	5.57	11.69	8.63
STS-49	58	5.73	7.89				6.81
AVERAGE	25.63	17.08	9.34	60.46	11.47	11.10	13.37

DIG



		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	9	1.55	2.67	9.28	1.55	8.35	4.95
STS-32	42	3.38	9.13				6.26
STS-33	36	2.45	8.67				5.56
STS-35	23	2.31	11.52				6.92
STS-36	32	2.12	11.45				6.79
STS-37	12	1.9	7.5				4.70
STS-38	27	1.92	6.98				4.45
STS-39	17	1.99	12.15				7.07
STS-40	18	3.2	11.93				7.57
STS-41	33	11.04	12.62				11.83
STS-42	17	7.27	10.39				8.83
STS-43	15	2.61	11.78	22.14	2.61	11.33	6.97
STS-44	14	3	13.01	25.66	3	13.01	8.01
STS-45	27	1.52	8.68				5.10
STS-48	17	1.74	11.69	15.84	1.74	11.69	6.72
STS-49	32	4.42	7.89				6.16
AVERAGE	23.19	3.28	9.88	18.23	2.23	11.10	6.74

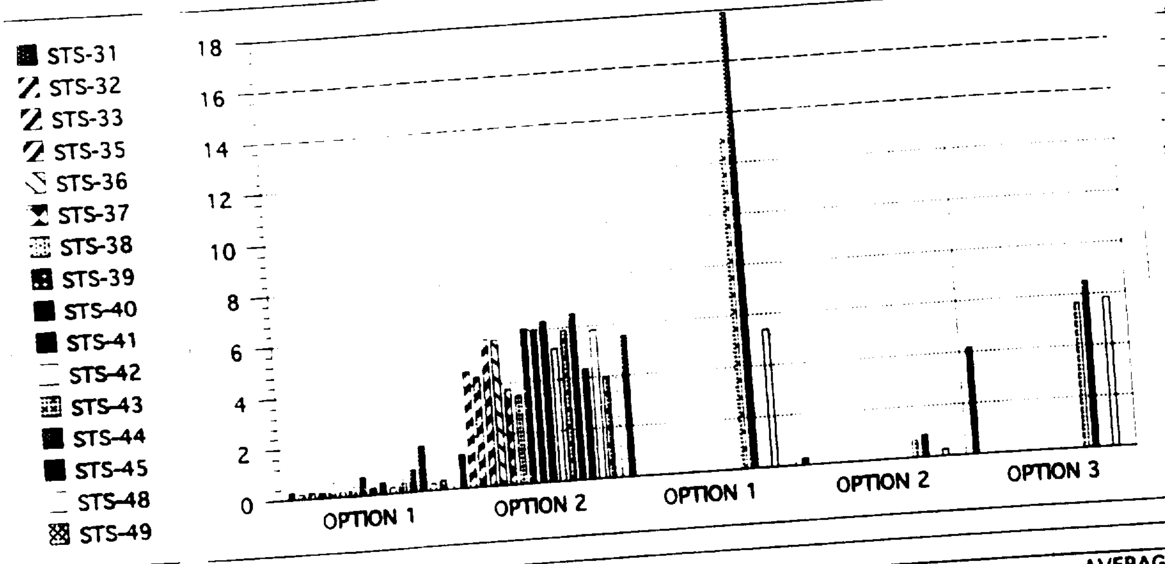
GNC



		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	10		2.67	24.8		8.35	8.35
STS-32	45		9.13				9.13
STS-33	86		8.67				8.67
STS-35	18		11.52				11.52
STS-36	21		11.45				11.45
STS-37	28		7.5				7.50
STS-38	9		6.98				6.98
STS-39	32		12.15				12.15
STS-40	32		11.93				11.93
STS-41	33		12.62				12.62
STS-42	34		10.39				10.39
STS-43	21		11.78	102.32		11.33	11.33
STS-44	0						0.00
STS-45	39	7.32	8.68				8.00
STS-48	7	59.8	11.69	111.53	59.8	11.69	35.75
STS-49	30	9.5	7.89				8.70
AVERAGE	27.81	25.54	9.67	79.55	59.80	10.46	9.91

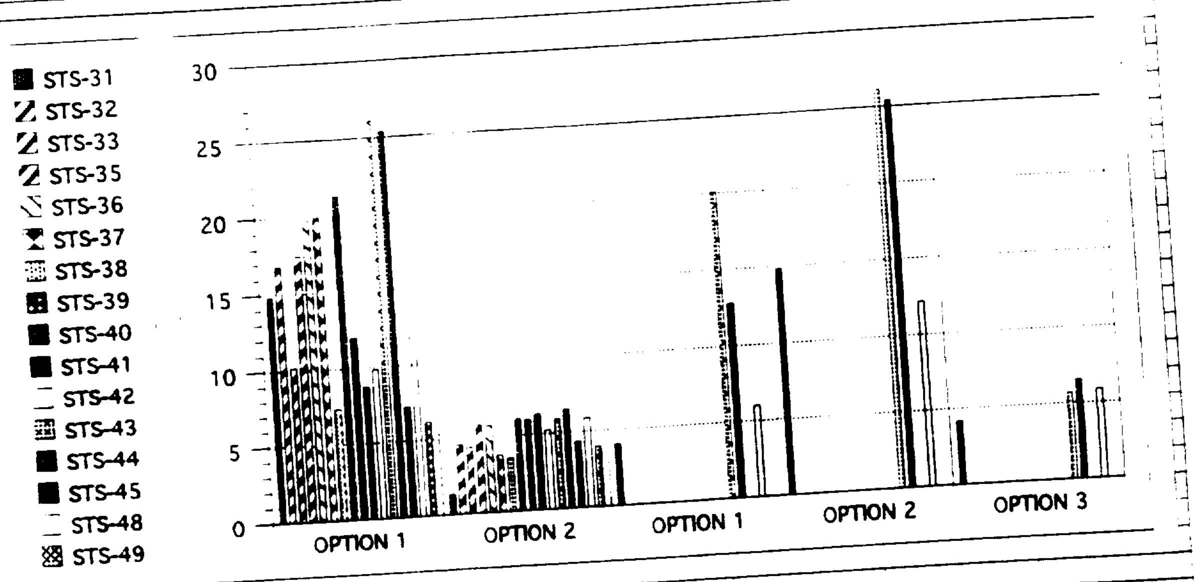
NOTE : The grand average (9.91) does not include STS-44 (0) or STS-48 (35.75). These entries would increase the grand average to 10.64.

INS



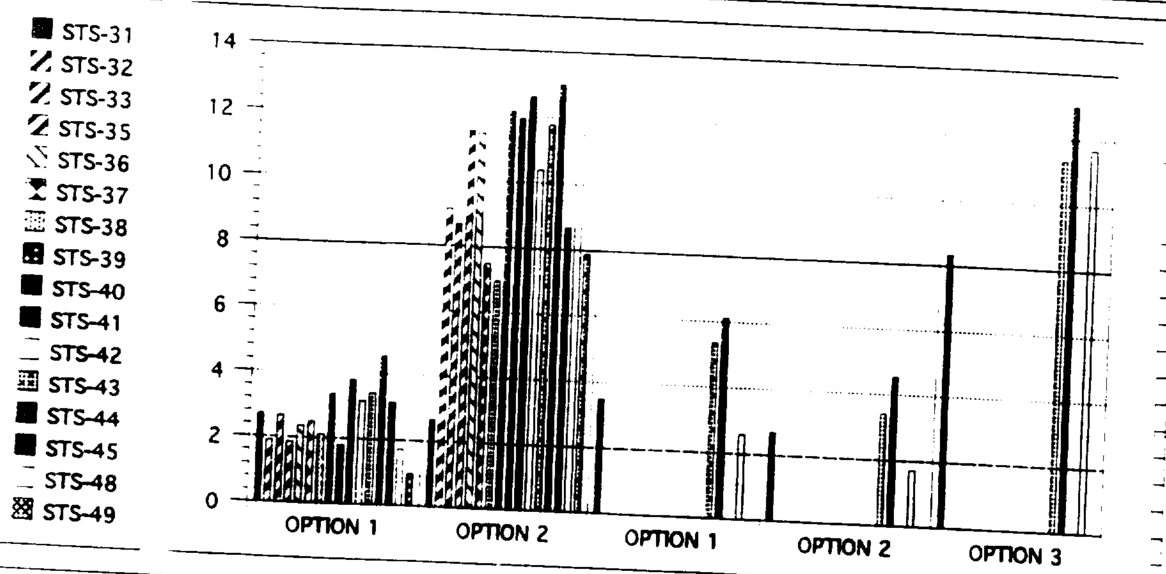
		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	21	0.28	1.34	5.54	0.28	4.18	2.23
STS-32	32	0.18	4.56				2.37
STS-33	45	0.24	4.33				2.29
STS-35	28	0.21	5.76				2.99
STS-36	16	0.6	5.72				3.16
STS-37	20	0.22	3.75				1.99
STS-38	28	0.35	3.49				1.92
STS-39	37	0.73	6.07				3.40
STS-40	45	0.28	5.96				3.12
STS-41	17	0.47	6.31				3.39
STS-42	24	0.26	5.2				2.73
STS-43	24	0.68	5.89	13.08	0.68	5.66	3.17
STS-44	23	0.88	6.51	17.88	0.88	6.51	3.70
STS-45	28	1.78	4.34				3.06
STS-48	27	0.27	5.84	5.4	0.27	5.84	3.06
STS-49	34	0.37	3.94				2.16
AVERAGE	28.06	0.49	4.94	10.48	0.53	5.55	2.79

ECL



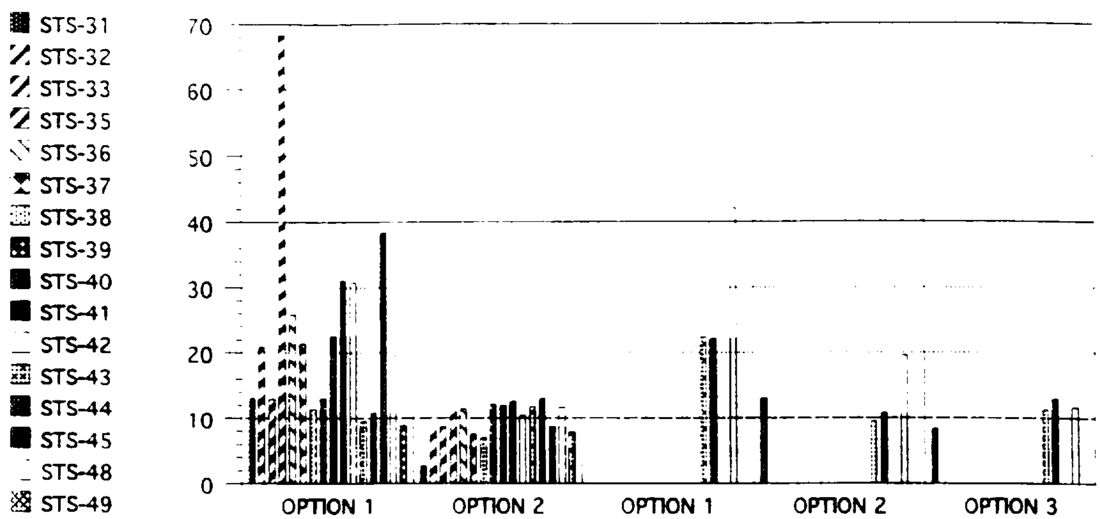
	DAYS	INITIAL OPTION 1	INITIAL OPTION 2	UPDATED OPTION 1	UPDATED OPTION 2	UPDATED OPTION 3	AVERAGE
STS-31	9	14.85	1.34	4.04	14.85	4.18	9.52
STS-32	25	16.84	4.56				10.70
STS-33	31	10.19	4.33				7.26
STS-35	17	17.45	5.76				11.61
STS-36	9	19.77	5.72				12.75
STS-37	40	19.92	3.75				11.84
STS-38	22	7.36	3.49				5.43
STS-39	21	21.27	6.07				13.67
STS-40	20	11.96	5.96				8.96
STS-41	16	8.7	6.31				7.51
STS-42	23	9.86	5.2				7.53
STS-43	30	26.08	5.89	20.08	26.08	5.66	15.87
STS-44	18	25.36	6.51	12.77	25.36	6.51	15.94
STS-45	28	7.25	4.34				5.80
STS-48	21	12.15	5.84	5.98	12.15	5.84	9.00
STS-49	59	6.16	3.94				5.05
AVERAGE	24.31	14.70	4.94	10.72	19.61	5.55	9.90

EPD/OEL



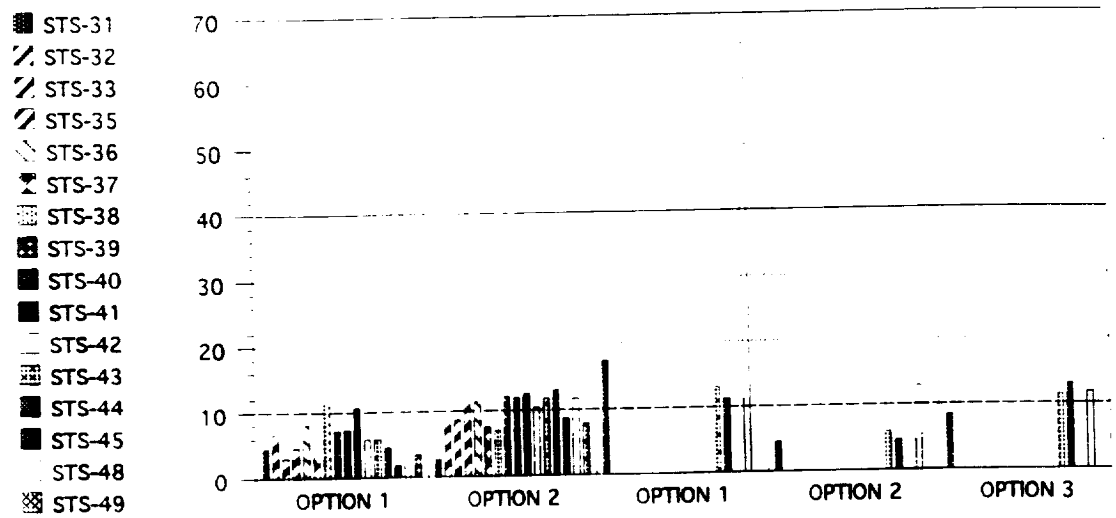
		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	11	2.69	2.67	3.49	2.69	8.35	5.52
STS-32	18	1.88	9.13				5.51
STS-33	23	2.64	8.67				5.66
STS-35	12	1.84	11.52				6.68
STS-36	12	2.36	11.45				6.91
STS-37	20	2.5	7.5				5.00
STS-38	16	2.1	6.98				4.54
STS-39	16	3.35	12.15				7.75
STS-40	14	1.79	11.93				6.86
STS-41	15	3.8	12.62				8.21
STS-42	18	3.17	10.39				6.78
STS-43	15	3.42	11.78	5.36	3.42	11.33	7.38
STS-44	12	4.56	13.01	6.1	4.56	13.01	8.79
STS-45	11	3.16	8.68				5.92
STS-48	16	1.71	11.69	2.58	1.71	11.69	6.70
STS-49	29	0.99	7.89				4.44
AVERAGE	16.13	2.62	9.88	4.38	3.10	11.10	6.41

FCP



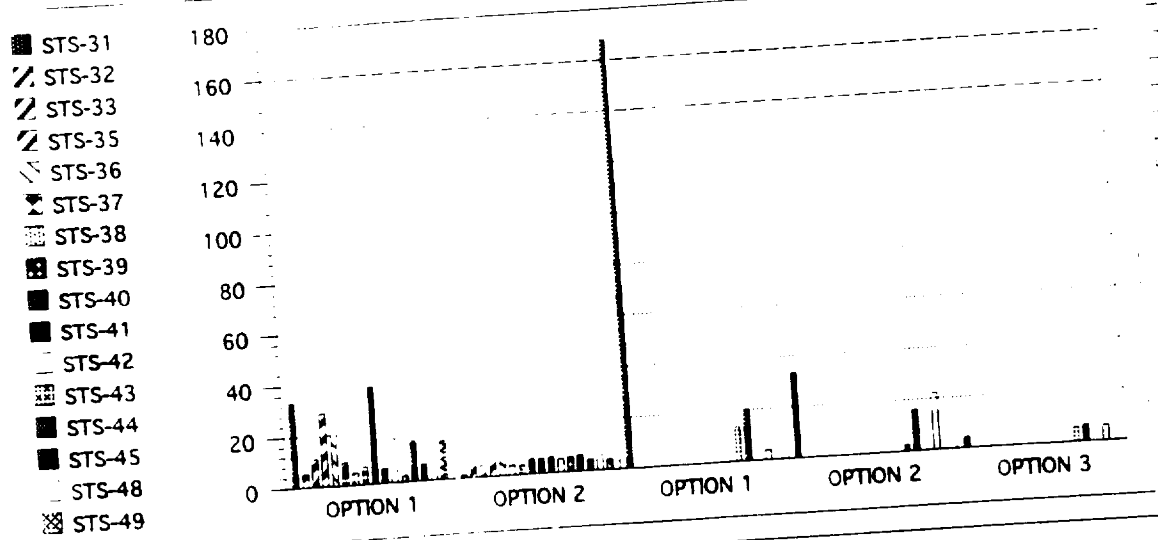
		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	0	13.11	2.67	0	13.11	8.35	10.73
STS-32	10	20.94	9.13				15.04
STS-33	32	12.91	8.67				10.79
STS-35	9	68.33	11.52				39.93
STS-36	2	25.81	11.45				18.63
STS-37	4	21.41	7.5				14.46
STS-38	14	11.45	6.98				9.22
STS-39	18	13.07	12.15				12.61
STS-40	33	22.5	11.93				17.22
STS-41	13	31.05	12.62				21.84
STS-42	7	30.67	10.39				20.53
STS-43	12	9.44	11.78	22.36	9.44	11.33	10.39
STS-44	10	10.85	13.01	22.1	10.85	13.01	11.93
STS-45	24	38.39	8.68				23.54
STS-48	12	19.59	11.69	42.15	19.59	11.69	15.64
STS-49	28	8.83	7.89				8.36
AVERAGE	14.25	22.40	9.88	21.65	13.25	11.10	16.30

FCS



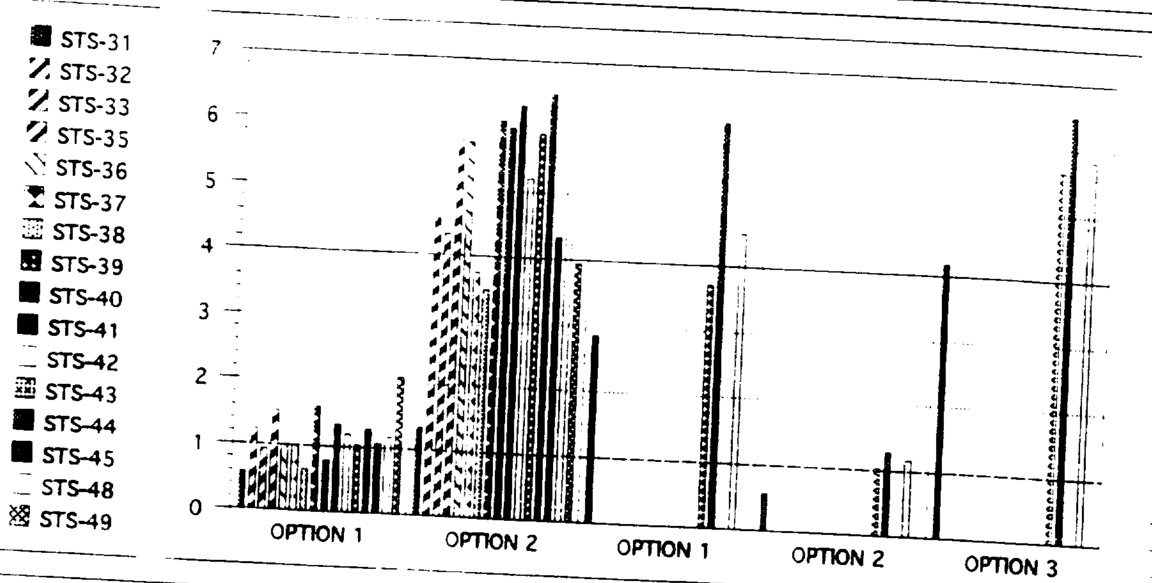
		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	16	4.52	2.67	17.36	4.52	8.35	6.44
STS-32	8	6.68	9.13				7.91
STS-33	30	3.04	8.67				5.86
STS-35	19	4.61	11.52				8.07
STS-36	14	8.08	11.45				9.77
STS-37	15	3.88	7.5				5.69
STS-38	31	11.68	6.98				9.33
STS-39	16	7.2	12.15				9.68
STS-40	13	7.38	11.93				9.66
STS-41	12	10.69	12.62				11.66
STS-42	35	5.87	10.39				8.13
STS-43	11	5.84	11.78	12.98	5.84	11.33	8.59
STS-44	11	4.59	13.01	11.3	4.59	13.01	8.80
STS-45	18	1.92	8.68				5.30
STS-48	27	12.85	11.69	65.42	12.85	11.69	12.27
STS-49	27	3.53	7.89				5.71
AVERAGE	18.94	6.40	9.88	26.77	6.95	11.10	8.30

FRC



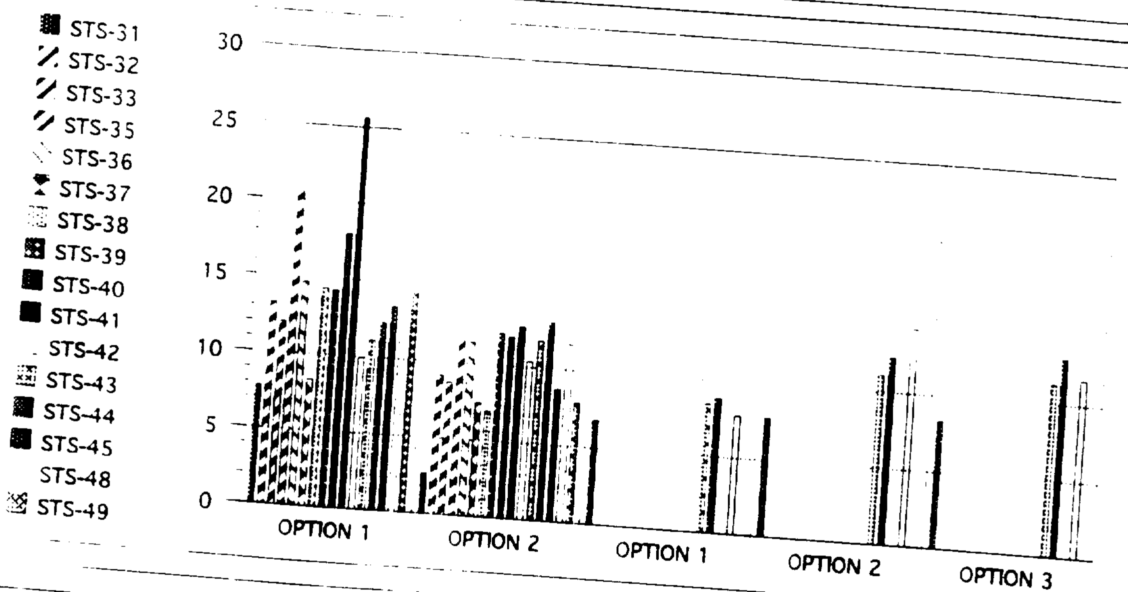
		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	47	33.22	1.34	167.93	33.22	4.18	18.70
STS-32	17	5.2	4.56				4.88
STS-33	11	10.9	4.33				7.62
STS-35	7	28.85	5.76				17.31
STS-36	30	21.8	5.72				13.76
STS-37	24	9.04	3.75				6.40
STS-38	13	4.83	3.49				4.16
STS-39	31	6.97	6.07				6.52
STS-40	14	37.99	5.96				21.98
STS-41	25	5.83	6.31				6.07
STS-42	5	17.27	5.2				11.24
STS-43	56	2.54	5.89	13.43	2.54	5.66	4.10
STS-44	12	16.03	6.51	19.93	16.03	6.51	11.27
STS-45	11	6.48	4.34				5.41
STS-48	2	22.06	5.84	3.83	22.06	5.84	13.95
STS-49	14	15.41	3.94				9.68
AVERAGE	19.94	15.28	4.94	51.28	18.46	5.55	10.19

HYD



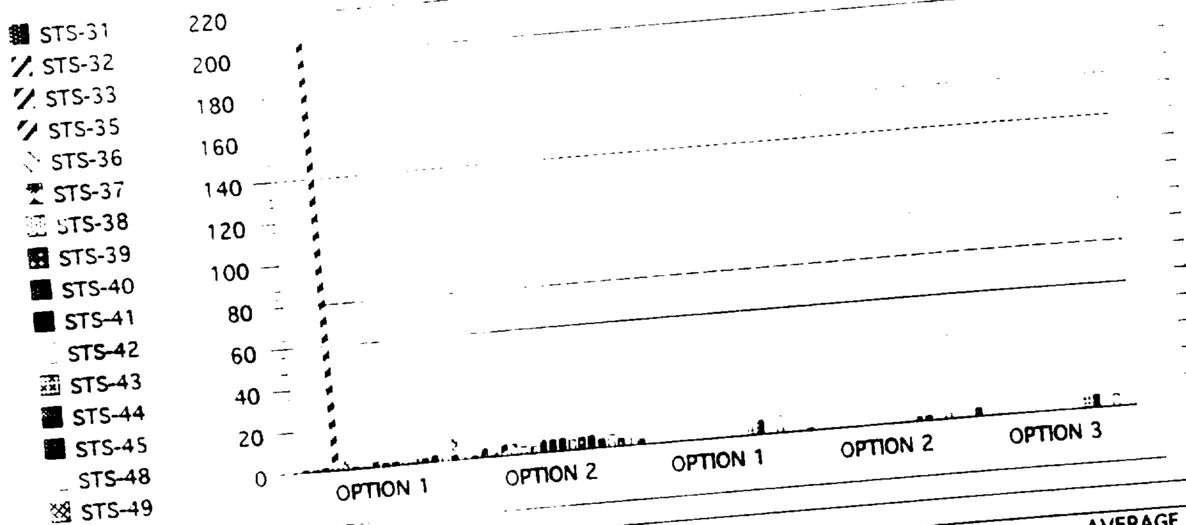
		INITIAL		UPDATED			
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	AVERAGE
STS-31	19	0.57	1.34	2.87	0.57	4.18	2.38
STS-32	17	1.23	4.56				2.90
STS-33	60	0.93	4.33				2.63
STS-35	23	1.52	5.76				3.64
STS-36	21	1	5.72				3.36
STS-37	23	1	3.75				2.38
STS-38	26	0.64	3.49				2.07
STS-39	37	1.6	6.07				3.84
STS-40	22	0.78	5.96				3.37
STS-41	25	1.34	6.31				3.83
STS-42	26	1.19	5.2				3.20
STS-43	16	1.03	5.89	3.71	1.03	5.66	3.35
STS-44	19	1.28	6.51	6.17	1.28	6.51	3.90
STS-45	19	1.07	4.34				2.71
STS-48	18	1.17	5.84	4.51	1.17	5.84	3.51
STS-49	38	2.09	3.94				3.02
AVERAGE	25.56	1.15	4.94	4.32	1.01	5.55	3.13

MEQ



		INITIAL		UPDATED			
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	AVERAGE
STS-31	21	7.77	2.67	6.85	7.77	8.35	8.06
STS-32	14	13.21	9.13				11.17
STS-33	37	12.02	8.67				10.35
STS-35	24	20.68	11.52				16.10
STS-36	21	14.65	11.45				13.05
STS-37	22	8.33	7.5				7.92
STS-38	18	14.34	6.98				10.66
STS-39	32	14.24	12.15				13.20
STS-40	30	18.03	11.93				14.98
STS-41	22	25.63	12.62				19.13
STS-42	25	9.95	10.39				10.17
STS-43	20	11.12	11.78	8.43	11.12	11.33	11.23
STS-44	18	12.31	13.01	8.83	12.31	13.01	12.66
STS-45	37	13.41	8.68				11.05
STS-48	16	14.23	11.69	7.79	14.23	11.69	12.96
STS-49	55	14.63	7.89				11.26
AVERAGE	25.75	14.03	9.88	7.98	11.36	11.10	12.12

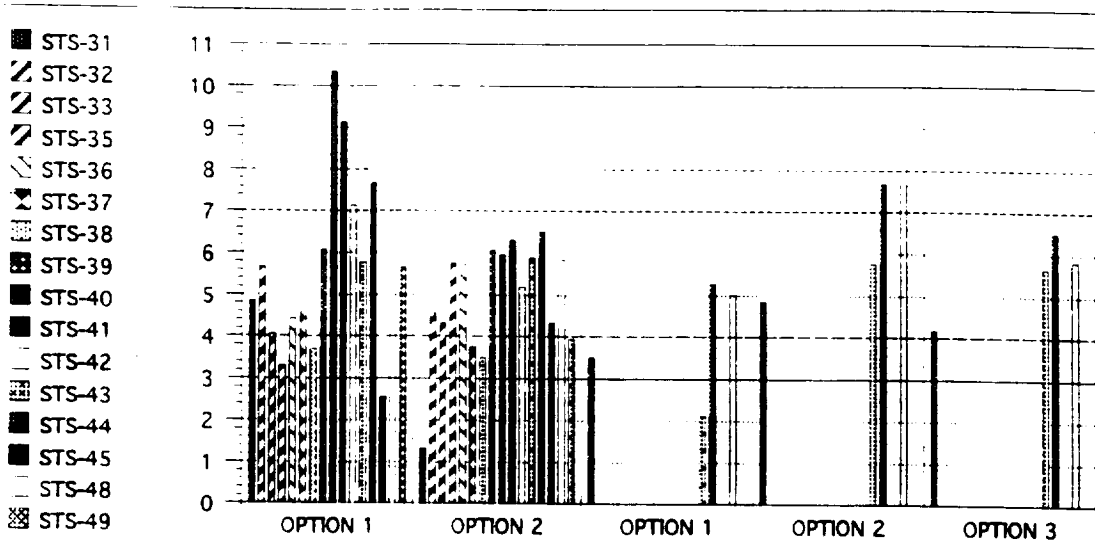
ME/SSME



		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	25	1.35	1.34	2.94	1.35	4.18	2.77
STS-32	27	1.01	4.56				2.79
STS-33	27	1.93	4.33				3.13
STS-35	22	209.03	5.76				5.76
STS-36	6	4.08	5.72				4.90
STS-37	23	1.07	3.75				2.41
STS-38	20	0.84	3.49				2.17
STS-39	31	2.92	6.07				4.50
STS-40	26	1.71	5.96				3.84
STS-41	19	1.91	6.31				4.11
STS-42	37	3.48	5.2	3.92	2.25	5.66	4.34
STS-43	22	2.25	5.89	6.92	2.47	6.51	3.96
STS-44	33	2.47	6.51				4.49
STS-45	49	3.26	4.34	8.16	2.85	5.84	3.80
STS-48	40	2.85	5.84				4.35
STS-49	16	10.21	3.94				7.08
AVERAGE	26.44	15.65	4.94	5.49	2.23	5.55	4.02

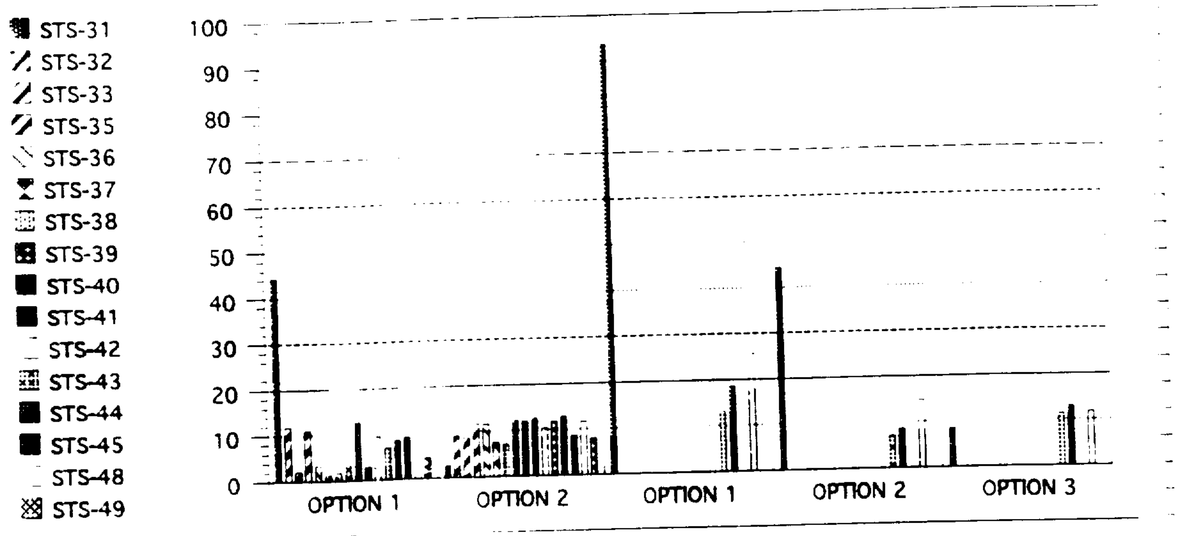
NOTE : STS-35, OPTION 1 is NOT included in the average.

MPS



		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	20	4.85	1.34	3.51	4.85	4.18	4.52
STS-32	16	5.67	4.56				5.12
STS-33	59	4.05	4.33				4.19
STS-35	17	3.3	5.76				4.53
STS-36	17	4.42	5.72				5.07
STS-37	24	4.59	3.75				4.17
STS-38	21	3.69	3.49				3.59
STS-39	32	6.08	6.07				6.08
STS-40	13	10.34	5.96				8.15
STS-41	29	9.14	6.31				7.73
STS-42	15	7.14	5.2				6.17
STS-43	11	5.77	5.89	2.12	5.77	5.66	5.72
STS-44	20	7.69	6.51	5.27	7.69	6.51	7.10
STS-45	16	2.57	4.34				3.46
STS-48	20	8.49	5.84	5.02	8.49	5.84	7.17
STS-49	48	5.66	3.94				4.80
AVERAGE	23.63	5.84	4.94	3.98	6.70	5.55	5.47

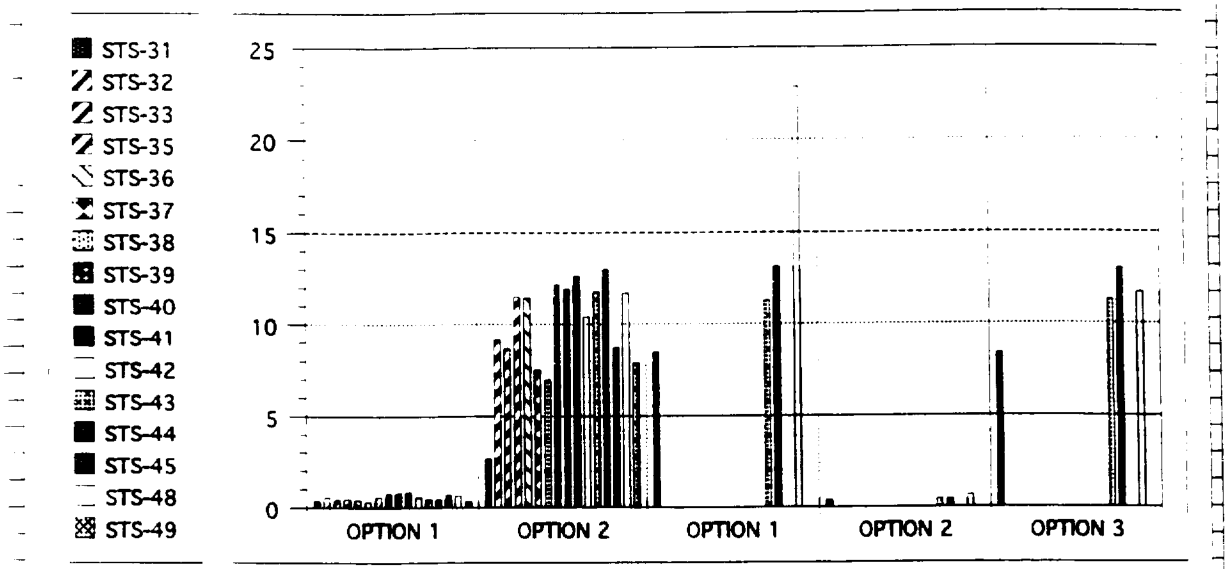
OMS



		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	20	44.3	2.67	93.69	44.3	8.35	8.35
STS-32	20	11.79	9.13				10.46
STS-33	41	2.15	8.67				5.41
STS-35	19	10.99	11.52				11.26
STS-36	12	3.44	11.45				7.45
STS-37	21	1.28	7.5				4.39
STS-38	17	1.76	6.98				4.37
STS-39	42	3.53	12.15				7.84
STS-40	37	12.66	11.93				12.30
STS-41	33	2.97	12.62				7.80
STS-42	23	9.42	10.39				9.91
STS-43	20	6.98	11.78	13.08	6.98	11.33	9.16
STS-44	21	8.55	13.01	18.62	8.55	13.01	10.78
STS-45	17	9.26	8.68				8.97
STS-48	20	14.71	11.69	25.51	14.71	11.69	13.20
STS-49	22	4.58	7.89				6.24
AVERAGE	24.06	9.27	9.88	37.73	18.64	11.10	8.62

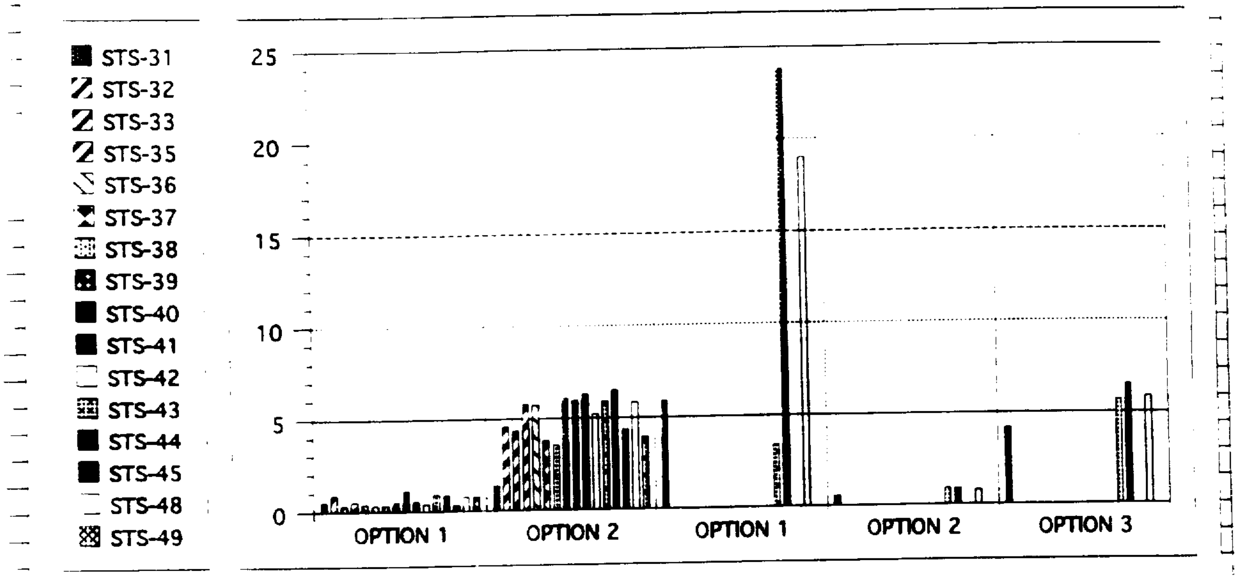
NOTE : STS-31, OPTION 2 is NOT included in the AVERAGE.

PVD



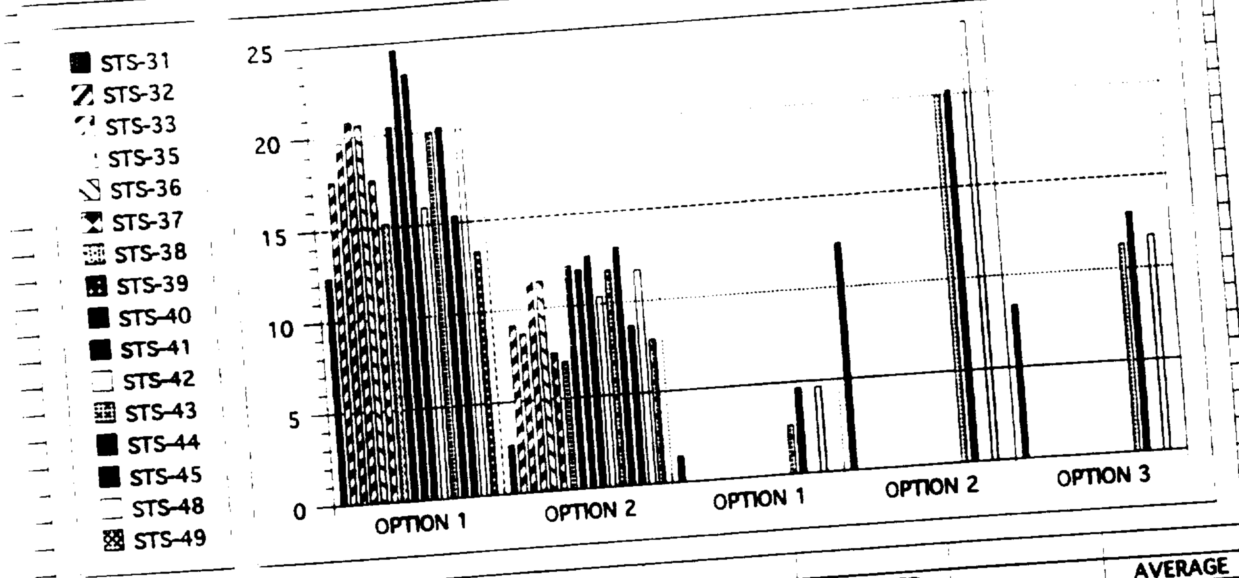
		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	13	0.39	2.67	8.45	0.39	8.35	8.35
STS-32	16	0.55	9.13				4.84
STS-33	32	0.44	8.67				4.56
STS-35	15	0.46	11.52				5.99
STS-36	19	0.42	11.45				5.94
STS-37	21	0.31	7.5				3.91
STS-38	16	0.59	6.98				3.79
STS-39	22	0.8	12.15				6.48
STS-40	12	0.8	11.93				6.37
STS-41	18	0.86	12.62				6.74
STS-42	15	0.57	10.39				5.48
STS-43	18	0.45	11.78	11.29	0.45	11.33	5.89
STS-44	19	0.45	13.01	13.11	0.45	13.01	6.73
STS-45	30	0.71	8.68				4.70
STS-48	27	0.65	11.69	22.87	0.65	11.69	6.17
STS-49	37	0.32	7.89				4.11
AVERAGE	20.63	0.55	9.88	13.93	0.49	11.10	5.63

PYR

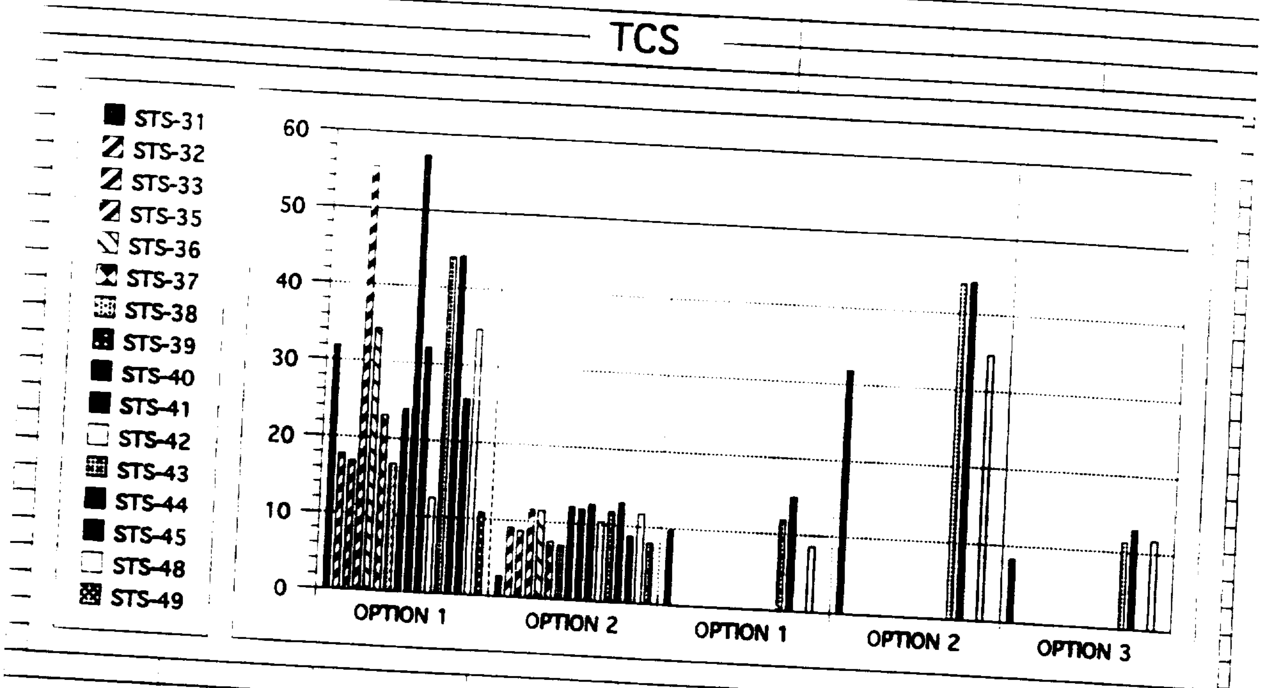


		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	6	0.52	1.34	5.9	0.52	4.18	2.35
STS-32	19	0.87	4.56				2.72
STS-33	31	0.31	4.33				2.32
STS-35	11	0.54	5.76				3.15
STS-36	19	0.37	5.72				3.05
STS-37	23	0.33	3.75				2.04
STS-38	8	0.34	3.49				1.92
STS-39	46	0.52	6.07				3.30
STS-40	24	1.12	5.96				3.54
STS-41	12	0.54	6.31				3.43
STS-42	25	0.37	5.2				2.79
STS-43	2	0.88	5.89	3.35	0.88	5.66	3.27
STS-44	15	0.84	6.51	23.81	0.84	6.51	3.68
STS-45	9	0.32	4.34				2.33
STS-48	16	0.75	5.84	18.99	0.75	5.84	3.30
STS-49	47	0.76	3.94				2.35
AVERAGE	19.56	0.59	4.94	13.01	0.75	5.55	2.84

STR

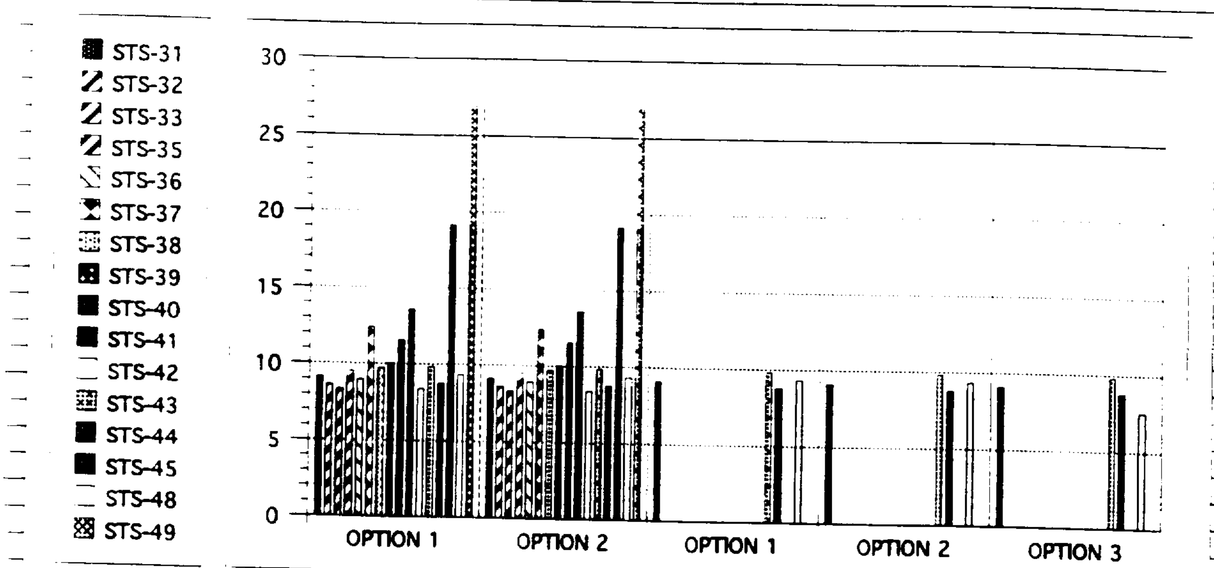


		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	13	12.37	2.67	1.39	12.37	8.35	10.36
STS-32	17	17.59	9.13				13.36
STS-33	39	19.69	8.67				14.18
STS-35	20	20.82	11.52				16.17
STS-36	16	20.62	11.45				16.04
STS-37	29	17.58	7.5				12.54
STS-38	43	15.2	6.98				11.09
STS-39	26	20.41	12.15				16.28
STS-40	25	24.62	11.93				18.28
STS-41	23	23.23	12.62				17.93
STS-42	29	15.91	10.39				13.15
STS-43	18	19.93	11.78	2.65	19.93	11.33	15.63
STS-44	28	20.22	13.01	4.64	20.22	13.01	16.62
STS-45	22	15.33	8.68				12.01
STS-48	28	23.88	11.69	4.65	23.88	11.69	17.79
STS-49	73	13.33	7.89				10.61
AVERAGE	28.06	18.80	9.88	3.33	19.10	11.10	14.50



		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	11	31.91	2.67	9.77	31.91	8.35	20.13
STS-32	15	17.76	9.13				13.45
STS-33	17	16.89	8.67				12.78
STS-35	13	55.41	11.52				33.47
STS-36	10	34.39	11.45				22.92
STS-37	15	23.04	7.5				15.27
STS-38	20	16.74	6.98				11.86
STS-39	12	23.97	12.15				18.06
STS-40	10	57.21	11.93				34.57
STS-41	11	32.17	12.62				22.40
STS-42	12	12.44	10.39				11.42
STS-43	11	44.03	11.78	11.88	44.03	11.33	27.68
STS-44	13	44.26	13.01	14.92	44.26	13.01	28.64
STS-45	10	25.57	8.68				17.13
STS-48	11	34.8	11.69	8.53	34.8	11.69	23.25
STS-49	26	10.82	7.89				9.36
AVERAGE	13.56	30.09	9.88	11.28	38.75	11.10	20.15

TILE



		INITIAL		UPDATED			AVERAGE
	DAYS	OPTION 1	OPTION 2	OPTION 1	OPTION 2	OPTION 3	
STS-31	28	9.15	9.15	9.15	9.15	9.15	9.15
STS-32	37	8.63	8.63				8.63
STS-33	71	8.32	8.32				8.32
STS-35	23	9.53	9.53				9.53
STS-36	27	8.96	8.96				8.96
STS-37	31	12.43	12.43				12.43
STS-38	27	9.74	9.74				9.74
STS-39	27	10.02	10.02				10.02
STS-40	35	11.58	11.58				11.58
STS-41	26	13.6	13.6				13.60
STS-42	28	8.4	8.4				8.40
STS-43	15	9.82	9.82	9.82	9.82	9.82	9.82
STS-44	17	8.77	8.77	8.77	8.77	8.77	8.77
STS-45	8	19.15	19.15				19.15
STS-48	20	9.34	9.34	9.34	9.34	7.55	8.45
STS-49	9	26.89	26.89				26.89
AVERAGE	26.81	11.52	11.52	9.27	9.27	8.82	11.46

Appendix D

External Tank/Titan Failure Data

Electrical

	#MA	#R&R	OPERATING HOURS	MTBM
STS 31R/ET-34	4	0	84	21
STS 32R/ET-32	8	0	23	2.875
STS 33R/ET-38	5	1	70	14
STS 35 /ET-35	12	0	144	12
STS 36 /ET-33	0	0	73	0
STS 37 /ET-37	5	0	73	14.6
STS 38 /ET-40	3	0	73	24.33
STS 39 /ET-46	1	0	84	84
STS 40 /ET-41	4	1	67	16.75
STS 41 /ET-39	3	0	68	22.67
STS 42 /ET-52	5	0	47	9.4
STS 43 /ET-47	1	0	74	74.00
STS 44 /ET-53	4	1	75	18.75
STS 45 /ET-44	0	0	57	0
STS 48 /ET-42	2	0	58	29
STS 49 /ET-43	0	0	94	0
TOTAL	57	3	1164	20.42

PROP/FLUIDS

	#MA	#R&R	OPERATING HOURS	MTBM
STS 31R/ET-34	12	1	84	7.00
STS 32R/ET-32	14	0	23	1.64
STS 33R/ET-38	17	3	70	4.12
STS 35 /ET-35	33	0	144	4.36
STS 36 /ET-33	20	0	73	3.65
STS 37 /ET-37	34	2	73	2.15
STS 38 /ET-40	28	4	73	2.61
STS 39 /ET-46	19	0	84	4.42
STS 40 /ET-41	24	10	67	2.79
STS 41 /ET-39	26	5	68	2.62
STS 42 /ET-52	12	4	47	3.92
STS 43 /ET-47	7	0	74	10.57
STS 44 /ET-53	14	4	75	5.36
STS 45 /ET-44	9	1	57	6.33
STS 48 /ET-42	9	0	58	6.44
STS 49 /ET-43	12	0	94	7.83
TOTAL	290	34	1164	4.01

RANGE SAFETY

	#MA	#R&R	OPERATING HOURS	MTBM
STS 31R/ET-34	1	0	84	84.00
STS 32R/ET-32	2	0	23	11.50
STS 33R/ET-38	3	1	70	23.33
STS 35 /ET-35	4	0	144	36.00
STS 36 /ET-33	1	0	73	73.00
STS 37 /ET-37	2	1	73	36.50
STS 38 /ET-40	0	0	73	0.00
STS 39 /ET-46	4	2	84	21.00
STS 40 /ET-41	2	1	67	33.50
STS 41 /ET-39	0	0	68	0.00
STS 42 /ET-52	0	0	47	0.00
STS 43 /ET-47	3	2	74	24.67
STS 44 /ET-53	0	0	75	0.00
STS 45 /ET-44	4	0	57	14.25
STS 48 /ET-42	0	0	58	0.00
STS 49 /ET-43	0	0	94	0.00
TOTAL	26	7	1164	44.77

STR

	#MA	#R&R	OPERATING HOURS	MTBM
STS 31R/ET-34	36	2	1	0.03
STS 32R/ET-32	25	0	1	0.04
STS 33R/ET-38	33	1	1	0.03
STS 35 /ET-35	55	0	1	0.02
STS 36 /ET-33	34	0	1	0.03
STS 37 /ET-37	56	16	1	0.02
STS 38 /ET-40	33	1	1	0.03
STS 39 /ET-46	23	2	1	0.04
STS 40 /ET-41	33	1	1	0.03
STS 41 /ET-39	38	0	1	0.03
STS 42 /ET-52	17	0	1	0.06
STS 43 /ET-47	11	0	1	0.09
STS 44 /ET-53	12	0	1	0.08
STS 45 /ET-44	14	1	1	0.07
STS 48 /ET-42	23	1	1	0.04
STS 49 /ET-43	9	0	1	0.11
TOTAL	452	25	16	0.0354

NOTE : Operating hours of 1 refers to one cycle.

TPS

	#MA	#R&R	OPERATING HOURS	MTBM
STS 31R/ET-34	44	0	1	0.02
STS 32R/ET-32	60	0	1	0.02
STS 33R/ET-38	62	0	1	0.02
STS 35 /ET-35	112	0	1	0.01
STS 36 /ET-33	63	0	1	0.02
STS 37 /ET-37	87	2	1	0.01
STS 38 /ET-40	61	0	1	0.02
STS 39 /ET-46	23	0	1	0.04
STS 40 /ET-41	38	0	1	0.03
STS 41 /ET-39	51	0	1	0.02
STS 42 /ET-52	21	0	1	0.05
STS 43 /ET-47	20	0	1	0.05
STS 44 /ET-53	23	0	1	0.04
STS 45 /ET-44	24	0	1	0.04
STS 48 /ET-42	26	0	1	0.04
STS 49 /ET-43	17	0	1	0.06
TOTAL	732	2	16	0.0219

NOTE : Operating hours of 1 refers to one cycle.

TITAN MTBM CALCULATIONS

	MA	REMOV	OP HRS	MTBM	RR
.ECT	19	19	669		
	-1	60	677		
	17	10	860		
	43	10	838		
	43	10	836		
	4	1	818		
TOT	197	110	4.698	23.85	0.56
PROP	5	3	677		
	12	1	838		
	78	57	836		
	8	2	818	102.25	0.25
TOT	103	63	3.169		
RG SAFE	3	1	677		
	2	1	838		
TOT	5	2	1.515	303.00	0.40
STRUCT	2	2	669		
	9	7	677		
	5	4	860		
	16	2	838		
	7	0	836		
	6	3	818		
TOT	45	18	4.698	104.40	0.40

Appendix E

Independent Variables

INDEPENDENT VARIABLE

Variable Name	Definition
DRY WGT	Empty weight (without fuel) of vehicle in pounds.
LEN+WING	Aircraft length plus wing span in feet.
WET AREA	Total external surface area of vehicle in square feet.
FUS VOL	Total volume of fuselage incubic feet excluding any engine inlet duct volume.
FUS AREA	External area of fuselage in square feet including canopy.
CREW SIZE	Total number of crew members.
NBR PASSENGERS	Maximum number of passengers.
ENGINES	Number of primary engines.
MSN LENGTH	Mission length in hours. May be adjusted by subsystem.
SUB WGTS	Total subsystem weight in pounds.
WHEELS	Total number of wheels.
ACTUATORS	Total number of actuators to operate all vehicle movable flight surfaces.
CONT SUR	Total number of control surfaces - ailerons, rudders, elevator tabs, flaps, spoilers and slats.
ECS WGT	Total weight in pounds of the environmental control system including heating, cooling and anti-icing equipment.
KVA MAX	Total electrical power output of engines, motors and APU driven generators/alternators in KVA.
SUBSYS	Total number of aircraft subsystems requiring use of hydraulic or pneumatic power.

FUEL TK	Number of separate internal fuel cells, bladders and tanks.
AV WGT	Weight in pounds of avionics equipment uninstalled (does not include wiring, shelves, ducts, fasteners).
TOT SUBS	Total number of avionics (AN nomenclature) subsystems.
AV INSTA	Weight in pounds of brackets, shelves, wiring and plugs used on avionics equipment.
DIF SUBS	Total number of different avionics subsystems (two or more identical units count as one).
BTU COOL	Total cooling capacity of air conditioning equipment used for personnel and equipment cooling. Measured in BTU/HR/1000.

Appendix F

Reliability and Maintainability Program

RAMX.BAS Program

```
DECLARE SUB SUMMARY ()
DECLARE SUB ACWGT ()
DECLARE SUB MANDISPLAY ()
DECLARE SUB SPAREDISPLAY ()
DECLARE SUB ABORT ()
DECLARE SUB SECONDARY ()
DECLARE SUB MANPWR ()
DECLARE SUB INIT ()
DECLARE SUB SPARES ()
DECLARE SUB BOOSTER ()
DECLARE SUB TURNTIME ()
DECLARE SUB SPACEMTBM ()
DECLARE SUB POFFEQS ()
DECLARE SUB REMEQS ()
DECLARE SUB MAINTDIS ()
DECLARE SUB EQS ()
DECLARE SUB REDUNREL ()
DECLARE SUB RELDISPLAY ()
10 'NASA, LANGLEY RESEARCH CENTER
20 'MTBM COMPUTATIONAL MODEL - NASA RESEARCH GRANT -
30 'DEVELOPED BY C. EBELING, UNIV OF DAYTON  1/93, 6/93 (updated)
35 '   ******** COMBINED PRE/CONCEPTUAL MODEL **********
40 '
50 'SAVE AS "WORK.BAS"    Mean Time Between Maintenance -REVISED
60 '
65 COMMON SHARED YR, B, X1, X2, LF, VR1, VR2, VR3, VR4, VR5, VR
66 COMMON SHARED VFMA, TVFMA, SVFMA, CVFMA, OMHMA, OFMHMA, TMA, AMHMA
67 COMMON SHARED SCHP, VMH, TOMH, TFMH, APF, P1, P2, P3, WAV, FH42, FH44
68 COMMON SHARED FMA11, FMA12, VNAM$, ARR, TNR, TS
   COMMON SHARED SMP, TMP, VMOH, MANF, WGTF, WING, WF, PWF
   COMMON SHARED ETREL, SRBREL, ETS, SRBS
   COMMON SHARED STP, STE, MTE, TME, STF, MTF, TMF, C1
70 DIM SHARED WBS$(35), X(50), NAM$(50), THRS(35), MHMA(35), MH(35), MP(35),
OMH(35), FMH(35)
71 DIM SHARED SEL$(35), T(10), CP$(9), CA(35)
72 DIM SHARED GOH(35), LOH(35), TOH(35), OOH(35), ROH(35), R(35), TSKT(35),
POH(35)
73 DIM SHARED V(15), SNAM$(15), FMAT(35), FMAC(35), FMAS(35), S(35), SMA(35),
SMR(35)
74 DIM SHARED MW(35), C(35), CM(35), OP$(35), TG(35), PWTS(35)
75 DIM SHARED FMA(35), PF(35), PA(35), Z(500), Y(500), RR(35), W(35), NR(35),
FR(35)
76 DIM SHARED NRD(35), K(35), R1(35), R2(35), R3(35), R4(35), R5(35)
77 DIM SHARED PWT1(35), PWT2(35), PWT3(35), PWT4(35), SRR(35)
   DIM SHARED ETSUB$(5), ETMBA(5), ETHRS(5), ETABR(5), ETMTR(5), ETR(5),
ETCREW(5)
   DIM SHARED SRBSUB$(5), SRBMBA(5), SRBHRS(5), SRBABR(5), SRBMTR(5), SRBR(5),
SRBCREW(5)
   COMMON SHARED WBS$(), X(), NAM$(), THRS(), MHMA(), MH(), MP(), OMH(), FMH()
   COMMON SHARED SEL$(), T(), CP$(), CA()
   COMMON SHARED GOH(), LOH(), TOH(), OOH(), ROH(), R(), TSKT(), POH()
   COMMON SHARED V(), SNAM$(), FMAT(), FMAC(), FMAS(), S(), SMA(), SMR()
   COMMON SHARED MW(), C(), CM(), OP$(), TG(), PWTS()
   COMMON SHARED FMA(), PF(), PA(), Z(), Y(), RR(), W(), NR(), FR()
   COMMON SHARED NRD(), K(), R1(), R2(), R3(), R4(), R5()
   COMMON SHARED PWT1(), PWT2(), PWT3(), PWT4(), SRR()
   COMMON SHARED ETSUB$(), ETMBA(), ETHRS(), ETABR(), ETMTR(), ETR(), ETCREW()
   COMMON SHARED SRBSUB$(), SRBMBA(), SRBHRS(), SRBABR(), SRBMTR(), SRBR(),
SRBCREW()
```

```
ERRSUB: 'ERROR HANDLING ROUTINE
        IF ERR = 53 OR ERR = 61 OR ERR = 71 THEN
           IF ERR = 53 THEN PRINT "FILE NOT FOUND"
           IF ERR = 61 THEN PRINT "DISK FULL"
           IF ERR = 71 THEN PRINT "DISK NOT READY"
           INPUT "ENTER RETURN"; RET
           RESUME 100  'MAIN MENU
        ELSE
           PRINT "UNRECOVERABLE ERROR"
           ON ERROR GOTO 0
        END IF

79 RFLG = 0'REPEAT FLAG
80 '
   ON ERROR GOTO ERRSUB
85 GOSUB 1000 'OPENING BANNER
90 CALL INIT 'INITIALIZATION
92 GOSUB 900 'INITIALIZE MSN PROFILES
93 GOSUB 1520  'INITIALIZE SUBSYS WEIGHTS
95 GOSUB 2900  'CLEAN-UP  ADJUST SHUTTLE MTBM
97 CLS : COLOR 12: LOCATE 10, 20: PRINT "STANDBY..... INITIALIZING ALL VALUES..."
98 GOSUB 1942 'INITIAL COMP
100 'MAIN MENU
110 CLS : COLOR 10
120 PRINT TAB(15); "NASA LRC - RELIABILITY/MAINTAINABILITY MODEL"
130 PRINT : PRINT TAB(25); "MAIN MENU": PRINT
135 COLOR 11
140 PRINT TAB(15); "NBR"; TAB(35); "SELECTION": PRINT
150 PRINT TAB(15); "1........READ INPUT FROM A FILE"
155 PRINT TAB(15); "2........INPUT PARAMETER MENU"
159 COLOR 12
160 PRINT TAB(15); "3........COMPUTE R&M PARAMETERS"
161 COLOR 11
165 PRINT TAB(15); "4........OUTPUT REPORT MENU"
170 PRINT TAB(15); "5........SAVE INPUT PARAMETERS"
172 PRINT TAB(15); "6........SAVE OUTPUT FOR COST MODEL"
    PRINT TAB(15); "7........CHANGE VEHICLE/FILE NAME"
175 PRINT TAB(15); "8........TERMINATE SESSION"
    IF X(16) = 0 THEN TNAM$ = "PRECONCEPTUAL MODE"
    IF X(16) = 1 THEN TNAM$ = "WEIGHT-DRIVEN MODE"
    IF X(16) = 2 THEN TNAM$ = "WEIGHT & VARIABLE DRIVEN MODE"
    COLOR 14: LOCATE 22, 10: PRINT "YOU ARE CURRENTLY IN THE "; TNAM$
177 LOCATE 20, 10: COLOR 13: PRINT "VEHICLE/FILE NAME IS  "; VNAM$
180 COLOR 10: LOCATE 17, 20: INPUT "ENTER SELECTION"; NBO
190 IF NBO = 1 THEN GOSUB 1700
200 IF NBO = 2 THEN GOSUB 300
205 IF NBO = 3 THEN GOSUB 1900
210 IF NBO = 4 THEN GOSUB 5800
215 IF NBO = 5 THEN GOSUB 9600
217 IF NBO = 6 THEN GOSUB 9500
    IF NBO = 7 THEN GOSUB CHG
220 IF NBO = 8 THEN GOTO DONE
230 GOTO 110
299 '
CHG: CLS : COLOR 14: LOCATE 12, 12: INPUT "ENTER NEW NAME"; VNAM$: GOTO 110
DONE:  CLS : COLOR 3
       LOCATE 12, 20: INPUT "DO YOU WISH TO SAVE INPUT PARAMETERS?-(Y/N)"; ANS$
       IF ANS$ = "Y" OR ANS$ = "y" THEN GOSUB 9600
       PRINT : COLOR 14: CLS : LOCATE 12, 28: PRINT "SESSION TERMINATED"
       END
```

```
300 ' INPUT PARAMETER MENU *******
310 CLS : COLOR 14
320 PRINT TAB(15); "NASA LRC - RELIABILITY/MAINTAINABILITY MODEL"; TAB(60); VNAM$
330 PRINT : PRINT TAB(25); "INPUT PARAMETER MENU": PRINT
340 PRINT TAB(15); "NBR"; TAB(35); "SELECTION": PRINT
345 COLOR 3
350 PRINT TAB(15); "1........ADD/DELETE A SUBSYSTEM"
355 PRINT TAB(15); "2........SELECT SHUTTLE/AIRCRAFT"
360 PRINT TAB(15); "3........UPDATE/DISPLAY PRIMARY SYSTEM PARAMETERS"
365 PRINT TAB(15); "4........UPDATE/DISPLAY SUBSYSTEM WEIGHTS"
370 PRINT TAB(15); "5........UPDATE/DISPLAY SECONDARY VARIABLES"
385 PRINT TAB(15); "6........UPDATE/DISPLAY COMPUTATIONAL FACTORS"
390 PRINT TAB(15); "7........UPDATE/DISPLAY MISSION PROFILE"
395 PRINT TAB(15); "8........UPDATE/DISPLAY SYSTEM OPERATING HRS"
400 PRINT TAB(15); "9........UPDATE/DISPLAY REDUNDANCY CONFIGURATION"
403 PRINT TAB(15); "10.......UPDATE/DISPLAY LRB/ET RELIABILITY DATA"
405 PRINT TAB(15); "11.......UPDATE/DISPLAY SHUTTLE MTBM'S & MTTR'S"
    PRINT TAB(15); "12.......CHANGE SCHEDULED MAINTENANCE"
407 PRINT TAB(15); "13.......RETURN TO MAIN MENU"
408 COLOR 14
410 LOCATE 22, 20: INPUT "ENTER SELECTION"; NB1
415 IF NB1 = 1 THEN GOSUB 12300
420 IF NB1 = 2 THEN GOSUB 14000
425 IF NB1 = 3 THEN GOSUB 1049
430 IF NB1 = 4 THEN GOSUB 1400
435 IF NB1 = 5 THEN GOSUB 11000
445 IF NB1 = 6 THEN GOSUB 12500
450 IF NB1 = 7 THEN GOSUB 1600
455 IF NB1 = 8 THEN GOSUB 1300
460 IF NB1 = 9 THEN GOSUB 13000
463 IF NB1 = 10 THEN CALL BOOSTER
465 IF NB1 = 11 THEN GOSUB 1800
    IF NB1 = 12 THEN GOSUB UNSCH
466 IF NB1 = 13 THEN RETURN
495 GOTO 310
899 '
900 'INITIALIZE SUBSYSTEM MSN PROFILES
910 FOR I = 1 TO 33
920 POH(I) = T(5): GOH(I) = T(0): LOH(I) = T(1): TOH(I) = T(2) - T(1): OOH(I) =
T(3) - T(2): ROH(I) = T(4) - T(3): POH(I) = T(5)
921 NEXT I
922 OOH(10) = 0: ROH(10) = 0
    POH(9) = 0: GOH(9) = 0: LOH(9) = 0: TOH(9) = 0: OOH(9) = 0: ROH(9) = 1
923 'GOH(5)=0:OOH(5)=0
924 'OOH(12)=0
930 RFLG = 1
990 RETURN
999 '
1000 'INPUT MODULE
1010 KEY OFF: CLS : COLOR 11
1020 LOCATE 6, 15: PRINT "VEHICLE RELIABILITY/MAINTAINABILITY MODEL"
1030 PRINT : PRINT TAB(20); "NASA - LANGLEY RESEARCH CENTER": COLOR 14
1040 LOCATE 14, 20: INPUT "ENTER VEHICLE/FILE NAME"; VNAM$
     IF VNAM$ = "" THEN VNAM$ = "NO_NAME"
1045 RETURN
1048 '
```

```
1049 'PRIMARY MENU
     I1 = 1: I2 = 10
1050 COLOR 11: CLS : PRINT TAB(25); "INPUT MODULE - PRIMARY & SYSTEM VARIABLES"
     PRINT
     IF  I2  =  20  THEN  COLOR  7:  PRINT  TAB(10);  "SYSTEM  PARAMETER  VALUES
(continued)": PRINT
1060 PRINT TAB(15); "NBR"; TAB(20); "VARIABLE"; TAB(55); "CURRENT VALUE"
1062 PRINT : COLOR 7
1065 IF I1 = 1 THEN PRINT TAB(10); "PRIMARY DRIVER VARIABLES": PRINT
     COLOR 14
1070 FOR I = I1 TO I2
1075 IF I = 6 THEN COLOR 7: PRINT : PRINT TAB(10); "SYSTEM PARAMETER VALUES":
PRINT
     COLOR 14
1080 PRINT TAB(15); I; TAB(20); NAM$(I); TAB(55); X(I)
     IF I = 2 THEN PRINT TAB(15); I; TAB(20); "WING SPAN (FT)"; TAB(55); WING
COLOR 13
1095 IF I = 16 THEN PRINT TAB(20); "0-PRECONCEPTUAL"
1096 IF I = 16 THEN PRINT TAB(20); "1-WEIGHT DRIVEN"
1097 IF I = 16 THEN PRINT TAB(20); "2-WEIGHT & VARIABLE DRIVEN"
     NEXT I
     COLOR 2
1100 PRINT : INPUT "ENTER NBR OF VARIABLE TO BE CHANGED - 0 IF NONE"; NBR
     IF NBR = 1 AND X(16) = 1 OR NBR = 1 AND X(16) = 2 THEN GOTO 1131
1110 IF NBR = 0 THEN GOTO 1131
1115 IF NBR > 20 OR NBR < 0 THEN GOTO 1050
1120 IF NBR = 2 THEN INPUT "ENTER LENGTH, WING SPAN"; X(2), WING ELSE INPUT
"ENTER NEW VALUE"; X(NBR)
1130 CLS : GOTO 1050
1131 IF I1 = 1 THEN I1 = 11: I2 = 20: CLS : GOTO 1050
1135 YR = X(7): B = X(9): LF = X(10): X1 = X(1): X2 = X(2) + WING
1140 IF X(16) = 0 THEN GOSUB 1500
1145 IF X(16) = 0 OR X(16) = 1 THEN CALL SECONDARY
     IF X(19) = 1 THEN FOR I = 20 TO 24: OP$(I) = "DELETE": NEXT I
     IF X(19) = O THEN WBS$(19) = "13.10 AVIONICS-GN&C" ELSE WBS$(19) = "13.XX
AGGREGATED AVIONICS"
1150 RETURN

1200 'MODULE TO INPUT MOD FACTOR
1201 IO = 1: IE = 18
1205 CLS : COLOR 7: PRINT TAB(20); "SUBSYSTEM MTBM CALIBRATION FACTOR"
1206 PRINT TAB(20); "SPACE VEH-MTBM = CAL FAC x ACFT-MTBM"
1210 PRINT TAB(3); "NBR  SUBSYSTEM"; TAB(45); "CAL FACTOR"
1230 FOR I = IO TO IE
     IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 11
1235 IF OP$(I) = "DELETE" THEN GOTO 1250
1240 PRINT TAB(3); I; TAB(10); WBS$(I); TAB(45); MW(I)
1250 NEXT I
     COLOR 7
1260 PRINT : INPUT "ENTER NBR OF SUBSYSTEM TO BE CHANGED - 0 IF NONE"; NBR
1265 IF NBR > 33 THEN GOTO 1205
1270 IF NBR = 0 THEN GOTO 1291
1280 INPUT "ENTER NEW FACTOR"; MW(NBR)
1290 GOTO 1205
1291 IF IO = 1 THEN IO = 19: IE = 33: GOTO 1205
1295 GOSUB 12200
1298 RETURN
```

```
1300 'DISPLAY SUBSYSTEM OPERATING TIMES
1301 IO = 1: IE = 17
1303 CLS : PRINT : COLOR 7: PRINT TAB(5); "SUBSYSTEM OPERATING TIMES"
     POH(9) = 0: GOH(9) = 0: LOH(9) = 0: TOH(9) = 0: OOH(9) = 0: ROH(9) = 1
1305 PRINT TAB(1); "TOTAL MISSION TIME"; TAB(20); T(4); " HRS"; TAB(30); "MAX PAD
TIME"; T(0); " HRS"
1306 PRINT TAB(1); "NBR  SUBSYSTEM"; TAB(32); "RECOV"; TAB(39); "PAD"; TAB(46);
"BOOST"; TAB(52); "RE TIME"; TAB(61); "ORBIT"; TAB(68); "REENTRY"
1310  PRINT  TAB(32);  "TIME";  TAB(39);  "TIME";  TAB(46);  "TIME";  TAB(52);
"TO-ORBIT"; TAB(61); "TIME"; TAB(68); "TIME"
1330 FOR I = IO TO IE
     IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 11
     IF I = 9 AND SEL$(I) <> "SHUTTLE" THEN COLOR 13
1335 IF OP$(I) = "DELETE" THEN GOTO 1350
1340 PRINT TAB(1); I; TAB(5); WBS$(I); TAB(32); POH(I); TAB(39); GOH(I); TAB(46);
LOH(I); TAB(53); TOH(I); TAB(60); OOH(I); TAB(67); ROH(I)
1350 NEXT I
     COLOR 7
1360 PRINT : INPUT "ENTER NBR OF SUBSYSTEM TO BE CHANGED - 0 IF NONE"; NBR
1365 IF NBR > 33 THEN GOTO 1301
1370 IF NBR = 0 THEN GOTO 1393
1380 INPUT "ENTER NEW VALUES SEPARATED BY COMMAS"; D6$, D5$, D1$, D2$, D3$, D4$
     IF D6$ = "0" THEN POH(NBR) = 0 ELSE D6 = VAL(D6$)
     IF D5$ = "0" THEN GOH(NBR) = 0 ELSE D5 = VAL(D5$)
     IF D1$ = "0" THEN LOH(NBR) = 0 ELSE D1 = VAL(D1$)
     IF D2$ = "0" THEN TOH(NBR) = 0 ELSE D2 = VAL(D2$)
     IF D3$ = "0" THEN OOH(NBR) = 0 ELSE D3 = VAL(D3$)
     IF D4$ = "0" THEN ROH(NBR) = 0 ELSE D4 = VAL(D4$)
1381 IF D1 > 0 THEN LOH(NBR) = D1
1382 IF D2 > 0 THEN TOH(NBR) = D2
1383 IF D3 > 0 THEN OOH(NBR) = D3
1384 IF D4 > 0 THEN ROH(NBR) = D4
1385 IF D5 > 0 THEN GOH(NBR) = D5
     IF D6 > 0 THEN POH(NBR) = D6
1390 GOTO 1303
1393 IF IO = 1 THEN IO = 18: IE = 33: GOTO 1303
1397 RETURN
1399 '
1400 ' SUBSYSTEM WEIGHT DISPLAY
1401 IF X(16) = 0 THEN GOSUB 14200
1403 IO = 1: IE = 18
1405 WAV = 0: COLOR 7: CLS : PRINT TAB(20); "SUBSYSTEM WEIGHTS"
1410 PRINT TAB(3); "NBR  SUBSYSTEM"; TAB(45); "WEIGHT IN LBS"
     COLOR 5: PRINT TAB(10); "WEIGHT FACTOR IS CURRENTLY"; PWF: PRINT
1411 IF X(16) = 0 THEN ADD = X1: GOTO 1430
1412 ADD = 0: COLOR 11
1413 FOR I = 1 TO 33
1414 IF OP$(I) = "DELETE" THEN W(I) = 1: GOTO 1416
     W(I) = WF * W(I)
1415 ADD = ADD + W(I)
1416 NEXT I
     WF = 1
1417 X1 = ADD: X(1) = ADD
1430 COLOR 11
     FOR I = IO TO IE
1435 IF OP$(I) = "DELETE" THEN GOTO 1450
1440 PRINT TAB(3); I; TAB(10); WBS$(I); TAB(45); W(I)
1450 NEXT I
1455 IF IO = 19 THEN COLOR 14: PRINT : PRINT TAB(3); "TOTAL WGT"; TAB(45); ADD:
PRINT
     COLOR 7
1456 IF X(16) = 0 THEN PRINT : INPUT "ENTER RETURN.."; RET: GOTO 1493
```

```
1460 PRINT : INPUT "ENTER NBR OF SUBSYSTEM TO BE CHANGED - 0 IF NONE"; NBR
1465 IF NBR > 33 THEN GOTO 1405
1470 IF NBR = 0 THEN GOTO 1493
1480 INPUT "ENTER NEW WEIGHT"; W(NBR)
1490 GOTO 1405
1493 IF IO = 1 THEN IO = 19: IE = 33: GOTO 1405
1495 FOR I = 19 TO 24: WAV = WAV + W(I): NEXT I
1496 IF X(16) = 1 THEN CALL SECONDARY
     ANS$ = "N"
     IF X(16) = 1 OR X(16) = 2 THEN INPUT "CHANGE WEIGHT FACTOR-(Y/N)"; ANS$
     IF ANS$ = "Y" OR ANS$ = "y" THEN INPUT "ENTER NEW FACTOR"; WF: PWF = PWF *
WF: GOTO 1403
1497 RETURN
'
1500 'MODULE TO COMPUTE SUBSYSTEM WEIGHTS FROM PERCENTS
1520 TSM = 0
1530 FOR I = 1 TO 33
1540 IF OP$(I) = "DELETE" AND PWTS(I) > 0 THEN OP$(I) = "COMPUTE"
1545 IF PWTS(I) = 0 THEN OP$(I) = "DELETE"
1550 TSM = TSM + PWTS(I)
1560 NEXT I
     SUM = 0
     IF X(19) = 1 THEN FOR I = 20 TO 24: OP$(I) = "DELETE": SUM = SUM + PWTS(I):
PWTS(I) = 0: NEXT I: PWTS(19) = PWTS(19) + SUM
1570 FOR I = 1 TO 33
1575 'PWTS(I) = PWTS(I) / TSM
1580 W(I) = PWTS(I) * X1
1583 IF W(I) <= 0 THEN W(I) = 1
1585 NEXT I
1595 RETURN
1599 '
1600 'MODULE TO ESTABLISH MISSION PROFILE
1615 CLS : COLOR 7: KEY OFF
1630 NBR = 0
1635 LOCATE 3, 25: PRINT "MISSION PROFILE"
1640 LOCATE 7, 10: PRINT "NBR"; TAB(50); "TIME IN HOURS": COLOR 11
     LOCATE 9, 10: PRINT "1"; TAB(20); "GROUND RECOVERY/PROCESSING TIME";
TAB(55); T(5)
1645 LOCATE 11, 10: PRINT "2"; TAB(20); "PAD TIME"; TAB(55); T(0): COLOR 7
1650 LOCATE 13, 5: PRINT "LAUNCH TIME AT T=0": COLOR 11
1655 LOCATE 14, 10: PRINT "3"; TAB(20); "POWERED PHASE COMPLETION TIME"; TAB(55);
T(1)
1660 LOCATE 15, 10: PRINT "4"; TAB(20); "ORBIT INSERTION TIME"; TAB(55); T(2)
1665 LOCATE 16, 10: PRINT "5"; TAB(20); "ORBIT COMPLETION TIME"; TAB(55); T(3)
1670 LOCATE 17, 10: PRINT "6"; TAB(20); "REENTRY TIME"; TAB(55); T(4)
1675 PRINT : PRINT : COLOR 2
1680 INPUT "ENTER NUMBER TO BE CHANGED OR 0 IF NONE"; NBR
1685 IF NBR > 16 THEN GOTO 1615
     IF NBR = 1 THEN INPUT "ENTER NEW GROUND TIME"; T(5): GOTO 1615
1690 IF NBR > 1 THEN NBR = NBR - 2: INPUT "ENTER NEW TIME"; T(NBR): GOTO 1615
1692 INPUT "DO YOU WISH TO UPDATE SUBSYS OPERATING TIMES-Y/N"; AN$
1693 IF AN$ = "Y" OR AN$ = "y" THEN GOSUB 900
1697 RETURN
1699 '
1799 '
```


C-3

```
1800 'UPDATE/DISPLAY SHUTTLE PARAMETERS
1801 IO = 1: IE = 18
1805 COLOR 7: CLS : PRINT TAB(20); "SHUTTLE MTBM (HRS/FAILURE) VALUES"
1810 PRINT TAB(3); "NBR  SUBSYSTEM"; TAB(45); "MTBM"
1820 FOR I = IO TO IE
1825 IF OP$(I) = "DELETE" THEN GOTO 1835
1826 IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 11
     IF I = 9 THEN PRINT TAB(3); I; TAB(10); WBS$(I); TAB(45); SMA(I); "
MSN/FAILURE"
1830 IF I <> 9 THEN PRINT TAB(3); I; TAB(10); WBS$(I); TAB(45); SMA(I)
1835 NEXT I
1839 PRINT
1840 COLOR 12: PRINT "NOTE: indicates shuttle value currently in use": COLOR 7
1841 PRINT : INPUT "ENTER NBR OF SUBSYSTEM TO BE CHANGED - 0 IF NONE"; NBR
1845 IF NBR > 33 THEN GOTO 1805
1850 IF NBR = 0 THEN GOTO 1865
1855 INPUT "ENTER NEW MTBM"; SMA(NBR)
1860 GOTO 1805
1865 IF IO = 1 THEN IO = 19: IE = 33: GOTO 1805
1870 GOSUB 2600    'MTTR MENU
1898 RETURN
1899 '
1900 'COMPUTATIONAL SEQUENCING MODULE
1930 '
     CLS : COLOR 11: PRINT TAB(20); "COMPUTATION SELECTION MENU"
     LOCATE 8, 1
     PRINT TAB(25); "FACTOR"; TAB(50); "OPTION"
     PRINT
     PRINT TAB(15); "1.....CRITICAL FAILURE RATES"; TAB(50); CP$(1)
     PRINT TAB(15); "2.....REMOVAL RATES"; TAB(50); CP$(2)
     PRINT TAB(15); "3.....CREW SIZES"; TAB(50); CP$(3)
     PRINT TAB(15); "4.....PERCENT OFF-EQUIP"; TAB(50); CP$(4)
     PRINT TAB(15); "5.....SCHD MAINT PERCENT"; TAB(50); CP$(5)
     COLOR 12
     PRINT TAB(15); "6.....CANCEL REQUEST"
     PRINT : COLOR 2
     PRINT TAB(15); "RETURN.....PROCEED WITH COMPUTATION..."
     PRINT
     IF NBR = 6 THEN NBR = 0: RETURN
     COLOR 11: INPUT "ENTER NUMBER TO CHANGE"; NBR
     IF NBR > 5 OR NBR < 0 THEN GOTO 1930
     IF NBR = 0 THEN GOTO 1940
     IF CP$(NBR) = "RECOMPUTE" THEN CP$(NBR) = "DO NOT RECOMPUTE" ELSE CP$(NBR)
= "RECOMPUTE"
     GOTO 1930
1940 CLS : COLOR 12: LOCATE 12, 22: PRINT "COMPUTING R&M PARAMETERS..."
1941 WAV = 0
1942 FOR I = 19 TO 24: WAV = WAV + W(I): NEXT I
1945 'P1 = .202: P2 = .014: P3 = .784
     IF X(16) = 0 THEN GOSUB 1500
     IF X(16) = 0 OR X(16) = 1 THEN CALL SECONDARY
     IF CP$(3) = "RECOMPUTE" THEN GOSUB 12000 'COMPUTE CREW SIZES
1950 CALL EQS        'REGRESSION MTBF/MHMA  UNADJUSTED
     IF CP$(4) = "RECOMPUTE" THEN CALL POFFEQS 'COMPUTE POFF
1952 IF CP$(1) = "RECOMPUTE" THEN CALL ABORT            'CRITICAL FAILURE RATE
1953 IF CP$(2) = "RECOMPUTE" THEN CALL REMEQS'REMOVAL RATE
1955 GOSUB 2500   'TECH ADJUSTMENT
1960 CALL SPACEMTBM 'SPACE ADJUSTMENT
1965 GOSUB 2700   'CRITICAL FAILURES
1970 GOSUB 2800   'DETERMINE RELIABILITY
1975 CALL REDUNREL 'REDUNDANT RELIABILITY
1980 CALL MANPWR 'COMPUTE MANPOWER
```

```
1985 CALL SPARES 'COMPUTE SPARES
1990 RETURN
1999 '
2500 'TECHNOLOGY ADJUSTMENT MODULE
2510 Y = 0
2520 FOR I = 1 TO 33
2530 IF OP$(I) = "DELETE" THEN GOTO 2560
     IF SEL$(I) = "SHUTTLE" THEN XYZ = 1992 ELSE XYZ = 1986
2540 FMAT(I) = FMA(I) * (1 + TG(I)) ^ (YR - XYZ)
2550 Y = Y + 1 / FMAT(I)
2560 NEXT I
2570 TVFMA = 1 / Y
2580 RETURN
2600 'UPDATE/DISPLAY SHUTTLE PARAMETERS - MTTR
2601 IO = 1: IE = 18
2605 COLOR 7: CLS : PRINT TAB(20); "SHUTTLE MTTR VALUES"
2610 PRINT TAB(3); "NBR  SUBSYSTEM"; TAB(45); "MTTR"
2615 PRINT
2620 FOR I = IO TO IE
2625 IF OP$(I) = "DELETE" THEN GOTO 2635
2626 IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 11
2630 PRINT TAB(3); I; TAB(10); WBS$(I); TAB(45); SMR(I)
2635 NEXT I
2640 COLOR 12: PRINT "NOTE: indicates shuttle value currently in use": COLOR 7
2641 PRINT : INPUT "ENTER NBR OF SUBSYSTEM TO BE CHANGED - 0 IF NONE"; NBR
2645 IF NBR > 33 THEN GOTO 2605
2650 IF NBR = 0 THEN GOTO 2665
2655 INPUT "ENTER NEW MTTR"; SMR(NBR)
2660 GOTO 2605
2665 IF IO = 1 THEN IO = 19: IE = 33: GOTO 2605
     RETURN
UNSCH: CLS : COLOR 14
     LOCATE 5, 20: PRINT "SCHEDULED MAINTENANCE - OPTIONAL INPUT"
     PRINT : PRINT : COLOR 11
     PRINT TAB(5); "SCHEDULED MAINTENANCE IS"; 100 * SCHP; "% OF UNSCHEDULED
ON-VEHICLE MAINTENANCE"
     PRINT : PRINT TAB(5); "THIS HAS RESULTED IN"; SCHP * TOMH; " HOURS OF
SCHEDULED MAINTENANCE PER MSN"
     LOCATE 15, 20: INPUT "DO YOU WISH TO CHANGE THIS PERCENT-(Y/N)"; ANS$: COLOR
15
     IF ANS$ = "y" OR ANS$ = "Y" THEN LOCATE 17, 20: INPUT "ENTER NEW PERCENT";
SCHP ELSE GOTO 2698
     SCHP = SCHP / 100: CP$(5) = "DO NOT RECOMPUTE"
     PRINT : PRINT TAB(5); "NEW VALUE IS"; SCHP * TOMH; " HOURS OF SCHEDULED
MAINTENANCE"
     PRINT : PRINT : COLOR 2: INPUT "ENTER RETURN.."; RET
2698 RETURN
2699 '
2700 'DETERMINE CRITICAL FMA
2710 YY = 0
2720 FOR I = 1 TO 33
2730 IF OP$(I) = "DELETE" THEN GOTO 2760
2740 FMAC(I) = FMAS(I) / PA(I)
2750 YY = YY + 1 / FMAC(I)
2760 NEXT I
2770 CVFMA = 1 / YY
2780 RETURN
```

```
2800 'MODULE TO DETERMINE RELIABILITIES - CRITICAL FAILURES ONLY
2810 VR = 1
2820 FOR J = 1 TO 33
2830 T0 = GOH(J): T1 = T0 + LOH(J): T2 = T1 + TOH(J)
2840 T3 = T2 + OOH(J): T4 = T3 + ROH(J)
2850 IF OP$(J) = "DELETE" THEN R(J) = 1: GOTO 2890
2860 L1 = 1 / FMAC(J): L2 = LF * L1
2870 A = (B * T(2) ^ (B - 1) / L1) ^ (1 / B)
2880 R(J) = EXP(-L1 * (T2 + T0 - T1) - L2 * (T1 - T0) - (T3 / A) ^ B + (T2 / A)
^ B - L1 * (T4 - T3))
2890 VR = VR * R(J)
2895 NEXT J
2897 RETURN
2899 '
2900 'CLEAN UP DURING INITIALIZATION
2905 FOR I = 19 TO 24: WAV = WAV + W(I): NEXT I
2910 Y = SMA(1): TW = W(1) / (W(1) + W(2) + W(3)): FR = (1 / Y) * TW: SMA(1) =
1 / FR
2915 TW = W(2) / (W(1) + W(2) + W(3)): FR = (1 / Y) * TW: SMA(2) = 1 / FR
2920 TW = W(3) / (W(1) + W(2) + W(3)): FR = (1 / Y) * TW: SMA(3) = 1 / FR
2925 Y = SMA(4): TW = W(4) / (W(4) + W(5)): FR = (1 / Y) * TW: SMA(4) = 1 / FR
2930 TW = W(5) / (W(4) + W(5)): FR = (1 / Y) * TW: SMA(5) = 1 / FR
2940 'Y = SMA(9): TW = W(9) / (W(9) + W(18) + W(30) + W(32)): FR = (1 / Y) * TW:
SMA(9) = 1 / FR
     Y = SMA(32)
2945 TW = W(18) / (W(9) + W(18) + W(30) + W(32)): FR = (1 / Y) * TW: SMA(18) =
1 / FR
2950 TW = W(30) / (W(9) + W(18) + W(30) + W(32)): FR = (1 / Y) * TW + 1 /
SMA(30): SMA(30) = 1 / FR
2955 TW = W(32) / (W(9) + W(18) + W(30) + W(32)): FR = (1 / Y) * TW: SMA(32) =
1 / FR
     FOR I = 1 TO 33: PWTS(I) = PWT1(I): NEXT I ' reset weights from shuttle
2995 RETURN
2999 '
5699 '
5800 'DISPLAY MENU
5810 CLS : COLOR 11
5815 PRINT TAB(15); "NASA LRC - RELIABILITY/MAINTAINABILITY MODEL"; TAB(60);
VNAM$
5820 PRINT : PRINT TAB(25); "OUTPUT REPORT MENU": PRINT : COLOR 15
5830 PRINT TAB(15); "NBR"; TAB(35); "SELECTION": PRINT
5835 PRINT TAB(15); "1........RELIABILITY REPORT"
5840 PRINT TAB(15); "2........MAINTAINABILITY REPORT"
5850 PRINT TAB(15); "3........MANPOWER REQUIREMENTS"
5860 PRINT TAB(15); "4........SPARES REQUIREMENTS"
5870 PRINT TAB(15); "5........VEHICLE TURN TIME REPORT"
     PRINT TAB(15); "6........SYSTEM PERFORMANCE SUMMARY"
5880 PRINT TAB(15); "7........RETURN TO MAIN MENU"
     COLOR 2
5890 LOCATE 20, 20: INPUT "ENTER SELECTION"; NB3
5900 IF NB3 = 1 THEN CALL RELDISPLAY
5910 IF NB3 = 2 THEN CALL MAINTDIS
5920 IF NB3 = 3 THEN CALL MANDISPLAY
5930 IF NB3 = 4 THEN CALL SPAREDISPLAY
5940 IF NB3 = 5 THEN CALL TURNTIME
     IF NB3 = 6 THEN CALL SUMMARY
5950 IF NB3 = 7 THEN RETURN
5960 GOTO 5810
5990 RETURN
6999 '
7199 '
```

```
9500 'MODULE TO WRITE FHBMA TO A FILE
9510 CLS : COLOR 5
9520 'LOCATE 8, 20: INPUT "ENTER FILE NAME"; DNAM$
9530 OPEN VNAM$ + ".CST" FOR OUTPUT AS #1
     WRITE #1, VNAM$
9540 FOR I = 1 TO 33
9550 WRITE #1, S(I), MP(I)
9555 IL = I
9560 NEXT I
9561 WRITE #1, SMP
9565 PRINT : PRINT : PRINT TAB(5); "LAST RECORD WRITTEN TO "; VNAM$
9566 PRINT : PRINT S(IL), MP(IL), SMP
9570 CLOSE #1
9580 LOCATE 22, 10: INPUT "ENTER RETURN...."; RET
9590 RETURN
9599 '
1700 'MODULE TO READ FROM A FILE
1701 CLS : COLOR 10
1705 'INPUT "ENTER FILE NAME"; DNAM$
1707 LOCATE 5, 10: PRINT "INPUT DATA WILL BE READ FROM "; VNAM$; ".DAT"
1708 LOCATE 7, 10: INPUT "ENTER RETURN TO PROCEED OR A POSITIVE NBR TO ABORT";
RET
     IF RET > 1 THEN RETURN
1710 OPEN VNAM$ + ".DAT" FOR INPUT AS #3
     INPUT #3, VNAM$, SCHP, WING
1720 FOR I = 1 TO 33
1725 INPUT #3, WBS$(I), W(I), MW(I), CM(I), PWTS(I)
     INPUT #3, C(I), PF(I), PA(I), RR(I), CA(I)
1730 INPUT #3, POH(I), GOH(I), LOH(I), TOH(I), OOH(I), ROH(I)
1731 INPUT #3, OP$(I), TG(I), NRD(I), K(I), SEL$(I), SMA(I), SMR(I)
1735 NEXT I
1740 FOR I = 1 TO 12
1745 INPUT #3, SNAM$(I), V(I)
1750 NEXT I
1751 FOR I = 1 TO 20: INPUT #3, NAM$(I), X(I): NEXT I
1755 FOR I = 0 TO 5
1760 INPUT #3, T(I)
1765 NEXT I
     INPUT #3, ETREL, STE, ETS, TME, MTE
     FOR I = 1 TO 5
     INPUT #3, ETSUB$(I), ETMBA(I), ETHRS(I), ETABR(I), ETMTR(I), ETCREW(I)
     NEXT I
     INPUT #3, SRBREL, STF, SRBS, TMF, MTF
     FOR I = 1 TO 4
     INPUT #3, SRBSUB$(I), SRBMBA(I), SRBHRS(I), SRBABR(I), SRBMTR(I), SRBCREW(I)
     NEXT I
1770 CLOSE #3
1780 PRINT : PRINT TAB(10); "DATA SUCCESSFULLY READ"
     LOCATE 11, 10: INPUT "DO YOU WISH TO CHANGE VEHICLE/FILE NAME? - Y/N"; ANS$
     IF ANS$ = "Y" OR ANS$ = "y" THEN LOCATE 13, 10: INPUT "ENTER NEW NAME";
VNAM$
1785 RFLG = 1
     FOR I = 1 TO 6: CP$(I) = "DO NOT RECOMPUTE": NEXT I
     WF = 1: PWF = 1
1795 RETURN
```

```
9600 'MODULE TO WRITE INPUT DATA TO A FILE
9602 CLS : COLOR 3
9605 LOCATE 10, 10: PRINT "DATA WILL BE WRITTEN TO "; VNAM$; ".DAT"
     LOCATE 12, 10: INPUT "ENTER RETURN TO PROCEED OR A POSITIVE NBR TO ABORT";
RET
     IF RET >= 1 THEN RETURN
9610 OPEN VNAM$ + ".DAT" FOR OUTPUT AS #2
     WRITE #2, VNAM$, SCHP, WING
9615 FOR I = 1 TO 33
9620 WRITE #2, WBS$(I), W(I), MW(I), CM(I), PWTS(I)
     WRITE #2, C(I), PF(I), PA(I), RR(I), CA(I)
9621 WRITE #2, POH(I), GOH(I), LOH(I), TOH(I), OOH(I), ROH(I)
9622 WRITE #2, OP$(I), TG(I), NRD(I), K(I), SEL$(I), SMA(I), SMR(I)
9625 NEXT I
9630 FOR I = 1 TO 12
9635 WRITE #2, SNAM$(I), V(I)
9640 NEXT I
9642 FOR I = 1 TO 20: WRITE #2, NAM$(I), X(I): NEXT I
9645 FOR I = 0 TO 5
9650 WRITE #2, T(I)
9655 NEXT I
     WRITE #2, ETREL, STE, ETS, TME, MTE
     FOR I = 1 TO 5
     WRITE #2, ETSUB$(I), ETMBA(I), ETHRS(I), ETABR(I), ETMTR(I), ETCREW(I)
     NEXT I
     WRITE #2, SRBREL, STF, SRBS, TMF, MTF
     FOR I = 1 TO 4
     WRITE #2, SRBSUB$(I), SRBMBA(I), SRBHRS(I), SRBABR(I), SRBMTR(I), SRBCREW(I)
     NEXT I

9690 CLOSE #2
9695 RETURN

10000 'INPUT DATA
10005 DATA 1.00 WING GROUP,2.00 TAIL GROUP,3.00 BODY GROUP
10007 DATA 3.10 TANKS-LOX,3.20 TANKS-LH2,4.10 IEP-TILES,4.20 IEP-TCS
10008 DATA 4.30 IEP-PVD
10010 DATA 5.00 LANDING GEAR,6.00 PROPULSION-MAIN,7.00 PROPULSION-RCS
10020 DATA 8.00 PROPULSION-OMS,9.10 POWER-APU,9.20 POWER-BATTERY
10022 DATA 9.30 POWER-FUEL CELL,10.00 ELECTRICAL
10030 DATA 11.00 HYDRAULICS/PNEUMATICS,12.00 AERO SURF ACTUATORS
10033 DATA 13.10 AVIONICS-GN&C,13.20 AV-HEALTH MONITOR
10034 DATA 13.30 AVIONICS-COMM & TRACK,13.40 AV-DISPLAYS & CONTR
10035 DATA 13.50 AVIONICS-INSTRUMENTS,13.60 AVIONICS-DATA PROC
10040 DATA 14.10 ENVIRONMENTAL CONTROL,14.20 ECS-LIFE SUPPORT
10050 DATA 15.00 PERSONNEL PROVISIONS, 16.10 REC & AUX-PARACHUTES
10055 DATA 16.20 REC & AUX-ESCAPE SYS,16.30 REC&AUX-SEPARATION
10056 DATA 16.40 REC&AUX-CROSS FEED
10060 DATA 16.50 REC & AUX DOCKING SYS,16.60 REC&AUX MANIPULATOR
10150 DATA DRY WGT (LBS),LENGTH (FT),CREW SIZE,NBR PASSENGERS
10152 DATA NBR MAIN ENGINES, ADJ SHUTTLE MTBM-SPACE 0-NO 1-YES,TECHNOLOGY YR
10155 DATA DEFAULT ABORT RATE, WIEBULL SHAPE PARAMETER
10160 DATA LAUNCH FACTOR,AVAIL MANHRS/MONTH,PERCENT INDIRECT WORK
10170 DATA SPARE FILL RATE OBJ,AVG CREW SIZE-SCHD MAINT,PLANNED MISSIONS/MONTH
10180 DATA MODE INDICATOR,VEHICLE INTEGRATION TIME (HRS),LAUNCH PAD TIME (HRS)
      DATA AGGREGATE AVIONICS 0-NO/1-YES,DEFAULT PERCENT OFF MANHRS
11699 '
11700 DATA FUSELAGE AREA,FUSELAGE VOLUME,WETTED AREA
11710 DATA NBR WHEELS,NBR ACTUATORS,NBR CONTR SURFACES,KVA MAX
11720 DATA NBR HYDR SUBSYS,NBR FUEL TANKS (INTERNAL)
11730 DATA TOT NBR AVIONICS SUBSYS
11740 DATA NBR DIFF AVIONICS SUBSYS,BTU COOLING
```

```
11750 'TECH GROWTH RATES
11760 DATA .082,.082,.082,0,0,.082,.082,.082,.033,.011,.011,.011
11765 DATA .056,.056,.056,0,.092,.056
11770 DATA .22,.22,.22,.22,.22,.22,.0062,.0062,.036,.083,.083,.083,.083,.083
11775 DATA .083
11780 'WGT DISTRIBUTION PERCENTAGES-LARGE VEHICLE
11790 DATA .081,.003,.174,.054,.114,0,.143,.008,.043,.208,.018,.019
11791 DATA 0,.001,.007,.035
11792 DATA 0,.007,.003,0,.004,.005,.003,.003,.016,.005,.008
11793 DATA .014,.012,.005,.007,0,0
11794 'WGT DISTR - SHUTTLE
11795 DATA .1,.017,.277,.015,.017,.133,.02,.011,.04,.131,.02,.019,.006,0
11796 DATA .007,.065,.012,.018,.006,0,.01,.013,.004,.008,.013,.02,.012,0
11797 DATA 0,.006,0,0,0
'  WGT DISTRIBUTION - SMALL VEHICLE
DATA .096,.004,.114,.018,.018,0,.109,0,.064,0,.017,.017,.116,.018,.014,.063
DATA 0,.009,.016,.008,.011,.007,0,.027,.038,.045,.074,.08,.001,.01,0,.006,0
11810 'SHUTTLE MTBM'S    MAINT ACTIONS
11820 DATA .96,.96,.96,8.31,8.31,.129,3.69,64.3,9999,7.02,13.06,40.31
11825 DATA 7.43,9999,30.07,17.4,5.62,9999,34.41,9999,66.22,34.52,47.2
11826 DATA 9999,24.47,9999,7.2,9999,9999,15.6,9999,4.85,9999
11830 ' SHUTTLE MTTR VALUES
      DATA14.5,14.5,14.5,5.47,5.47,11.46,20.15,5.63,12.12,4.02,10.19,8.62,4.37
11850 DATA 0,16.3,6.41,3.13,12.12,9.91,0,10.88,13.37,4.76,0,9.9,9.9,8.3,0
11860 DATA 0,7.48,0,12.12,0
      ' SHUTTLE REMOVAL RATES
     DATA.143,.143,.143,.216,.216,.0073,.481,.391,.219,0,.159,.303,.443,0,.261
     DATA .088,.305,.219,.392,0,.333,.466,.482,0,.293,.293,.174,0,0,.257,0,.219,0
 'ET PARAMETERS
     DATA ELECTRICAL,20.42,72,.001,13.68,4.5
     DATA PROP-FLUIDS,4,72,.001,18,4.5
     DATA RANGE SAFETY,44.77,72,.001,64.65,4.5
     DATA STRUCTURES,.0354,1,.001,6.83,4.5
     DATA THERMAL-TPS,.0219,1,.001,1.55,4.5
 'SRB PARAMETERS
     DATA ELECTRICAL,35.21,669,.001,1,4.5
     DATA PROPULSION,70,677,.001,1,4.5
     DATA RANGE SAFETY,102,677,.001,1 ,4.5
     DATA STRUCTURES,75,667,.001,1,4.5

12000 'CREW SIZE CALCULATIONS
12110 C(1) = 1.5 - .000032 * V(3) + .009172 * SQR(V(3))
12120 C(2) = C(1): C(3) = C(1): C(4) = C(1): C(5) = C(1): C(6) = C(1): C(7) =
C(1): C(8) = C(1)
12130 C(18) = C(1): C(9) = C(1)
12140 C(10) = 2.43: C(11) = 2.43: C(12) = 2.43
12150 C(13) = 2.43: C(14) = 2.43: C(15) = 2.43
12160 C(16) = -1.48 - .002833 * X2 + .814656 * LOG(X2)
12170 C(17) = C(16): C(25) = C(16): C(26) = C(16)
12180 C(19) = 2.18: C(20) = C(19): C(21) = C(19): C(22) = C(19): C(23) = C(19):
C(24) = C(19)
12190 C(28) = 1.7893 + .0009872 * SQR(X1)
12195 C(27) = (C(16) + C(28)) / 2
12196 C(29) = C(28): C(30) = C(28): C(31) = C(28): C(32) = C(28): C(33) = C(28)
      TFC = 1
      FOR I = 1 TO 33
      IF I = 13 OR I = 23 OR I = 25 OR I = 26 OR I = 10 OR I = 11 OR I = 17 OR
I = 4 OR I = 5 OR I = 30 THEN TFC = 2
      IF SEL$(I) = "SHUTTLE" THEN C(I) = TFC * 4.5
      TFC = 1
      NEXT I
12198 RETURN
```

```
12199 '
11000 COLOR 7: CLS : PRINT : PRINT TAB(5); "SECONDARY INDEP VARIABLES": PRINT
11010 PRINT TAB(10); "NBR"; TAB(20); "VARIABLE"; TAB(45); "CURRENT VALUE"
11020 PRINT : PRINT : COLOR 11
11030 IF V(8) = 1 THEN V(8) = 0
11040 FOR I = 1 TO 12
11050 PRINT TAB(10); I; TAB(20); SNAM$(I); TAB(45); V(I)
11060 NEXT I
11061 PRINT : COLOR 7
11065 IF X(16) = 0 OR X(16) = 1 THEN INPUT "ENTER RETURN..."; RET: GOTO 11100
11070 PRINT : INPUT "ENTER NBR OF VARIABLE TO BE CHANGED - 0 IF NONE"; NBR
11075 IF NBR > 16 THEN GOTO 11000
11080 IF NBR <> 0 THEN INPUT "ENTER NEW VALUE"; V(NBR): GOTO 11000
11100 IF V(8) = 0 THEN V(8) = 1
11110 RETURN
11119 '

12200 'MODULE TO INPUT MOD FACTOR FOR MAINTENANCE
12201 IO = 1: IE = 18
12202 COLOR 7
12205 CLS : PRINT TAB(20); "SUBSYSTEM MH/MA CALIBRATION FACTOR"
12206 PRINT TAB(20); "CAL MH/MA = CAL FAC x COMPUTED-MH/MA": COLOR 11
12210 PRINT TAB(3); "NBR  SUBSYSTEM"; TAB(45); "CAL FACTOR"
12220 PRINT
12230 FOR I = IO TO IE
      IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 11
12235 IF OP$(I) = "DELETE" THEN GOTO 12250
12240 PRINT TAB(3); I; TAB(10); WBS$(I); TAB(45); CM(I)
12250 NEXT I
      COLOR 7
12260 PRINT : INPUT "ENTER NBR OF SUBSYSTEM TO BE CHANGED - 0 IF NONE"; NBR
12270 IF NBR = 0 THEN GOTO 12293
12280 INPUT "ENTER NEW FACTOR"; CM(NBR)
12290 GOTO 12205
12293 IF IO = 1 THEN IO = 19: IE = 33: GOTO 12202
12295 RETURN
12300 ' MENU TO DELETE A SUBSYSTEM
12301 IO = 1: IE = 18
12305 CLS : PRINT TAB(20); "OPTION TO DELETE/RESTORE A SUBSYSTEM": PRINT
12310 PRINT TAB(3); "NBR  SUBSYSTEM"; TAB(45); "OPTION"
12320 PRINT
12330 FOR I = IO TO IE
12335 IF OP$(I) = "DELETE" THEN COLOR 4 ELSE COLOR 3
12340 PRINT TAB(3); I; TAB(10); WBS$(I); TAB(45); OP$(I)
12350 NEXT I
      COLOR 7
12360 PRINT : INPUT "ENTER NBR OF SUBSYSTEM TO BE CHANGED - 0 IF NONE"; NBR
12365 IF NBR > 33 THEN GOTO 12305
12370 IF NBR <= 0 THEN GOTO 12393
12380 IF OP$(NBR) = "COMPUTE" THEN OP$(NBR) = "DELETE": GOTO 12305
12385 IF OP$(NBR) = "DELETE" THEN OP$(NBR) = "COMPUTE"
12390 GOTO 12305
12393 IF IO = 1 THEN IO = 19: IE = 33: GOTO 12305
      INPUT "DO YOU WISH TO CHANGE A SUBSYSTEM NAME"; ANS$
      IF ANS$ = "Y" OR ANS$ = "y" THEN GOTO BO
      RETURN
```

```
B0:    IO = 1: IE = 18
B1:    CLS : PRINT TAB(20); "OPTION TO CHANGE SUBSYSTEM NAME": PRINT
       PRINT TAB(3); "NBR  SUBSYSTEM"; TAB(45); "SELECTION"
       PRINT
       FOR I = IO TO IE
       IF OP$(I) = "DELETE" THEN COLOR 4 ELSE COLOR 3
       PRINT TAB(3); I; TAB(10); WBS$(I); TAB(45); OP$(I)
       NEXT I
       COLOR 7
       PRINT : INPUT "ENTER NBR OF SUBSYSTEM FOR NAME CHANGE-0 IF NONE"; NBR
       IF NBR > 33 THEN GOTO B1
       IF NBR = 0 THEN GOTO B2
       INPUT "ENTER NEW WBS/NAME"; WBS$(NBR)
       GOTO B1
B2:    IF IO = 1 THEN IO = 19: IE = 33: GOTO B1
       RETURN

12400 ' MENU TO DEFAULT ON TECH GROWTH FACTOR
12401 IO = 1: IE = 18
12403 COLOR 7
12405 CLS : PRINT TAB(25); "OPTION TO CHANGE ANNUAL"
12406 PRINT TAB(20); "TECHNOLOGY GROWTH FACTOR": PRINT
12410 PRINT TAB(3); "NBR  SUBSYSTEM"; TAB(45); "ANNUAL GROWTH RATE"
12430 FOR I = IO TO IE
12435 IF OP$(I) = "DELETE" THEN GOTO 12450
      IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 11
12440 PRINT TAB(3); I; TAB(10); WBS$(I); TAB(45); TG(I)
12450 NEXT I
      COLOR 7
12460 PRINT : INPUT "ENTER NBR OF SUBSYSTEM TO BE CHANGED - 0 IF NONE"; NBR
12465 IF NBR > 33 THEN GOTO 12405
12470 IF NBR = 0 THEN GOTO 12493
12480 INPUT "ENTER NEW FACTOR"; TG(NBR)
12490 GOTO 12405
12493 IF IO = 1 THEN IO = 19: IE = 33: GOTO 12403
12497 RETURN
12500 'COMPUTATIONAL FACTORS MENU
12510 CLS : COLOR 14
12520 PRINT TAB(15); "COMPUTATIONAL FACTORS MENU "; TAB(60); VNAM$
12530 PRINT
12540 PRINT TAB(15); "NBR"; TAB(35); "SELECTION": PRINT
12550 COLOR 3
12560 PRINT TAB(15); "1........TECHNOLOGY GROWTH FACTOR"
12570 PRINT TAB(15); "2........CRITICAL FAILURE (2) RATES"
12580 PRINT TAB(15); "3........SUBSYSTEM REMOVAL RATES "
12585 PRINT TAB(15); "4........MTBM/MTTR CALIBRATION   "
12590 PRINT TAB(15); "5........CREW SIZES  "
      PRINT TAB(15); "6........PERCENT OFF-EQUIP"
12595 PRINT TAB(15); "7........RETURN TO INPUT MENU"
12600 LOCATE 22, 20: INPUT "ENTER SELECTION"; NB7
12610 IF NB7 = 1 THEN GOSUB 12400
12620 IF NB7 = 2 THEN GOSUB 12700
12630 IF NB7 = 3 THEN GOSUB 12800
12640 IF NB7 = 4 THEN GOSUB 1200
12645 IF NB7 = 5 THEN GOSUB 13800
      IF NB7 = 6 THEN GOSUB PCTOFF
12650 IF NB7 = 7 THEN RETURN
12660 GOTO 12500
```

```
12700 'CRITICAL FAILURE RATE DISPLAY/UPDATE
12701 IO = 1: IE = 18
12703 COLOR 7
12705 CLS : PRINT TAB(25); "OPTION TO CHANGE"
12706 PRINT TAB(20); "CRITICAL FAILURE RATE": PRINT
12710 PRINT TAB(3); "NBR  SUBSYSTEM"; TAB(45); "CRITICAL FAILURE RATE"
12730 FOR I = IO TO IE
12735 IF OP$(I) = "DELETE" THEN GOTO 12750
      IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 11
12740 PRINT TAB(3); I; TAB(10); WBS$(I); TAB(45); PA(I)
12750 NEXT I
      COLOR 7
12760 PRINT : INPUT "ENTER NBR OF SUBSYSTEM TO BE CHANGED - 0 IF NONE"; NBR
12765 IF NBR > 33 THEN GOTO 12705
12770 IF NBR = 0 THEN GOTO 12793
12780 INPUT "ENTER NEW RATE"; PA(NBR)
      CP$(1) = "DO NOT RECOMPUTE"
12790 GOTO 12705
12793 IF IO = 1 THEN IO = 19: IE = 33: GOTO 12703
12797 RETURN
12799 '
12800 'REMOVAL RATE DISPLAY/UPDATE
12801 IO = 1: IE = 18
12803 COLOR 7
12805 CLS : PRINT TAB(25); "OPTION TO CHANGE"
12806 PRINT TAB(20); "REMOVAL RATE": PRINT
12810 PRINT TAB(3); "NBR  SUBSYSTEM"; TAB(45); "REMOVAL RATE"
12830 FOR I = IO TO IE
12835 IF OP$(I) = "DELETE" THEN GOTO 12850
      IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 11
12840 PRINT TAB(3); I; TAB(10); WBS$(I); TAB(45); RR(I)
12850 NEXT I
      COLOR 7
12860 PRINT : INPUT "ENTER NBR OF SUBSYSTEM TO BE CHANGED - 0 IF NONE"; NBR
12865 IF NBR > 33 THEN GOTO 12805
12870 IF NBR = 0 THEN GOTO 12893
12880 INPUT "ENTER NEW RATE"; RR(NBR)
      CP$(2) = "DO NOT RECOMPUTE"
12890 GOTO 12805
12893 IF IO = 1 THEN IO = 19: IE = 33: GOTO 12803
12897 RETURN
12899 '
PCTOFF: 'PERCENT OFF EQUIPMENT DISPLAY/UPDATE
      IO = 1: IE = 18
      COLOR 7
BACK1: CLS : PRINT TAB(25); "OPTION TO CHANGE"
      PRINT TAB(20); "PERCENT OFF EQUIP": PRINT
      PRINT TAB(3); "NBR  SUBSYSTEM"; TAB(45); "PERCENT OFF-EQUIP"
FOR I = IO TO IE
      IF OP$(I) = "DELETE" THEN GOTO SKIP1
      IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 11
      PRINT TAB(3); I; TAB(10); WBS$(I); TAB(45); PF(I)
SKIP1: NEXT I
      COLOR 7
      PRINT : INPUT "ENTER NBR OF SUBSYSTEM TO BE CHANGED - 0 IF NONE"; NBR
      IF NBR > 33 THEN GOTO PCTOFF
      IF NBR = 0 THEN GOTO SKIP2
      INPUT "ENTER NEW PERCENT"; PF(NBR)
      CP$(4) = "DO NOT RECOMPUTE"
      GOTO BACK1
SKIP2: IF IO = 1 THEN IO = 19: IE = 33: GOTO BACK1
      RETURN
```

```
13000 'RELIABILITY MODULE WITH REDUNDANCY
13001 IO = 1: IE = 18
13005 COLOR 7: CLS : PRINT TAB(25); "SUBSYSTEM REDUNDANCY ": PRINT
13010 PRINT TAB(1); "NBR"; TAB(5); "WBS"; TAB(40); "NBR REDUNDANT SUBSYS";
TAB(65); "MIN NBR RQD"
13030 FOR I = IO TO IE
13040 IF OP$(I) = "DELETE" THEN GOTO 13090
13050 IF (I >= 10 AND I <= 15) OR (I >= 19 AND I <= 24) THEN COLOR 14
13060 IF (I >= 10 AND I <= 15) OR (I >= 19 AND I <= 24) THEN PRINT TAB(1); I;
TAB(5); WBS$(I); TAB(40); NRD(I); TAB(65); K(I): GOTO 13090
13070 COLOR 11
13080 PRINT TAB(1); I; TAB(5); WBS$(I); TAB(40); NRD(I)
13090 NEXT I
      COLOR 7
13100 PRINT : INPUT "ENTER NBR OF SUBSYS TO BE CHANGED - 0 IF NONE"; NBR
13110 IF NBR = 0 THEN GOTO 13173
13120 INPUT "ENTER NBR REDUNDANT SUBSYSTEMS- "; NRD(NBR)
13140 IF NRD(NBR) > 0 AND (NBR = 10 OR NBR = 11 OR NBR = 12) THEN INPUT "ENTER
MIN NBR TO OPERATE"; K(NBR)
13150 IF NRD(NBR) > 0 AND (NBR = 13 OR NBR = 14 OR NBR = 15) THEN INPUT "ENTER
MIN NBR TO OPERATE"; K(NBR)
13160 IF NRD(NBR) > 0 AND NBR >= 19 AND NBR <= 24 THEN INPUT "ENTER MIN NBR TO
OPERATE"; K(NBR)
13170 GOTO 13005
13173 IF IO = 1 THEN IO = 19: IE = 33: GOTO 13005
13177 RETURN
13179 '
13799 '
13800 'DISPLAY/UPDATE SCREEN FOR CREW SIZES
13801 IO = 1: IE = 18
13803 COLOR 7
13805 CLS : PRINT TAB(20); "OPTION TO CHANGE CREW SIZES & ASSIGNED CREWS": PRINT
13810 PRINT TAB(3); "NBR  SUBSYSTEM"; TAB(40); "CREW SIZE"; TAB(52); "NBR CREWS
ASSIGNED"
13830 FOR I = IO TO IE
13835 IF OP$(I) = "DELETE" THEN GOTO 13850
      IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 11
13840 PRINT TAB(3); I; TAB(10); WBS$(I); TAB(40); C(I); TAB(55); CA(I)
13850 NEXT I
      COLOR 7
13860 PRINT : INPUT "ENTER NBR OF SUBSYSTEM TO BE CHANGED - 0 IF NONE"; NBR
13865 IF NBR > 33 THEN GOTO 13805
13870 IF NBR = 0 THEN GOTO 13893
13880 INPUT "ENTER NEW CREW SIZE & NBR CREWS ASSIGNED"; C(NBR), CA(NBR)
      IF CA(NBR) = 0 THEN CA(NBR) = 1
      CP$(3) = "DO NOT RECOMPUTE"
13890 GOTO 13805
13893 IF IO = 1 THEN IO = 19: IE = 33: GOTO 13803
13897 RETURN
13899 '
13999 '
14000 'SHUTTLE DATA MODULE
14005 IO = 1: IE = 18
```

```
14105 ' MENU TO SELECT MTBM OPTION
14106 CLS : COLOR 7: PRINT TAB(20); "OPTION TO SELECT AIRCRAFT VS SHUTTLE MTBM":
PRINT
14110 PRINT TAB(3); "NBR  SUBSYSTEM"; TAB(45); "OPTION"
14130 FOR I = IO TO IE
14135 IF OP$(I) = "DELETE" THEN GOTO 14150
14136 IF SEL$(I) = "SHUTTLE" THEN COLOR 4 ELSE COLOR 3
14137 IF I = 6 OR I = 7 OR I = 8 OR I = 15 OR I = 31 OR I = 32 OR I = 33 THEN
TNM$ = "SHUTTLE ONLY" ELSE TNM$ = SEL$(I)
14140 PRINT TAB(3); I; TAB(10); WBS$(I); TAB(45); TNM$
14150 NEXT I
14155 COLOR 7
14160 PRINT : INPUT "ENTER NBR OF SUBSYSTEM TO BE CHANGED - 0 IF NONE"; NBR
14165 IF NBR > 33 THEN GOTO 14106
14166 IF NBR = 6 OR NBR = 7 OR NBR = 8 OR NBR = 15 OR NBR = 31 OR NBR = 32 OR NBR
= 33 THEN GOTO 14106
14170 IF NBR = 0 THEN GOTO 14192
14180 IF SEL$(NBR) = "SHUTTLE" THEN SEL$(NBR) = "AIRCRAFT": GOTO 14106
14185 IF SEL$(NBR) = "AIRCRAFT" THEN SEL$(NBR) = "SHUTTLE"
14190 GOTO 14106
14192 IF IO = 1 THEN IO = 19: IE = 33: GOTO 14106
14193 COLOR 7
14195 RETURN
14199 '
14200 ' UPDATE DISPLAY WEIGHT PERCENTS
14202 GOSUB 14300
 IF WGTF = 1 THEN FOR I = 1 TO 33: PWTS(I) = PWT1(I): NEXT I
 IF WGTF = 2 THEN FOR I = 1 TO 33: PWTS(I) = PWT2(I): NEXT I
 IF WGTF = 3 THEN FOR I = 1 TO 33: PWTS(I) = PWT3(I): NEXT I
 IF WGTF = 4 THEN CALL ACWGT
 IF WGTF = 4 THEN FOR I = 1 TO 33: PWTS(I) = PWT4(I): NEXT I
14204 IO = 1: IE = 18
14205 CLS : COLOR 7: PRINT TAB(25); "WEIGHT PERCENTAGES "
14206 PRINT TAB(20); "PRECONCEPTUAL MODE ONLY": PRINT : COLOR 11
      IF WGTF = 0 THEN PRINT TAB(40); "CURRENT DISTRIBUTION"
14207 IF WGTF = 1 THEN PRINT TAB(40); "DISTR BASED ON LARGE VEHICLE WGTS"
14208 IF WGTF = 2 THEN PRINT TAB(40); "DISTR BASED ON SHUTTLE WEIGHTS"
14209 IF WGTF = 3 THEN PRINT TAB(40); "DISTR BASED ON SMALL VEHICLE WGTS"
      IF WGTF = 4 THEN PRINT TAB(40); "DISTR BASED ON AIRCRAFT WGTS"
14210 PRINT TAB(3); "NBR  SUBSYSTEM"; TAB(45); "PCT OF TOT DRY WGT"
14214 TPCT = 0
14215 FOR I = 1 TO 33
      TPCT = TPCT + 100 * PWTS(I)
      NEXT I
14230 FOR I = IO TO IE
14235 ' IF OP$(I) = "DELETE" THEN GOTO 14250
      IF X(19) = 1 AND I > 19 AND I < 25 THEN GOTO 14250
14236 COLOR 3
14237 TEMP = CINT(1000 * PWTS(I)): TEMP = TEMP / 10
14240 PRINT TAB(3); I; TAB(10); WBS$(I); TAB(45); TEMP
14250 NEXT I
14255 IF IO = 19 THEN COLOR 14: PRINT : PRINT TAB(40); "TOT="; TPCT
      COLOR 7
14260 PRINT : INPUT "ENTER NBR OF SUBSYSTEM TO BE CHANGED - 0 IF NONE"; NBR
14265 IF NBR > 33 THEN GOTO 14205
14270 IF NBR = 0 THEN GOTO 14290
14280 INPUT "ENTER NEW PERCENT"; PWTS(NBR)
14285 PWTS(NBR) = PWTS(NBR) / 100: GOTO 14205
14290 IF IO = 1 THEN IO = 19: IE = 33: GOTO 14205
      IF IO = 19 AND TPCT < 99.9 THEN COLOR 13: PRINT : INPUT "PERCENTS MUST SUM
TO 100"; RET: GOTO 14204
      IF IO = 19 AND TPCT > 100.1 THEN COLOR 13: PRINT : INPUT "PERCENTS MUST SUM
```

```
TO 100"; RET: GOTO 14204
14293 GOSUB 1500
14295 RETURN

14300 'SELECT WEIGHT DISTRIBUTION
14310 CLS : COLOR 7
14320 LOCATE 5, 20: PRINT "SELECT WEIGHT DISTRIBUTION": PRINT : COLOR 11
14330 PRINT TAB(15); "1 - LARGE VEHICLE DISTR": PRINT
14350 PRINT TAB(15); "2 - SHUTTLE WGT DISTR": PRINT
14360 PRINT TAB(15); "3 - SMALL VEHICLE DISTR": PRINT
      PRINT TAB(15); "4-  AIRCRAFT WGT DISTR": PRINT
      COLOR 13
      PRINT TAB(15); "RETURN - MAINTAIN CURRENT DISTRIBUTION": PRINT
      COLOR 7
14370 PRINT : INPUT "SELECT DISTRIBUTION...."; WGTF
14380 IF WGTF < 0 OR WGTF > 4 THEN GOTO 14310
14390 RETURN

SUB ABORT
14500 'ABORT RATE CALCULATIONS
14505 FOR I = 1 TO 33: PA(I) = X(8): NEXT I'  SET DEFAULT ABORT RATE

'  WBS 1,2,3  STRUCTURES ****
14510 AB11 = .031213 + 1.956E-07 * X1 - 1.5456E-04 * SQR(X1)
14511 IF AB11 <= 0 THEN AB11 = .00128
14512 IF AB11 > .02065 THEN AB11 = .02065
14513 PA(1) = AB11: PA(2) = AB11
14520 AB12 = .04232 + 3.8775E-07 * X1 - 2.51883E-04 * SQR(X1)
14521 IF AB12 > .02 THEN AB12 = .02
      IF AB12 < 0 THEN AB12 = 0
14522 PA(3) = (AB11 / FMA11 + AB12 / FMA12) / (1 / FMA11 + 1 / FMA12)

'  WBS 5 LANDING GEAR ****
14530 AB13 = -2.4321 + .0059112 * X2 + 1.1457 * LOG(X2) - .33925 * SQR(X2)
14531 IF AB13 < 0 THEN PA(9) = .00185 ELSE PA(9) = AB13
14532 IF PA(9) > .08 THEN PA(9) = .08

'  ENGINES****
14630 FOR I = 10 TO 12
14631 PA(I) = .048164 - .0001268 * X2
14632 IF PA(I) < .0013 THEN PA(I) = .0013
14633 NEXT I

' WBS 9.10  APU ****
      PA(13) = .064

' WBS 10.00 ELECTRICAL ****
14580 PA(16) = -39.95984 + 11.09214 * LOG(X1) - 1.0178226# * LOG(X1) ^ 2 +
.0309075 * LOG(X1) ^ 3
14581 IF PA(16) <= 0 THEN PA(16) = .00248
14582 IF PA(16) > .142 THEN PA(16) = .142

' WBS 11.00 HYDRAULICS ****
14600 PA(17) = 5000.2535# - 7578.183 / SQR(LOG(X1)) - 453.612 * LOG(X1) + 24.6005
* LOG(X1) ^ 2 - .5276227 * LOG(X1) ^ 3
14601 IF PA(17) <= 0 THEN PA(17) = .00084
14602 IF PA(17) > .1304 THEN PA(17) = .1304

' WBS 12.00 ACTUATORS ****
14540 AB14 = .711953 - .1881388 * LOG(X2) + .0209882 * SQR(X2)
14541 IF AB14 < 0 THEN PA(18) = 6.000001E-04 ELSE PA(18) = AB14
14542 IF PA(18) > .08128 THEN PA(18) = .08128
```

```
'   AVIONICS  GENERIC
14610 PAG = .0502749 + 2.605132E-07 * X1 - 2.288197E-04 * SQR(X1)
14611 IF PAG < 0 THEN PAG = .00152
14612 IF PAG > .02376 THEN PAG = .02376
      FOR I = 19 TO 24: PA(I) = PAG: NEXT I
14615 IF X(19) = 0 THEN PA(19) = .01: PA(21) = .011: PA(23) = .015:
' WBS 14.XX  ENVIRONMENTAL ****
14570 PA(25) = .082199 + 5.0072E-07 * X1 - 4.0612E-04 * SQR(X1)
14571 IF PA(25) < 0 THEN PA(25) = .00152
14572 IF PA(25) > .05222 THEN PA(25) = .05222
14573 PA(26) = PA(25)
' WBS 15.00 PERSONNEL PROVISIONS ****
14620 PA(27) = .0185
      '  ET/SRB ABORT RATES
      FOR I = 1 TO 5: ETABR(I) = X(8): SRBABR(I) = X(8): NEXT I
END SUB

SUB ACWGT
     ' MODULE TO COMPUTE SUBSYSTEM WEIGHTS - ACFT EQS
     SUM = 0
     FOR I = 1 TO 33: W(I) = 0: NEXT I
     W(1) = -4485026.7# + 1351022.5# * LOG(X1) - 135432! * (LOG(X1)) ^ 2 + 4522.4
* (LOG(X1)) ^ 3
     IF W(1) <= 0 THEN W(1) = 795
     W(2) = -290909.9 + 91929.4 * LOG(X1) - 9709.901 * (LOG(X1)) ^ 2 + 343.5 *
(LOG(X1)) ^ 3
     IF W(2) <= 0 THEN W(2) = 302
     W(3) = 39713145.2# + 1417950.4# * LOG(X1) - 40472209# / SQR(LOG(X1)) -
12993808.8# * SQR(LOG(X1))
     IF W(3) <= 0 THEN W(3) = 2140
     W(9) = -49535! + .282563 * X1 + 6873.7 * LOG(X1) - 160.1 * SQR(X1)
     IF W(9) <= 0 THEN W(9) = 527
     W(18) = -9849.5 + .0459666 * X1 + 1364.8 * LOG(X1) - 26.248 * SQR(X1)
     IF W(18) <= 0 THEN W(18) = 100
     W(13) = -910.4 + 100.22 * LOG(X1) + 1.3835 * SQR(X1)
     IF W(13) <= 0 THEN W(13) = 157
     W(25) = -719.15 + 5.56265 * X2 + 56.882 * SQR(X2)
     IF W(25) <= 0 THEN W(25) = 63
     W(26) = W(25) / 2: W(25) = W(25) / 2
     W(16) = -757.97 + 11.222 * SQR(X1)
     IF W(16) <= 0 THEN W(16) = 310
     W(17) = 575.27 + .022216 * X1 - 5.0608 * SQR(X1)
     IF W(17) <= 0 THEN W(17) = 147
     W(27) = 66255.6 - 14720.4 * LOG(X1) + 818.19 * (LOG(X1)) ^ 2
     IF W(27) <= 0 THEN W(27) = 284
     AV = -10901.5 + 1261.52 * LOG(X1)
     IF AV <= 0 THEN AV = 303
     FOR I = 19 TO 24: W(I) = AV / 6: NEXT I
     ' W(4) = .11 * X1: W(6) = .01 * X1: W(7) = .04 * X1: W(8) = .02 * X1: W(16)
= .1 * X1
     W(10) = -7141.92 + 89.1053 * SQR(X1)
     FOR I = 1 TO 33
     SUM = SUM + W(I)
     NEXT I
     FOR I = 1 TO 33
     PWT4(I) = W(I) / SUM
     'IF W(I) = 0 THEN OP$(I) = "DELETE" ELSE OP$(I) = "COMPUTE"
     NEXT I
END SUB
```

```
SUB BOOSTER
6000 ' ET/ BOOSTER ROCKET MODULE
6010 CLS : COLOR 7
6020 PRINT TAB(20); "EXTERNAL FUEL TANK INPUT DATA"
6030 PRINT : COLOR 11
6035 PRINT TAB(1); "NBR"; TAB(5); "SUBSYSTEM"; TAB(18); "MTBM"; TAB(26); "OPER
HRS"; TAB(36); "CRIT FAIL RT"; TAB(50); "MTTR"; TAB(59); "CREW SIZE"
     PRINT
     FOR I = 1 TO 5
     PRINT TAB(1); I; TAB(5); ETSUB$(I); TAB(18); ETMBA(I); TAB(26); ETHRS(I);
TAB(36); ETABR(I); TAB(50); ETMTR(I); TAB(59); ETCREW(I)
     NEXT I
     COLOR 2
     INPUT "ENTER NUMBER FOR CHANGE"; NBR
     IF NBR > 5 THEN GOTO 6010
     IF NBR = 0 THEN GOTO COMP
     INPUT "ENTER NEW PARAMETERS SEPARATED BY COMMAS"; ETMBA(NBR), ETHRS(NBR),
ETABR(NBR), ETMTR(NBR), ETCREW(NBR)
     GOTO 6010
COMP: INPUT "ENTER SCHD MAINT AS A PCT OF UNSCH MAINT"; ETS

     COLOR 7: ETREL = 1
     PRINT TAB(20); "COMPUTED"; TAB(40); "MISSION"; TAB(59); "MANHR DRIVEN"
     PRINT  TAB(1);  "SUBSYSTEM";  TAB(18);  "  RELIABILITY";  TAB(32);  "UNSCH
MANHRS"; TAB(47); "SCH MANHRS"; TAB(59); "MANPWR": PRINT
     COLOR 11: STE = 0: MTE = 0: TME = 0
     FOR I = 1 TO 5
     ETR(I) = EXP(-ETHRS(I) / (ETMBA(I) / ETABR(I)))
     ETREL = ETREL * ETR(I)
     TE = (ETHRS(I) / ETMBA(I)) * ETMTR(I) * ETCREW(I)
     A3 = (TE + ETS * TE) * X(15) / (X(11) * (1 - X(12)))
     A3 = INT(A3 + .999)
     TME = TME + A3
     MTE = MTE + ETHRS(I) / ETMBA(I)
     STE = STE + TE
     PRINT TAB(5); ETSUB$(I); TAB(20); ETR(I); TAB(32); TE; TAB(47); ETS * TE;
TAB(60); A3
     NEXT I

6036 PRINT : COLOR 12
6050 PRINT TAB(1); "OVERALL ET "; TAB(20); ETREL; TAB(32); STE; TAB(47); ETS *
STE; TAB(60); TME
     PRINT  :  COLOR  3:  PRINT  TAB(2);  "note:   set  reliability=1  to  eliminate
subsystem"
     COLOR 2
6070 INPUT "ENTER NEW RELIABILITY-OR RETURN TO USE COMPUTED"; NBR
6080 IF NBR > 0 THEN ETREL = NBR

BAK: CLS : COLOR 7
     PRINT TAB(20); "LIQUID ROCKET BOOSTER INPUT DATA"
     COLOR 11
     PRINT TAB(1); "NBR"; TAB(5); "SUBSYSTEM"; TAB(18); "MTBM"; TAB(26); "OPER
HRS"; TAB(36); "CRIT FAIL RT"; TAB(50); "MTTR"; TAB(59); "CREW SIZE"
     PRINT
     FOR I = 1 TO 4
     PRINT TAB(1); I; TAB(5); SRBSUB$(I); TAB(18); SRBMBA(I); TAB(26); SRBHRS(I);
TAB(36); SRBABR(I); TAB(50); SRBMTR(I); TAB(59); SRBCREW(I)
     NEXT I
     PRINT : COLOR 2
     INPUT "ENTER NUMBER FOR CHANGE"; NBR
     IF NBR > 4 THEN GOTO BAK
     IF NBR = 0 THEN GOTO COM2
```

```
     INPUT "ENTER NEW PARAMETERS SEPARATED BY COMMAS"; SRBMBA(NBR), SRBHRS(NBR),
SRBABR(NBR), SRBMTR(NBR), SRBCREW(NBR)
     GOTO BAK
COM2: INPUT "ENTER SCHD MAINT AS A PCT OF UNSCH MAINT"; SRBS
      COLOR 7: SRBREL = 1: TMF = 0: MTF = 0: STF = 0
      PRINT TAB(20); "COMPUTED"; TAB(40); "MISSION"; TAB(61); "MANHR DRIVEN"
      PRINT TAB(1); "SUBSYSTEM"; TAB(18); "RELIABILITY"; TAB(32); "UNSCH MANHRS";
TAB(47); "SCHED MANHRS"; TAB(61); "MANPWR": PRINT
      COLOR 11
      FOR I = 1 TO 4
      SRBR(I) = EXP(-SRBHRS(I) / (SRBMBA(I) / SRBABR(I)))
      SRBREL = SRBREL * SRBR(I)
      TF = (SRBHRS(I) / SRBMBA(I)) * SRBMTR(I) * SRBCREW(I)
      A4 = (TF + TF * SRBS) * X(15) / (X(11) * (1 - X(12)))
      A4 = INT(A4 + .999)
      TMF = TMF + A4
      MTF = MTF + SRBHRS(I) / SRBMBA(I)
      STF = STF + TF
      PRINT TAB(5); SRBSUB$(I); TAB(20); SRBR(I); TAB(32); TF; TAB(47); SRBS *
TF; TAB(61); A4
      NEXT I

     PRINT : COLOR 12
     PRINT TAB(1); "OVERALL SRB"; TAB(20); SRBREL; TAB(32); STF; TAB(47); SRBS
* STF; TAB(61); TMF
     PRINT : COLOR 3: PRINT TAB(2); "note:  set reliability=1 to eliminate
subsystem"
     PRINT : COLOR 2
     PRINT : INPUT "ENTER NEW RELIABILITY-OR RETURN TO USE COMPUTED"; NBR
     IF NBR > 0 THEN SRBREL = NBR

'RETURN TO MAIN

END SUB
```

```
SUB EQS
 'MTBM/MTTR CALCULATIONS BY WBS
 'WBS 1,2 & 3  AIRFRAME        ***********
     S1 = W(1) + W(2) + W(3)
     P1 = W(1) / S1: P2 = W(2) / S1: P3 = 1 - P1 - P2
3020 FMA11 = 15.231 + .006057 * W(2) - .137575 * SQR(W(1) + W(2) + W(3)) -
.000723 * V(3)
3022 IF FMA11 < 1.4 THEN FMA11 = 1.4
3025 FMA(1) = FMA11 / P1: FMA(2) = FMA11 / P2
3030 MH11 = 16.5732 - .3511567 * W(3) / V(2) - .74556 * LOG(X1)
3031 IF MH11 < 3.9 THEN MH = 3.9
3032 MHMA(1) = MH11: MHMA(2) = MH11
 'WUC12  AIRCREW COMPARTMENT       *************
3110 FMA12 = 3428.49 - .0142 * X1 - 423.96 * LOG(X1) + 11.05 * SQR(X1) + 111.567
* X(3) - 360.72 * SQR(X(3)) + .01865 * W(3) - 4.83566 * SQR(W(3)) - .25785 *
(X(3) + X(4))
3112 IF FMA12 < 5.6 THEN FMA12 = 5.6' 25TH PERCENTILE RANGE
3115 TP = P3 / FMA11 + 1 / FMA12: FMA(3) = 1 / TP'CHECK LINE 3715 FOR FMA(3)
3120 MH12 = 7.0855 - 1.6667 / SQR(X(3) + X(4)) + .098778 * (X2 + X(4))
3121 IF MH12 < 3.2 THEN MH12 = 3.2
3123 MHMA(3) = ((1 / FMA11) * MH11 + (1 / FMA12) * MH12) / (1 / FMA11 + 1 /
FMA12)
 '

 'WUC46  FUEL SYS  WBS 3.10/3.20  ********
4710 BMA46 = 494.8 - 54.06 * X1 + .903 * SQR(V(3)) - 50.712 * X(5) + 16.39 * V(9)
+ 151.37 * SQR(X(5)) - 83.12 * SQR(V(9)) - .0004 * (W(4) + W(5)) + .2756 *
SQR(W(4) + W(5))
4711 IF BMA46 < 8.37 THEN BMA46 = 8.37
4712 IF BMA46 > 84 THEN BMA46 = 84
4714 Y = (W(4) / (W(4) + W(5))) * (1 / BMA46)
4715 Z = (W(5) / (W(4) + W(5))) * (1 / BMA46)
4716 FMA(4) = 1 / Y: FMA(5) = 1 / Z
4720 MH46 = -180.85 + .00126 * X1 + .6663 * X2 - .0121 * V(3) + 11.7288 * LOG(X1)
- 1.635 * SQR(V(3)) - 20.309 * V(9) + 87.164 * SQR(V(9)) - .00131 * (W(10) +
W(11) + W(12)) + .45 * SQR(W(4) + W(5))
4721 IF MH46 < 7 THEN MH46 = 7
4722 IF MH46 > 21.34 THEN MH46 = 21.34
4723 MHMA(4) = MH46: MHMA(5) = MH46
'
' WBS 4.XX  THERMAL PROTECTION SYSTEM ****************
' TILES,TCS, & PVD - NOT AVAILABLE FROM AIRCRAFT  - INDICES 6,7 & 8

'WUC13/WBS9   LANDING GEAR SYSTEMS     ****************
3210 SMA13 = 22.2723 - .00313 * V(3) + .19511 * X2 - 5.47476 * SQR(V(4)) +
.003161 * W(9) - .5171441 * SQR(W(9))
3212 IF SMA13 < .4 THEN SMA13 = .4
     IF SMA13 > 19.1 THEN SMA13 = 19.1
3213 'FMA(9) = 72.4 + 14.568 * V(4) + .0994 * X2 - 12.41 * LOG(X1) - 65.6 *
SQR(V(4)) - .00568 * W(9) + 18.598 * LOG(W(9))
3214 'IF FMA(9) < 1.4 THEN FMA(9) = 1.4
      FMA(9) = SMA13
3220 MHMA(9) = -156.95 + 55.984 * LOG(W(9)) - 6.095 * (LOG(W(9))) ^ 2 + .212817
* (LOG(W(9))) ^ 3
3221 IF MHMA(9) < 1.9 THEN MHMA(9) = 1.9
```

```
'******WUC23 PROPULSION SYSTEM **** WBS 6, 7 & 8 ********
FOR I = 10 TO 12
4170 FMA(I) = 34.1 + 9.853001E-04 * W(I) - .312232 * SQR(W(I))
4171 IF FMA(I) < 1.4 THEN FMA(I) = 1.4
4175 MHMA(I) = 52.6324 + .0009122 * W(I) - .3936 * SQR(W(I))
4176 IF MHMA(I) < 4.1 THEN MHMA(I) = 4.1
4177 IF MHMA(I) > 21.1 THEN MHMA(I) = 21.1
NEXT I
'
'WUC24      APU  WBS 9.10
3410 FMA(13) = 4996.525 - 1.906 * V(7) + 46.35 * SQR(V(7)) - 2.735 * W(13) +
284.549 * SQR(W(13)) - 1642.99 * LOG(W(13))
3411 IF FMA(13) < 14.5 THEN FMA(13) = 14.5
3420 MHMA(13) = -451.4 + .09054 * V(7) - 2.9654 * SQR(V(7)) + .2657 * W(13) -
26.1 * SQR(W(13)) + 150.5 * LOG(W(13))
3421 IF MHMA(13) < 5.2 THEN MHMA(13) = 5.2
3422 IF MHMA(13) > 17.2 THEN MHMA(13) = 10!
'
'  BATTERY WBS9.20 ************
    FMA(14) = 3570
    MHMA(14) = 1.907 + .000006975# * X1

'WBS 9.30  POWER, FUEL CELL ******************
'  NOT AVAIL ON AIRCRAFT - INDEX 15

'WUC 42/44   WBS 10  *** ELECTRICAL SYS ******
3609 FMA(16) = 1193.13 - .0755 * W(16) + 6.758773 * SQR(W(16)) - .715596 * X2 -
167.24 * LOG(X1) + 2.2308 * SQR(X1) + 29.10236 * LOG(V(7)) - .00127 * V(7) ^ 2
3611 FH44 = 1
3613 FH42 = 1
3614 IF FMA(16) < 5.15 THEN FMA(16) = 5.15
3                                          6
'MHMA(16)=-18392.3+1694.6*LOG(X1)-92.8412*(LOG(X1))^2+27629/SQR(LOG(X1))+2*LOG
(X1)^3                                                        2                  0
3621 MH42 = -95.161 + 20.3158 * LOG(X1) - .98356 * (LOG(X1)) ^ 2
3622 MH44 = 2300.04 + 474.11 * LOG(X1) - 452.295 * LOG(X2) - .146285 * X1 / X2
- 2769.85 * SQR(LOG(X1)) + 1788.4 * SQR(LOG(X2))
3623 MHMA(16) = (MH42 + MH44) / 2
3624 IF MHMA(16) < 1! THEN MHMA(16) = 4.1
'
'WUC45 WBS11  HYDRAULICS SYS      ******************
3810 FMA(17) = 396.258 - .00622 * V(3) + 35.635 * V(8) - 779.83 * SQR(V(8)) +
975.56 * LOG(V(8)) + 8.812899 * SQR(W(17)) - 105.728 * LOG(W(17))
3812 IF FMA(17) < 4.7 THEN FMA(17) = 4.7
3820 MH45 = 2.41235 * LOG(X1) - .16306 * LOG(X1) ^ 2
3821 MHMA(17) = MH45
3822 IF MHMA(17) < 2.4 THEN MHMA(17) = 2.4
'
'WUC14  WBS 12.00 AERO SURFACE ACTUATORS    **************
3310 FMA(18) = 26.29 - 1.1136 * SQR(W(18)) + .9516 * V(5) - 1.9 * V(6) + .3505
* X2 - .00357 * V(3)
3312 IF FMA(18) < 2.8 THEN FMA(18) = 2.8
3320 MHMA(18) = 26.238 - 1.1067 * V(5) - 1.6658 * V(6) - .00328 * V(3) + .0006018
* X2 - 6.2827 * LOG(W(18)) + 14.289 * SQR(V(5))
3321 IF MHMA(18) < 2.1 THEN MHMA(18) = 2.1
```

```
' WBS 12.XX AVIONICS  GENERAL  *******
3910 FOR I = 19 TO 24
3911 MHMA(I) = 131.395 + 1.0394 * V(11) - 9.035 * SQR(V(10)) - .0154 * WAV +
2.864 * SQR(WAV) - 26.193 * LOG(WAV)
3912 IF MHMA(I) < 4.6 THEN MHMA(I) = 4.6
     FMA(I) = -36.92 - 4.496 * V(10) + 45.756 * SQR(V(10)) - .1231 * WAV / V(10)
+ .0236 * WAV - 2.453 * SQR(WAV)
     IF FMA(I) < 1.5 THEN FMA(I) = 1.5
     NEXT I
     IF X(19) = 1 THEN GOTO 3511  'USE AV GEN
     FMA(22) = 54.2
     MHMA(22) = 8.95
4350 FMA(23) = 330.26 + .0003821 * X1 - .451534 * X2 + 137.3431 * X(5) - 1.129
* V(9) - 381.666 * SQR(X(5))
4351 IF FMA(23) < 7 THEN FMA(23) = 7
4355 MHMA(23) = -229.62 + .0003 * X1 + .0985 * X2 + 23.4948 * LOG(X1) - .44697
* SQR(X1) - 25.3067 * X(5) + .17796 * V(9) + 74.155 * SQR(X(5))
4356 IF MHMA(23) < 3.5 THEN MHMA(23) = 3.5
4357 IF MHMA(23) > 12.6 THEN MHMA(23) = 12.6
4400 FMA(19) = -415.17 - .000317 * X1 + .2757 * X2 + .2242 * WAV - 26.744 *
SQR(WAV) + 155.28 * LOG(WAV) - .3679 * WAV / V(10)
4405 IF FMA(19) <= 3.3 THEN FMA(19) = 3.3
4410 FMA(20) = 323.913 - 16.0757 * SQR(WAV) + 16.974 * X2 + .1735 * WAV + 23.82
* V(11) - 2.305 * WAV / V(10)
4415 IF FMA(20) < 4.2 THEN FMA(20) = 4.2
4420 FMA(21) = 353.21 - .0338 * X2 + 10.74 * V(10) - 107.64 * SQR(V(10)) - 7.82
* LOG(WAV)
4425 IF FMA(21) < 7.9 THEN FMA(21) = 7.9
     FMA(24) = 29.13
     MHMA(24) = 4.75 + .2446 * LOG(X1)

'WUC41/47 WBS14.XX  ENVIRONMENTAL CONTROL  **************
3511 FH41 = 454.387 - .000547 * X1 + .821 * X2 - 107.5185 * LOG(X2)
3512 FH47 = 6613.12 - 1.485 * X2 - 1358.3 * LOG(X1) + 73.58 * (LOG(X1)) ^ 2 -
.725852 * X1 / X2
3513 FMA(25) = FH41: FMA(26) = FH47
3515 IF FMA(25) < 7.68 THEN FMA(25) = 7.68
     IF FMA(26) < 13.8 THEN FMA(26) = 13.8
3520 MH41 = .6886774 * LOG(X1)
3521 MH47 = 5.7432 + .018525 * LOG(X1) - 3.36575E-03 * SQR(X1)
3522 MHMA(25) = MH41: MHMA(26) = MH47
3523 IF MHMA(25) < 1! THEN MHMA(25) = 1!

 'WUC49   MISC UTILITIES            ***********************
 ' WUC49/96  WBS15   PERSONNEL PROVISIONS  ****************
4020 FMA(27) = 17952.8 + .00579 * X1 + 170 * X(3) - 10.136 * X2 + 21.15 * (X(3)
+ X(4)) - 461.34 * SQR(X(3) + X(4)) - 1.893 * W(27) + 421.8 * SQR(W(27)) - 4054
* LOG(W(27))                   0                          2                     1
4
'FH49=58226.97+.0168*X1-42.358*X2-27480.6*LOG(X2)+79.598*LOG(X1)^2+3131.24*LOG
(X2)^2-8.6965*X1/X2
4023 IF FMA(27) < 46.7 THEN FMA(27) = 46.7
4030 MHMA(27) = 9.51317 + .03508 * X2 - .000721 * W(27) - 4.52 * SQR(X(3))
4031 'MH49=.0831*LOG(X1)^2-.0116*X1/X2
4033 IF MHMA(27) < 2.2 THEN MHMA(27) = 2.2
 '
```

```
'WUC91/93/97  WBS 16  ***** RECOVERY & AUX SYS ********
4205 FMA(28) = 23030.42 + 236.89 * X2 - 4657.052 * SQR(X2)
4206 IF FMA(28) < 101.1 THEN FMA(28) = 101.1
4208 MHMA(28) = 6.95
4210 FMA91 = -2032.57 + 10.54 * SQR(X1) - 23.91 * X2 + .16436 * WAV - 20.27 *
V(10) + 352.2 * SQR(X2)
4211 IF FMA91 < 18.9 THEN FMA91 = 18.9
4212 FMA97 = 8962.941 + 22.477 * SQR(X1) - .0202 * X1 - 1172.605 * LOG(X1)
4213 IF FMA97 < 65.9 THEN FMA97 = 65.9
4214 Y = 1 / FMA97: TW = W(29) / (W(29) + W(30)): FMA(30) = 1 / ((1 - TW) * Y)
4215 Z = 1 / FMA91: FMA(29) = 1 / (Z + TW * Y)
4220 MHMA91 = -1368.29 + .000704 * X1 + 21064.55 / SQR(X1) + 138.37 * LOG(X1) -
1.131 * SQR(X1)
4221 IF MHMA91 < 1.4 THEN MHMA91 = 1.4':IF MHMA91>8.3 THEN MHMA91=8.3
4222 MHMA(29) = (MHMA91 + 4.03) / 2
4223 MHMA(30) = 4.03
 '
4900 'APPLY MTBM & MHMA CALIBRATION FACTORS  'COMPUTE SHUTTLE MHMA
4910 FOR I = 1 TO 33
     IF SEL$(I) = "SHUTTLE" THEN FMA(I) = SMA(I)
   ' COMPUTE SHUTTLE OFF MANHRS
     IF SEL$(I) = "SHUTTLE" THEN MHMA(I) = C(I) * SMR(I) + PF(I) * C(I) * SMR(I)
/ (1 - PF(I))
4920 FMA(I) = MW(I) * FMA(I)
4925 MHMA(I) = CM(I) * MHMA(I)
4930 NEXT I

5000 'SCHEDULED MAINTENANCE MODULE
     IF CP$(5) = "DO NOT RECOMPUTE" THEN GOTO 5050
5010 'SCHP = 23.924 - .0545 * X2 - 10.563 * LOG(X2) + 3.039 * SQR(X2) + .0215 *
W(3) / V(2) + .00067 * V(1)
SCHP = -3.861213 - .0449 * X2 + 3.2794 * LOG(X1) + .02297 * SQR(X1) - .0176 *
(LOG(X1)) ^ 3 - 7.289 * LOG(X2) + 2.36973 * SQR(X2)
     IF SCHP < .132 THEN SCHP = .132
     IF SCHP > .794 THEN SCHP = .794

5050 'VEHICLE ROLL-UP   - UNADJUSTED MTBM
5060 Y = 0
5070 FOR I = 1 TO 33
5080 IF OP$(I) = "DELETE" THEN GOTO 5110
5100 Y = Y + 1 / FMA(I)
5110 NEXT I
5220 VFMA = 1 / Y

END SUB
```

```
SUB INIT
500 ' INITIALIZATION MODULE
520 FOR I = 1 TO 33
525 MW(I) = 1: NRD(I) = 1: K(I) = 1
526 CM(I) = 1: W(I) = 1: CA(I) = 1
527 OP$(I) = "COMPUTE"
528 SEL$(I) = "AIRCRAFT"
529 FMAS(I) = 1
530 READ WBS$(I)
540 NEXT I
550 SEL$(6) = "SHUTTLE": SEL$(7) = "SHUTTLE": SEL$(8) = "SHUTTLE"
555 SEL$(15) = "SHUTTLE"
560 SEL$(31) = "SHUTTLE": SEL$(32) = "SHUTTLE": SEL$(33) = "SHUTTLE"
580 FOR I = 1 TO 20
590 READ NAM$(I)
600 NEXT I
610 FOR I = 1 TO 12
620 READ SNAM$(I)
630 NEXT I
    FOR I = 1 TO 6: CP$(I) = "RECOMPUTE": NEXT I
640 FOR I = 1 TO 33: READ TG(I): NEXT I'TECH GROWTH RATES
650 FOR I = 1 TO 33: READ PWT1(I): NEXT I'WGT DISTR PERCENTS-AMLS (LARGE)
652 FOR I = 1 TO 33: READ PWT2(I): NEXT I    'WGT DISTR PERCENTS-SHUTTLE
653 FOR I = 1 TO 33: READ PWT3(I): NEXT I'WGT DISTR PERCENTS-PLSS (SMALL)
    FOR I = 1 TO 33: PWTS(I) = PWT2(I): NEXT I ' initialize wght distr
660 FOR I = 1 TO 33: READ SMA(I): NEXT I'  SHUTTLE MAINT ACTION MTBM
665 FOR I = 1 TO 33: READ SMR(I): NEXT I'  SHUTTLE MTTR
    FOR I = 1 TO 33: READ SRR(I): NEXT I' SHUTTLE REMOVAL RATES
680 FOR I = 1 TO 5  'READ IN ET PARAMETERS
    READ ETSUB$(I), ETMBA(I), ETHRS(I), ETABR(I), ETMTR(I), ETCREW(I)
    NEXT I
    FOR I = 1 TO 4  'READ IN LRB PARAMETERS
    READ SRBSUB$(I), SRBMBA(I), SRBHRS(I), SRBABR(I), SRBMTR(I), SRBCREW(I)
    NEXT I

690 '                **** DEFAULT VALUES ******
    WF = 1: PWF = 1' INITIAL WEIGHT FACTOR
700 X(1) = 10000! 'DRY WEIGHT - LBS
710 X(2) = 70  'LENGTH + WING SPAN - FT
    WING = 30  'TEMP WING SPAN
720 X(3) = 2'CREW SIZE
730 X(4) = 8'NBR PASSENGERS
740 X(5) = 3 ' NBR ENGINES
745 X(6) = 0 'FLAG FOR SPACE ADJ TO MTBM - SHUTTLE
750 X(7) = 1996 'TECHNOLOGY YR
760 X(8) = .001 'DEFAULT ABORT RATE
770 X(9) = .28 'WEIBULL SHAPE PARAMETER
780 X(10) = 20   'LAUNCH FAILURE RATE FACTOR
790 X(11) = 144  ' AVAIL HRS PER MONTH
800 X(12) = .15 'PERCENT INDIRECT WORK
810 X(13) = .95 'SPARES FILL RATE GOAL
815 X(14) = 7 ' AVG CREW SIZE-SCHEDULED
816 X(15) = 1'PLANNED MSN PER MONTH
817 X(16) = 0 'INITIALIZE IN PRECONCEPTUAL MODE
    X(17) = 0 'INTEGRATION TIME
    X(18) = 24 'LAUNCH PAD TIME
    X(19) = 0 'DO NOT AGGREGATE AVIONICS
    X(20) = .2  'DEFAULT % OFF MANHRS
818 WGTF = 1
    ETREL = 1: SRBREL = 1 'INITIAL ET/SRB RELIABILITIES
820 T(0) = 2: T(1) = .14: T(2) = 1: T(3) = 71: T(4) = 72: T(5) = 10
    YR = X(7): B = X(9): LF = X(10): X1 = X(1): X2 = X(2) + WING : END SUB
```

```
SUB MANPWR
7000 'MANPOWER COMPUTATION MODULE ******
     VMOH = 0: OMHMA = 0: OFMHMA = 0
7005 TMA = 0: VMH = 0: AMHMA = 0: KK = 0: TOMH = 0: TFMH = 0: APF = 0: TMP = 0
7010 MANF = (X(11) * (1 - X(12))) / (4.345 * 5 * 8)' HR AVAIL FACTOR
7020 FOR I = 1 TO 33
     POFF = PF(I)
7030 IF OP$(I) = "DELETE" THEN GOTO 7140
7035 KK = KK + 1
7040 THRS(I) = POH(I) + GOH(I) + LOH(I) + TOH(I) + OOH(I) + ROH(I)
7045 MA = THRS(I) / FMAS(I)
7046 TMA = TMA + MA
7050 MH(I) = MA * MHMA(I)
7055 OMHMA = OMHMA + (1 - POFF) * MHMA(I): OFMHMA = OFMHMA + POFF * MHMA(I)
7060 VMH = VMH + MH(I)
     AMHMA = AMHMA + MHMA(I)
7070 MEN = (MH(I) * X(15)) / (X(11) * (1 - X(12)))
7080 MP(I) = INT(MEN + .999)
7085 TMP = TMP + MP(I)
7090 OMH(I) = (1 - POFF) * MH(I)
7100 FMH(I) = POFF * MH(I)
7110 TOMH = TOMH + OMH(I)
7120 TFMH = TFMH + FMH(I)
7130 APF = APF + 1 - PF(I)
7140 NEXT I
7150 APF = APF / KK
7155 OMHMA = OMHMA / KK: OFMHMA = OFMHMA / KK
7160 AMHMA = AMHMA / KK
7170 SMP = (SCHP * TOMH * X(15)) / (X(11) * (1 - X(12)))
7180 SMP = INT(SMP + .999)
7190 TMP = TMP + SMP
' MIN CREW SIZE
     STP = 0: C1 = 0
     FOR I = 1 TO 33
      IF OP$(I) = "DELETE" THEN GOTO N1
      'IF C(I) > MP(I) THEN TP = C(I) ELSE TP = MP(I)
      STP = STP + C(I)
      C1 = C1 + CA(I) * C(I)
N1:  NEXT I
     STP = INT(STP + .999)
     C1 = INT(C1 + .999)

END SUB

SUB REDUNREL
13180 ' RELIABILITY SUBROUTINE
13185 ' LAUNCH RELIABILITY
13190 VR1 = 1
13200 FOR I = 1 TO 33
13210 IF OP$(I) = "DELETE" THEN GOTO 13260
13220 L1 = 1 / FMAC(I): T = GOH(I)
13230 RT = EXP(-L1 * T)
13240 IF (I >= 10 AND I <= 15) OR (I >= 19 AND I <= 24) THEN GOSUB 13300 ELSE
R1(I) = 1 - (1 - RT) ^ NRD(I)
13250 VR1 = VR1 * R1(I)
13260 NEXT I
13270 GOTO 13400
```

```
13300 'K OUT OF N SUBSYSTEM CALCULATION
13305 R1(I) = 0
13310 NN = NRD(I): GOSUB 13355: MFAC = FAC
13315 FOR J = K(I) TO NRD(I)
13320 NN = J: GOSUB 13355: JFAC = FAC
13325 NN = NRD(I) - J: GOSUB 13355
13330 C = MFAC / (JFAC * FAC)
13335 R1(I) = R1(I) + C * RT ^ J * (1 - RT) ^ (NRD(I) - J)
13340 NEXT J
13345 RETURN
13350 '
13355 'FACTORIAL SUBROUTINE
13360 IF NN = 0 THEN FAC = 1: RETURN
13365 FAC = 1
13370 FOR JK = 1 TO NN
13375 FAC = FAC * JK
13380 NEXT JK
13385 RETURN
13400 'END OF POWERED PHASE
13405 VR2 = 1
13410 FOR I = 1 TO 33
13415 IF OP$(I) = "DELETE" THEN GOTO 13440
13420 L = 1 / FMAC(I): T = GOH(I) + LOH(I)
13425 RT = EXP(-L * (GOH(I) + LF * (T - GOH(I))))
13430 IF I = 10 OR I = 11 OR I = 12 THEN GOSUB 13445 ELSE R2(I) = 1 - (1 - RT)
^ NRD(I)
13435 VR2 = VR2 * R2(I)
13440 NEXT I
13443 GOTO 13500
13445 'K OUT OF N SUBSYSTEM CALCULATION
13450 R2(I) = 0
13455 NN = NRD(I): GOSUB 13355: MFAC = FAC
13460 FOR J = K(I) TO NRD(I)
13465 NN = J: GOSUB 13355: JFAC = FAC
13470 NN = NRD(I) - J: GOSUB 13355
13475 C = MFAC / (JFAC * FAC)
13480 R2(I) = R2(I) + C * RT ^ J * (1 - RT) ^ (NRD(I) - J)
13485 NEXT J
13487 RETURN
13500 'ORBIT INSERTION
13505 VR3 = 1
13510 FOR I = 1 TO 33
13515 IF OP$(I) = "DELETE" THEN GOTO 13540
13517 TX0 = GOH(I): TX1 = TX0 + LOH(I)
13520 L = 1 / FMAC(I): T = GOH(I) + LOH(I) + TOH(I)
13525 RT = EXP(-L * ((T + TX0 - TX1) + LF * (TX1 - TX0)))
13530 IF I = 10 OR I = 11 OR I = 12 THEN GOSUB 13545 ELSE R3(I) = 1 - (1 - RT)
^ NRD(I)
13535 VR3 = VR3 * R3(I)
13540 NEXT I
13543 GOTO 13600
13545 'K OUT OF N SUBSYSTEM CALCULATION
13550 R3(I) = 0
13555 NN = NRD(I): GOSUB 13355: MFAC = FAC
13560 FOR J = K(I) TO NRD(I)
13565 NN = J: GOSUB 13355: JFAC = FAC
13570 NN = NRD(I) - J: GOSUB 13355
13575 C = MFAC / (JFAC * FAC)
13580 R3(I) = R3(I) + C * RT ^ J * (1 - RT) ^ (NRD(I) - J)
13585 NEXT J
13587 RETURN
```

```
13600 'RENTRY
13605 VR4 = 1
13610 FOR I = 1 TO 33
13612 IF OP$(I) = "DELETE" THEN GOTO 13640
13615 TX0 = GOH(I): TX1 = TX0 + LOH(I): TX2 = TX1 + TOH(I)
13620 L1 = 1 / FMAC(I): T = GOH(I) + LOH(I) + TOH(I) + OOH(I)
13621 L2 = LF * L1
13622 A = (B * T(2) ^ (B - 1) / L1) ^ (1 / B)
13625 RT = EXP(-L1 * (TX2 + TX0 - TX1) - L2 * (TX1 - TX0) - (T / A) ^ B + (TX2
/ A) ^ B)
13630 IF I = 10 OR I = 11 OR I = 12 THEN GOSUB 13645 ELSE R4(I) = 1 - (1 - RT)
^ NRD(I)
13635 VR4 = VR4 * R4(I)
13640 NEXT I
13643 GOTO 13700
13645 'K OUT OF N SUBSYSTEM CALCULATION
13650 R4(I) = 0
13655 NN = NRD(I): GOSUB 13355: MFAC = FAC
13660 FOR J = K(I) TO NRD(I)
13665 NN = J: GOSUB 13355: JFAC = FAC
13670 NN = NRD(I) - J: GOSUB 13355
13675 C = MFAC / (JFAC * FAC)
13680 R4(I) = R4(I) + C * RT ^ J * (1 - RT) ^ (NRD(I) - J)
13685 NEXT J
13687 RETURN
13745 'K OUT OF N SUBSYSTEM CALCULATION
13750 R5(I) = 0
13755 NN = NRD(I): GOSUB 13355: MFAC = FAC
13760 FOR J = K(I) TO NRD(I)
13765 NN = J: GOSUB 13355: JFAC = FAC
13770 NN = NRD(I) - J: GOSUB 13355
13775 C = MFAC / (JFAC * FAC)
13780 R5(I) = R5(I) + C * RT ^ J * (1 - RT) ^ (NRD(I) - J)
13785 NEXT J
13790 RETURN

13700 'MISSION COMPLETION
13705 VR5 = 1
13710 FOR I = 1 TO 33
13712 IF OP$(I) = "DELETE" THEN GOTO 13740
13715 TX0 = GOH(I): TX1 = TX0 + LOH(I): TX2 = TX1 + TOH(I): TX3 = TX2 + OOH(I)
13720 L1 = 1 / FMAC(I): T = GOH(I) + LOH(I) + TOH(I) + OOH(I) + ROH(I)
13721 L2 = LF * L1
13722 A = (B * T(2) ^ (B - 1) / L1) ^ (1 / B)
13725 RT = EXP(-L1 * (TX2 + TX0 - TX1) - L2 * (TX1 - TX0) - (TX3 / A) ^ B + (TX2
/ A) ^ B - L1 * (T - TX3))
13730 IF I = 10 OR I = 11 OR I = 12 THEN GOSUB 13745 ELSE R5(I) = 1 - (1 - RT)
^ NRD(I)
13735 VR5 = VR5 * R5(I)
13740 NEXT I
END SUB

SUB REMEQS
5500 'REMOVAL RATE EQUATIONS
5510 R11 = .1934 - 6.309E-07 * W(3)
5511 R12 = .20268 + .000588 * V(12)
5512 RR(1) = R11: RR(2) = R11: RR(3) = (R11 + R12) / 2

5580 R46 = .5623 - .0955 * X(5)
5581 IF R46 < .164 THEN R46 = .164
5582 IF R46 > .389 THEN R46 = .389
5583 RR(4) = R46: RR(5) = R46
```

```
'     THERMAL SYSTEMS - SHUTTLE BASED
      FOR I = 6 TO 8: RR(I) = SRR(I): NEXT I

5520 RR(9) = .8639 - .02963 * X2
5521 IF RR(9) < .22 THEN RR(9) = .22

5610 FOR I = 10 TO 12
5611 RR(I) = .6211 - .0024872 * SQR(W(I))
5612 IF RR(I) < .157 THEN RR(I) = .157
5613 'IF RR(I)>.5120001 THEN RR(I)=.5120001
5614 NEXT I

5540 RR(13) = .579 - .0007512 * SQR(X1)
5541 IF RR(13) < 0 THEN RR(13) = .01
5542 RR(15) = SRR(15) 'SHUTTLE BASED
     RR(14) = .273

5560 RR42 = -.38533 - .001 * X2 + .17715 * LOG(X2)
5561 IF RR42 < .23 THEN RR42 = .23: IF RR42 > .539 THEN RR42 = .539
5562 RR44 = 2.3651 + .00201 * X2 - .41152 * LOG(X2)
5563 IF RR44 < .53 THEN RR44 = .53: IF RR44 > .872 THEN RR44 = .872
5565 RR(16) = (RR42 / FH42 + RR44 / FH44) / (1 / FH42 + 1 / FH44)

5570 RR(17) = .368

5530 RR(18) = .4527 - .0006677 * X2
5531 IF RR(18) < 0 THEN RR(18) = .07

5590 RRG = .39735 - 4.2659E-07 * X1 + 2.1635E-04 * SQR(X1)
5591 IF RRG < 0 THEN RRG = .235
5592 IF RRG > .726 THEN RRG = .726
     FOR I = 19 TO 24: RR(I) = RRG: NEXT I
5595 IF X(19) = 0 THEN RR(19) = .4: RR(21) = .4: RR(23) = .51
     RR(24) = -1.3 + .14458 * LOG(X1)   'A/C COMPUTER SYSTEMS
     IF RR(24) <= .235 THEN RR(24) = RRG
     IF RR(24) >= .726 THEN RR(24) = RRG

5550 R41 = .5294 - 8.914E-05 * W(25)
5551 IF R41 < 0 THEN R41 = .168
5552 R47 = .6026 - .0006758 * SQR(X1)
5553 RR(25) = R41: RR(26) = R47

5600 RR(27) = .274

5620 R97 = 2.532 - .22837 * LOG(V(3))
5621 IF R97 < 0 THEN R97 = .128
5622 R91 = 2.3489 - .35852 * LOG(X2)
5623 IF R91 < 0 THEN R91 = .461'SET EQUAL TO MEAN VALUE
5624 IF R91 > 1 THEN R91 = .461
5625 IF R97 > 1 THEN R97 = .968
'    RR(28) =  ???  DRAG CHUTE
5626 RR(29) = (R91 + R97) / 2
     RR(30) = R97
     RR(32) = SRR(32)

' BEGAN SHUTTLE VALUES
     FOR I = 1 TO 33
     IF SEL$(I) = "SHUTTLE" THEN RR(I) = SRR(I)
     NEXT I

END SUB
```

```
SUB SPACEMTBM
2000 'MODULE TO DETERMINE SPACE ADJ MTBM
2010 YZ = 0: YX = 1
2020 FOR J = 1 TO 33
2030 T0 = GOH(J): T1 = T0 + LOH(J): T2 = T1 + TOH(J)
2040 T3 = T2 + OOH(J): T4 = T3 + ROH(J)
2050 IF OP$(J) = "DELETE" THEN GOTO 2100
2055 IF SEL$(J) = "SHUTTLE" AND X(6) = 0 THEN MEAN = FMAT(J): GOTO 2080
2060 L1 = 1 / FMAT(J): L2 = LF * L1
2070 GOSUB 2200
2080 FMAS(J) = MEAN
2090 YZ = YZ + 1 / MEAN
2095 YX = YX * RT4
2100 NEXT J
2110 SVFMA = 1 / YZ: VR = YX
2120 GOTO TEND
'
2200 'MODULE TO COMPUTE SPACE ADJUSTED MTBM
2210 A = (B * T(2) ^ (B - 1) / L1) ^ (1 / B)
2220 A1 = (1 - EXP(-L1 * T0)) / L1
2230 A2 = EXP(-L1 * T0) * (1 - EXP(-L2 * (T1 - T0))) / L2
2240 A3 = EXP(-L2 * (T1 - T0)) * (EXP(-L2 * T0) / L2 - EXP(-L2 * (T2 + T0 - T1))
/ L2)
2255 GOSUB 2320 'FIND A4 USING SIMPSON'S RULE
2260 A4 = EXP(-L1 * (T2 + T0 - T1) - L2 * (T1 - T0) + (T2 / A) ^ B) * AREA
2270 A5 = EXP(-L1 * (T2 + T0 - T1) - L2 * (T1 - T0) - (T3 / A) ^ B + (T2 / A) ^
B) * (1 - EXP(-L1 * (T4 - T3))) / L1
2280 MEAN = A1 + A2 + A3 + A4 + A5
2290 RT4 = EXP(-L1 * (T2 + T0 - T1) - L2 * (T1 - T0) - (T3 / A) ^ B + (T2 / A)
^ B - L1 * (T4 - T3))
2300 MEAN = MEAN / (1 - RT4)
2310 RETURN
2320 N = INT((T3 - T2) / .5)
2330 IF N = 0 THEN AREA = 0: RETURN
2340 DX = (T3 - T2) / N
2350 FX = 4
2360 Z(0) = T2: Y(0) = EXP(-(Z(0) / A) ^ B): SUM = Y(0)
2370 FOR I = 1 TO N
2380 Z(I) = Z(I - 1) + DX
2390 Y(I) = EXP(-(Z(I) / A) ^ B)
2400 IF I = N THEN FX = 1
2410 SUM = SUM + FX * Y(I)
2420 IF FX = 4 THEN FX = 2 ELSE FX = 4
2430 NEXT I
2440 AREA = DX * SUM / 3
2450 RETURN
TEND:  ' RETURN TO MAIN PRGM

END SUB
```

```
SUB SPARES
8000 'SPARES CALCULATIONS
8010 ARR = 0: TS = 0: KK = 0: TNR = 0
8020 FOR I = 1 TO 33
8030 IF OP$(I) = "DELETE" THEN GOTO 8180
8040 NR(I) = RR(I) * (THRS(I) / FMAS(I))' MEAN NBR REMOVALS
8045 MN = NR(I)
8050 GOSUB 8300  'COMPUTE FILL RATE RQMT - POISSON DISTR
8055 S(I) = STK: FR(I) = F
8060 TNR = TNR + NR(I)
8150 ARR = ARR + RR(I)
8160 TS = TS + S(I)
8170 KK = KK + 1
8180 NEXT I
8190 ARR = ARR / KK
8200 GOTO BOT
8300 ' COMPUTE SPARES USING POISSON DIST
8310 P = EXP(-MN): F = P
8320 IF P >= X(13) THEN JD = 1: GOTO 8370
8330 JD = 1: F = P
8340 P = P * MN / JD
8350 JD = JD + 1: F = F + P
8360 IF F < X(13) THEN GOTO 8340
8370 STK = JD - 1
8380 RETURN
BOT: 'RETURN TO MAIN

END SUB
```

RAM2.BAS Program

```
'NASA, LANGLEY RESEARCH CENTER
'MTBM COMPUTATIONAL MODEL - NASA RESEARCH GRANT -
'DEVELOPED BY C. EBELING, UNIV OF DAYTON  1/93, 6/93 (updated)
'   ******** COMBINED PRE/CONCEPTUAL MODEL **********
'
'SAVE AS "RAM2.BAS"    Mean Time Between Maintenance -REVISED
'
COMMON SHARED YR, B, X1, X2, LF, VR1, VR2, VR3, VR4, VR5, VR
COMMON SHARED VFMA, TVFMA, SVFMA, CVFMA, OMHMA, OFMHMA, TMA, AMHMA
COMMON SHARED SCHP, VMH, TOMH, TFMH, APF, P1, P2, P3, WAV, FH42, FH44
COMMON SHARED FMA11, FMA12, VNAM$, ARR, TNR, TS
COMMON SHARED SMP, TMP, VMOH, MANF, WGTF, WING, WF, PWF
COMMON SHARED ETREL, SRBREL, ETS, SRBS
COMMON SHARED STP, STE, MTE, TME, STF, MTF, TMF, C1
DIM SHARED WBS$(35), X(50), NAM$(50), THRS(35), MHMA(35), MH(35), MP(35),
OMH(35), FMH(35)
DIM SHARED SEL$(35), T(10), CP$(9), CA(35)
DIM SHARED GOH(35), LOH(35), TOH(35), OOH(35), ROH(35), R(35), TSKT(35),
POH(35)
DIM SHARED V(15), SNAM$(15), FMAT(35), FMAC(35), FMAS(35), S(35), SMA(35),
SMR(35)
DIM SHARED MW(35), C(35), CM(35), OP$(35), TG(35), PWTS(35)
DIM SHARED FMA(35), PF(35), PA(35), Z(500), Y(500), RR(35), W(35), NR(35),
FR(35)
DIM SHARED NRD(35), K(35), R1(35), R2(35), R3(35), R4(35), R5(35)
DIM SHARED PWT1(35), PWT2(35), PWT3(35), PWT4(35), SRR(35)
DIM SHARED ETSUB$(5), ETMBA(5), ETHRS(5), ETABR(5), ETMTR(5), ETR(5),
ETCREW(5)
DIM SHARED SRBSUB$(5), SRBMBA(5), SRBHRS(5), SRBABR(5), SRBMTR(5), SRBR(5),
SRBCREW(5)

COMMON SHARED WBS$(), X(), NAM$(), THRS(), MHMA(), MH(), MP(), OMH(), FMH()
COMMON SHARED SEL$(), T(), CP$(), CA()
COMMON SHARED GOH(), LOH(), TOH(), OOH(), ROH(), R(), TSKT(), POH()
COMMON SHARED V(), SNAM$(), FMAT(), FMAC(), FMAS(), S(), SMA(), SMR()
COMMON SHARED MW(), C(), CM(), OP$(), TG(), PWTS()
COMMON SHARED FMA(), PF(), PA(), Z(), Y(), RR(), W(), NR(), FR()
COMMON SHARED NRD(), K(), R1(), R2(), R3(), R4(), R5()
COMMON SHARED PWT1(), PWT2(), PWT3(), PWT4(), SRR()
COMMON SHARED ETSUB$(), ETMBA(), ETHRS(), ETABR(), ETMTR(), ETR(), ETCREW()
COMMON SHARED SRBSUB$(), SRBMBA(), SRBHRS(), SRBABR(), SRBMTR(), SRBR(),
SRBCREW()
```

```
SUB MAINTDIS
7500 ' DISPLAY MODULE FOR MAINTAINABILITY REPORT
     X = 0: Y = 0: Z = 0: K = 0 'AVIONICS ROLLUP
     FOR I = 19 TO 24
     IF OP$(I) = "DELETE" THEN GOTO NX5
     K = K + 1
     X = X + THRS(I) / FMAS(I)
     Y = Y + MHMA(I)
     Z = Z + (THRS(I) / FMAS(I)) * MHMA(I)
NX5: NEXT I
     YA = Y / K
7505 IO = 1: IE = 18
7510 CLS : COLOR 14
7520 PRINT TAB(25); "MAINTAINABILTY REPORT-page 1"
7530 PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60);
"TIME: "; TIME$
7548 COLOR 7
7550 PRINT TAB(1); "WBS"; TAB(30); "MAINT ACTIONS/MSN"; TAB(50); "TOT MANHR/MA";
TAB(65); "AVG MANHRS/MSN"
7570 FOR I = IO TO IE
7580 IF OP$(I) = "DELETE" THEN GOTO 7592
     IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 15
7590 PRINT TAB(1); WBS$(I); TAB(32); THRS(I) / FMAS(I); TAB(50); MHMA(I);
TAB(65); (THRS(I) / FMAS(I)) * MHMA(I)
     IF I = 24 THEN COLOR 14: PRINT TAB(5); "AVIONICS ROLLUP"; TAB(29); X;
TAB(47); YA; "(AVG)"; TAB(63); Z
7592 NEXT I
7593 PRINT : COLOR 2
7594 IF IO = 1 THEN IO = 19: IE = 33: PRINT : INPUT "ENTER RETURN..."; RET: GOTO
7510
7595 COLOR 13
7600 PRINT TAB(5); "TOTALS"; TAB(32); TMA; TAB(50); AMHMA; "(AVG)"; TAB(65); VMH
7610 COLOR 2
7620 INPUT "ENTER RETURN ..."; RET
7630 IO = 1: IE = 18
7640 CLS : COLOR 14
7650 PRINT TAB(25); "MAINTAINABILTY REPORT - page 2"
     X = 0: Y = 0: Z = 0: K = 0 'AVIONICS ROLLUP
     FOR I = 19 TO 24
     IF OP$(I) = "DELETE" THEN GOTO NX6
     K = K + 1
     X = X + OMH(I)
     Y = Y + FMH(I)
     Z = Z + 1 - PF(I)
NX6: NEXT I
     ZA = Z / K
7660 PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60);
"TIME: "; TIME$
7680 COLOR 7
7690 PRINT TAB(1); "WBS"; TAB(32); "ON-VEH MH"; TAB(47); "OFF-VEH MH"; TAB(60);
"PERCENT ON-VEH"
7710 FOR I = IO TO IE
7720 IF OP$(I) = "DELETE" THEN GOTO 7740
     IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 15
7730 PRINT TAB(1); WBS$(I); TAB(32); OMH(I); TAB(50); FMH(I); TAB(65); 1 - PF(I)
     IF I = 24 THEN COLOR 14: PRINT TAB(5); "AVIONICS ROLLUP"; TAB(29); X;
TAB(47); Y; TAB(62); ZA; "(AVG)"
7740 NEXT I
7750 PRINT : COLOR 2
7752 IF IO = 1 THEN IO = 19: IE = 33: PRINT : INPUT "ENTER RETURN.."; RET: GOTO
7640
     COLOR 13
```

```
      PRINT TAB(3); "UNSCHEDULED"; TAB(32); TOMH; TAB(50); TFMH; TAB(65); APF;
"(AVG)"
7755 PRINT TAB(5); "SCHEDULED"; TAB(32); .98 * SCHP * TOMH; TAB(50); .02 * SCHP
* TOMH
7770 PRINT TAB(5); "TOTAL"; TAB(32); TOMH + .98 * SCHP * TOMH; TAB(50); TFMH +
.02 * SCHP * TOMH
7780 COLOR 2
7790 INPUT "ENTER RETURN ..."; RET

END SUB

SUB MANDISPLAY
7800 'MANPOWER DISPLAY
     X = 0: Y = 0: Z = 0  'AVIONICS ROLLUP
     FOR I = 19 TO 24
     IF OP$(I) = "DELETE" THEN GOTO NX8
     X = X + MH(I)
     Z = Z + MP(I)
NX8: NEXT I
     Y = X(15) * X
7803 IO = 1: IE = 18: ASTP = 0
7805 CLS : COLOR 14
7810 PRINT TAB(25); "MANPOWER REPORT "
7820 PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60);
"TIME: "; TIME$
     COLOR 3
     PRINT TAB(5); "AVAIL HRS/MO="; X(11); TAB(40); "INDIRECT WORK="; 100 *
X(12); "%"
7830 PRINT TAB(5); "COMPUTED MNHR AVAIL FAC ="; MANF
7840 COLOR 7
     LOCATE 4, 52: PRINT "PERSONNEL BASED UPON"
7850 PRINT TAB(1); "WBS"; TAB(27); "MANHRS/MSN"; TAB(42); "MANHRS/MO"; TAB(58);
"MANHRS"; TAB(65); "MIN CREW"
7870 FOR I = IO TO IE
7880 IF OP$(I) = "DELETE" THEN GOTO 7900
     IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 15
     IF I >= 19 AND I <= 24 THEN ASTP = ASTP + C(I)
7890 PRINT TAB(1); WBS$(I); TAB(30); MH(I); TAB(45); X(15) * MH(I); TAB(59);
MP(I); TAB(65); C(I)
     IF I = 24 THEN COLOR 14: PRINT TAB(5); "AVIONICS ROLLUP"; TAB(28); X;
TAB(43); Y; TAB(58); Z; TAB(63); ASTP
7900 NEXT I
7910 COLOR 2
7912 IF IO = 1 THEN IO = 19: IE = 33: INPUT "ENTER RETURN ..."; RET: GOTO 7805
     COLOR 11
     PRINT TAB(5); "UNSCHEDULED"; TAB(30); VMH; TAB(45); VMH * X(15); TAB(59);
TMP - SMP; TAB(65); STP
7915 PRINT TAB(5); "SCHEDULED"; TAB(30); SCHP * TOMH; TAB(45); X(15) * SCHP *
TOMH; TAB(59); SMP; TAB(65); X(14)
7920 COLOR 13
7930 PRINT TAB(5); "TOTAL"; TAB(30); VMH + SCHP * TOMH; TAB(45); (VMH + SCHP *
TOMH) * X(15); TAB(59); TMP; TAB(65); STP + X(14): COLOR 14
7940 COLOR 2
7950 INPUT "ENTER RETURN TO CONTINUE..."; RET

END SUB

SUB POFFEQS
3000 'POFF EQUATIONS
     FOR I = 1 TO 33: PF(I) = X(20): NEXT I'DEFAULT VALUE
```

```
3010 'WBS 1,2 & 3  AIRFRAME          ***********
3050 PF(1) = .0835: PF(2) = .0835: PF(3) = (.0835 + .088) / 2
3100 'WUC12  AIRCREW COMPARTMENT          *************
3200  'WUC13/WBS9   LANDING GEAR SYSTEMS      ****************
3250 PF(9) = .02774 - 4.07E-06 * X1 - .00194 * X2 + .19316 * SQR(V(4)) + .007156
* SQR(W(9))
3251 IF PF(9) < .134 THEN PF(9) = .134
3252 IF PF(9) > .54 THEN PF(9) = .54
3299 '
4100 '******WUC23 PROPULSION SYSTEM **** WBS 6, 7 & 8 ********
4160 FOR I = 10 TO 12
4165 PF(I) = 1.14633 + 4.572E-05 * W(I) - .011456 * SQR(W(I))
4166 IF PF(I) < .2 THEN PF(I) = .2
4167 IF PF(I) > .725 THEN PF(I) = .725
4180 NEXT I

3400 'WUC24     APU  WBS 9.10               ***************
3450 PF(13) = -109.83 - .1645 * LOG(X1) + .1427 * V(7) - 6.1517 * SQR(V(7)) +
15.751 * LOG(V(7)) + .066 * W(13) - 5.6832 * SQR(W(13)) + 29.071 * LOG(W(13))
3451 IF PF(13) < .03 THEN PF(13) = .03
3452 IF PF(13) > .29 THEN PF(13) = .29
3465 PF(14) = 0
3499 '

3600 'WUC 42/44   WBS 10  *** ELECTRICAL SYS ******
3650 PF42 = -26.565 - .00271 * V(7) + .005143 * W(16) - .74878 * SQR(W(16)) +
6.621 * LOG(W(16))
3651 IF PF42 < .054 THEN PF42 = .054
3652 IF PF42 > .53 THEN PF42 = .53
3653 PF44 = 3.061 + 1.178E-05 * X1 - .000127 * V(3) - .42392 * LOG(X1) + .13468
* SQR(X2)
3654 IF PF44 < .03 THEN PF44 = .03
3655 IF PF44 > .47 THEN PF44 = .47
3656 PF(16) = (PF42 / FH42 + PF44 / FH44) / (1 / FH42 + 1 / FH44)
3799 '
3800 'WUC45 WBS11  HYDRAULICS SYS        ******************
3850 PF(17) = .07614 - .00181 * X2 + .001543 * SQR(X1)
3851 IF PF(17) < .014 THEN PF(17) = .014
3852 IF PF(17) > .33 THEN PF(17) = .33
3899 '
3300 'WUC14  WBS 12.00 AERO SURFACE ACTUATORS    **************
3350 PF(18) = 5.51246 + .002663 * V(5) - .000566 * W(18) - 1.193 * LOG(W(18)) +
.10556 * SQR(W(18))
3351 IF PF(18) < .04 THEN PF(18) = .04
3352 IF PF(18) > .29 THEN PF(18) = .29
3399 '

3900 ' WBS 12.XX AVIONICS  GENERAL  *******
3950 PF(19) = 7.1662 + .0209 * V(11) - .00128 * WAV + .1774 * SQR(WAV) - 1.734
* LOG(WAV) + .0067 * WAV / V(10)
3951 IF PF(19) < .193 THEN PF(19) = .193
3952 IF PF(19) > .532 THEN PF(19) = .532
3955 PF(20) = PF(19): PF(21) = PF(19): PF(22) = PF(19): PF(23) = PF(19): PF(24)
= PF(19)
4360 PF(23) = -8.734101 + .0000122 * X1 + .007198 * X2 + .80066 * LOG(X1) - .02
* SQR(X1) - 1.45834 * X(5) + .02554 * V(9) + 4.19646 * SQR(X(5))
4361 IF PF(23) < .05 THEN PF(23) = .05
4362 IF PF(23) > .44 THEN PF(23) = .44
```

```
3500 'WUC41/47 WBS14.XX  ENVIRONMENTAL CONTROL  **************
3550 PF47 = 23.852 - .00902 * X2 - 5.247 * LOG(X1) + .301 * LOG(X1) ^ 2 - .00212
* X1 / X2
3551 IF PF47 < .02 THEN PF47 = .02
3552 IF PF47 > .33 THEN PF47 = .33
3553 PF(25) = .0932: PF(26) = PF47

4010 ' WUC49/96  WBS15   PERSONNEL PROVISIONS  ****************
4050 PF49 = .19888 + 4.938E-06 * X1 - .00205 * SQR(X1) + .0004877 * V(7)
4051 IF PF49 < .002 THEN PF49 = .002
4052 IF PF49 > .45 THEN PF49 = .45
4053 PF96 = -5.4686 + .16835 * X2 - .00448 * V(3) + .36521 * X(4) - 4.1528 *
SQR(X(4)) + .178 * SQR(W(27))
4054 IF PF96 < .23 THEN PF96 = .23
4055 IF PF96 > .98 THEN PF96 = .98
4057 PF(27) = (PF49 + PF96) / 2
4099 '
4200 ' WUC91/93/97  WBS 16  ***** RECOVERY & AUX SYS ********
4230 FOR I = 28 TO 33: PA(I) = .004678: NEXT I
4253 PF91 = 4.654 - .45718 * LOG(X1) + .00242 * SQR(X1)
4254 IF PF91 < .011 THEN PF91 = .011
4255 IF PF91 > .84 THEN PF91 = .84
4257 PF(29) = (PF91 + .01) / 2: PF(28) = .287: PF(30) = .01' CHECK THIS
4270 FOR I = 1 TO 33: IF PF(I) > 1 THEN PF(I) = 1
4271 NEXT I

END SUB

SUB RELDISPLAY
9000 '***** DISPLAY MODULE FOR RELIABILITY REPORT *******
     X = 0: Y = 0: Z = 0    'AVIONICS ROLLUP
     FOR I = 19 TO 24
     IF OP$(I) = "DELETE" THEN GOTO NX1
     X = X + 1 / FMA(I): XA = 1 / X
     Y = Y + 1 / FMAT(I): YA = 1 / Y
     Z = Z + 1 / FMAS(I): ZA = 1 / Z
NX1: NEXT I
9005 IO = 1: IE = 18
9010 CLS : COLOR 14
9020 PRINT TAB(25); "RELIABILITY REPORT - page 1"
9030 PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60);
"TIME: "; TIME$
9048 COLOR 7
9050 PRINT : PRINT TAB(1); "WBS"; TAB(25); "CALIBRATED MTBM"; TAB(48); "TECH
ADJ"; TAB(61); "SPACE ADJ"
9070 FOR I = IO TO IE
9080 IF OP$(I) = "DELETE" THEN GOTO 9092
9085 IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 15
     IF I = 9 THEN PRINT TAB(1); WBS$(I); "  MSN'S/FAILURE "; TAB(35); FMA(I);
TAB(48); FMAT(I); TAB(61); FMAS(I)
9090 IF I <> 9 THEN PRINT TAB(1); WBS$(I); TAB(35); FMA(I); TAB(48); FMAT(I);
TAB(61); FMAS(I)
     IF I = 24 THEN COLOR 14: PRINT TAB(5); "AVIONICS ROLLUP"; TAB(32); XA;
TAB(45); YA; TAB(58); ZA
9092 NEXT I
9093 PRINT : COLOR 2
9094 IF IO = 1 THEN IO = 19: IE = 33: INPUT "ENTER RETURN.."; RET: CLS : GOTO
9010
9095 COLOR 13
9100 PRINT TAB(5); "VEHICLE"; TAB(35); VFMA; TAB(48); TVFMA; TAB(61); SVFMA
9105 COLOR 2
9110 INPUT "ENTER RETURN ..."; RET
```

```
9120 CLS
     X = 0: Y = 0: Z = 1: K = 0 'AVIONICS ROLLUP
     FOR I = 19 TO 24
     IF OP$(I) = "DELETE" THEN GOTO NX2
     K = K + 1
     X = X + PA(I)
     Y = Y + 1 / FMAC(I): YA = 1 / Y
     Z = Z * R(I)
NX2: NEXT I
     IF K = 0 THEN K = 1
     XA = X / K
9125 IO = 1: IE = 18
9130 COLOR 14: PRINT TAB(20); "RELIABILITY REPORT - page 2"
9140 PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60);
"TIME: "; TIME$
9160 COLOR 7
9170 PRINT TAB(1); "WBS"; TAB(33); "CRITICAL"; TAB(48); "CRITICAL"; TAB(60);
"SUBSYS NON-"
9171 PRINT TAB(33); "FAIL RATE"; TAB(48); "MTBM"; TAB(60); "REDUNDANT MSN REL"
9190 FOR I = IO TO IE
9200 IF OP$(I) = "DELETE" THEN GOTO 9220
9205 IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 15
9210 PRINT TAB(1); WBS$(I); TAB(33); PA(I); TAB(48); FMAC(I); TAB(65); R(I)
     IF I = 24 THEN COLOR 14: PRINT TAB(5); "AVIONICS ROLLUP"; TAB(27); XA;
"AVG"; TAB(45); YA; TAB(62); Z
9220 NEXT I
9230 PRINT : COLOR 2
9235 IF IO = 1 THEN IO = 19: IE = 33: INPUT "ENTER RETURN.."; RET: CLS : GOTO
9130
9240 COLOR 13
9250 PRINT TAB(5); "VEHICLE"; TAB(48); CVFMA; TAB(65); VR
9260 COLOR 2
9270 INPUT "ENTER RETURN ..."; RET
9280 CLS
9285 IO = 1: IE = 18
9300 COLOR 14: PRINT TAB(20); "RELIABILITY REPORT (REDUNDANCY) - page 3"
     X = 1: Y = 1: Z = 1     'AVIONICS ROLLUP
     FOR I = 19 TO 24
     IF OP$(I) = "DELETE" THEN GOTO NX3
     X = X * R1(I)
     Y = Y * R2(I)
     Z = Z * R3(I)
NX3: NEXT I

9305 PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60);
"TIME: "; TIME$
9310 COLOR 7
9315 PRINT TAB(1); "WBS"; TAB(33); "LAUNCH"; TAB(45); "END OF"; TAB(60); "ORBIT"
9320 PRINT TAB(33); "TIME"; TAB(45); "POWER FLT"; TAB(60); "INSERTION"
9330 FOR I = IO TO IE
9335 IF OP$(I) = "DELETE" THEN GOTO 9345
9337 IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 15
9340 PRINT TAB(1); WBS$(I); TAB(33); R1(I); TAB(45); R2(I); TAB(60); R3(I)
   IF I = 24 THEN COLOR 14: PRINT TAB(5); "AVIONICS ROLLUP"; TAB(30); X; TAB(42);
Y; TAB(57); Z
9345 NEXT I
9350 PRINT
9355 IF IO = 1 THEN IO = 19: IE = 33: INPUT "ENTER RETURN.."; RET: CLS : GOTO
9300
     COLOR 13
9360 PRINT TAB(5); "VEHICLE"; TAB(33); VR1; TAB(45); VR2; TAB(60); VR3
9365 COLOR 2
```

```
9370 INPUT "ENTER RETURN ..."; RET
9380 CLS
     X = 1: Y = 1: Z = 1     'AVIONICS ROLLUP
     FOR I = 19 TO 24
     IF OP$(I) = "DELETE" THEN GOTO NX4
     X = X * R4(I)
     Y = Y * R5(I)
NX4: NEXT I

9385 IO = 1: IE = 18
9400 COLOR 14: PRINT TAB(20); "RELIABILITY REPORT (REDUNDANCY) - page 4"
9405 PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60);
"TIME: "; TIME$
9410 COLOR 7
9415 PRINT TAB(1); "WBS"; TAB(45); "REENTRY"; TAB(60); "MISSION"
9420 PRINT TAB(60); "COMPLETION"
9430 FOR I = IO TO IE
9435 IF OP$(I) = "DELETE" THEN GOTO 9445
9437 IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 15
9440 PRINT TAB(1); WBS$(I); TAB(45); R4(I); TAB(60); R5(I)
     IF I = 24 THEN COLOR 14: PRINT TAB(5); "AVIONICS ROLLUP"; TAB(42); X;
TAB(57); Y
9445 NEXT I
9450 PRINT : COLOR 2
9455 IF IO = 1 THEN IO = 19: IE = 33: INPUT "ENTER RETURN.."; RET: CLS : GOTO
9400
     COLOR 13
9460 PRINT TAB(5); "VEHICLE"; TAB(45); VR4; TAB(60); VR5
9465 COLOR 2
9470 INPUT "ENTER RETURN ..."; RET
END SUB

SUB SECONDARY
11120 'SUBROUTINE TO COMPUTE SECONDARY VARIABLES
11122 'WETTED AREA
11123 V(3) = 486.026 + .1510165 * X2 ^ 2
11130 'NBR WHEELS
11140 V(4) = 2.189572 + 6.66297E-05 * X(1) - 1.38718E-10 * X(1) ^ 2
11150 V(4) = CINT(V(4))
11160 IF V(4) < 3 THEN V(4) = 3
11170 'NBR CONTROL SURFACES
11180 V(6) = 3.588737 + .0005281 * X(1) + .09493 * X2 - .00517 * V(3)
11190 IF V(6) < 6 THEN V(6) = 6
11200 V(6) = INT(V(6))
11210 'NBR ACTUATORS
11220 V(5) = -41 - .001425 * X1 + 2.0752E-09 * X1 ^ 2 + .007467 * V(3) - 1.0377
* SQR(V(3)) + .4828 * SQR(X1) + 14.97 * SQR(V(6)) - .017811 * V(6) ^ 2
11230 IF V(5) < 5 THEN V(5) = 5
11240 V(5) = INT(V(5))
11280 'KVA MAX
11290 V(7) = -214.812 + .001098 * X(1) + 25.1571 * LOG(X(1))
11300 IF V(7) < 11 THEN V(7) = 11
11340 'NBR AVIONICS SYSTEMS   (TOTSUBS)
11350 V(10) = -40.4242 - 1.879E-05 * X(1) + 6.192823 * LOG(X(1))
11360 IF V(10) < 9 THEN V(10) = 9
11370 V(10) = CINT(V(10))
11420 'NBR DIFFERENT AVIONICS SUBSYSTEMS
11430 V(11) = 9.674 - 1.858 * LOG(X(1)) + .87684 * V(10) + 1.4557 * LOG(WAV)
11440 IF V(11) < 5 THEN V(11) = 5: IF V(11) > V(10) THEN V(11) = V(10)
11450 V(11) = CINT(V(11))
```

```
11460 'BTU COOLING
11470 V(12) = -1114.52 - 12.0178 * X2 + .009405 * X2 ^ 2 + 230.872 * SQR(X2)
11480 IF V(12) < 25 THEN V(12) = 25
11510 'NBR HYDRAULICS SUBSYSTEMS
11520 V(8) = 13.48 - .56854 * X2 + .002409 * V(3) + .433276 * SQR(X1)
11530 IF V(8) < 8 THEN V(8) = 8
11540 V(8) = CINT(V(8))
11550 'NBR INTERNAL FUEL TANKS
11560 V(9) = -13.2236 + 1.851772 * LOG(X(1))
11570 IF V(9) < 2 THEN V(9) = 2
11580 IF V(9) > 12 THEN V(9) = 12
11590 V(9) = CINT(V(9))
11620 'FUSELAGE AREA
11630 V(1) = -8832.74 + .082862 * X(1) + 1274.76 * LOG(X(1)) - 32.456 * SQR(X(1))
11640 IF V(1) < 478 THEN V(1) = 478
11650 'FUSELAGE VOLUME
11660 V(2) = -47618.5 + 22143 * LOG(X2) - 5743.09 * SQR(X2) + .42623 * X2 ^ 2
11670 IF V(2) < 571 THEN V(2) = 571

END SUB

SUB SPAREDISPLAY
8500 ' DISPLAY SPARES RESULTS
     X = 0: Y = 0: Z = 0: K = 0 'AVIONICS ROLLUP
     FOR I = 19 TO 24
     IF OP$(I) = "DELETE" THEN GOTO NX7
     K = K + 1
     X = X + RR(I)
     Y = Y + NR(I)
     Z = Z + S(I)
     ZX = ZX + FR(I)
NX7: NEXT I
     XA = X / K
     ZX = ZX / K
8505 IO = 1: IE = 18
8510 CLS : COLOR 14
8520 PRINT TAB(25); "SUBSYSTEM SPARES REPORT"
8530 PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60);
"TIME: "; TIME$
     COLOR 3: PRINT TAB(5); "NOTE:  failures are assumed to be Poisson"
8545 COLOR 7
     PRINT TAB(32); "REMOVAL"; TAB(42); "MEAN DEMAND"; TAB(56); "SPARES";
TAB(65); "EFFECTIVE"
8550 PRINT TAB(1); "WBS"; TAB(32); "RATE/MA"; TAB(42); "PER MISSION"; TAB(56);
" RQMT"; TAB(65); "FILL RATE"
8570 FOR I = IO TO IE
8580 IF OP$(I) = "DELETE" THEN GOTO 8600
     IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 15
8590 PRINT TAB(1); WBS$(I); TAB(30); RR(I); TAB(41); NR(I); TAB(55); S(I);
TAB(65); FR(I)
     IF I = 24 THEN COLOR 14: PRINT TAB(5); "AVIONICS ROLLUP"; TAB(25); XA;
"(AVG)"; TAB(40); Y; TAB(56); Z; TAB(62); ZX; "(AVG)"
8600 NEXT I
     COLOR 2
8615 IF IO = 1 THEN IO = 19: IE = 33: INPUT "ENTER RETURN.."; RET: GOTO 8510
8620 COLOR 13
8630 PRINT TAB(5); "TOTALS"; TAB(27); ARR; "(AVG)"; TAB(43); TNR; TAB(55); TS
8640 COLOR 2: INPUT "ENTER RETURN ..."; RET

END SUB
```

```
SUB SUMMARY
  CLS : COLOR 10
  PRINT TAB(20); "SYSTEM PERFORMANCE SUMMARY - page 1"
  PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60); "TIME:
"; TIME$
  COLOR 14: PRINT : PRINT TAB(30); "RELIABILITY REPORT "
  PRINT :
  COLOR 7
  PRINT  TAB(1);  "CATEGORY";  TAB(33);  "LAUNCH";  TAB(45);  "END  OF";  TAB(60);
"ORBIT"
  PRINT TAB(33); "TIME"; TAB(45); "POWER FLT"; TAB(60); "INSERTION"
  PRINT : COLOR 12
  PRINT TAB(5); "VEHICLE"; TAB(33); VR1; TAB(45); VR2; TAB(60); VR3
  IF SRBREL < 1 THEN PRINT TAB(5); "VEHICLE+LRB"; TAB(33); SRBREL * VR1; TAB(45);
SRBREL * VR2; TAB(60); SRBREL * VR3
  IF ETREL < 1 THEN PRINT TAB(5); "VEHICLE+LRB+ET"; TAB(33); ETREL * SRBREL *
VR1; TAB(45); ETREL * SRBREL * VR2; TAB(60); ETREL * SRBREL * VR3
  PRINT : COLOR 7
  PRINT TAB(1); TAB(45); "REENTRY"; TAB(60); "MISSION"
  PRINT TAB(60); "COMPLETION": COLOR 12
  PRINT TAB(5); "VEHICLE"; TAB(45); VR4; TAB(60); VR5
  IF SRBREL < 1 THEN PRINT TAB(5); "VEHICLE+LRB"; TAB(45); SRBREL * VR4; TAB(60);
SRBREL * VR5
  IF ETREL < 1 THEN PRINT TAB(5); "VEHICLE+LRB+ET"; TAB(45); ETREL * SRBREL *
VR4; TAB(60); ETREL * SRBREL * VR5
  PRINT


  COLOR 2
  IF MTE = 0 THEN MTE = 1
  PRINT : INPUT "ENTER RETURN.."; RET
  CLS : COLOR 10
  PRINT TAB(20); "SYSTEM PERFORMANCE SUMMARY  - page 2"
  PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60); "TIME:
"; TIME$
     PRINT : COLOR 14: PRINT TAB(30); "MAINTAINABILITY REPORT"
     COLOR 7: PRINT TAB(65); "UNSCHED"
     PRINT  TAB(1);  "CATEGORY";  TAB(30);  "MAINT  ACTIONS/MSN";  TAB(50);  "TOT
MANHR/MA"; TAB(65); "AVG MANHRS/MSN"
     PRINT : COLOR 12
     PRINT TAB(5); "VEHICLE"; TAB(32); TMA; TAB(50); AMHMA; "(AVG)"; TAB(65); VMH
/ MTE; TAB(65); STE
     IF ETREL < 1 THEN PRINT TAB(5); "EXTERNAL TANK"; TAB(32); MTE; TAB(50); STE
     IF SRBREL < 1 THEN PRINT TAB(5); "BOOSTER"; TAB(32); MTF; TAB(50); STF /
MTF; TAB(65); STF
     PRINT : COLOR 7
     PRINT TAB(32); "ON-VEH MH"; TAB(47); "OFF-VEH MH"; TAB(60); "PERCENT ON-VEH"
     COLOR 12: PRINT TAB(5); "VEHICLE"
     PRINT TAB(7); "UNSCHED"; TAB(32); TOMH; TAB(50); TFMH
     PRINT TAB(7); "SCHEDULED"; TAB(32); .98 * SCHP * TOMH; TAB(50); .02 * SCHP
* TOMH
     PRINT TAB(7); "TOTALS"; TAB(32); TOMH + .98 * SCHP * TOMH; TAB(50); TFMH +
.02 * SCHP * TOMH; TAB(65); APF; "(AVG)"
     PRINT TAB(5); "EXTERNAL TANK"
     IF ETREL < 1 THEN PRINT TAB(7); "SCHED/UNSCHED"; TAB(32); STE + ETS * STE
     PRINT TAB(5); "BOOSTER"
     IF ETREL < 1 THEN PRINT TAB(7); "SCHED/UNSCHED"; TAB(32); STF + SRBS * STF
     COLOR 2: PRINT : INPUT "ENTER RETURN.."; RET

     CLS : COLOR 10
     SCMP = X(14): B1 = 0: B4 = 0: A2 = 0: B2 = 0: A1 = 0
     PRINT TAB(20); "SYSTEM PERFORMANCE SUMMARY - page 3"
```

```
    PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60);
"TIME: "; TIME$
    PRINT : COLOR 14: PRINT : PRINT TAB(30); "MANPOWER/SPARES REPORT"
    PRINT : COLOR 13: PRINT TAB(5); "SPARES-VEHICLE"; TAB(30); TS
    PRINT : COLOR 7
    PRINT TAB(1); "CATEGORY"; TAB(25); "MANHR DRIVEN"; TAB(40); "MANHR DRIVEN";
TAB(55); "CREW SZ"; TAB(65); "TOT CREW"
    PRINT TAB(25); "AGGREGATE"; TAB(40); "BY SUBSYS"; TAB(55); "BY SUBSYS";
TAB(65); "BY SUBSYS"
    PRINT : COLOR 12
    PRINT TAB(3); "VEHICLE"
    A2 = (VMH * X(15)) / (X(11) * (1 - X(12)))
    A2 = INT(A2 + .999)
    B2 = (SCHP * TOMH * X(15)) / (X(11) * (1 - X(12)))
    B2 = INT(B2 + .999)
    PRINT TAB(5); "UNSCH MANPWR"; TAB(25); A2; TAB(40); TMP - SMP; TAB(55); STP;
TAB(65); C1
    PRINT TAB(5); "SCHED MANPWR"; TAB(25); B2; TAB(40); SMP; TAB(55); SCMP;
TAB(65); SCMP
    PRINT TAB(5); "TOTAL"; TAB(25); A2 + B2; TAB(40); TMP; TAB(55); STP + SCMP;
TAB(65); C1 + SCMP
    PRINT TAB(3); "EXT TANK"
    A1 = ((ETS * STE + STE) * X(15)) / (X(11) * (1 - X(12)))
    A1 = INT(A1 + .999)
    B1 = ETCREW(1) + ETCREW(2) + ETCREW(3) + ETCREW(4) + ETCREW(5)
    B1 = INT(B1 + .999)
    IF ETREL < 1 THEN PRINT TAB(5); "SCHD/UNSCH MANPWR"; TAB(25); A1; TAB(40);
TME; TAB(55); B1; TAB(65); B1
    PRINT TAB(3); "LRB"
    A4 = ((SRBS * STF + STF) * X(15)) / (X(11) * (1 - X(12)))
    A4 = INT(A4 + .999)
    B4 = SRBCREW(1) + SRBCREW(2) + SRBCREW(3) + SRBCREW(4)
    B4 = INT(B4 + .999)
    IF ETREL = 1 THEN B1 = 0
    IF SRBREL = 1 THEN B4 = 0
    IF SRBREL < 1 THEN PRINT TAB(5); "SCHD/UNSCH MANPWR"; TAB(25); A4; TAB(40);
TMF; TAB(55); B4; TAB(65); B4
    PRINT : PRINT TAB(10); "TOTALS"; TAB(25); A2 + B2 + A1 + A4; TAB(40); TMP
+ TME + TMF; TAB(55); STP + SCMP + B1 + B4; TAB(65); C1 + SCMP + B1 + B4
    COLOR 2
  PRINT : INPUT "ENTER RETURN.."; RET
    CLS
  ' VEHICLE TURN TIME SUMMARY
    TT = 0: TI = 0: TMAX = 0
    SUM = 0: CT = 0: SUMC = 0
    FOR I = 1 TO 33
    IF OP$(I) = "DELETE" THEN GOTO N1
    CT = CT + 1
    SUMC = SUMC + C(I)
    IF SEL$(I) = "SHUTTLE" THEN TSKT(I) = SMR(I) ELSE TSKT(I) = (1 - PF(I)) *
MHMA(I) / C(I)
    TI = (THRS(I) / FMAS(I)) * TSKT(I) / CA(I)
    IF TI > TMAX THEN TMAX = TI: JJ = I
    TT = TT + TI
    SUM = SUM + TSKT(I)
```

```
N1:  NEXT I
     SCHT = .98 * SCHP * TOMH / X(14)
     GTT = TT + SCHT: ATSK = SUM / CT
     IF TMAX < SCHT THEN TMAX = SCHT
     PRINT TAB(20); "SYSTEM PERFORMANCE SUMMARY - page 4"
     PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60);
"TIME: "; TIME$
     COLOR 14: PRINT : PRINT TAB(35); "VEHICLE TURN TIMES": PRINT
     COLOR 14
     PRINT TAB(35); "MIN TURN TIME"; TAB(55); "MAX TURN TIME"
     PRINT TAB(1); "ONE SHIFT/DAY MAINTENANCE": COLOR 15
     DVTT = (T(0) + T(4)) / 24 + (TMAX + X(17) + X(18)) / 8
     MDVTT = (T(0) + T(4)) / 24 + (TT + SCHT + X(17) + X(18)) / 8
     PRINT TAB(5); "TOT VEHICLE TURNAROUND TIME"; TAB(35); DVTT; "DAYS"; TAB(55);
MDVTT
     PRINT TAB(5); "AVG MISSIONS/MONTH/VEHICLE"; TAB(35); 21 / DVTT; TAB(55); 21
/ MDVTT
     PRINT TAB(5); "COMPUTED FLEET SIZE "; TAB(35); INT(X(15) / (21 / DVTT) +
.99); TAB(55); INT(X(15) / (21 / MDVTT) + .99)
     PRINT
     COLOR 14: PRINT TAB(1); "TWO SHIFTS/DAY MAINTENANCE": COLOR 15
     DVTT = (T(0) + T(4)) / 24 + (TMAX + X(17) + X(18)) / 16
     MDVTT = (T(0) + T(4)) / 24 + (TT + SCHT) / 16
     PRINT TAB(5); "TOT VEHICLE TURNAROUND TIME"; TAB(35); DVTT; "DAYS"; TAB(55);
MDVTT
     PRINT TAB(5); "AVG MISSIONS/MONTH/VEHICLE"; TAB(35); 21 / DVTT; TAB(55); 21
/ MDVTT
     PRINT TAB(5); "COMPUTED FLEET SIZE "; TAB(35); INT(X(15) / (21 / DVTT) +
.99); TAB(55); INT(X(15) / (21 / MDVTT) + .99)
     PRINT
     COLOR 14: PRINT TAB(1); "THREE SHIFTS/DAY MAINTENANCE": COLOR 15
     DVTT = (T(0) + T(4)) / 24 + (TMAX + X(17) + X(18)) / 24
     MDVTT = (T(0) + T(4)) / 24 + (TT + SCHT) / 24
     PRINT TAB(5); "TOT VEHICLE TURNAROUND TIME"; TAB(35); DVTT; "DAYS"; TAB(55);
MDVTT
     PRINT TAB(5); "AVG MISSIONS/MONTH/VEHICLE"; TAB(35); 21 / DVTT; TAB(55); 21
/ MDVTT
     PRINT TAB(5); "COMPUTED FLEET SIZE "; TAB(35); INT(X(15) / (21 / DVTT) +
.99); TAB(55); INT(X(15) / (21 / MDVTT) + .99)
     PRINT : COLOR 2: INPUT "ENTER RETURN..."; RET

END SUB

SUB TURNTIME
9700 'MODULE TO DISPLAY VEHICLE TURN TIME
9705 TT = 0: TI = 0: TMAX = 0
9706 SUM = 0: CT = 0: SUMC = 0
9710 FOR I = 1 TO 33
9715 IF OP$(I) = "DELETE" THEN GOTO 9735
9716 CT = CT + 1
     SUMC = SUMC + C(I)
9720 IF SEL$(I) = "SHUTTLE" THEN TSKT(I) = SMR(I) ELSE TSKT(I) = (1 - PF(I)) *
MHMA(I) / C(I)
     TI = (THRS(I) / FMAS(I)) * TSKT(I) / CA(I)
     IF TI > TMAX THEN TMAX = TI: JJ = I
9730 TT = TT + TI
9733 SUM = SUM + TSKT(I)
9735 NEXT I
     AVCREW = SUMC / CT
9740 SCHT = .98 * SCHP * TOMH / X(14)
9750 GTT = TT + SCHT: ATSK = SUM / CT
```

```
9800 ' DISPLAY VEHICLE TURN TIME
     W = 0: X = 0: Y = 0: Z = 0: K = 0'AVIONICS ROLLUP
     FOR I = 19 TO 24
     IF OP$(I) = "DELETE" THEN GOTO NX10
     K = K + 1
     X = X + CA(I)
     Y = Y + TSKT(I)
     Z = Z + (THRS(I) / FMAS(I)) * TSKT(I) / CA(I)
     W = W + THRS(I) / FMAS(I)
NX10: NEXT I
     YA = Y / K
9805 IO = 1: IE = 18
9810 CLS : COLOR 14
9820 PRINT TAB(25); "VEHICLE TURN TIME REPORT - page 1"
9830 PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60);
"TIME: "; TIME$
9845 COLOR 7
     PRINT TAB(25); "ON-VEHICLE"; TAB(38); " TOT "; TAB(52); "NBR CREWS";
TAB(62); "AVG SUBSYS REPAIR"
9850 PRINT TAB(1); "WBS"; TAB(25); "MTTR (HRS)"; TAB(38); "MAIN ACT"; TAB(52);
"ASSIGNED"; TAB(62); "TIME PER MSN"
9870 FOR I = IO TO IE
9880 IF OP$(I) = "DELETE" THEN GOTO 9900
     IF SEL$(I) = "SHUTTLE" THEN COLOR 12 ELSE COLOR 15
     IF I = JJ THEN COLOR 19
9885 TEMP = (THRS(I) / FMAS(I)) * TSKT(I) / CA(I)
     IF I = JJ THEN TSAVE = TEMP
9890 PRINT TAB(1); WBS$(I); TAB(28); TSKT(I); TAB(40); THRS(I) / FMAS(I);
TAB(54); CA(I); TAB(62); TEMP
     IF I = 24 THEN COLOR 14: PRINT TAB(5); "AVIONICS ROLLUP"; TAB(27); "AVG"; YA;
TAB(40); W; TAB(53); X; TAB(61); Z; "TOT"
9900 NEXT I
     COLOR 2
9905 IF IO = 1 THEN IO = 19: IE = 33: PRINT : INPUT "ENTER RET"; RET: CLS : GOTO
9810
     PRINT : COLOR 13
     PRINT TAB(1); "AVG CREW SIZE"; AVCREW; TAB(26); "AVG TASK TIME"; ATSK;
TAB(60); TT; "(TOTAL)"
9910 PRINT : COLOR 2: INPUT "ENTER RETURN....."; RET
9920 CLS : COLOR 14
9921 PRINT TAB(25); "VEHICLE TURN TIME REPORT - page 2"
9922 PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60);
"TIME: "; TIME$
     COLOR 15: PRINT : PRINT TAB(5); "CATEGORY"; TAB(52); "MIN TURN TIMES": PRINT
     PRINT TAB(5); "SCHD MAINT MSN TASK TIME"; TAB(55); SCHT; "HRS"
     PRINT TAB(5); "UNSCHEDULED MAINTENANCE TIME"; TAB(55); TSAVE; "HRS"
     PRINT TAB(5); "INTEGRATION TIME"; TAB(55); X(17); "HRS"
     PRINT TAB(5); "LAUNCH PAD TIME"; TAB(55); X(18); "HRS"
     PRINT TAB(5); "MISSION TIME -INC GRND PWR TIME"; TAB(55); T(0) + T(4); "HRS"
     IF TSAVE < SCHT THEN TSAVE = SCHT
     VTT = T(0) + T(4) + TSAVE + X(17) + X(18): COLOR 12
     PRINT TAB(5); "TOT VEHICLE TURNAROUND TIME"; TAB(55); VTT; "TOTAL HRS"
     COLOR 14
     PRINT TAB(1); "ONE SHIFT/DAY MAINTENANCE"
     DVTT = (T(0) + T(4)) / 24 + (TSAVE + X(17) + X(18)) / 8
     PRINT TAB(5); "TOT VEHICLE TURNAROUND TIME"; TAB(55); DVTT; "DAYS"
     PRINT TAB(5); "AVG MISSIONS/MONTH/VEHICLE"; TAB(55); 21 / DVTT
     PRINT TAB(5); "COMPUTED FLEET SIZE "; TAB(55); INT(X(15) / (21 / DVTT) +
.99)
     PRINT TAB(1); "TWO SHIFTS/DAY MAINTENANCE"
     DVTT = (T(0) + T(4)) / 24 + (TSAVE + X(17) + X(18)) / 16
     PRINT TAB(5); "TOT VEHICLE TURNAROUND TIME"; TAB(55); DVTT; "DAYS"
```

```
      PRINT TAB(5); "AVG MISSIONS/MONTH/VEHICLE"; TAB(55); 21 / DVTT
      PRINT TAB(5); "COMPUTED FLEET SIZE "; TAB(55); INT(X(15) / (21 / DVTT) +
.99)
      COLOR 3
      PRINT TAB(5); "NOTE:  assumes parallel unsch/sched maint tasks, 8 hr shifts,
and 21 work days a month"
      COLOR 2
      PRINT : INPUT "ENTER RETURN ..."; RET
      CLS : COLOR 14
      PRINT TAB(25); "VEHICLE TURN TIME REPORT - page 3"
      PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60);
"TIME: "; TIME$
      COLOR 15: PRINT : PRINT TAB(5); "CATEGORY"; TAB(52); "MAX TURN TIMES": PRINT
      PRINT TAB(5); "SCHD MAINT MSN TASK TIME"; TAB(55); SCHT; "HRS"
      PRINT TAB(5); "UNSCHED MAINT TIME"; TAB(55); TT; "HRS"
      PRINT TAB(5); "INTEGRATION TIME"; TAB(55); X(17); "HRS"
      PRINT TAB(5); "LAUNCH PAD TIME"; TAB(55); X(18); "HRS"
      PRINT TAB(5); "MISSION TIME -INC GRND TIME"; TAB(55); T(0) + T(4); "HRS"
      VTT = T(0) + T(4) + TT + SCHT + X(17) + X(18): COLOR 12
      PRINT TAB(5); "TOT VEHICLE TURNAROUND TIME"; TAB(55); VTT; "TOTAL HRS"
      COLOR 14: PRINT TAB(1); "ONE SHIFT/DAY MAINTENANCE"
      DVTT = (T(0) + T(4)) / 24 + (TT + SCHT + X(17) + X(18)) / 8
      PRINT TAB(5); "TOT VEHICLE TURNAROUND TIME"; TAB(55); DVTT; "DAYS"
      PRINT TAB(5); "AVG MISSIONS/MONTH/VEHICLE"; TAB(55); 21 / DVTT
9960  PRINT TAB(5); "COMPUTED FLEET SIZE "; TAB(55); INT(X(15) / (21 / DVTT) +
.99)
      PRINT TAB(1); "TWO SHIFTS/DAY MAINTENANCE"
      DVTT = (T(0) + T(4)) / 24 + (TT + SCHT) / 16
      PRINT TAB(5); "TOT VEHICLE TURNAROUND TIME"; TAB(55); DVTT; "DAYS"
      PRINT TAB(5); "AVG MISSIONS/MONTH/VEHICLE"; TAB(55); 21 / DVTT
      PRINT TAB(5); "COMPUTED FLEET SIZE "; TAB(55); INT(X(15) / (21 / DVTT) +
.99)
      COLOR 3
      PRINT TAB(5); "NOTE:  assumes sequential tasks, 8 hr shifts, and 21 work
days a month"
      COLOR 2
9985  PRINT : INPUT "ENTER RETURN ..."; RET
      CLS : COLOR 14
      PRINT TAB(25); "VEHICLE TURN TIME REPORT - page 4"
      PRINT TAB(1); "VEHICLE IS "; VNAM$; TAB(35); "DATE: "; DATE$; TAB(60);
"TIME: "; TIME$
      COLOR 15: PRINT : PRINT TAB(5); "CATEGORY": PRINT
      PRINT TAB(1); "THREE SHIFTS/DAY MAINTENANCE"; TAB(52); "MIN TURN TIMES"
      DVTT = (T(0) + T(4)) / 24 + (TSAVE + X(17) + X(18)) / 24
      COLOR 14: PRINT TAB(5); "TOT VEHICLE TURNAROUND TIME"; TAB(55); DVTT; "DAYS"
      PRINT TAB(5); "AVG MISSIONS/MONTH/VEHICLE"; TAB(55); 21 / DVTT
      PRINT TAB(5); "COMPUTED FLEET SIZE "; TAB(55); INT(X(15) / (21 / DVTT) +
.99)
      PRINT
      COLOR 15: PRINT TAB(1); "THREE SHIFTS/DAY MAINTENANCE"; TAB(52); "MAX TURN
TIMES"
      DVTT = (T(0) + T(4)) / 24 + (TT + SCHT) / 24
      COLOR 14: PRINT TAB(5); "TOT VEHICLE TURNAROUND TIME"; TAB(55); DVTT; "DAYS"
      PRINT TAB(5); "AVG MISSIONS/MONTH/VEHICLE"; TAB(55); 21 / DVTT
      PRINT TAB(5); "COMPUTED FLEET SIZE "; TAB(55); INT(X(15) / (21 / DVTT) +
.99)
      COLOR 3: PRINT
      PRINT TAB(5); "NOTE:  assumes 8 hr shifts, and 21 work days a month"
      COLOR 2
      PRINT : INPUT "ENTER RETURN ..."; RET

END SUB
```