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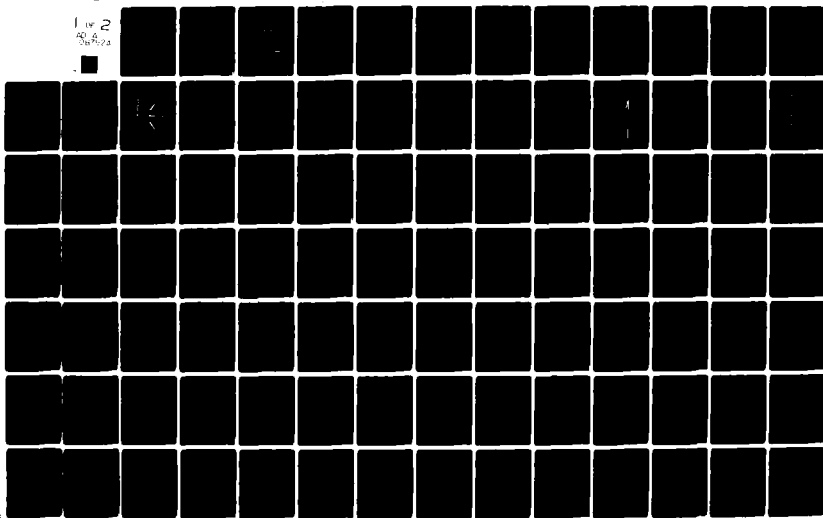
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LANDING SYSTEM RELIABILITY AND SAFETY MODEL

L. FUDGE
L. GEPHART
G. YINGLING

UNIVERSITY OF DAYTON
MANAGEMENT SCIENCE
DAYTON, OHIO 45469

AUGUST 1979

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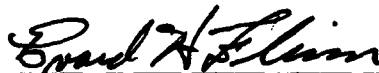
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JOHN W. DAVISON
Project Engineer
Control Management Group



EVARD H. FLINN, Chief
Control Systems Development Branch
Flight Control Division

FOR THE COMMANDER



MORRIS A. OSTGAARD, Acting Chief
Flight Control Division
AF Flight Dynamics Laboratory

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FOREWARD

This document is the technical report on a total systems analysis procedure developed for identifying the safety hazards and risks associated with the use of a defined flight control system for low visibility approach and landing (Category III). The analysis includes the ground transmitting system with monitoring, airborne automatic flight control, the pilot and copilot operating in the system, and crew procedures. Actual data from Category III experience in a specially equipped C-141 aircraft, along with equipment failure data from C-141 fleet experience, was used to test and confirm the modeling techniques.

The reliability/safety analysis program reported herein is a part of a broad joint Federal Aviation Administration (FAA) and Air Force (AF) effort for gathering data on the psychological, physiological, and procedural aspects of landing a large turbojet aircraft in actual low visibility weather down to and including Category IIIc weather (zero ceiling and zero visibility).

There are a number of reports and papers dealing with parts of the total program. For the reader who needs an insight into the total program, extracts of important details are included in the appendices. Where more detailed information and data are required, references may be obtained for further study.

Program management for the overall joint program has been provided by the Air Force Flight Dynamics Lab (AFFDL/FGT) under Project 2187, Low Visibility Terminal Area Operations, with Reliability/Safety Analysis support of the All Weather Landing System Program (AWLS) provided by the University of Dayton under contract F33615-74-C-3075, dated June 3, 1974. Flight tests were conducted by the 4950th Test Wing of the Aeronautical Systems Division at Wright Patterson Air Force Base, Ohio.

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SECTION I

INTRODUCTION

1.1 OBJECTIVE

The objective of the work reported in this document was to provide an analytical means whereby an existing or proposed airborne/ground guidance system could be analyzed from a safety/reliability and risk assessment point of view. A further objective was to test the analytical system (model) with actual flight experience data and correct it, where needed, in order to increase confidence in the model.

1.2 BACKGROUND

The aviation community and the FAA have been working for many years toward the ultimate goal of all-weather landings. The high cost of disruptions to jet flights caused by weather diversions has given impetus to development of an all-weather capability for jet aircraft. The requirements of the military for all-weather operations are self evident and of high priority.

Standards of performance have been developed by special committees working under the AWOP (All Weather Operations Panel) of the ICAO (International Civil Aviation Organization). With the establishment of ICAO performance standards and definition of approach limitations based upon decision height and runway visual range (RVR), (see Table I), very significant developments have taken place in the fields of guidance and control. A result of these developments is the acceptance of fully automatic landings which require total reliance on the autopilot, at least as the prime system.

Although instrument flight has progressed to a remarkable level of capability over the years, the attainment of safe and routine low visibility landings is yet to be realized. With some minor exceptions, the currently accepted operational limitation in the aviation community is 1200 feet runway visibility. Although several organizations have conducted flight test programs to investigate this unknown environment and made significant contributions, the problem of complete all-weather capability has not been solved.

In an effort to gain more experience and data and to perhaps better define this environment, the FAA and the Air Force jointly conducted an All Weather Landing System (AWLS) test program in which this reliability/safety analysis program played an important role.

Table 1

International Civil Aviation Organization Weather Criteria

<u>Category</u>	<u>Decision Height</u>	<u>Runway Visual Range</u>
	<u>(feet)</u>	<u>(feet/meters)*</u>
I	200	2600/800
II	100	1200/400
IIIa	none	700/200
IIIb	none	150/50
IIIc	none	0/0

* note: While one meter is 3.280 feet, the above definitions indicate the approximately equivalent measurements in feet/meters which are the generally accepted values.

1.3 HISTORICAL DEVELOPMENT OF PRESENT PROGRAM

FAA interest in the development of an all-weather landing capability in the C-141 began early in the basic C-141 development program. Initially, Category II capability was of primary interest. Later, interest was shown by the FAA in the development of a Category III capability in the C-141. The Lockheed-Georgia Co. made a series of modifications to the Category II system in NC-141A-61-2775 and, starting in 1968, carried out a series of flight tests of the resulting Category III configuration for the FAA at the National Aviation Facility Experimental Center (NAFEC), Atlantic City, New Jersey. The objective of the flight tests was to obtain adequate data to define minimum performance and equipment/requirements criteria for Category III operations and to identify existing system deficiencies which were prohibiting actual Category III operations. The test is reported in a NAFEC report, NA-69-18 (RD-69-34), dated October 1969. At the termination of the test conducted by Lockheed, NC-141-61-2775 was delivered to the Aeronautical Systems Division (ASD) at Wright Patterson Air Force Base, Ohio for continuation of testing. The ultimate goal was to validate the C-141 AWLS for Category III operation.

Development of the C-141 AWLS was established as a joint FAA/USAF effort. The guidelines for working relations between the two organizations were defined in Interagency Working Agreement, DOT-FA-70-WAI-173, dated October 1969.

The ASD (4950th/EN) flight test program, under the supervision and engineering direction of the Systems Engineering Directorate of ASD, lasted from 13 Dec 1969 until 11 April 1972. The results of the program are reported in Flight Test Report ENE-72-20, dated 14 Nov 1972. The flight test objectives were never attained since, as reported, "the level of performance of the C-141 AWLS was so poor that the primary effort during this period of testing was forced to be directed, almost exclusively, toward trouble shooting and correcting AWLS problems." No conclusions pertaining to the flight test objectives could be made.

At this time, the responsibility for test direction and management was transferred to the Traffic Control and Landing (TRACALS) System Project Office (SPO)

at the Electronics Systems Division (ESD) at Hanscomb Air Force Base in Cambridge Mass. At the request of ESD, the responsibility for continuing the work to fulfill the agreement with the FAA, was transferred to the Flight Dynamics Laboratory at Wright Patterson Air Force Base. ESD retained overall management responsibility.

After inspection of the system and consultation with the 4950th Test Wing of ASD and the FAA, AFFDL recommended that a complete clean-up and updating of the AWLS and aircraft be accomplished. It was specific that the clean-up include at least the installation of a dual inertial system (INS), installation of a modern flight control system, and the elimination of all inputs to the AWLS from the C-12 compass system which had been a primary source of trouble.

A contract was let to the Lear-Siegler, Inc. Contract Maintenance facility at Mobile Alabama for the clean-up of the AWLS and the accomplishment of an aircraft periodic inspection. The aircraft was at Mobile for almost nine months. The first flight following clean-up was on 26 Oct 1972. After safety-of-flight discrepancies were corrected, the aircraft was returned to Wright Patterson Air Force Base in Nov. 1972.

With the return of the aircraft to WPAFB, several efforts were begun simultaneously. The primary effort was to optimize the AWLS and the instrumentation, and to start a failure/degraded performance computer simulation. Also, the integration of the Maxson Independent Landing Monitor radar, later referred to as the ALR, and the Sperry Electronic Attitude Director Indicator (ALR/EADI) was initiated. The results of this effort and the optimization and pre-experimental flight test phases are reported in Technical Memorandum AFFDL-TM-109-FGSA, dated April 1974 and cover the period 1 Nov. 1972 to 19 Feb. 1974. It should be noted, however, that the ALR/EADI (later called ILM/EADI) equipments were not used during the operational flight tests nor in the safety/reliability analysis.

In 1974, interest developed in computer modeling techniques as a tool for safety and reliability analysis of the total ground/airborne all weather landing system. Various mathematical modeling schemes exist which deal with parts of

the total ground/airborne system in assessing safety and reliability. None have dealt with the total ground/airborne system in a Category III situation using actual data from Category III experience to test and confirm the modeling techniques.

A contract was established with the University of Dayton in 1974. The program is unique in that the modeling techniques developed have been tested and adjusted using data from actual Category III landing experience in a specially equipped C-141 aircraft. As a result, a total ground/airborne system computer-modeling technique has been developed, tested and validated to a degree that it can be used with a high degree of confidence as a design tool in future system developements and risk assessment.

SECTION II

SYSTEM DEFINITION AND CONFIGURATION

The emphasis in this reliability/safety analysis stressed a total systems concept which included modeling of the ground-based Instrument Landing System (ILS) with monitoring, the airborne control system used in the automatic mode with the pilot and crew "in the loop", and both safety pilot and crew procedures. (Figure 1). A few words about each is in order.

Due to the limited number of certified Category III ILS ground installations, the flight test program was planned from the initial phases to gain Category III weather experience using Category II ILS ground installations. A typical Category II ILS provides an oncoming aircraft with guidance information on height and ground track for a visual take-over by the pilot at 100 feet. Therefore, it was necessary for the airborne control system of the test aircraft to be modified in order to provide additional automatic guidance capabilities below the 100 foot altitude that are required for a Category III landing. These additional guidance capabilities would allow for automatic flare, decrab, and rollout.

The basic control system for the C-141 test aircraft included the flight control system and the Category II all-weather-landing-system (AWLS). These systems were modified and augmented to provide the additional automatic capabilities necessary for a Category III landing using the previously mentioned Category II ILS. The modifications included such items as the Sperry 350 B Attitude Director Indicators (ADIs), Dual C-5 (Wilcox 800C and 806C) ILS receivers for glideslope, dual Collins (51RV2B) ILS receivers for localizer, dual flare computers, an updated Test Program Logic Computer (TPLC), and dual radar altimeters. The system was augmented with a Category III adaptor (designed and built by AFFDL) for aircraft functions required below 100 feet and dual Litton (LTN-51) inertial platforms. Also provided was a digital data recording system, a test director's console with basic flight instruments to allow additional pilots and engineers to monitor progress along the flight profile. In addition, a Numax Independent Landing Monitor and a Sperry Electronic Attitude

TOTAL SYSTEMS APPROACH

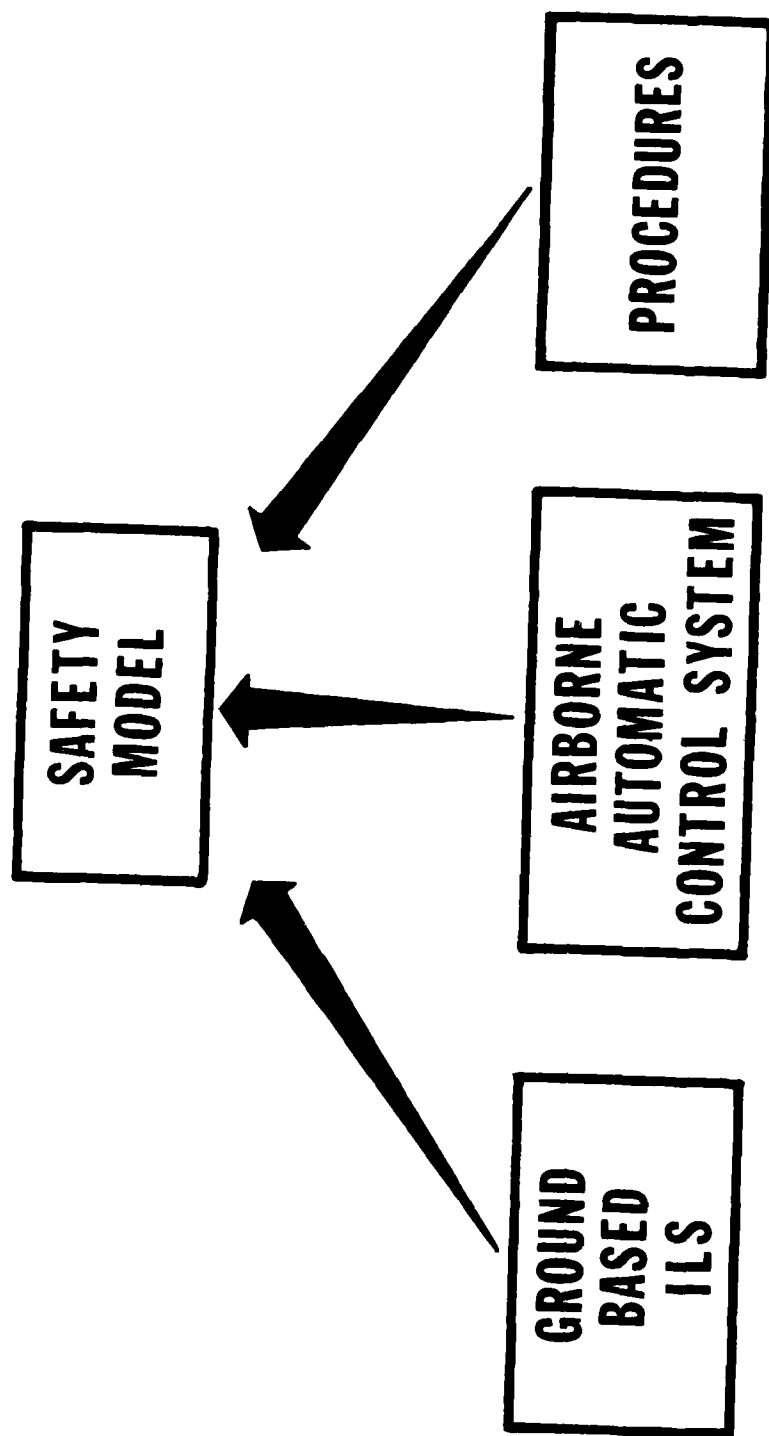


FIGURE 1

Director (EADI) were installed for experimental purposes and with the hope that they could eventually be used in the program. The Independent Landing Monitor (ILM) provided a perspective view of the runway on approach and during landing which was superimposed on the Sperry EADI in such a way that the runway could be seen as background to the steering information provided by the EADI. However, because of many maintenance problems with the ILM, the system was not used effectively during the test program and was not a part of the safety/reliability analysis.

A functional block diagram of the system initially used is illustrated in Figure 2. During the latter stages of the flight test program, an alternate system configuration was evaluated. This configuration employed a Simplified Terminal Area Control Computer (STACC) which was developed as the first step towards replacing the C-141 guidance and control system with more advanced (digital) avionics. The STACC was more efficiently designed than its counterpart equipment by virtue of combining functions and by using current electronics. The STACC replaced the following standard C-141 avionics: (1) flight director computers, (2) automatic flight control system (ATCS) coupler, (3) flare computers. In addition to this equipment, the STACC included circuitry to replace the Category III adapter that converted the standard C-141 Category II system into a Category III AWLS. The STACC consisted of two (2) identical and interchangeable boxes that were cross monitored and equalized before feeding into the downstream autopilot computers. The equalized output of one box was used to drive the autopilot and the copilot display systems and the equalized output of the second box was used to drive the pilot and test director's display systems. The STACC system embodiments are shown in Figures 3, 4, and 5.

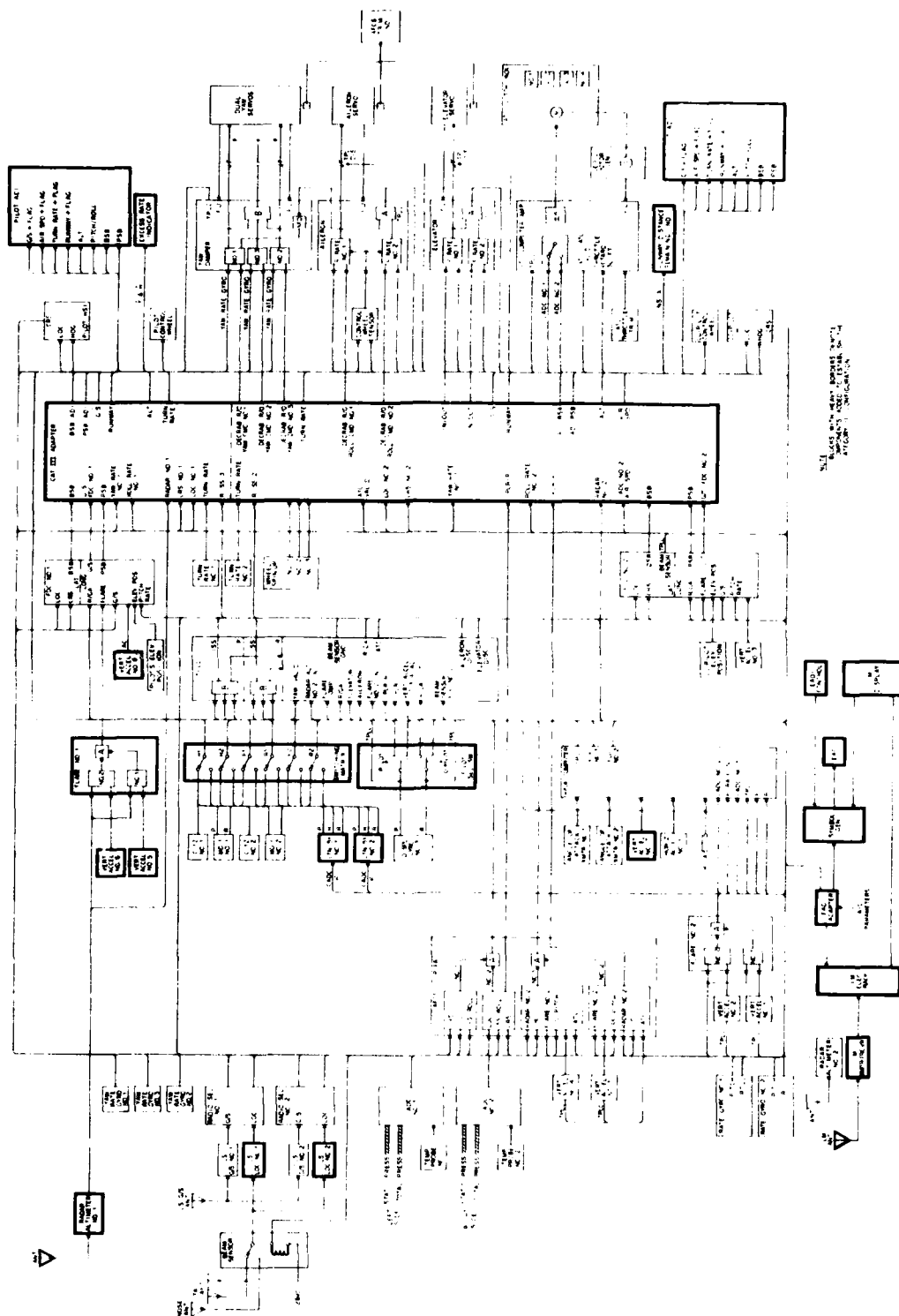


FIGURE 2 AWLS System Block Diagram

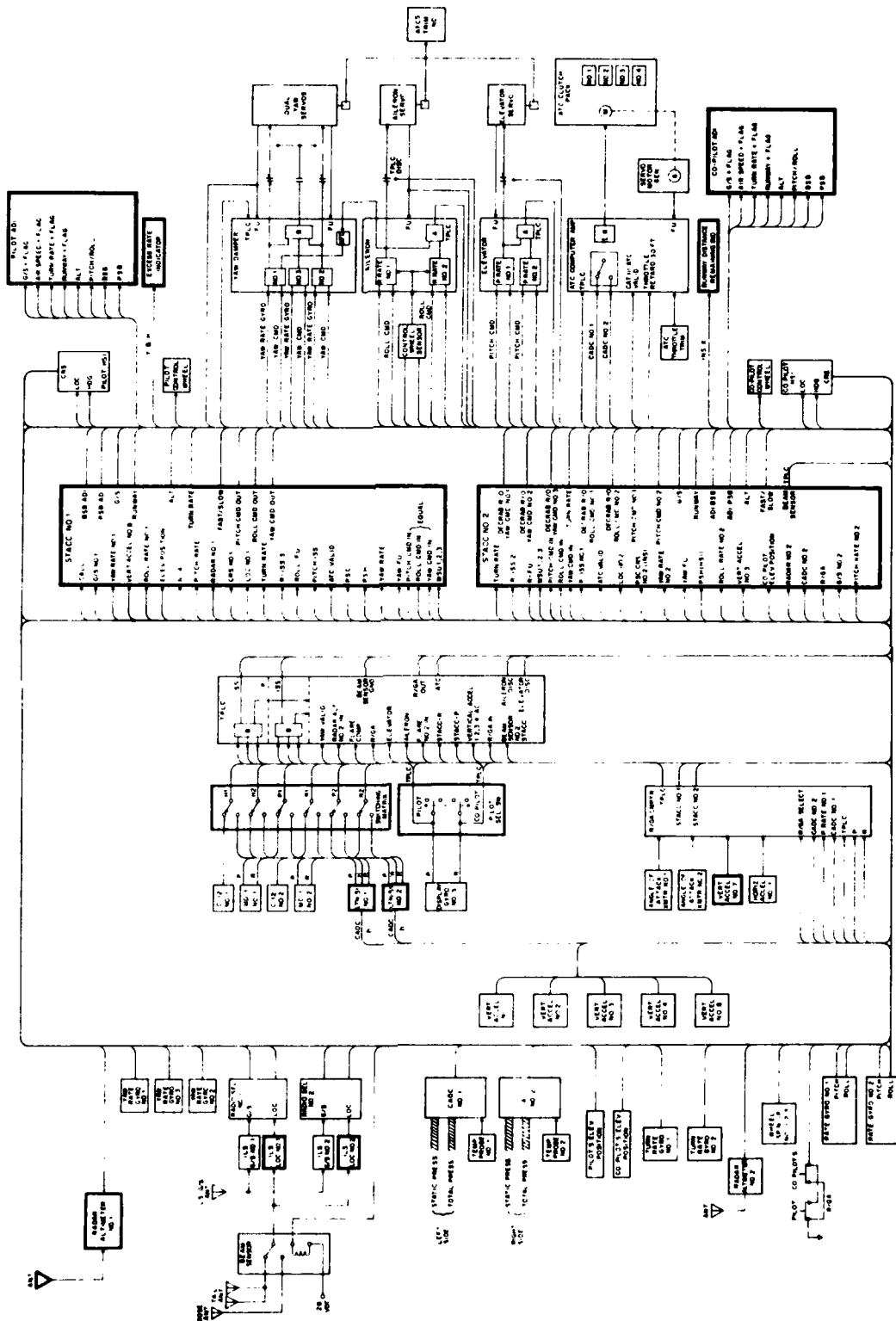


FIGURE 3 STACC System Diagram

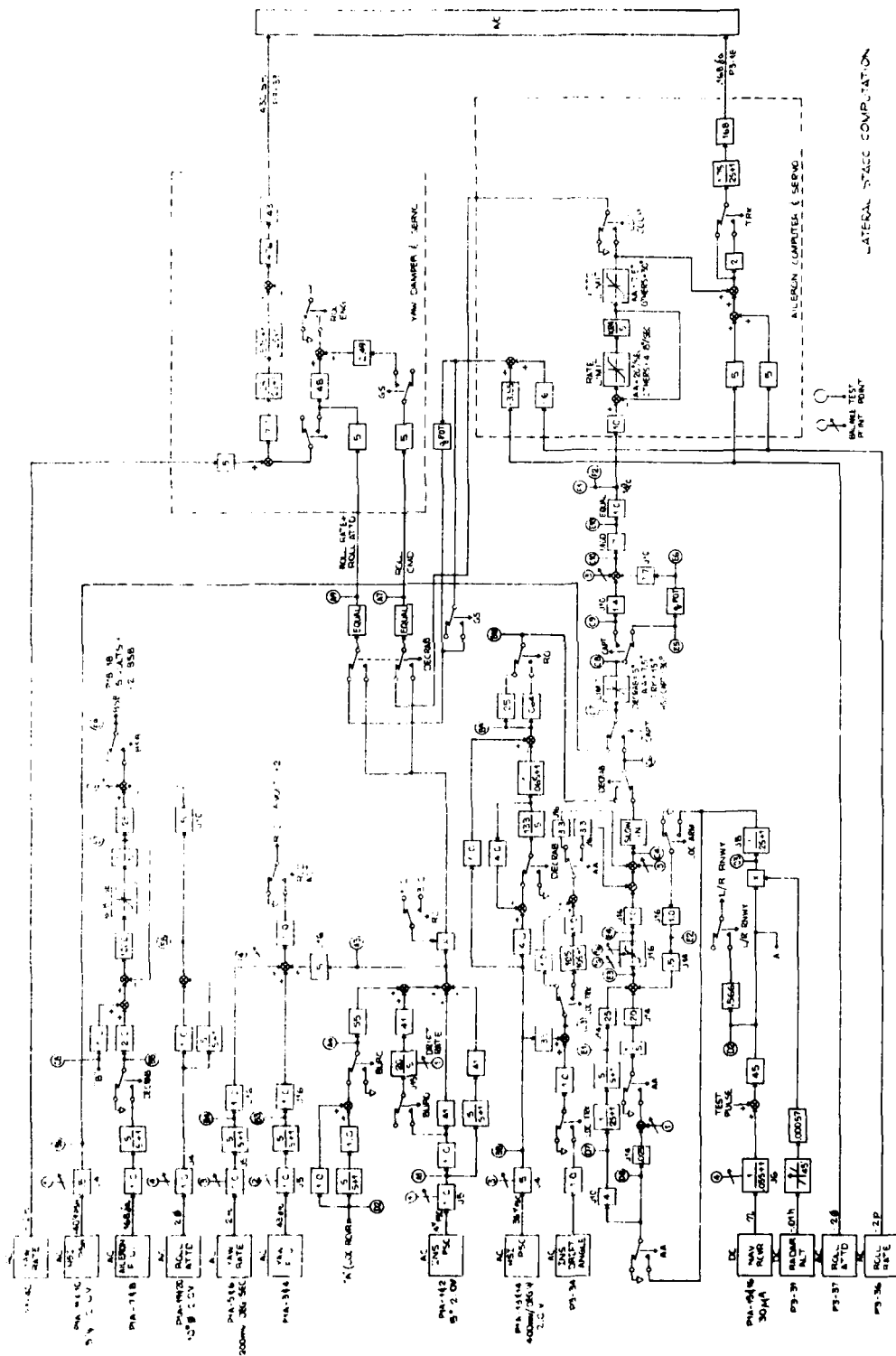
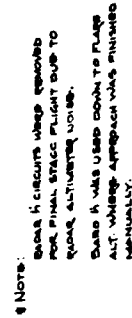


FIGURE 5 Lateral STACC Computation



TEST	POINTS
1. The first step in the process of creating a new product is to identify a market need.	10
2. A product that is unique and has a competitive advantage is more likely to succeed in the market.	10
3. The most important factor in determining the success of a new product is the quality of the product.	10
4. A product that is marketed in a way that is consistent with its benefits is more likely to succeed.	10
5. The most important factor in determining the success of a new product is the timing of the product's introduction.	10
6. A product that is marketed in a way that is consistent with its benefits is more likely to succeed.	10
7. The most important factor in determining the success of a new product is the quality of the product.	10
8. A product that is marketed in a way that is consistent with its benefits is more likely to succeed.	10
9. The most important factor in determining the success of a new product is the timing of the product's introduction.	10
10. A product that is marketed in a way that is consistent with its benefits is more likely to succeed.	10

FIGURE 6 Longitudinal STACC Computation

SYSTEM PERFORMANCE MODEL

The modeling approach adopted in this program was used for both the reliability and safety analyses. It accommodates the total systems configuration by partitioning the system into a set of time/function related modules.

The basic airborne control system is composed of a dual automatic system backed up by a manual system. It presented command information for vertical and lateral control of the aircraft by displaying the information on the pilot and copilot attitude director indicators. The fault monitoring capability of the system provides coverage of failures occurring in the sensitive (or critical) functions of the dual automatic operation. If a detectable failure occurs in the dual automatic system, the affected axis (vertical or lateral) is disengaged and the pilot is alerted of the failure. From a functional standpoint, the pilot may decide to manually fly the disengaged axis or completely disengage the automatic system. However, in Category III weather, procedures require that an immediate go-around maneuver be initiated in response to a detected system failure.

From a safety viewpoint, only that portion of the landing sequence representing a significant safety hazard had to be modeled in the analysis. This critical portion of the landing sequence is shown diagrammatically in Figure 7. It may be observed that the critical landing sequence is divided into four discrete and contiguous time intervals: (1) flare engage to decrab engage, (2) decrab engage to touchdown, (3) touchdown to wheel spin-up and (4) rollout.

Guidance signals from the ground based instrument landing system (ILS) were provided via a localizer radio frequency beam for lateral control and via a glide slope radio frequency beam for vertical control. The localizer and glide slope transmitting systems are physically separate and independent from each other.

The first logical partition of our systems model was to separate the vertical and lateral control functions for the airborne control system and the ILS. Once these partitions were defined, the specific system functions and crew procedures

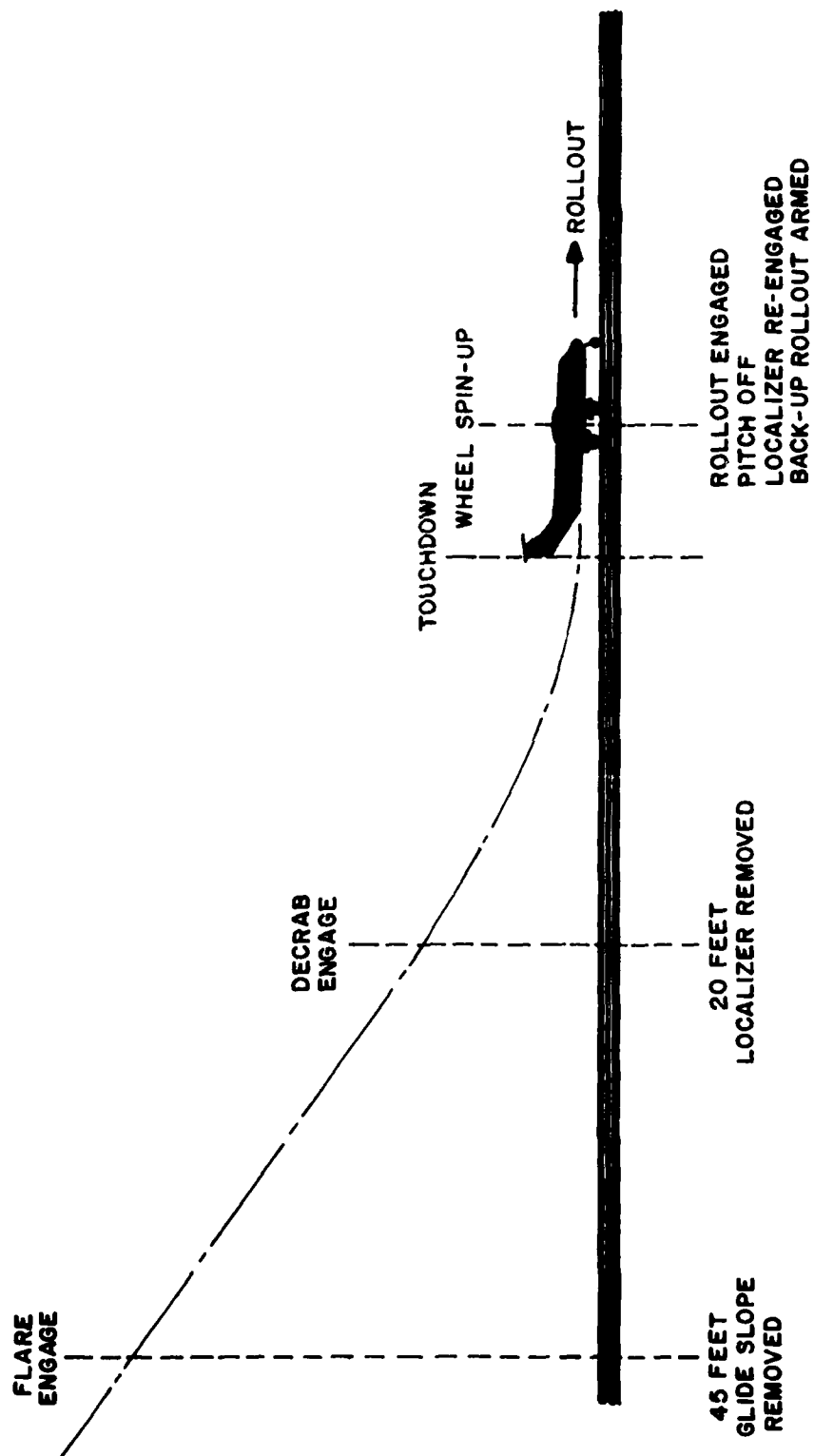


FIGURE 7 Landing Sequence

were related to their respective partition. The actual process of relating system functions, procedures, and equipments to the partitioned lateral and vertical axes was used to analyze the approach and landing sequence in considerable detail. The results of this analysis revealed that certain equipments or functions were only used during specific segments of the landing sequence, while other equipments were essential during the entire approach and landing sequence.

The equipment utilization for the vertical and lateral partitions is illustrated in Figures 8 and 9 respectively. This equipment utilization information was integrated to represent the total equipment utilization or operation for the airborne control system as a function of aircraft progression through the landing sequence.

The next step in the analysis sequence was to develop a mathematical model to represent the reliability of the airborne control system and procedures. Essential to this model was a compilation of the equipment failure characteristics.

The majority of the equipment in the airborne control system has had extensive fleet exposure. Failure rate data for the standard C-141 equipment was obtained from C-141 shop maintenance records for a one year period from May 1974 to April 1975. Wilcox (800C and 806C) ILS receivers, identical to those used on the test aircraft, are currently being used on the C-5 and their failure rate data was obtained from the C-5 fleet maintenance records for a six month period from April 1975 through September 1975. It is assumed that by using a sufficient data base, the effect of time lags, between flight-line remove and replace actions and shop repair actions, on maintenance records could be minimized. Failure rate information for the Sperry 350B Attitude Director Indicators, Litton LTN-51 Inertial Platforms, and the Collins 51RV2B ILS Receivers was not readily available from military fleet maintenance records and was obtained from the respective manufacturers. The custom-built Category III Adapter and Runway Distance Remaining Indicator failure rate data was obtained from the flight log and maintenance records for the test aircraft. Failure rate data for the Simplified Terminal Area Control Computer (STACC) was estimated from similar equipment.

LATERAL MODEL PARTITION

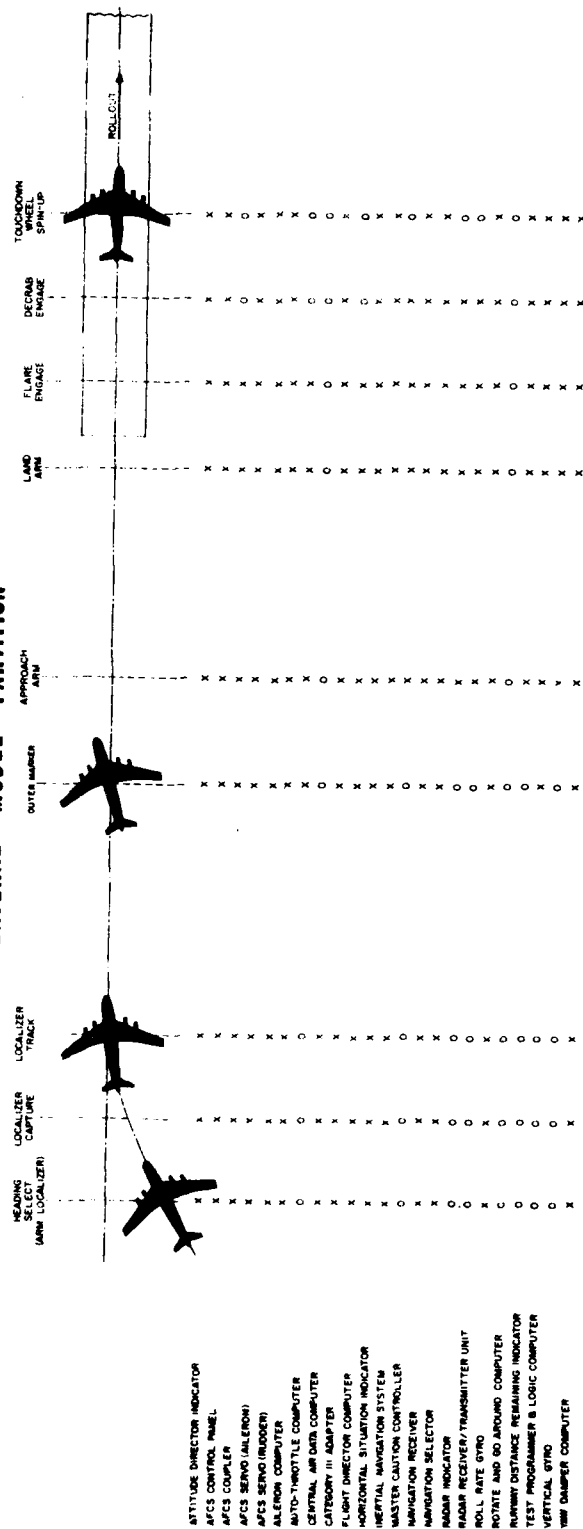


FIGURE 9 Lateral Mode Partition

The first generation calculations of the failure rates for the equipment was at the so-called box level with items such as accelerometers, transmitters, etc., which furnish pertinent information to the various pieces of equipment, included in their respective box level calculations. This box level failure rate information is presented in Table 2. In most instances the box level failure rates were apportioned down to the so-called card level (second generation) by evaluating the on-equipment maintenance actions with respect to the card level shop repairs. An itemized summary of the card level failure rates is included in Appendix A.

A few basic assumptions regarding the equipment failure rates were invoked. First of all, each piece of equipment was assumed to be independent and, secondly, possess a constant hazard rate. The constant hazard rate assumption implies an exponential distribution of inter-failure times (or a Poisson process) and is considered very common place for electronic type equipment.

Table 2
EQUIPMENT FAILURE RATE INFORMATION

Equipment	Failure Rate (failures/hour)	MTBF (hours)
AFCS Aileron Servo	0.000366	2732.240
AFCS Control Panel	0.001584	631.305
AFCS Coupler	0.006054	165.180
AFCS Elevator Servo	0.000126	7936.508
AFCS Rudder Servo	0.002348	425.894
Aileron Computer	0.002773	360.620
Attitude Director Indicator	0.009636	103.778
Automatic Throttle Computer	0.001396	716.332
Category III Adapter	0.008895	112.423
Central Air Data Computer System	0.024055	41.571
Elevator Computer	0.003641	274.650
Flare Computer	0.001558	641.849
Flight Director Computer	0.001017	983.284
Glideslope Receiver	0.002003	499.251
Horizontal Situation Indicator	0.002910	343.643
Inertial Navigation System	0.000968	1033.058
Master Caution Controller	0.001596	626.566
Navigation Receiver	0.000678	1474.926
Navigation Selector	0.001368	730.994
Pitch Attitude Gyro	0.002621	381.534
Pitch Rate Gyro	0.000650	1538.462
Radar Indicator	0.002028	493.097
Radar Receiver Transmitter Unit	0.004262	234.682
Roll Rate Gyro	0.000650	1538.462
Rotate and Go-Around Computer	0.002927	341.647
Runway Distance Remaining Indicator	0.005438	183.900
Simplified Terminal Area Control Computer	0.005059	197.668
Test Programmer and Logic Computer	0.002452	407.830
Vertical Gyro	0.002621	381.543
YAW Damper Computer	0.003289	304.044

A few words about each assumption are in order. By assuming a Poisson process, the individual equipment failure rates (λ) and hazard rates ($Z(t)$) are essentially constant and equivalent. Therefore, the mean time between failures (MTBF) and the reliability function ($R(t)$) for each piece of equipment can be described as follows:

$$R(t) = \exp \left[- \int_0^t Z(\tau) d\tau \right] \\ = e^{-\lambda t}$$

where t = operational time interval
 and $MTBF = \int_0^\infty R(t) dt = \int_0^\infty e^{-\lambda t} dt$
 $= \frac{1}{\lambda}$

Earlier it was pointed out that procedures required a go-around in response to a detected system failure during a Category III weather landing. This means that the failure of a single piece of required operational equipment would cause the landing sequence to be aborted and a go-around initiated. Now when this requirement is examined with the assumption of equipment independency, it is evident, from an essentiality standpoint, that we are modeling a series structure. The reliability or probability of successfully completing the landing sequence was represented as follows:

$$R(t) = \prod_{i=1}^n e^{-\lambda_i t} = e^{-(\sum_{i=1}^n \lambda_i) t}$$

where λ_i = failure rate for equipment (i)
 and t = operational time interval.

The Poisson process has an additional feature relative to its "lack of memory". Specifically, since the hazard rate is constant, each piece of equipment is just as likely to fail at time 't' as it is to fail at time 't' + delta 't'. This effectively gives license to reset time to zero after each confirmation of successful performance. In our model the first comprehensive indication that all systems are operational occurs at the completion of the diagnostic pre-land test and is annunciated at the approach arm. Prior to the

pre-land test annunciation, selected latent failures on portions of the operating but non-functional equipment could be detected but not get annunciated. Therefore, for these reasons the model validation process was restricted to the approach and landing sequence from approach arm through rollout.

SECTION IV

GROUND SYSTEM DISCUSSION *

As mentioned under System Definition and Configuration, the flight test program used a Category II ILS ground facility to gain Category III experience by adding additional automatic guidance capabilities below 100 feet to the aircraft control system. The study, however, included modeling a Category III ILS with Traveling Wave Antenna and examined two specified techniques for redundant real-time integral monitoring.

A Category III ILS provides aircraft with guidance information from the coverage limit of the facility to and along the surface of the runway. The system analyzed had operational performance of Category III, that is, operation with no decision height limitation. Initially, the system was used in Category IIIA operations in which use was made of external visual references during the final phases of landing with runway visual range (RVR) of not less than 700 feet. As the flight test program progressed, both Category II and Category III facilities were used at various locations throughout the country. Fourteen landings were made in reported RVRs of zero.

The ILS basically consists of two separate stations, the localizer and the glideslope. In addition to these stations, a central point for station control and the display of station status exists at the control tower. Up to three marker beacons are also used in a typical ILS installation. The localizer provides guidance in the horizontal plane and the glideslope station provides guidance in the vertical plane.

The localizer antenna group radiates two VHF carriers, each amplitude modulated by 90 and 150 Hz and with both carrier frequencies within a particular VHF channel. The radiation field pattern of one carrier produces a course sector which radiates ± 10 degrees either side of the runway center line and the other produces a clearance radiation field pattern outside that sector to ± 60 degrees from the course line.

The glideslope station produces a UHF composite field radiation pattern that provides a straight line descent path in the vertical plane and a clearance pattern to provide low angle coverage. Both carriers (course and clearance)

are within a particular UHF channel. Again, 90 and 150 Hz tones are used with the 150 Hz tone predominating below the path angle and the 90 Hz tone predominating above the path angle. The low angle clearance, radiated by the second carrier, is provided by a 150 Hz tone.

There are two transmitter sections incorporated into the localizer station. One transmitter is designated as the main transmitter; the other is designated the standby transmitter. The output signals from the main and standby transmitting units are routed to a changeover and test unit where transmitter transfer capabilities are accomplished. The signals received from the control unit determine which transmitter operates into the antenna, the main or standby. When the main transmitter is connected to the antenna system, the standby transmitter operates into dummy loads. When the standby unit is connected to the antenna system, the main unit is turned off. Within the changeover and test unit, there exists circuitry for use in monitoring standby transmitter parameters.

The glideslope station is very similar to that of the localizer. Some major differences are:

- (1) The glideslope does not possess either a far field monitor or an identification unit/monitors.
- (2) The glideslope antenna depends on the ground plane to form the radiation pattern.
- (3) Triplicate near-field monitors are used for the glideslope.
- (4) No shutdown alert warning signal is provided.

The changeover and test unit provides the same function as that of the localizer; transfer transmitter signals of the main and standby unit into either the antenna systems (including distribution circuits) or dummy loads. Also within the changeover and test unit, there exists circuitry for monitoring the standby transmitter parameters.

The far-field monitor has its own alarm processing circuitry to minimize the quantity of telephone lines needed for remote transmission. Each far field monitor channel provides two alarm outputs, a Category III alarm and a Category II alarm. The difference between these two alarm outputs is merely in tolerance limits.

In order to know the true integrity of the signal in space at all times, integral monitoring along with localizer far-field and glideslope near-field detectors, are used. Out-of-tolerance radiation must be limited without limiting system performance.

Integral monitoring is accomplished by use of detectors which sample the localizer and glideslope radiation in very close proximity to each excited element. These proximity detectors are thus insensitive to the effects of environmental conditions or aircraft overflights. The detected signals are then combined to correspond to the signal received by the approaching aircraft in the far-field of the transmitting antenna. Glideslope near-field detectors have been retained for monitoring radiated signals, but are considered to serve only a secondary role. The localizer far-field monitor will guard against substandard system performance from major obstructions moving in front of the localizer structure. Monitor redundancy is used to achieve the desired level of monitor reliability.

Two specified schemes of monitoring logic were analyzed for safety/reliability and risk. As shown in Figure 10, the monitoring process demodulates the monitor inputs into three components:

- (1) Radio Frequency Energy (RF)
- (2) Difference in Depth Modulation (DDM), and
- (3) Sum of Depth Modulation (SDM)

Within the monitoring system, each of these components is compared with a standard established by ICAO and the FAA. A measured quantity outside the set boundary conditions will result in logic of "1" to the central control indicating an "out-of-tolerance condition".

Scheme I shows the monitored parameters (RF, DDM, SDM) and their logic levels fed to a NAND gate within each of three integral monitor boxes. The outputs of each of these three NAND gates are compared within the voter wherein at least 2 of the three must be "good".

In Scheme II, the three components (RD, DDM, SDM) from each of three integral monitors are not fed to a NAND gate but are sent to a voter where at least 2 of the three outputs of each must be correct.

Figure 11 presents the signal flow diagram for the monitored information when the main localizer transmitter radiates into the antenna. Corresponding reliability diagram, along with the associated reliability equation and attendant failure rates are presented in Figure 12. Both of these are for Scheme I.

The analogous localizer information for Scheme II is in Figure 13; the corresponding reliability diagram, equations and failure rates are given in Figure 14.

Analogously, the glideslope information for Scheme I is given in Figure 15 and Figure 16.

Under the assumption of a constant hazard function and independence of failure rates, reliabilities were calculated using a double precision computer program. The analysis showed Scheme I to be preferred with scheduled preventative maintenance; without such maintenance, Scheme II would, after a period of time, have a higher reliability. Both ensure overall reliability and safety.

*Note: Above information extracted from Mathematical Modeling of Monitoring Concepts by Fuchs and Fileccia, 1975.

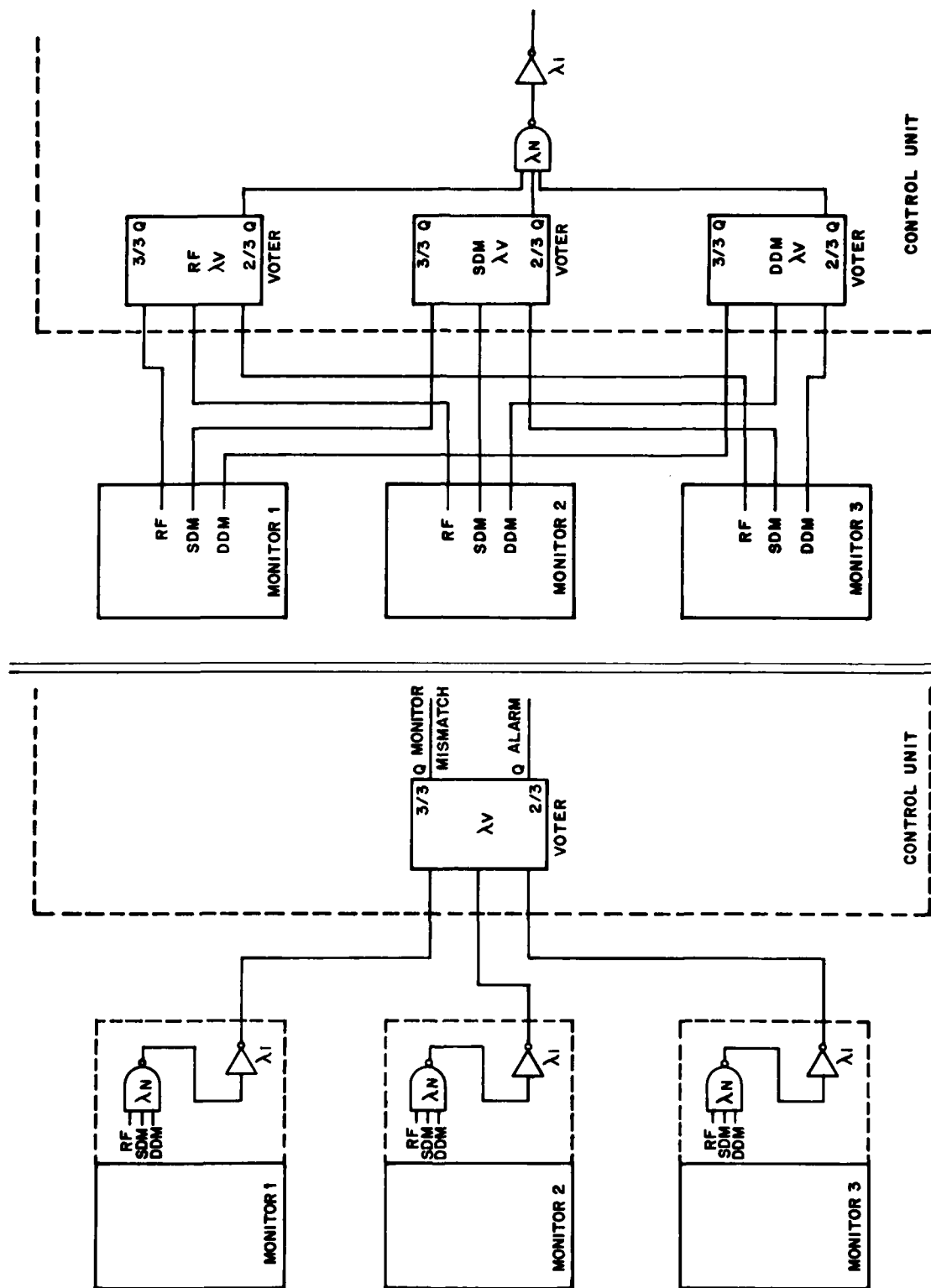


FIGURE 10 Monitor Logic

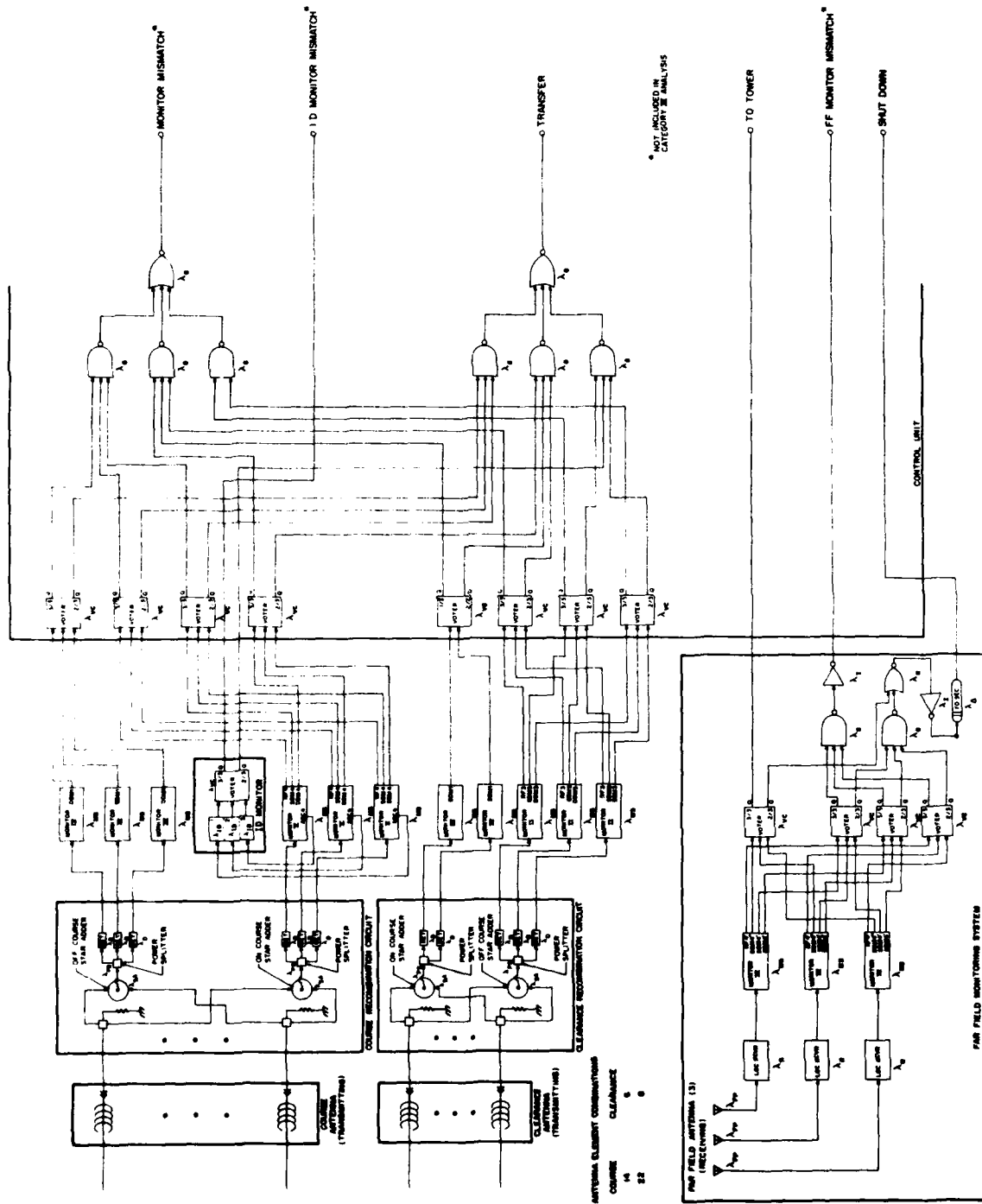


FIGURE 13 Localizer Monitoring Schema II

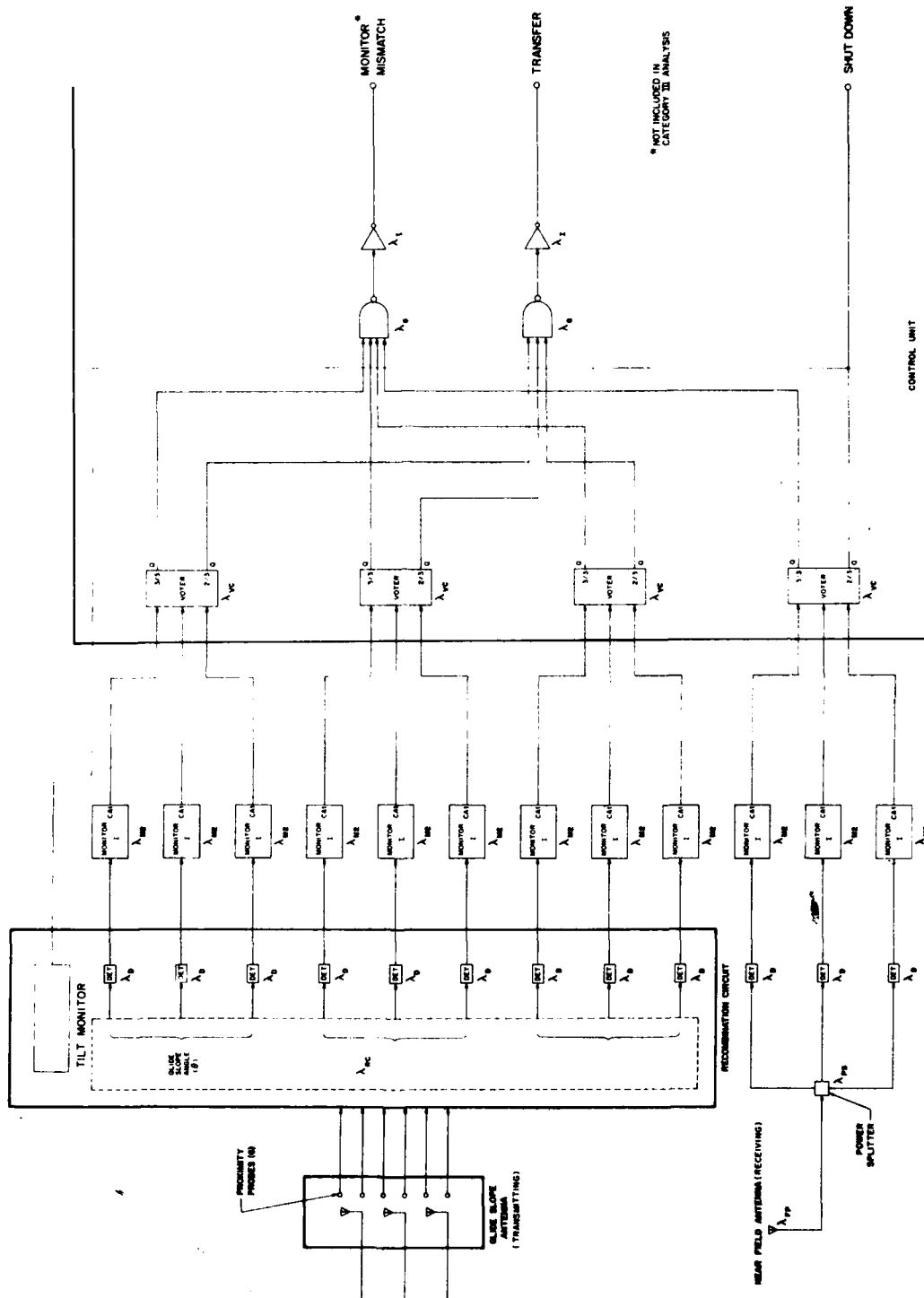


FIGURE 15 Glide Slope Monitoring - Schema I

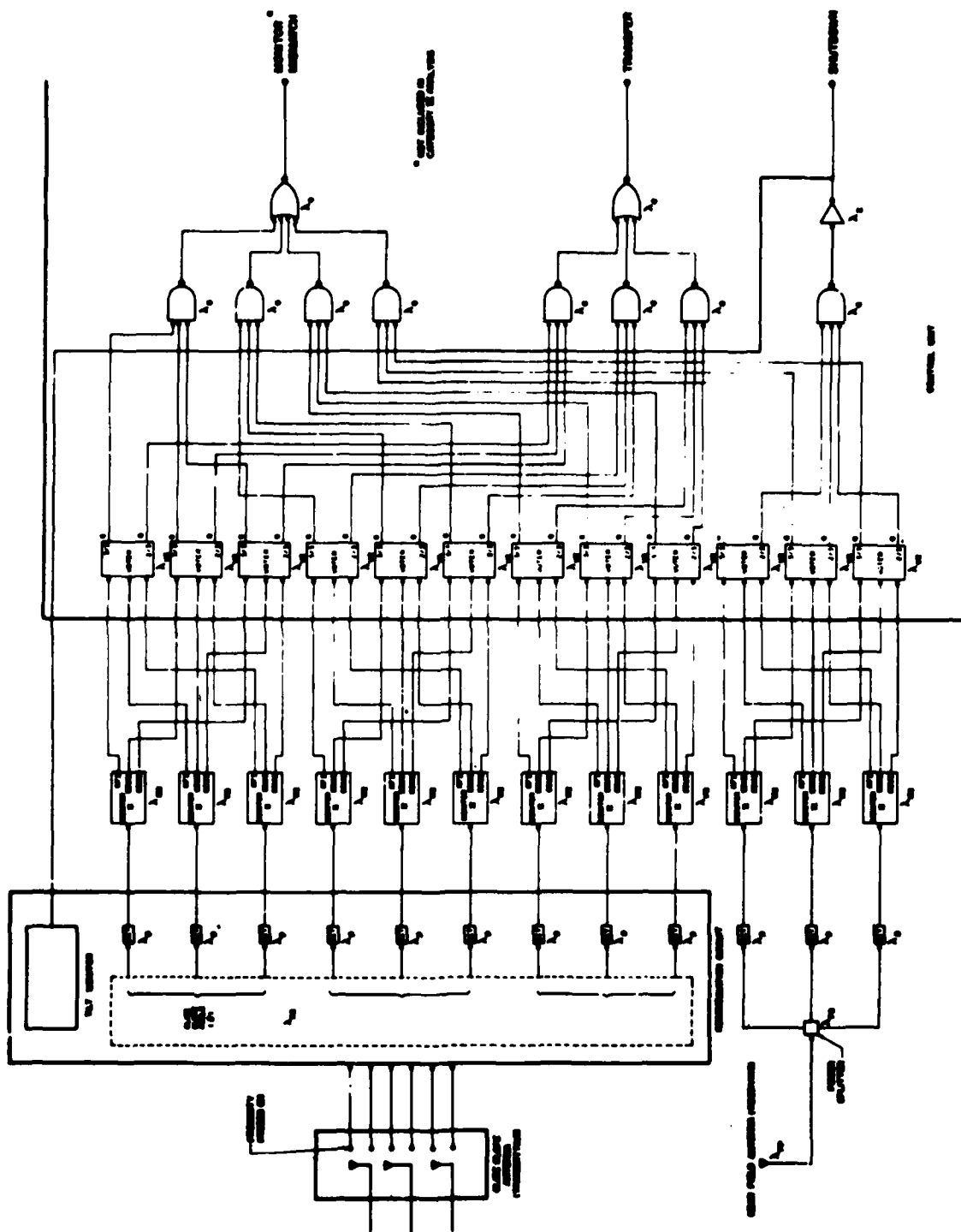
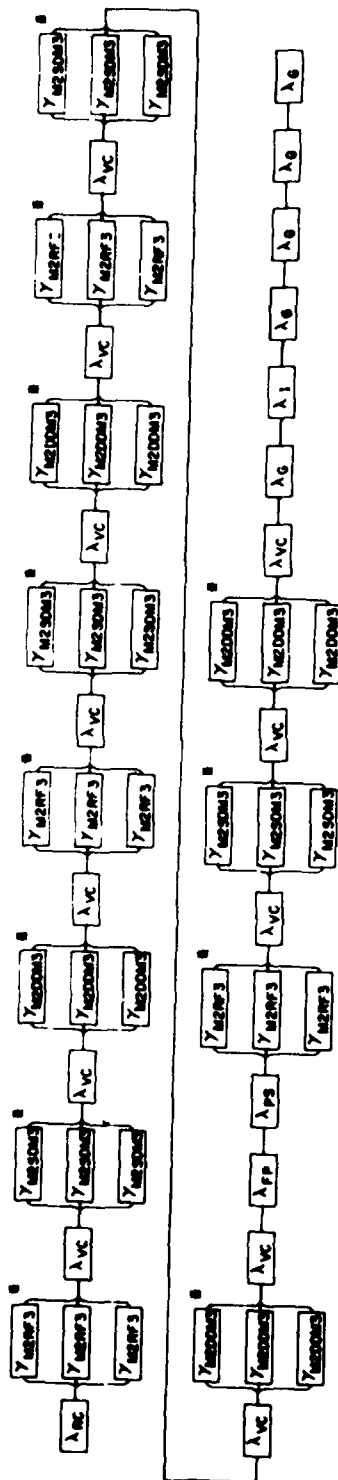


FIGURE 17 Glide Slope Monitoring - Schema II



3 AT LEAST 2 OUT OF 3

$$R(t) = [e^{-t(\lambda_{VC} + \lambda_{PP} + \lambda_{PS} + 12\lambda_{VC} + 15\lambda_G + \lambda_1 + 18Y_{M2SDM3} + 18Y_{M2SRF3} + 18Y_{M2SDM3})}] \cdot [3 \cdot 2e^{-t(Y_{M2SRF3})}]^4 \cdot [3 \cdot 2e^{-t(Y_{M2SDM3})}]^4$$

λ_0	$\cdot 10 \times 10^{-6}$
λ_{PP}	$\cdot 0.1$
λ_0	$\cdot 1.0$
λ_1	$\cdot 0.1$
λ_{M2}	$\cdot 100.0$
λ_{PS}	$\cdot 0.1$
λ_{VC}	$\cdot 0.8$
λ_{VC}	$\cdot 5.0$

Y_{M2SDM3}	$\cdot 0.4(\lambda_0 + \lambda_{M2}) \cdot 40.4 \times 10^{-6}$
Y_{M2SRF3}	$\cdot 0.31(\lambda_0 + \lambda_{M2}) \cdot 20.2$
Y_{M2SDM3}	$\cdot 0.4(\lambda_0 + \lambda_{M2}) \cdot 40.4$

RELIABILITY ANALYSIS OF GLIDE SLOPE MONITORING SCHEME 2

FIGURE 18

SECTION V

RELIABILITY ANALYSIS

Complete reliability analyses, based on the discussion in the previous section, were formulated for the two system configurations based on the Category III adapter and the STACC. These analyses were programmed for use on the WPAFB CDC-6600 computer system. Each computer program calculated the reliability or probability of successfully completing each model segment of the landing sequence and also composite probability values for (a) the completion of the entire landing sequence from localizer capture through rollout and (b) the completion of the landing sequence subsequent to the approach arm. The details of these computer programs (including listings) are presented in Appendix B.

One of the significant features of the programs is that they provide for a sensitivity analysis capability to determine the variability effects relative to (a) the time intervals for each model segment and (b) the individual equipment MTBF values. The sensitivity analyses were based on Monte Carlo simulation techniques which require process generators to be used to provide random sample values for the individual equipment MTBF values and landing segment time values during each iteration of the simulation. These sample values for MTBF and time were employed to determine the reliability (or probability of success) for each interval of landing sequence. By running the simulation for a large number of iterations, the sensitivity effects of MTBF and time on reliability were determined along with the inherent variability (or risk) associated with the reliability values.

At this point it is appropriate to discuss the process generators employed in this Monte Carlo simulation. The individual process generators for equipment MTBF were assumed to follow uniform distributions with the limits of variability set at plus and minus ten percent from the nominal values listed in Table 2. Part of the rationale for choosing a uniform distribution for equipment MTBF was to accentuate the variability effects on the attendant reliability calculations. The process generators for the time intervals of the landing

sequence in Figure 7, were based on the individual time distributions from operational flight test data. This data indicated that the time distributions could be adequately represented by a series of normal distributions with the values for the mean (μ) and standard deviation ($\sqrt{\sigma}$) listed in Table 3. The mathematics for both of these process generators is completely described in Appendix B. The completed computer programs were employed to determine the system reliability information. The reliability analyses results showing the influence of landing sequence time variability and equipment MTBF variability were determined and are presented in Table 4. The results for the system configuration based on the STACC are superior in each interval of the landing sequence. This difference was attributable to the fact that the STACC replaced several individual pieces of equipment and resulted in a lower overall system failure rate.

Additional computer runs were made to determine if landing segment time variability or equipment MTBF variability was more significant with respect to the overall system reliability. In order to accomplish this task the time and MTBF parameters were varied sequentially between zero variability and the nominal variability values previously discussed. This resulted in four sets of computer runs for each system configuration. For the system configuration based on the Category III adapter the results in Table 5 for the reliability from the approach arm to runway stop were obtained. From this data it is evident that both the time and MTBF variability affect the attendant reliability. However, the effect of MTBF variability is slightly more significant than the effect of time variability. This point is illustrative of the need to design and develop flight control systems with a minimum and controlled failure rate.

It should again be mentioned that a complete set of computer printouts are provided in Appendix B.

Table 3

TIME DISTRIBUTION DATA

Time Segment	Mean (seconds)	Standard Deviation (seconds)
localizer capture to arm glideslope	210*	—
arm glideslope to glideslope capture	30*	—
preland test	30*	—
1000 feet to 100 feet	81.54**	1.95**
100 feet to flare engage	5.35	0.42
flare engage to decrab	3.07	0.33
decrab to wheel spin-up	4.02	0.33
wheel spin-up to stop	22.73	0.53

* point estimate

** extrapolated from recorded data for 200 foot to 150 foot segment

Note: The mean and standard deviation values were obtained from recorded data for Missions 171, 175, 179, and 185.

Table 4 RELIABILITY ANALYSIS RESULTS

	<u>Category III Adapter</u>	<u>STACC</u>
Localizer Capture to Arm Glideslope		
Mean of Reliability	.9958494	.9964784
Std. Dev. of Reliability	.0000683	.0000611
Arm Glideslope to Glideslope Capture		
Mean of Reliability	.9993891	.9994794
Std. Dev. of Reliability	.0000098	.0000088
Glideslope Capture to Approach Arm		
Mean of Reliability	.9993570	.9994474
Std. Dev. of Reliability	.0000100	.0000088
Approach Arm to Land Arm (100 Feet)		
Mean of Reliability	.9978379	.9980751
Std. Dev. of Reliability	.0000377	.0000412
Land Arm (100 Feet) to Flare Engage (45 Feet)		
Mean of Reliability	.9998851	.9998733
Std. Dev. of Reliability	.0000074	.0000067
Flare Engage (45 Feet) to Decrab (20 Feet)		
Mean of Reliability	.9999203	.9999293
Std. Dev. of Reliability	.0000057	.0000048
Decrab (20 Feet) to Touchdown		
Mean of Reliability	.9998935	.9999072
Std. Dev. of Reliability	.0000054	.0000042
Touchdown to Stop		
Mean of Reliability	.9995344	.9995604
Std. Dev. of Reliability	.0000108	.0000087
Total Reliability From Approach Arm to Stop		
Mean of Reliability	.9970431	.9973469
Std. Dev. of Reliability	.0000684	.0000712
Total Reliability For Complete Model		
Mean of Reliability	.9916602	.9927685
Std. Dev. of Reliability	.0001786	.0001700

Table 5 Sensitivity Effects For Reliability Values For Interval From Approach Arm to
Runway Stop (Category III Adapter System Configuration)

Equipment MTBF Variability		
	Zero	Ten Percent
Zero	Mean = .9970469 Std. Dev. = .0000000	Mean = .9970363 Std. Dev. = .0000564
Based on Operational Flight test Data *	Mean = .9970536 Std. Dev. = .0000451	Mean = .9970431 Std. Dev. = .0000684

* From Table 3

Landing Segment
Time Variability

SECTION VI

MODEL VALIDATION

The only way to accurately determine if the reliability model calculations were credible was to compare them to the operational flight history for the test aircraft. Since the Category III adapter system configuration was the only one to have a large operational exposure, it was selected as the vehicle for possible model validation.

The operational data for model validation was obtained by examining the flight log and maintenance records for the test aircraft. Information on 205 automatic approach/landings made during mission 116 to 159 produced the confirmed failures listed in Table 6. This table shows that six failures occurred during the 205 approach/landings. However, since the only comprehensive confirmation of acceptable system performance is the preland test (initiated at glideslope capture and completed at Approach Arm), the exact times of failures occurring prior to the preland test could not be accurately determined. This effectively reduces the number of useable failure rate data down to 1 failure for 200 automatic approach/landings. Thus, for the 205 automatic approach/landings reviewed in the analysis, only 1 failure occurred after the Approach Arm. This can be compared to the model predicted reliability of 0.9970431 (see Table 4) or comparatively 0.61 failures for the 205 automatic approach/landings. This very close agreement between the actual and model predicted number of failures serves to demonstrate a rigorous validation of the basic reliability modeling techniques.

Table 6 AWLS Equipment Failures * (Category III Adapter Configuration)

Mission	Confirmed Equipment Failures
116	Localizer Receiver Before Glideslope Engage
129	Glideslope Receiver At Approach Arm
129	TPLC At Approach Arm
137	Coupler At Approach Arm
145	Elevator Computer At Approach Arm
145	Flare Computer At Flare Engage

* Failures were compiled for 205 Automatic Landings made during missions 116 to 159.

SECTION VII

SAFETY ANALYSIS

The safety analyses were based on a total systems concept as outlined earlier in the section on the "Systems Performance Model." A separate analysis was performed on each respective system configuration (i. e., Category III Adapter and STACC). These analyses were combined with respective reliability analysis programs for use on the WPAFB CDC-6600 computer system.

While the complete landing sequence (Figure 7 and 8) was modeled in the reliability analysis, the safety analysis modeling was restricted to that portion of the landing sequence which resulted in a significant hazard to safety for the test aircraft. After much discussion with the test pilots and systems support personnel, the general consensus was that the test aircraft could complete a successful go-around in response to any airborne control system or ILS failure prior to flare engage. It was estimated that the critical time for the go-around maneuver was approximately 3 seconds. This would allow the pilots enough time to make the required go-around control changes and arrest the sink rate of the aircraft for climb-out. Thus the safety analysis need only model the critical sequence from flare engage through rollout (see Figure 7).

From Figure 7, the critical portion of the landing sequence was composed of four separate time intervals: (1) flare engage to decrab, (2) decrab engage to touchdown, (3) touchdown to wheel spin-up, and (4) rollout. In order to understand the safety modeling approach, the basic sequence of events associated with each of the four time intervals will be examined. Prior to flare engage, the aircraft is following the guidance provided by the ground based Category III ILS. The ILS guidance is provided via a localizer radio frequency beam for lateral control and via a glideslope beam for vertical control. At the point of flare engagement the aircraft deviates from glideslope path and begins a maneuver which allows it to flare out parallel to the runway. This is accomplished by maintaining an active localizer control and disengaging the glideslope control.

The vertical guidance is then provided by the flare computers internal to the automatic flight control system. During the decrab maneuver, any heading corrections for cross winds are removed and the aircraft is aligned with the runway. This is accomplished by removing the localizer control and maintaining correct attitude control of the aircraft strictly through the use of computers internal to the automatic flight control system. The point of touchdown is self-explanatory and the aircraft control system continues to maintain active control at this point. Finally, the rollout mode is engaged at the point of wheel spin-up, which occurs when the wheels reach a speed of 60 knots. From a procedural standpoint, if wheel spin-up is not detected, an immediate go-around is initiated. For rollout, the localizer or horizontal control is re-engaged for lateral guidance purposes. If either the ground based localizer system or the aircraft localizer receivers fail between the time of localizer disengagement at decrab and localizer re-engagement at wheel spin-up, the back-up rollout mode would be engaged at wheel spin-up rather than the primary rollout mode. The back-up rollout mode uses preset heading information from the inertial navigation system (INS) rather than the localizer (Ref. 5).

From this discussion, it is evident that the safety analysis is merely an extension of the reliability analysis in terms of the basic system modeling approach with the analysis based on model segments and their respective equipment utilization factors. However, the purpose of the safety analysis was to complement the reliability analysis and breakdown the system unreliability to determine how much of this unreliability represented a hazard to the system operation. The key to breaking down this unreliability was directly tied to the identification of the minimum set of critical equipment necessary for the system to recover from an equipment failure. This equipment was identified through numerous discussions with the test pilots and system support personnel. Specifically, the critical equipment was related to the control functions required for a successful go-around maneuver and a successful rollout maneuver. If any system failure occurred prior to wheel spin-up, procedures dictate an immediate go-

around. Thus the capability for a successful go-around is crucial to the system safety prior to wheel spin-up. It was also determined that if a failure occurred after wheel spin-up, the test aircraft was required, through procedure, to stay on the ground. This makes the primary and back-up rollout capabilities crucial to system safety subsequent to wheel spin-up. The minimum sets of critical equipment, for both system configurations are presented in Figures 18, 19 and 20. In Figure 20, the set of critical equipment for a go-around maneuver is shown with three sets of guidance sensors. The dual INS is the primary set of sensors. If either one or both of the INS failed, it was assumed that there would not be sufficient time to manually switch-in either the roll and pitch gyros or the vertical gyro because of the proximity of the aircraft to the runway.

The next step in the safety analysis was to combine the calculated reliability information with failure probabilities for the respective sets of critical equipment in order to determine which combinations of single and multiple failures would represent a hazard to system safety. This was effectively accomplished by using a decision tree (or fault tree) approach where the combined effects of the airborne control system and the ground ILS were represented in composite form. The general categories of failures included in the decision tree are as follows:

Ground ILS - operational

- failed

Airborne control system - operational

- either pilot or copilot channel of information lost due to critical failure
- both pilot and copilot channels of information lost due to critical failures
- wheel spin-up not detected due to failure
- non-critical failure

The specific relationships of equipment operation and/or failure were represented for each segment of the landing sequence. Figures 21 and 22 describe the resulting decision tree developed for this analysis.

Each distinctive path through the tree represents the specific occurrence

CRITICAL EQUIPMENT FOR ROLLOUT MODE (CATEGORY III ADAPTER)

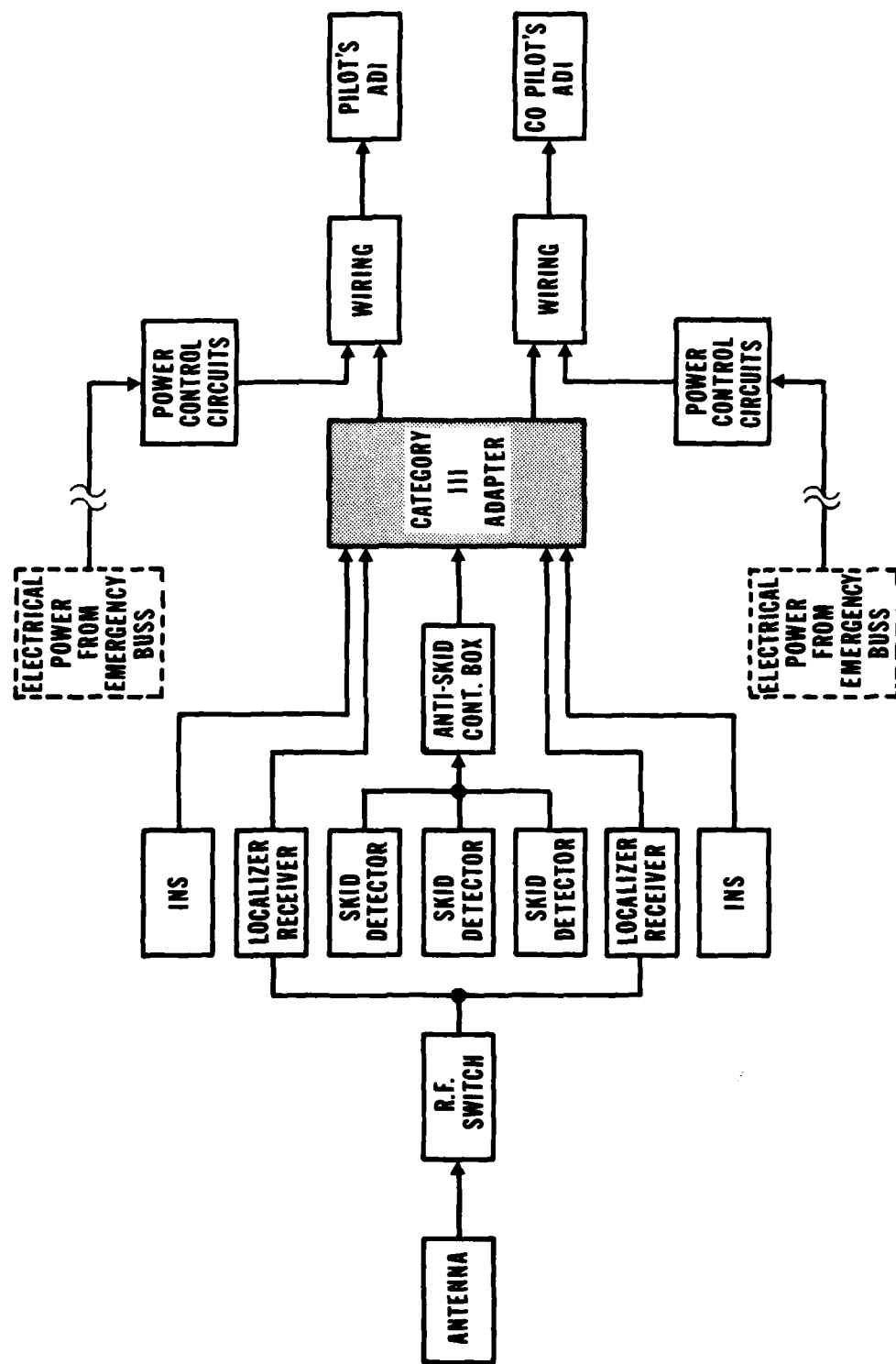


FIGURE 18a

CRITICAL EQUIPMENT FOR ROLLOUT MODE (STACC)

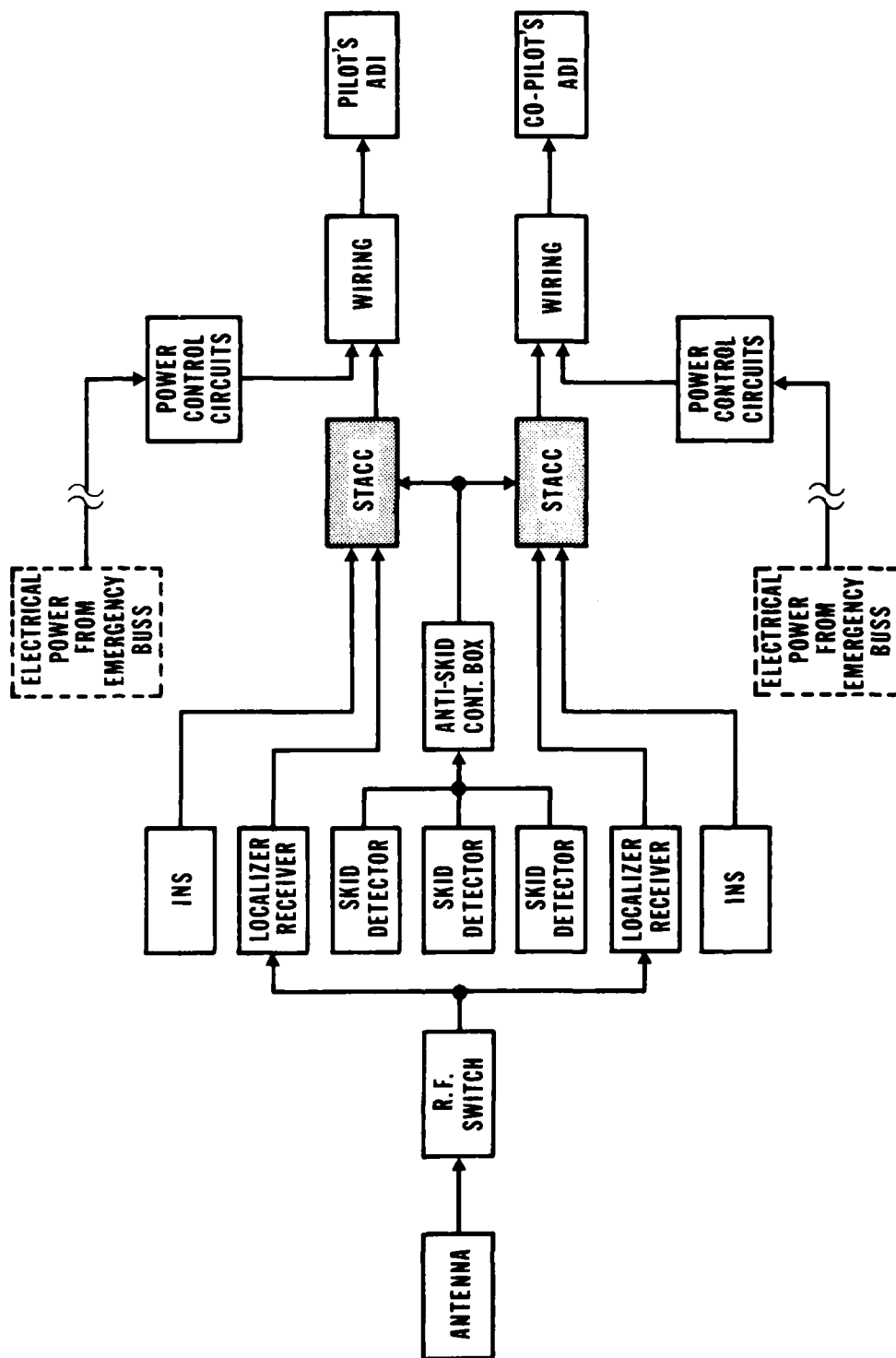


FIGURE 19

CRITICAL EQUIPMENT FOR GO-AROUND MODE

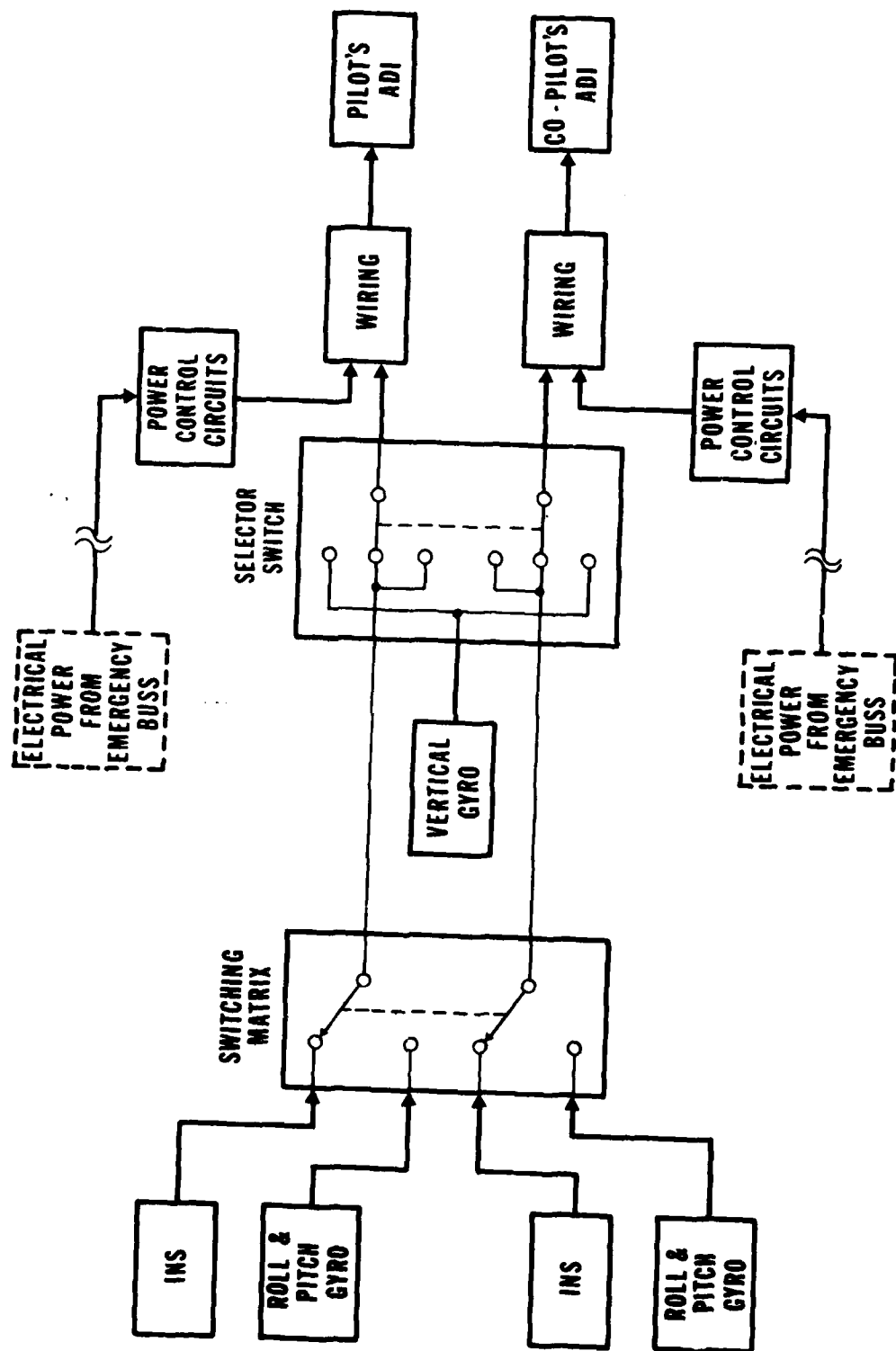


FIGURE 20

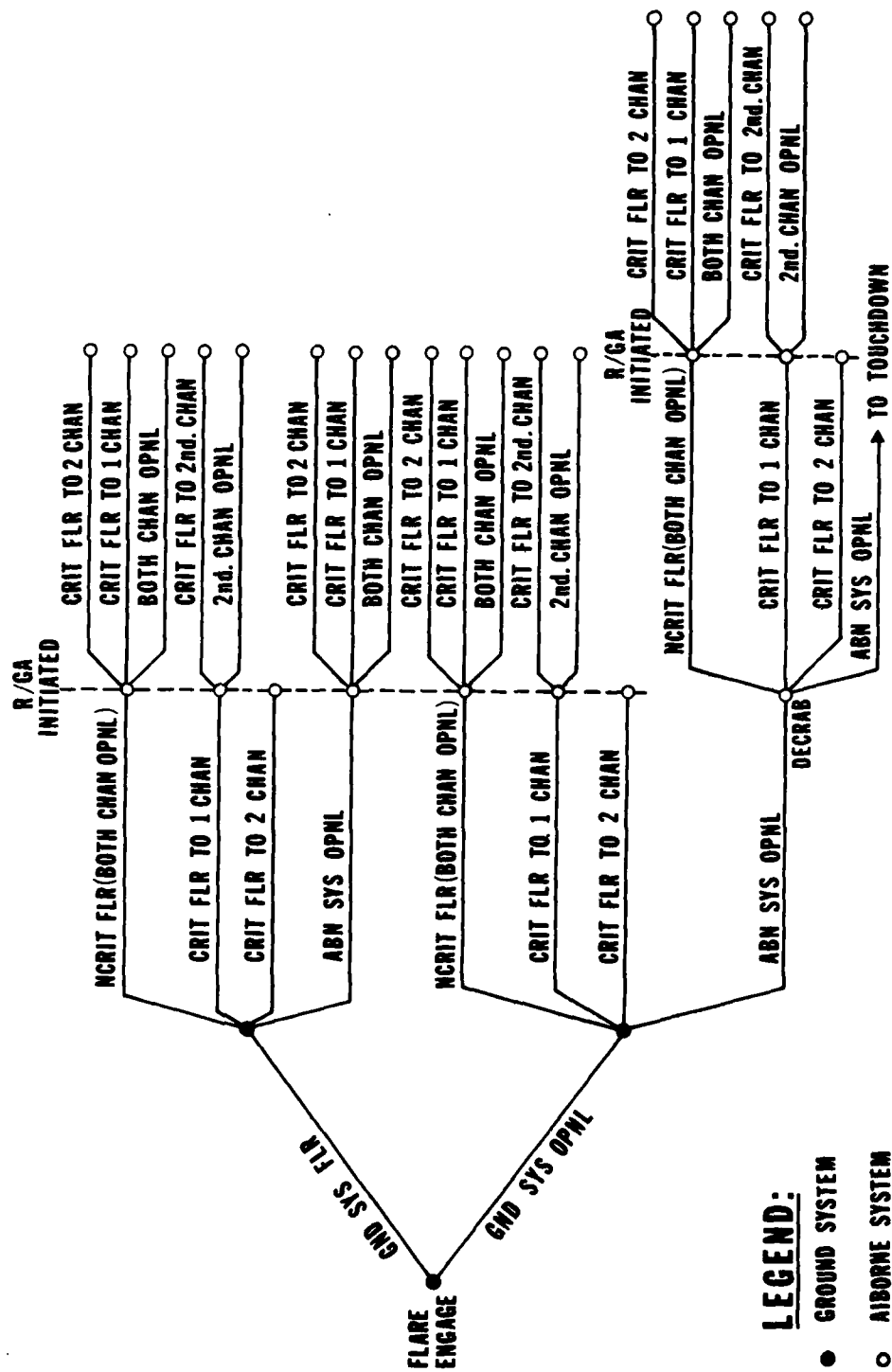
of a combination of events. The individual paths can be subdivided into a series of branches (or limb) which represent the various events. For example, the probability of successful operation (or reliability) for the total system would be represented by the bottom path through the tree.

It was the purpose of the safety analysis to determine which of the paths through the tree were hazardous to the overall system performance. These hazardous paths were represented by paths or branches which terminated in a loss of valid information to both the pilot and copilot. There was a total of seventeen such hazardous paths through the tree. Finally, the total hazard to safety for the system was obtained by summing the individual probabilities of the seventeen hazardous paths. The other paths were grouped into categories for summarization.

As stated earlier, the safety analysis computations were jointly programmed with the reliability analysis. Thus, there were safety analyses for both system configurations with each configuration having four separate computer runs to study the variant effects of equipment MTBF and landing sequence time. The safety analysis results showing the influence of landing sequence time variability and equipment MTBF variability were determined and are presented in Table 7. The results for the two system configurations are similar except for the calculated hazard to safety. Here the STACC configuration shows a hazard to safety that is approximately six orders of magnitude better than for Category III adapter configuration. This dramatic improvement in the safety calculations was attributable to the replacement of the Category III adapter, which was essentially a single point failure, with the dual redundant STACC (see Figures 18 and 19).

Upon further study of the hazards to safety, it was revealed that the original model needed some refinements. Specifically, the original model assumed that the criticality of equipment failures occurring during rollout were evenly weighted regardless of where they occurred during rollout. Said another way, the criticality of a failure at 120 knots was assumed to be equivalent to the criticality of the same failure at 20 knots. This is obviously an

DECISION TREE



LEGEND:

- GROUND SYSTEM
- AIRBORNE SYSTEM

FIGURE 21

R/GA INITIATED

TO DECRAB

ABN SYS OPNL

TOUCHDOWN

WHL SPN-UP NOT DET

WHL SPN-UP

WHEEL SPIN-UP

GND SYS OPNL FR DECRAB TO WHL SPN-UP

BACK-UP ROLLOUT

ROLLOUT

GND SYS FLR FR DECRAB TO WHL SPN-UP

GND SYS FLR (BACK-UP ROLLOUT MODE)

NCRIT FLR (BOTH CHAN OPNL)

CRIT FLR TO 1 CHAN

CRIT FLR TO 2 CHAN

ABN SYS OPNL

BACK-UP ROLLOUT MODE

CRIT FLR TO 1 CHAN

CRIT FLR TO 2 CHAN

SYS OPNL

CRIT FLR TO 2 CHAN

CRIT FLR TO 1 CHAN

BOTH CHAN OPNL

CRIT FLR TO 2nd. CHAN

2nd. CHAN OPNL

CRIT FLR TO 2 CHAN

CRIT FLR TO 1 CHAN

BOTH CHAN OPNL

NCRIT FLR (BOTH CHAN OPNL)

CRIT FLR TO 1 CHAN

CRIT FLR TO 2 CHAN

ABN SYS OPNL

CRIT FLR (BOTH CHAN OPNL)

CRIT FLR TO 1 CHAN

CRIT FLR TO 2 CHAN

ABN SYS OPNL

CRIT FLR (BOTH CHAN OPNL)

CRIT FLR TO 1 CHAN

CRIT FLR TO 2 CHAN

SYS OPNL

LEGEND:

● GROUND SYSTEM

○ AIRBORNE SYSTEM

FIGURE 22

Table 7 Safety Analysis Results

		Category III Adapter	STACC
System Operational			
Probability	=	.9993485	.9993971
Standard Deviation	=	.0000146	.0000128
Non-Critical Failure and Successful Go-Around			
Probability	=	.0002018	.0001780
Standard Deviation	=	.0000081	.0000066
Critical Failure to Single Channel and Successful Go-Around			
Probability	=	.0000041	.0000042
Standard Deviation	=	.0000003	.0000002
Wheel Spin-up not Detected and Successful Go-Around			
Probability	=	.0000005	.0000005
Standard Deviation	=	2.1×10^{-8}	2.1×10^{-8}
Non-Critical Failure During Rollout			
Probability	=	.0004028	.0004024
Standard Deviation	=	.0000098	.0000092
Back-up Rollout Mode			
Probability	=	.0000042	.0000044
Standard Deviation	=	.0000002	.0000002
Critical Failure to Single Channel During Rollout Mode			
Probability	=	.0000046	.0000134
Standard Deviation	=	.0000002	.0000006
Localizer Failure and Successful Go-Around			
Probability	=	3.5×10^{-8}	3.6×10^{-8}
Standard Deviation	=	2.7×10^{-9}	2.7×10^{-8}

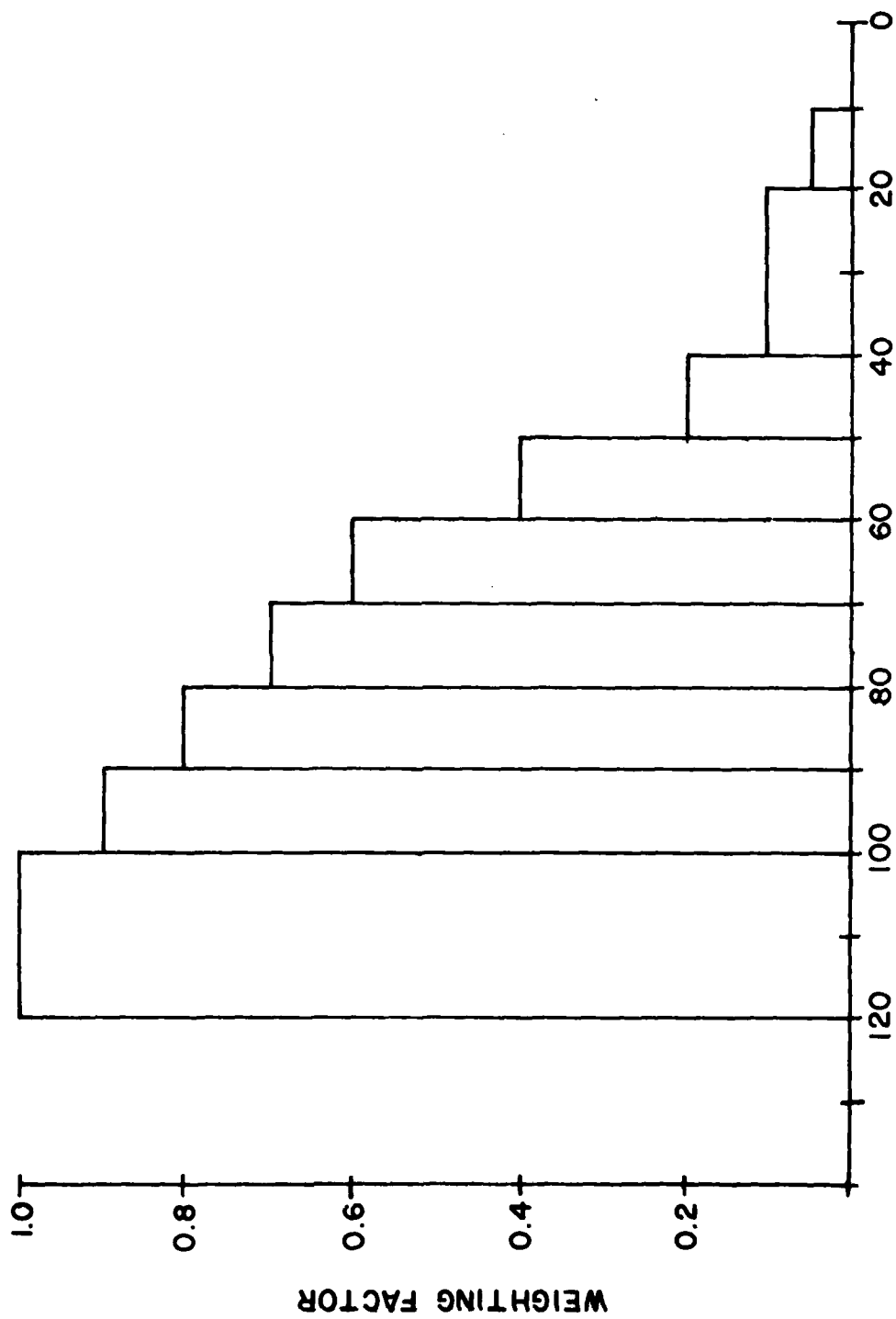
Table 7 - Cont.

Hazard to Safety Probability Standard Deviation	=	=	Category III	STACC
			Adapter	
			.0000327	5.0 X 10 ⁻¹¹
			.0000015	3.9 X 10 ⁻¹²

erroneous assumption. In order to achieve a more realistic modeling approach additional discussions with the test pilots and system support personnel were conducted. The results of these discussions produced two separate attenuation functions designed specifically to weight the criticality of equipment failures as a function of the aircraft ground speed and pilot visibility conditions. The first attenuation function (Figure 23) was developed for a fully automatic rollout maneuver and assumed that the pilot could not get any of the visual cues necessary for a manual takeover of the aircraft. Alternatively, the second attenuation function (Figure 24) was developed for an automatic rollout with manual assist capability. This function assumed that the pilot could indeed see the runway lighting patterns and provide a satisfactory back-up manual control capability. This second function was felt to be the more realistic because of the following statement by test pilot Major M. Lipscey. "The runway centerline lights complimented the touchdown zone lights and provided satisfactory rollout guidance for even the lowest RVR encountered during the tests. The overall ground lighting system was considered satisfactory for both a visual takeoff and landing rollout..." (Ref. 1)

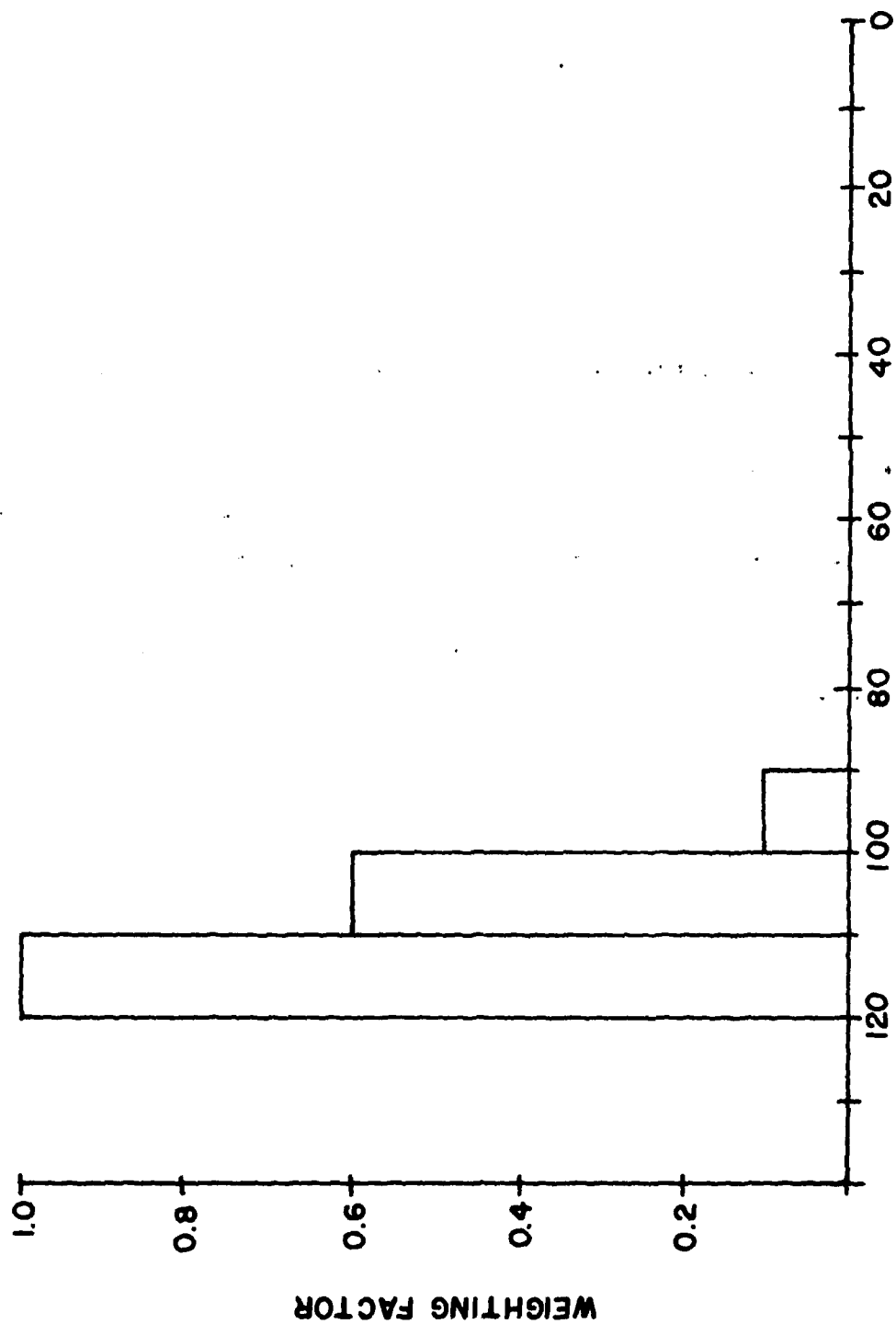
The utility of these attenuation functions was achieved by combining them with a typical runway speed profile for the test aircraft. Recorded flight data from mission 175 provided the runway speed profile information shown in Figure 25. Thus, by combining the runway speed profile with the respective attenuation functions, a time base weighting factor was defined and subsequently included in the decision tree analysis. These results are described in Table 8. It is relevant to again point out that only the hazards to safety for the rollout maneuver were attenuated. The other hazards to safety were unchanged.

From Table 8, it is evident that the safety of the STACC system configuration is again superior to the Category III adapter system configuration by approximately six orders of magnitude. The important thing to observe from this data is how attenuation functions affected the results. In all cases the hazards to safety are significantly reduced from their original calculations. For the second attenuation function (assumed to be the more realistic), the analysis



RUNWAY SPEED (KNOTS)
Attenuation Function - No Pilot

FIGURE 23



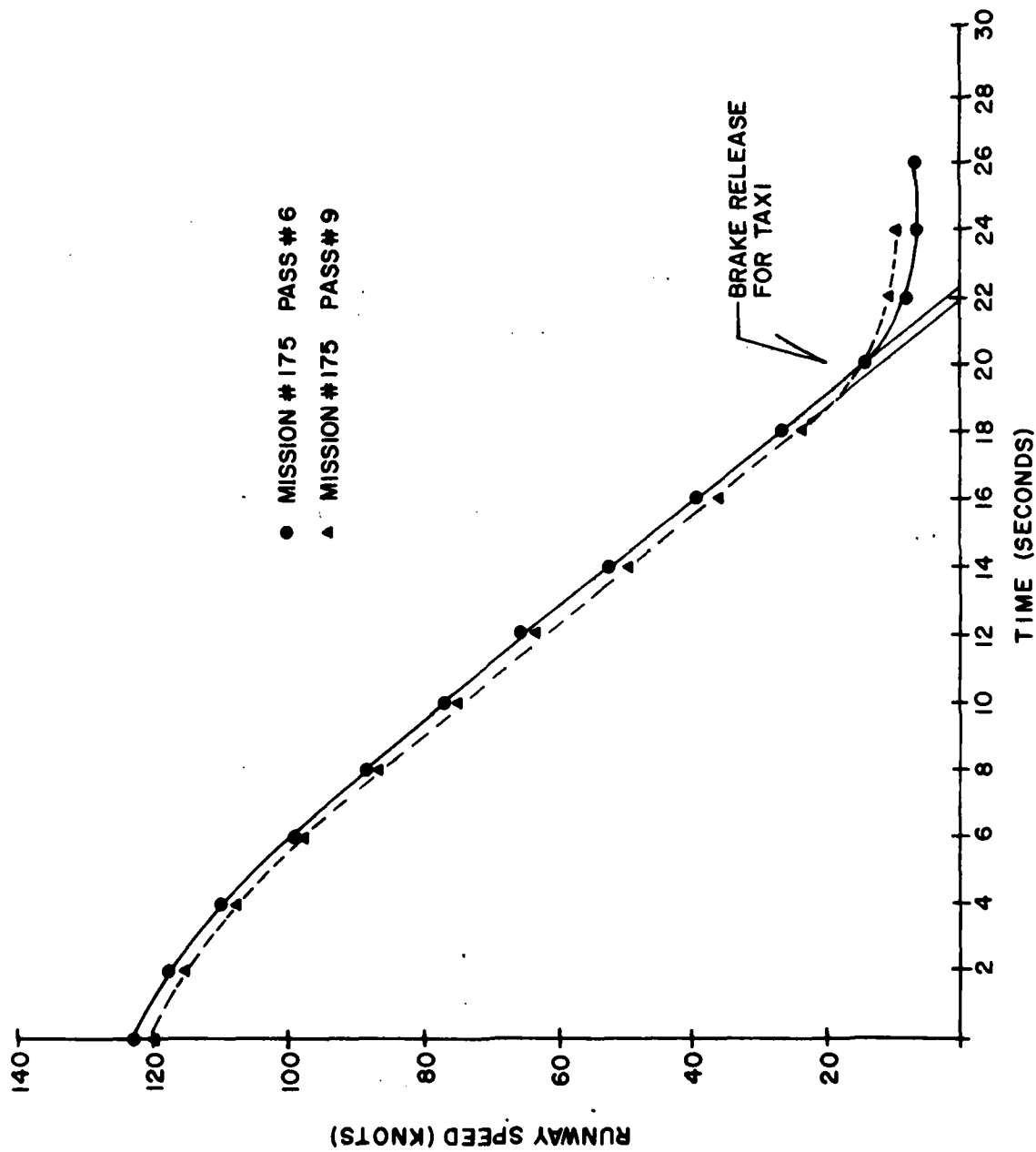
RUNWAY SPEED (KNOTS)
Attenuation Function Limited Visibility

FIGURE 24

predicts approximately 1 hazardous landing per 10^5 landings for the Category III adapter configuration and 1 hazardous landing per 10^{11} landings for the STACC configuration. The predicted standard deviations for these hazards are also relatively small. Thus, the variant effects of landing segment time and equipment MTBF appear to be of minor significance.

COMPARISON OF RESULTS

The results of this safety analysis were compared to accepted industry standards and experience. The Air Force specification MIL-F-9490D requires that a flight control system on a C-141-type aircraft be extremely reliable and provide a probability of aircraft loss of less than 5×10^{-7} per flight (or mission). However, when the aircraft is flown under an "environmental limit or operational restriction" the probability of aircraft loss can be increased by a factor of not more than 30 times. This was interpreted to mean that during a Category III weather landing the probability of aircraft loss due to the flight control system should not be greater than 1.5×10^{-5} . From Table 8, the hazards to safety, obtained by employing the second attenuation function assuming limited pilot visibility, meet the requirements outlined by MIL-F-9490D for flight control systems for both system configurations.



Runway Speed Profile
FIGURE 25

Table 8 Attenuated Safety Analysis Results *

	Category III Adapter	STACC
Original Hazard to Safety Probability =	.0000327	5.0×10^{-11}
Standard Deviation =	.0000015	3.9×10^{-12}
Attenuated Hazard to Safety (fully Automatic) Probability =	.0000200	2.3×10^{-11}
Standard Deviation =	.0000010	1.6×10^{-12}
Attenuated Hazard to Safety (Automatic/Manual Back-up) Probability =	.0000093	8.8×10^{-12}
Standard Deviation =	.0000006	5.9×10^{-13}

* Results show influence landing sequence time variability and equipment MTBF variability.

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APPENDIX A
EQUIPMENT FAILURE RATE INFORMATION

AFCS AILERON SERVO

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURES RATE (λ) FAILURES/HOUR
52ABA	Aileron Servo Actuator	1	36	0.000137
52ABB	Mount - Servo	1	0	0.000000
52ABC	Pulley	1	2	0.000008
52ABD	Cable	3	17	0.000065
52ABE	Position Transmitter	1	41	0.000156
			<u>96</u>	<u>0.000366</u>

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1}$ = 2732.240 HOURS

AFCS CONTROL PANEL

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ) FAILURES/HOUR
52AAA	Control Panel	1	42	0.000160
52AAB	Indicator - AFCS Trim	1	14	0.000053
52AAD	Control Wheel Sensor	1	95	0.000361
52AAE	Auto Pilot Disengage Switch	2	1	0.000004
52AAG	Junction Box Assembly	1	0	0.000000
52AAH	Terminal Strip	10	0	0.000000
52AAJ	Diode (Rectifier)	1	3	0.000011
52AAK	Converter	1	0	0.000000
52AAL	Controller	1	2	0.000008
52AAM	Wiring	1	3	0.000011
52AAN	Mach Trim Transmitter	1	0	0.000000
52EFO	Control Panel Autopilot	1	257	0.000976
			417	0.001584

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1}$ = 631.305 HOURS

AFCS COUPLER *

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ) FAILURES/HOUR
52EEA	Dual D/C, D/C Comparator	1	47	0.000179
52EEB	Limited Detector Integrator	1	107	0.000406
52EEC	Module SW. Card NR. 3	1	82	0.000311
52EED	Module SW. Card NR. 2	1	151	0.000574
52EEE	Module SW. Card NR. 1	1	163	0.000619
52EEF	Comparator	1	84	0.000319
52EEG	Comparator	1	15	0.000057
52EEH	Desensitizer	1	43	0.000163
52EEJ	Power Supply Assembly	1	279	0.001060
52EEK	Amplifier Filter	1	160	0.000608
52EEL	Detector Limiter	1	39	0.000148
52EEM	Desensitizer	1	48	0.000182
52EEN	Desensitizer	1	27	0.000103
52EEP	Detector Filter	1	29	0.000110
52EEQ	Compass Synchronizer	1	81	0.000308
52EER	Desensitizer	1	24	0.000091
52EES	Desensitizer	1	76	0.000289
52EET	Functions Assembly	1	43	0.000163
52EEU	Comparator	1	83	0.000315
56DJD	Accelerometer Vertical	1	13	0.000049
			1594	0.0006054

Total Flight Hours = 263254 Hours

MTBF = $(\Sigma \lambda)^{-1}$ = 165,180 Hours

* Replaced by STACC

AFCS ELEVATOR SERVO

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ) FAILURES/HOUR
52ADA	Elevator Servo Actuator	1	20	0.000076
52ADB	Mount - Elevator Servo	1	0	0.000000
52ADC	Pulley	1	0	0.000000
52ADD	Cable	3	12	0.000046
52ADE	Clutch	1	1	0.000004
			<u>33</u>	<u>0.000126</u>

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1} = 7936.508$ HOURS

AFCS RUDDER SERVO

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ) FAILURES/HOUR
52ACA	Yaw Damper Servo Actuator	2	173	0.000657
52ACB	Mount - Yaw Damper Servo	1	0	0.000000
52ACC	Control Dual Yaw Damper	1	46	0.000175
52ACD	Gyro - Single-Axis Rate	3	399	0.001516
52ACE	Brushes	4	0	0.000000
			<u>618</u>	<u>0.002348</u>

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1} = 425.894$ HOURS

AILERON COMPUTER

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
52ECA	Power Supply Assembly	1	79	0.000300
52ECB	Comparator Assembly	1	46	0.000175
52ECC	Adapter Assembly	1	100	0.000380
52ECD	Detector Assembly	1	31	0.000118
52ECE	Module Servo Assembly	1	14	0.000053
52ECF	Pre-Amp Assembly	1	110	0.000418
52ECG	Roll CWS Assembly	1	48	0.000182
52ECH	Servo Drive Assembly	1	32	0.000122
52ECJ	Command Modifier Limiter	1	132	0.000501
52ECK	Synchronizer	1	138	0.000524
			<u>730</u>	<u>0.002773</u>

TOTAL FLIGHT HOURS = 263254 HOURS

$MTBF = (\Sigma \lambda)^{-1} = 360.620 \text{ HOURS}$

ATTITUDE DIRECTOR INDICATOR

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE(N). FAILURES/HOUR
N/A	Sperry 350B ADI	2	N/A	0.000674*
51BGD	Transmitter-Rate-of-Turn	2	738	0.002803
51BGE	Power Adequacy Indicator	2	50	0.000190
51BGG	Gyro-Displacement Roll and Pitch	2	1514	0.005751
51BGH	Transformer - Isolation	2	N/A	0.000019**
51BGJ	Wiring	1	16	0.000061
N/A	Selecter Switch	1	N/A	0.000065**
N/A	Switching Matrix	1	N/A	0.000065**
N/A	Relay	2	N/A	0.000008**
			<u>2323</u>	<u>0.009636</u>

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1} = 103.778$ HOURS

* Failure Data from Manufacturer for DC-10 Fleet from September 1974 to August 1975.

** Estimated from similar equipment

AUTOMATIC THROTTLE COMPUTER

WORK UNIT CODE	DESCRIPTION	QTY/PA	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
56BBO	Speed Trimer	1	4	0.000015
56BCA	Amplifier Power	2	49	0.000186
56BCB	Amplifier Error Integrator	1	52	0.000198
56BCC	Board Signal Processor	1	43	0.000163
56BCD	Disengage Logic Power	1	18	0.000068
56BCE	Power Supply NR. 1	1	55	0.000209
56BCF	Board Assembly Self Test	1	48	0.000182
56BCG	Flare Prog. and Rate	1	29	0.000110
56BCH	Power Supply NR. 2	1	3	0.000011
56BCJ	Elec. Comp. Assembly	1	0	0.000000
56BEO	Clutch Pack	1	39	0.000148
56BGO	Motor Generator	1	28	0.000106
			<u>368</u>	<u>0.001396</u>

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\sum \lambda)^{-1}$ = 716.332 HOURS

CATEGORY III ADAPTER *

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
N/A	CAT III Adapter	1	N/A	0.005438 *
13ACA	Touchdown Switch	4	132	0.000501
13ACB	Touchdown Relay	10	21	0.000080
13BCA	Switch NLG	1	45	0.000171
13DCA	Skid Detector	8	128	0.000486
13DCB	Control Box, Anti-Skid	1	428	0.001626
13HBN	Touchdown Control Box	1	156	0.000593
			<u>910</u>	<u>0.008895</u>

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1} = 112.423$ HOURS

** No Failure Rate Data Available - No failures occurred for 183.9 Flight Test Hours from July 1974 to June 1975 so assumed a maximum of 1 Failure per 183.9 Hours.

* Replaced By STACC

CENTRAL AIR DATA COMPUTER SYSTEM

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE(A), FAILURES/HOUR
51AAA	CADC	2	2410	0.009155
51AAB	Airspeed Machmeter Indicator	2	726	0.002758
51AAC	Indicator-Altitude-Rate-of-Climb 2	1	1668	0.006336
51AAD	Indicator True Airspeed	1	68	0.000258
51AAE	Computer Primary	1	7	0.000027
51AAF	Mach Module	1	2	0.000008
51AAG	Mechanism-Pressure Altitude	1	5	0.000019
51AAJ	Sensor Section Assy Impact Pressure 1	1	0	0.000000
51AAK	True Airspeed Module	1	16	0.000061
51AAL	Impact Pressure Module	1	4	0.000015
51AAM	Amplifier - Electronic Control	1	2	0.000008
51AAN	Amplifier - Monitoring	1	0	0.000000
51AAP	Amplifier - Buffer	1	0	0.000000
51AAQ	Amplifier - Isolation	1	0	0.000000
51AAR	Power Supply Regulated	1	6	0.000023
51AAS	Relay Assy	1	1	0.000004
51AAT	Sensor - Temperature	1	2	0.000008
51AAU	Wiring	1	15	0.000057
51AAV	Amplifier-Monitor Rate	1	0	0.000000
51ABO	Amplifier-Altitude-Rate-of-Climb 2	2	343	0.001303
51ACO	Amplifier-Airspeed Mach	2	139	0.000528

CENTRAL AIR DATA COMPUTER SYSTEM (cont'd)

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
51BAO	Pilot Static System	1	244	0.000927
51BFA	Total Temperature Probe	2	84	0.000319
51BFB	Switch-De-Ice	1	3	0.000011
51BFC	Total Temperature Indicator	1	174	0.000661
51BFD	Wiring	1	6	0.000023
51BHA	Altimeter Pressure	2	407	0.001546
			<u>6332</u>	<u>0.024055</u>

TOTAL FLIGHT HOURS = 263254 HOURS

$$MTBF = (\Sigma \lambda)^{-1} = \frac{1}{0.024055} = 41.571 \text{ HOURS}$$

ELEVATOR COMPUTER *

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
52EAA	Adapter Assembly	1	91	0.000346
52EAB	PCW Steering	1	62	0.000236
52EAC	CWS Steering	1	55	0.000209
52EAD	Comparator Assembly	1	78	0.000296
52EAE	Power Supply Assembly	1	95	0.000361
52EAF	Washout Module	1	141	0.000536
52EAG	Synchronizer	1	63	0.000239
52EAH	Preamplifier	1	70	0.000266
52EAJ	Servo Amplifier	1	211	0.000802
52EAK	Servo Module Assembly	1	54	0.000205
52EAL	Fail Safe Amplitude Detector	1	32	0.000122
56DJC	Transmitter	1	6	0.000023
			<u>958</u>	<u>0.003641</u>

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1} = 274.650$ HOURS

* Modified for STACC

FLARE COMPUTER *

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
56BLA	Module Altitude Indicator	1	17	0.000065
56BLB	Filter and Drivers	2	57	0.000217
56BLC	Logic and Self Test	1	25	0.000095
56BLD	Module Altitude Isolation	1	4	0.000015
56BLE	Comparator	1	10	0.000038
56BLF	Power Supply	1	34	0.000129
56BLG	Regulator Assembly	1	44	0.000167
56BLH	Subassembly	1	0	0.000000
56DJD	Accelerometer Vertical	1	14	0.000053
			<u>205</u>	<u>0.000779</u>

75

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1}$ = 641.849 HOURS

NOTE: Dual Flare Computers were used on the Test Aircraft so $\Sigma \lambda = (2)$ (0.000779)

* Replaced by STACC

FLIGHT DIRECTOR COMPUTER *

	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
56AFA	Level Detector	2	84	0.000319
56AER	Power Supply	2	16	0.000061
56AEC	Channel Latitude	2	38	0.000144
56AED	Channel Long	2	38	0.000144
56AEE	Logic Assembly	2	77	0.000292
56DJB	Transmitter	2	1	0.000004
56DJD	Accelerometer	1	14	0.000053
			<u>268</u>	<u>0.001017</u>

TOTAL FLIGHT HOURS = 263254 HOURS

$$MTBF = (\Sigma \lambda)^{-1} = 983.284$$

* Replaced by STACC

GLIDESLOPE RECEIVER

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
71EAA	Antenna	1	18	0.000068
71EAD	Wiring	1	9	0.000034
71GAO	Glideslope Receiver Radio	2	N/A 27	0.001901 * 0.002003

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1} = 499.251$ HOURS

* C-5 Failure Rate Data from April 1975 to September 1975 (46 Failures during 24203 Flight hours)

HORIZONTAL SITUATION INDICATOR

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE(λ), FAILURES/HOUR
51BCK	Horizontal Situation Indicator	2	$\frac{766}{766}$	$\frac{0.002910}{0.002910}$

TOTAL FLIGHT HOURS = 263254 HOURS

$MTBF = (\Sigma \lambda)^{-1} = 343.643 \text{ HOURS}$

INERTIAL NAVIGATION SYSTEM

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
N/A	Litton LTN-51 Platform	2	N/A	$\frac{0.000968^*}{0.000968}$

MTBF = $(\Sigma \lambda)^{-1} = 1033.058$ HOURS

* Failure Rate Data from Manufacturer

MASTER CAUTION CONTROLLER

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
56DAA	Circuit Board (Control Box)	3	41	0.000156
56DAB	Circuit Board (Control Box)	2	61	0.000232
56DCO	Panel - Fault	1	33	0.000125
56DEO	Panel-Display and Warning	2	65	0.000247
56DJH	Wiring	1	2	0.000008
56DJJ	Connectors	1	8	0.000030
56DJK	Coaxial Cable	1	0	0.000000
			210	0.000798

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1} = 626.566$ HOURS

NOTE: Two Master Caution Controllers were used on the Test Aircraft so
 $\Sigma \lambda = (2) (0.000798)$

NAVIGATION RECEIVER

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
56CDA	Antenna	1	0	0.000000
56CDB	R. F. Switch	1	3	0.000011
N/A	Collins 51RV2B Receiver	2	N/A	0.000667*
			3	0.000678

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\sum \lambda)^{-1}$ = 1474.926 HOURS

* FAILURE RATE DATA FROM MANUFACTURER

NAVIGATION SELECTOR

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE(λ), FAILURES/HOUR
51BGL	Pilot Navigation Selector Switch	1	17	0.000065
51BGM	Navigation Selector (Co-Pilot)	1	15	0.000057
51DJF	Selector Switch (Pilot)	2	169	0.000642
51DJG	Selector Switch (Co-Pilot)	1	159	0.000604
			<u>360</u>	<u>0.001368</u>

TOTAL FLIGHT HOURS = 263254 HOURS

$$MTBF = (\Sigma \lambda)^{-1} = 730.994$$

PITCH ATTITUDE GYRO

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
52AAF	Vertical Gyro	1	$\frac{690}{690}$	$\frac{0.002621}{0.002621}$

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1} = 381.534$ HOURS

PITCH RATE GYRO

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
52AAC	Gyro - Two Axis Rate	2	$\frac{171^*}{171}$	$\frac{0.000650}{0.000650}$

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1} = 1538.462$ HOURS

* Gyro Measures both Pitch and Roll Rate so the failures were divided equally between Pitch Rate Gyro and the Roll Rate Gyro.

WORK UNIT CODE	RADAR INDICATOR			
	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
72JBO	Indicator Assembly	1	$\frac{267}{267}$	$\frac{0.001014}{0.001014}$

TOTAL FLIGHT HOURS = 263254 HOURS

$MTBF = (\Sigma \lambda)^{-1} = 493.097 \text{ HOURS}$

NOTE: Two Radar Indicator were used on the Test Aircraft so
 $\Sigma \lambda = (2) (0.001014)$

RADAR RECEIVER TRANSMITTER UNIT

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
72JAO	RT Assembly	1	545	0.002070
72JCO	Antenna	1	16	0.000061
72JDO	Mount	1	0	0.000000
			<u>561</u>	<u>0.002131</u>

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1}$ = 234.632 HOURS

NOTE: Two Radar Receiver Transmitter Units were used in the Test Aircraft
so $\Sigma \lambda = (2) (0.002131)$

ROLL RATE GYRO

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (%), FAILURES/HOUR
52AAC	Gyro-Two Axis Rate	2	171*	$\frac{0.000650}{0.000650}$

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1}$ = 1538.462 HOURS

* Gyro measures both Pitch and Roll Rate so the failures were divided equally between the Pitch Rate Gyro and the Roll Rate Gyro

ROTATE AND GO-AROUND COMPUTER

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
56BJO	Computer Rotation Go-Around	1	464	0.001763
56DJD	Accelerometer - Vertical	1	14	0.000053
56DJE	Accelerometer - Horizontal	1	23	0.000087
14JBF	Angle of Attack Transducer	2	N/A	0.001024*
			501	0.002927

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1} = 341.647$ HOURS

* C-141 Failure Rate Data from August 1975 to January 1976
(134 Failures occurred during 130804 Flight Hours)

RUNWAY DISTANCE REMAINING INDICATOR

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
N/A	RDR Indicator	1	N/A	$\frac{0.005438^*}{0.005438}$

$$MTBF = (\Sigma \lambda)^{-1} = 183.9 \text{ HOURS}$$

* No Fleet Failure Rate Data Available - No failures occurred for 183.9 Test Flight Hours from July 1974 to June 1975 so assumed a maximum of 1 Failure per 183.9 Hours.

AD-A087 524

DAYTON UNIV OHIO

F/G 1/2

LANDING SYSTEM RELIABILITY AND SAFETY MODEL.(U)

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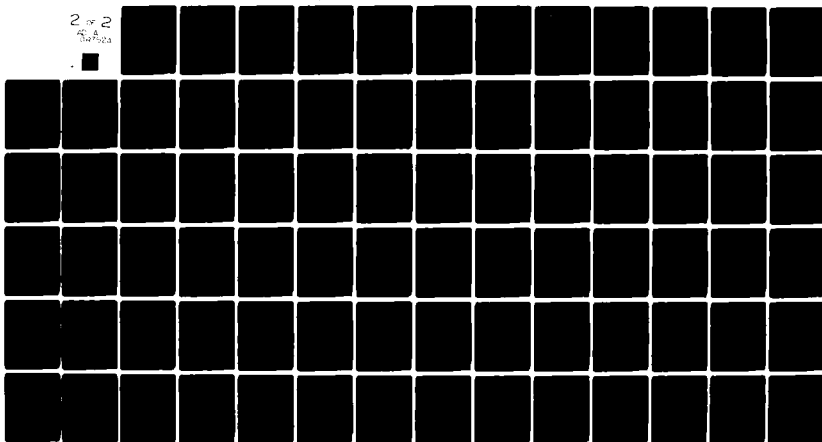
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SIMPLIFIED TERMINAL AREA CONTROL COMPUTER

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
N/A	STACC	2	N/A	0.001442*
13ACA	Touchdown Switch	4	132	0.000501
13ACB	Touchdown Relay	10	21	0.000080
13BCA	Switch NLG	1	45	0.000171
13DCA	Skid Detector	8	128	0.000486
13DCB	Control Box, Anti-Skid	1	428	0.001626
14HBN	Touchdown Control Box	1	156	0.000593
56DJB	Transmitter	2	1	0.000004
56DJD	Accelerometer	3	41	0.000156
			952	0.005059

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1}$ = 197.668 HOURS

* ESTIMATED FAILURE RATE BASED ON SIMILAR EQUIPMENT

TEST PROGRAMMER AND LOGIC COMPUTER

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
56DGA	Program Control Board	1	82	0.000311
56DGB	Indicator Logic Board	1	34	0.000129
56DGC	Monitor Logic Board	1	46	0.000175
56DGD	R/GA Gyro Monitor Board	1	112	0.000425
56DGE	Vertical Gyro Monitor Board	2	105	0.000399
56DGF	Special Circuits Board	2	49	0.000186
56DGG	Left Power Supply Board	1	97	0.000368
56DGH	Right Power Supply Board	1	92	0.000349
56DGJ	Clamp Circuit Board	1	0	0.000000
56DGK	Interrupter Circuit Board	1	8	0.000030
56DGL	Relay Assembly Board	1	4	0.000015
56DJA	Test Panel	1	17	0.000065
			<u>646</u>	<u>0.002452</u>

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1}$ = 407,830 HOURS

VERTICAL GYRO

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
52AAF	Vertical Gyro	1	690	$\frac{0.002621}{0.002621}$

TOTAL FLIGHT HOURS = 263254 HOURS

$MTBF = (\Sigma \lambda)^{-1} = 381.534 \text{ HOURS}$

YAW DAMPER COMPUTER

WORK UNIT CODE	DESCRIPTION	QTY/Pa	C-141 FLEET FAILURES FROM MAY 1974 to APRIL 1975	FAILURE RATE (λ), FAILURES/HOUR
52EBA	Module Logic	1	128	0.000486
52EBB	Adapter Module	1	70	0.000266
52EBC	Comparator Assembly	1	73	0.000277
52EBD	Signal Chain Comparator Assy.	1	106	0.000403
52EBE	Servo Drive	1	90	0.000342
52EBF	Filter YAW Rate	1	258	0.000980
52EBG	Simulator Module	1	93	0.000353
52EBH	Power Supply	1	48	0.000182
			<u>866</u>	<u>0.003289</u>

TOTAL FLIGHT HOURS = 263254 HOURS

MTBF = $(\Sigma \lambda)^{-1} = 304.044$ HOURS

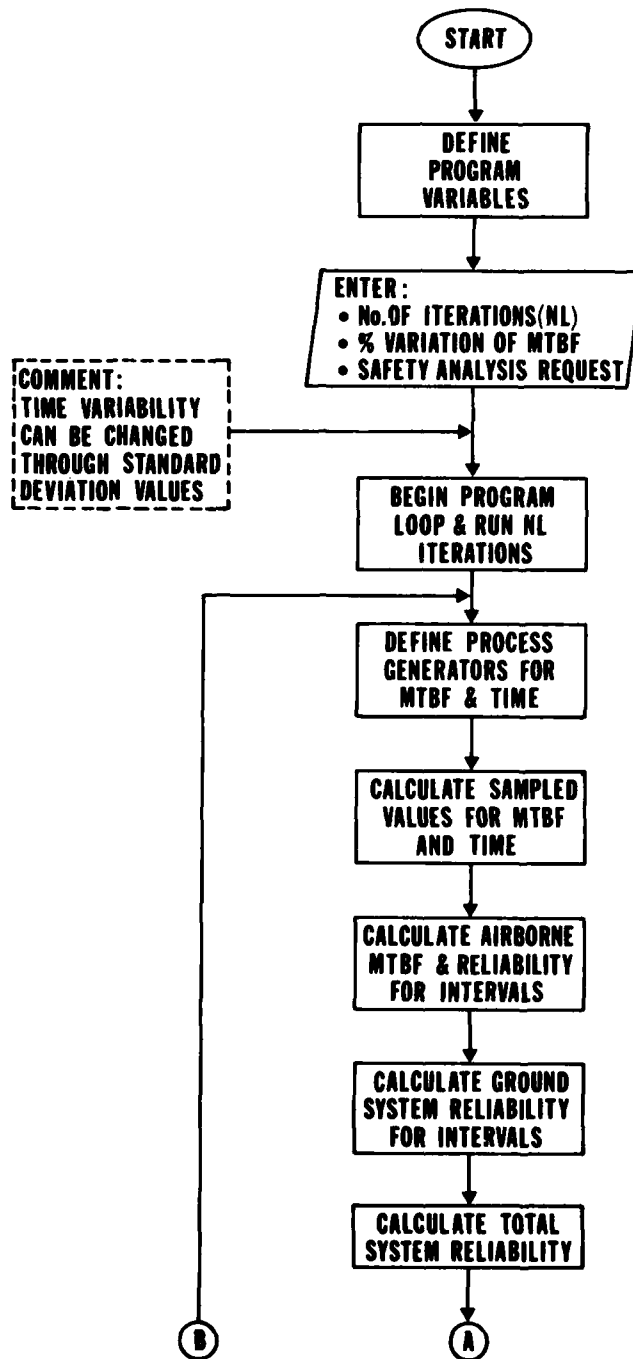
APPENDIX B

COMPUTER PROGRAM INFORMATION

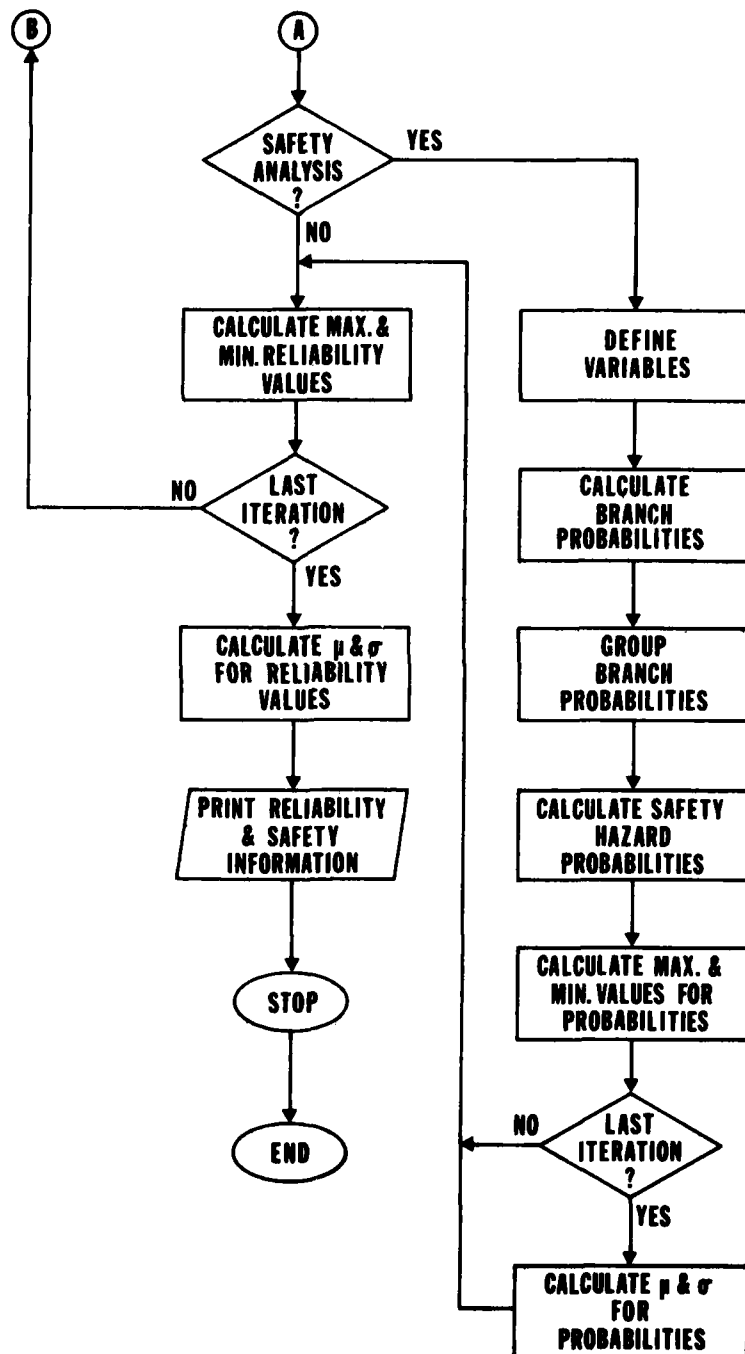
APPENDIX B

The computer programs for this reliability/safety analysis were designed to provide the respective calculations for both system configurations (Category III Adapter and STACC). Each system configuration had a separate computer program which provided the analysis via a Monte Carlo simulation. This simulation technique allowed the respective calculations to reflect the influence of MTBF and operational time variability on the reliability/safety values. Thus, the programs determined not only the nominal probability values but also determined the variability associated with each calculation. A simplified flow chart for the basic computer programs is illustrated in Figures B1 and B2. Descriptions of the basic process generators for the Monte Carlo simulations and computer printouts for both system configurations are included in this appendix.

COMPUTER ANALYSIS FLOW CHART

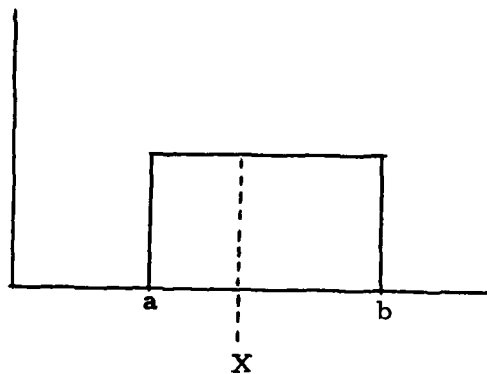


COMPUTER ANALYSIS FLOW CHART (Cont.)



Uniform Process Generator

For a uniformly distributed random variable X



$$f_X(X) = \frac{1}{b-a}, \quad a < X < b$$

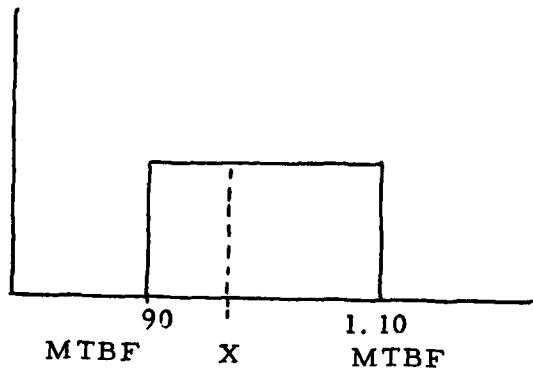
$$r = \int_a^X \frac{dz}{b-a}$$

$$r = \frac{X-a}{b-a}$$

$$\therefore X = a + r(b-a)$$

where r is a random number between 0 and 1.

The individual process generators for equipment MTBF were based on this uniform distribution with a variability of ± 10 percent from the nominal MTBF values. This is illustrated as follows:

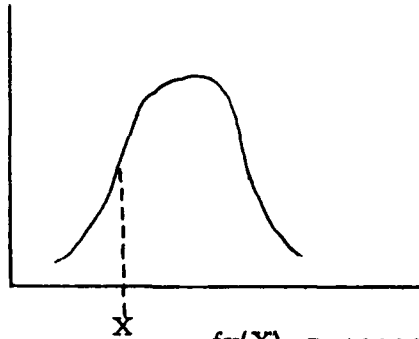


where the sampled values from the distributions can be represented by

$$X = .90\text{MTBF} + (r) (.20 \text{ MTBF}).$$

Normal Process Generator

For a normally distributed random variable X



where μ = mean
and σ^2 = variance

$$f_X(X) = \frac{1}{\sigma \sqrt{2\pi}} e^{-(t-\mu)^2 / (2\sigma^2)} dt$$

$$r = \int_{-\infty}^X \frac{1}{\sigma \sqrt{2\pi}} e^{-(t-\mu)^2 / (2\sigma^2)} dt$$

where r is a random number between 0 and 1. However, this integral cannot be evaluated analytically but can be evaluated with the use of an approximation for the cumulative standard normal distribution (mean 0 and variance 1). The standard normal distribution employs the following transformations:

$$Z = \frac{t - \mu}{\sigma}$$

$$dt = \sigma dZ$$

$$\text{therefore } r = \int_{-\infty}^{\frac{X-\mu}{\sigma}} \frac{1}{\sqrt{2\pi}} e^{-Z^2/2} dZ$$

Because of the symmetry of the normal distribution about the mean ($r=0.5$) and the computational approximation, the variable X can be represented as

$$X = \mu + \frac{r - 0.5}{|r - 0.5|} \sigma \left(V - \frac{2.515517 + 0.802853V + 0.010328V^2}{1 + 1.432788V + 0.189269V^2 + 0.001308V^3} \right)$$

$$\text{where } V = \sqrt{-2 \ln 0.5 (1 - |1 - 2r|)}$$

The normal distribution process generators were used to determine the sampled values for the modeled time segments of the landing profile. Values for the Mean (μ) and standard deviation (σ) for each time segment served as inputs to the respective process generators.

Reliability/Safety Analysis Results
(STACC System Configuration)

SAFETY ANALYSIS RESULTS

SYSTEM CONFIGURATION		
	CATEGORY III ADAPTER	STACC
SAFETY HAZARD (FULLY AUTOMATIC)	$\mu = 199 \times 10^{-7*}$ $\sigma = 10 \times 10^{-7*}$	$\mu = 23 \times 10^{-12*}$ $\sigma = 2 \times 10^{-12*}$
SAFETY HAZARD (AUTOMATIC/MANUAL ASSIST)	$\mu = 92 \times 10^{-7*}$ $\sigma = 6 \times 10^{-7*}$	$\mu = 9 \times 10^{-12*}$ $\sigma = 1 \times 10^{-12*}$

* Per Landing

Run # 1

Did Not Vary Either Equipment MTBF
or Segment Time Intervals

40=
50=
60=

1.024 CP SECONDS

77500B CM STORAGE US

XPER=0%.
STD DEV.=0.

70=
80=
90=
00=
10=*EOR
20=1\$AWLS
30=ONL
40=OXPER
50=OANS
60=0\$END

= 100.
= 0.0.
= 1.

70=
80=
90=
00=
10=
20=
30=
40=
50=

RELIABILITY ANALYSIS

60=
70=

LOC CAPTURE TO ARM G/S

80=
90=
00=
10=
20=
30=
40=
50=
60=
70=
80=
90=
00=

MEAN TIME = 210.
STD. DEV. OF TIME = 0.
MTBF = 16.6386060079658489090664236
VARIATION = 0.
MEAN OF RELIABILITY = .996496514754175684456161065
STD. DEV. OF RELIABILITY = 0.
MAX VALUE = .996496514754175684456161066
MIN VALUE = .996496514754175684456161066

10=
20=
30=
40=
50=
60=
70=
80=
90=
00=

ARM G/S TO G/S CAPTURE

MEAN TIME = 30.
STD. DEV. OF TIME = 0.
MTBF = 16.1019733511643811954869908
VARIATION = 0.
MEAN OF RELIABILITY = .999482065914006726408576944
STD. DEV. OF RELIABILITY = 0.
MAX VALUE = .999482065914006726408576945
MIN VALUE = .999482065914006726408576945

10=
20=
30=
40=
50=
60=
70=
80=
90=
00=
10=
20=
30=
40=
50=
60=
70=
80=
90=
00=

G/S CAPTURE TO APPROACH ARM

MEAN TIME = 30.
STD. DEV. OF TIME = 0.
MTBF = 15.1624983074491654628633497
VARIATION = 0.
MEAN OF RELIABILITY = .999450016346329925745560099
STD. DEV. OF RELIABILITY = 0.
MAX VALUE = .9994500163463299257455601
MIN VALUE = .9994500163463299257455601

0= APPROACH ARM TO LAND ARM (100 FEET)

10=

20= MEAN TIME = 81.54

30= STD. DEV. OF TIME = 0.

40= MTBF = 11.8318104032751170011556572

50= VARIATION = 0.

60= MEAN OF RELIABILITY = .998086053335585957904965218

70= STD. DEV. OF RELIABILITY = 0.

80= MAX VALUE = .998086053335585957904965219

90= MIN VALUE = .998086053335585957904965219

00=

10=

20= LAND ARM (100 FT) TO FLARE ENGAGE (45 FT)

30=

40= MEAN TIME = 5.35

50= STD. DEV. OF TIME = 0.

60= MTBF = 11.8318104032751170011556572

70= VARIATION = 0.

80= MEAN OF RELIABILITY = .999874309768683408940652405

90= STD. DEV. OF RELIABILITY = 0.

00= MAX VALUE = .999874309768683408940652406

10= MIN VALUE = .999874309768683408940652406

20=

30=

40=

50=

60= FLARE ENGAGE (45 FT) TO DECRAB (20 FT)

70=

80= MEAN TIME = 3.07

90= STD. DEV. OF TIME = 0.

00= MTBF = 12.1190205509405668046256485

10= VARIATION = 0.

20= MEAN OF RELIABILITY = .99992958101226159299344016

30= STD. DEV. OF RELIABILITY = 0.

40= MAX VALUE = .999929581012261592993440161

50= MIN VALUE = .999929581012261592993440161

60=

70=

80=

90=

00= DECRAB (20 FT) TO TOUCHDOWN

10=

20= MEAN TIME = 4.02

30= STD. DEV. OF TIME = 0.

40= MTBF = 12.1190205509405668046256485

50= VARIATION = 0.

60= MEAN OF RELIABILITY = .999907791124904092569491272

70= STD. DEV. OF RELIABILITY = 0.

80= MAX VALUE = .999907791124904092569491273

90= MIN VALUE = .999907791124904092569491273

00=

10=

20=

30=

40= TOUCHDOWN TO STOP

50=

60= MEAN TIME = 22.73

70= STD. DEV. OF TIME = 0.

80= MTBF = 14.3955465734716898297868169

90= VARIATION = 0.

00= MEAN OF RELIABILITY = .99956109209986805814802197

10= STD. DEV. OF RELIABILITY = 0.

10=
 20=
 30= TOUCHDOWN TO STOP
 40=
 50= MEAN TIME = 22.73
 60= STD. DEV. OF TIME = 0.
 70= MTBF = 14.3955465794716896297868169
 80= VARIATION = 0.
 90= MEAN OF RELIABILITY = .99956109209986805814802197
 00= STD. DEV. OF RELIABILITY = 0.
 10= MAX VALUE = .999561092099868058148021971
 20= MIN VALUE = .999561092099868058148021971
 30=
 40=
 50=
 60=
 70=
 80=
 90=

TOTAL RELIABILITY FROM APPROACH ARM TO STOP

00= MEAN OF RELIABILITY = .997360372385783855417979997
 10= STD. DEV. OF RELIABILITY = 0.
 20= MAX VALUE = .997360372385783855417979997
 30= MIN VALUE = .997360372385783855417979997
 40=
 50=
 60=
 70=
 80=
 90=

TOTAL RELIABILITY FOR COMPLETE MODEL

00= MEAN OF RELIABILITY = .992805050867921586088078687
 10= STD. DEV. OF RELIABILITY = 9.13345968917193040081249268E-28
 20= MAX VALUE = .992805050867921586088078688
 30= MIN VALUE = .992805050867921586088078688
 40=
 50=
 60=
 70=
 80=
 90=

SAFETY ANALYSIS

SYSTEM OPERATIONAL

00= PROBABILITY = .999398725063109384554684044
 10= STD. DEV. = 0.
 20= MAX VALUE = .999398725063109384554684045
 30= MIN VALUE = .999398725063109384554684045
 40=
 50=
 60=
 70=
 80=
 90=

NON-CRITICAL FAILURE AND SUCCESSFUL R/GA

00= PROBABILITY = .000177097416518783158734848692
 10= STD. DEV. = 0.
 20= MAX VALUE = .000177097416518783158734848692
 30= MIN VALUE = .000177097416518783158734848692
 40=
 50=
 60=
 70=
 80=
 90=

CRITICAL FAILURE TO SINGLE CHANNEL AND SUCCESSFUL R/GA

00= PROBABILITY = .00000418858433413708238411910654
 10= STD. DEV. = 0.
 20= MAX VALUE = .00000418858433413708238411910654
 30= MIN VALUE = .00000418858433413708238411910654
 40=
 50=

50=
 70=
 80=
 90= WHEEL SPIN-UP NOT DETECTED AND SUCCESSFUL R/GA
 00=
 10= PROBABILITY = 5.02417836143932675562906951E-7
 20= STD. DEV. = 0.
 30= MAX VALUE = 5.02417836143932675562906951E-7
 40= MIN VALUE = 5.02417836143932675562906951E-7
 50=
 60=
 70=
 80= NON-CRITICAL FAILURE DURING ROLLOUT
 90=
 00= PROBABILITY = .000401738258243065112817239977
 10= STD. DEV. = 0.
 20= MAX VALUE = .000401738258243065112817239977
 30= MIN VALUE = .000401738258243065112817239977
 40=
 50=
 60=
 70= BACK-UP ROLLOUT MODE
 80=
 90= PROBABILITY = .00000440905279122985843392858097
 00= STD. DEV. = 0.
 10= MAX VALUE = .00000440905279122985843392858097
 20= MIN VALUE = .00000440905279122985843392858097
 30=
 40=
 50=
 60= CRITICAL FAILURE TO SINGLE CHANNEL DURING ROLLOUT
 70=
 80= PROBABILITY = .0000133131075125501343315572358
 90= STD. DEV. = 0.
 00= MAX VALUE = .0000133131075125501343315572358
 10= MIN VALUE = .0000133131075125501343315572358
 20=
 30=
 40=
 50= LOCALIZER FAILURE AND SUCCESSFUL R/GA
 60=
 70= PROBABILITY = 3.57314729416175607915543686E-8
 80= STD. DEV. = 0.
 90= MAX VALUE = 3.57314729416175607915543687E-8
 00= MIN VALUE = 3.57314729416175607915543687E-8
 10=
 20=
 30=
 40= SAFETY HAZARD
 50=
 60= PROBABILITY = 4.93533930016005914144274766E-11
 70= STD. DEV. = 0.
 80= MAX VALUE = 4.93533930016005914144274766E-11
 90= MIN VALUE = 4.93533930016005914144274766E-11
 00=
 10=
 20=
 30= ATTENUATED SAFETY HAZARD (NO PILOT VISIBILITY)
 40=
 50= PROBABILITY = 2.28697741158848983268402639E-11
 60= STD. DEV. = 0.
 70= MAX VALUE = 2.28697741158848983268402639E-11
 80= MIN VALUE = 2.28697741158848983268402639E-11

10=
 20= ATTENUATED SAFETY HAZARD (NO PILOT VISIBILITY)
 30=
 40= PROBABILITY = 2. 28697741158848983268402639E-11
 50= STD. DEV. = 0.
 60= MAX VALUE = 2. 28697741158848983268402639E-11
 70= MIN VALUE = 2. 28697741158848983268402639E-11
 80=
 90=
 10=
 20= ATTENUATED SAFETY HAZARD (LIMITED PILOT VISIBILITY)
 30=
 40= PROBABILITY = 8. 69948112223602469043029332E-12
 50= STD. DEV. = 0.
 60= MAX VALUE = 8. 69948112223602469043029332E-12
 70= MIN VALUE = 8. 69948112223602469043029332E-12
 80=*EOR
 90=1 CSE NOS/BE L414H ECS CYBR CMR3 05/30/77
 10= 13. 41. 48. PATIAEI FROM /IA
 20= 13. 41. 48. IP 00000128 WORDS - FILE INPUT , DC 00
 30= 13. 41. 48. PAT(T25, I050, CM100000, STCSB) D760276. BUS
 40= 13. 41. 48. SINGER, UD, 229-4238
 50= 13. 41. 50. ATTACH(LGO, AWLSSBIN, CY=1)
 60= 13. 53. 34. MAP(PART)
 70= 13. 53. 37. LGO,
 80= 13. 54. 39. STOP
 90= 13. 54. 39. 2. 451 CP SECONDS EXECUTION TIME
 10= 13. 54. 39. GP 00001600 WORDS - FILE OUTPUT DC 40
 20= 13. 54. 39. MS 3584 WORDS (3584 MAX USED)
 30= 13. 54. 39. SCM 100000 WORDS MAXIMUM
 40= 13. 54. 39. CPA 3. 525 SEC. 1. 530 ADJ.
 50= 13. 54. 39. IO 1. 256 SEC. . 628 ADJ.
 60= 13. 54. 39. CM 123. 164 KWS. . 985 ADJ.
 70= 13. 54. 39. CRUS 3. 144
 80= 13. 54. 39. COST 6 18
 90= 13. 54. 39. PP 4. 712 SEC. DATE 07/20/77
 10= 13. 54. 39. EU END OF JOB, IA D760276.

Run # 2

Only Varied Equipment MTBF

30=CNL = 100,
 40=KPER = .1E+00,
 50=QANS = 1,
 60=Q=END

AWAS3
 KPER = 10%
 STD DEV. = 0.

RELIABILITY ANALYSIS

LOC CAPTURE TO ARM G/S

MEAN TIME = 210.
 STD. DEV. OF TIME = 0.
 MTBF = 15.5627623406178475965176369
 VARIATION = .1
 MEAN OF RELIABILITY = .996478421452194926970490519
 STD. DEV. OF RELIABILITY = .0000610778416965016436464592313
 MAX VALUE = .996674327260553816292498876
 MIN VALUE = .996255143360461563230251245

ARM G/S TO G/S CAPTURE

MEAN TIME = 30.
 STD. DEV. OF TIME = 0.
 MTBF = 15.11222965657696955989186
 VARIATION = .1
 MEAN OF RELIABILITY = .999479498920957791552271811
 STD. DEV. OF RELIABILITY = .00000884243447765012650059173113
 MAX VALUE = .99950896882347207308557752
 MIN VALUE = .999448205083568751601537483

G/S CAPTURE TO APPROACH ARM

MEAN TIME = 30.
 STD. DEV. OF TIME = 0.
 MTBF = 14.3440549608996800678151481
 VARIATION = .1
 MEAN OF RELIABILITY = .999447438901833410938287291
 STD. DEV. OF RELIABILITY = .00000875223069871343394466683671
 MAX VALUE = .999477421474920771691780689
 MIN VALUE = .999418690806811322048072891

APPROACH ARM TO LAND ARM (100 FEET)

MEAN TIME = 81.54
 STD. DEV. OF TIME = 0.
 MTBF = 11.2833913689005116325204183
 VARIATION = .1
 MEAN OF RELIABILITY = .998079400291759936396328902
 STD. DEV. OF RELIABILITY = .0000262004673455933736972541584

00=
 10=
 20= LAND ARM (100 FT) TO FLARE ENGAGE (45 FT)
 30=
 40= MEAN TIME = 5.35
 50= STD. DEV. OF TIME = 0.
 60= MTBF = 11.2833913689005116325204183
 70= VARIATION = .1
 80= MEAN OF RELIABILITY = .999873872423334894250693868
 90= STD. DEV. OF RELIABILITY = .00000172213711121400232970348099
 00= MAX VALUE = .999878901606933500322731622
 10= MIN VALUE = .999868208570007715160449289
 20=
 30=
 40=
 50=

60= FLARE ENGAGE (45 FT) TO DECRAB (20 FT)
 70=
 80= MEAN TIME = 3.07
 90= STD. DEV. OF TIME = 0.
 00= MTBF = 11.5326673825582027582611149
 10= VARIATION = .1
 20= MEAN OF RELIABILITY = .999929327373786374529087369
 30= STD. DEV. OF RELIABILITY = 9.81291744992160219657726629E-7
 40= MAX VALUE = .999932161730095615714954393
 50= MIN VALUE = .999926005248291995683657617
 60=
 70=
 80=
 90=
 00=

10= DECRAB (20 FT) TO TOUCHDOWN
 20= MEAN TIME = 4.02
 30= STD. DEV. OF TIME = 0.
 40= MTBF = 11.5326673825582027582611149
 50= VARIATION = .1
 60= MEAN OF RELIABILITY = .999907459006596490279906395
 70= STD. DEV. OF RELIABILITY = .00000128492086168637085852749738
 80= MAX VALUE = .999911170363908195015472414
 90= MIN VALUE = .999903108958799206471650732
 00=
 10=
 20=
 30=
 40=
 50=

60= TOUCHDOWN TO STOP
 70=
 80= MEAN TIME = 22.73
 90= STD. DEV. OF TIME = 0.
 00= MTBF = 13.6513713169459041354601865
 10= VARIATION = .1
 20= MEAN OF RELIABILITY = .999559214975485416468673836
 30= STD. DEV. OF RELIABILITY = .00000703163521841927942017239651
 40= MAX VALUE = .999578627073324155514074532
 50= MIN VALUE = .999537205580061432842527536
 60=
 70=
 80=
 90=
 00=

10= TOTAL RELIABILITY FROM APPROACH ARM TO STOP
 20=
 30= MEAN OF RELIABILITY = .99735083134723300172160595
 40= STD. DEV. OF RELIABILITY = .0000529797275820342162593578148
 50= MAX VALUE = .997457995736044521448362183
 60= MIN VALUE = .997229468470170683609161966
 70=
 80=
 90=
 00=

TOTAL RELIABILITY FOR COMPLETE MODEL

MEAN OF RELIABILITY = .992772425189371338779398818
 STD. DEV. OF RELIABILITY = .000162815844103776118325823798
 MAX VALUE = .993133361233540515222272374
 MIN VALUE = .992369572498193563281349944

SAFETY ANALYSIS

SYSTEM OPERATIONAL

PROBABILITY = .99939626327385432517445182
 STD. DEV. = .00000925290109949718077583080114
 MAX VALUE = .99942201303936275656514166
 MIN VALUE = .999366582092290915725770575

NON-CRITICAL FAILURE AND SUCCESSFUL R/GA

PROBABILITY = .000177753112001081511176853692
 STD. DEV. = .00000264800917791326728114019434
 MAX VALUE = .000186513530757958605394095254
 MIN VALUE = .000170187211564584883634553284

CRITICAL FAILURE TO SINGLE CHANNEL AND SUCCESSFUL R/GA

PROBABILITY = .00000419939233969040624611823134
 STD. DEV. = 1.80905143011333468002444311E-7
 MAX VALUE = .00000464496239594228114812916913
 MIN VALUE = .00000380948563436721987902515053

WHEEL SPIN-UP NOT DETECTED AND SUCCESSFUL R/GA

PROBABILITY = 5.03961800201092110482868413E-7
 STD. DEV. = 2.05756935132994103914297086E-8
 MAX VALUE = 5.57244253576658497525202552E-7
 MIN VALUE = 4.57638054399055093886714853E-7

NON-CRITICAL FAILURE DURING ROLLOUT

PROBABILITY = .000403546221526911008641642224
 STD. DEV. = .00000716903292552822001849110721
 MAX VALUE = .000426435549105544001375568022
 MIN VALUE = .000384473920938437528583362294

BACK-UP ROLLOUT MODE

Run # 3

Only Varied Segment Time Intervals

50=
60=
70=
80=
90=
100=
110=
120=
130=
140=
150=
160=
170=
180=
190=
200=
210=
220=
230=
240=
250=
260=
270=
280=
290=
300=
310=
320=
330=
340=
350=
360=
370=
380=
390=
400=
410=
420=
430=
440=
450=
460=
470=
480=
490=
500=
510=
520=
530=
540=
550=
560=
570=
580=
590=
600=
610=
620=
630=
640=
650=
660=
670=
680=
690=
700=
710=
720=
730=
740=
750=
760=
770=
780=
790=
800=
810=
820=
830=
840=
850=
860=
870=
880=
890=
900=
910=
920=
930=
940=
950=
960=
970=
980=
990=
1000=

RELIABILITY ANALYSIS

XPER = 0%
STD DEV. = 1.24

LOC CAPTURE TO ARM G/S

MEAN TIME = 210.
STD. DEV. OF TIME = 0.
MTBF = 16. 6386060079658489090664236
VARIATION = 0.
MEAN OF RELIABILITY = .996496514754175684456161065
STD. DEV. OF RELIABILITY = 0.
MAX VALUE = .996496514754175684456161066
MIN VALUE = .996496514754175684456161066

ARM G/S TO G/S CAPTURE

MEAN TIME = 30.
STD. DEV. OF TIME = 0.
MTBF = 16. 1019733511643811954869908
VARIATION = 0.
MEAN OF RELIABILITY = .999482065914006726408576944
STD. DEV. OF RELIABILITY = 0.
MAX VALUE = .999482065914006726408576945
MIN VALUE = .999482065914006726408576945

G/S CAPTURE TO APPROACH ARM

MEAN TIME = 30.
STD. DEV. OF TIME = 0.
MTBF = 15. 1624983074491654628633497
VARIATION = 0.
MEAN OF RELIABILITY = .999450016346329925745560099
STD. DEV. OF RELIABILITY = 0.
MAX VALUE = .9994500163463299257455601
MIN VALUE = .9994500163463299257455601

APPROACH ARM TO LAND ARM (100 FEET)

MEAN TIME = 81.54
STD. DEV. OF TIME = 1.95
MTBF = 11. 8318104032751170011556572
VARIATION = 0.
MEAN OF RELIABILITY = .998081885295249754394353438
STD. DEV. OF RELIABILITY = .0000279871249352988267141266639
MAX VALUE = .99817594519277718624134583
MIN VALUE = .997981323503313227547760547

LAND ARM (100 FT) TO FLARE ENGAGE (45 FT)

116

```

100=
101= PROBABILITY = .00000439729958162000474237389579
102= STD. DEV. = 6.31533813055210279401519803E-8
103= MAX VALUE = .00000464575564711776738483397374
104= MIN VALUE = .00000421844868726770889822829112
105=
106=
107= CRITICAL FAILURE TO SINGLE CHANNEL DURING ROLLOUT
108=
109= PROBABILITY = .0000132767476205928650511442638
110= STD. DEV. = 1.93839105169427672657102022E-7
111= MAX VALUE = .000014050036487464504463925894
112= MIN VALUE = .0000127347171269591698836062473
113=
114=
115= LOCALIZER FAILURE AND SUCCESSFUL R/GA
116=
117= PROBABILITY = 3.57442263918145417953250397E-8
118= STD. DEV. = 2.572688373422436591063380895E-9
119= MAX VALUE = 4.41774333000440023092185144E-8
120= MIN VALUE = 2.75088768349723598428603043E-8
121=
122=
123= SAFETY HAZARD
124=
125= PROBABILITY = 4.91512126602665516230429207E-11
126= STD. DEV. = 1.34156943516885299743324883E-12
127= MAX VALUE = 5.42418621266350633231748237E-11
128= MIN VALUE = 4.53918120697171214739004621E-11
129=
130=
131= ATTENUATED SAFETY HAZARD (NO PILOT VISIBILITY)
132=
133= PROBABILITY = 2.27621172337218714837683456E-11
134= STD. DEV. = 8.51322188733347504377530892E-13
135= MAX VALUE = 2.58424576706730372241530572E-11
136= MIN VALUE = 2.03676237465327778644253642E-11
137=
138=
139= ATTENUATED SAFETY HAZARD (LIMITED PILOT VISIBILITY)
140=
141= PROBABILITY = 8.67119539094073542047424197E-12
142= STD. DEV. = 4.61128820185638625907389339E-13
143= MAX VALUE = 1.02761497722397776479637723E-11
144= MIN VALUE = 7.42291266014296861480799325E-12
145=**EOR
146=1 CSE NOS/EE L414H ECS CYBR CMR3 05/30/77
147=14 13 10 PATIAGL FROM /IA
148=14 13 10 IF 00000256 WORDS - FILE INPUT , DC 00
149=14 13 10 PAT(T25, I050, CM100000, STCSE) D760276, BUS
150=14 13 10 SINGER, UD, 229-4238
151=14 13 14 ATTACH(LGO, AWL33BIN, CY=1)
152=1 5 17 33 MAP(PART)
153=15 17 35 LGO
154=15 18 18 STOP
155=15 18 18 2.423 CP SECONDS EXECUTION TIME
156=15 18 18 OF 00001664 WORDS - FILE OUTPUT , DC 40
157=15 18 19 MS 3584 WORDS ( 3584 MAX USED)
158=15 18 19 SCM 100000 WORDS MAXIMUM

```

Run # 4

Varied Both Equipment MTBF
and Segment Time Intervals

70=
 80=
 90=
 00=
 10=FOR
 20=TABLES
 30=ONL = 100,
 40=XPER = .1E+00,
 50=QANS = 1,
 60=0=END

AWLS3

XPER = 10%

STD.DEV. = vary

RELIABILITY ANALYSIS

LOC CAPTURE TO ARM G/S

20= MEAN TIME = 210.
 30= STD. DEV. OF TIME = 0.
 40= MTEF = 15. 5627623406178475965176369
 50= VARIATION = .1
 60= MEAN OF RELIABILITY = .996478421452194926970490519
 70= STD. DEV. OF RELIABILITY = .0000610778416965016436464592313
 80= MAX VALUE = .996674327260553816292498876
 90= MIN VALUE = .996255143360481563230251245

ARM G/S TO G/S CAPTURE

20= MEAN TIME = 30.
 30= STD. DEV. OF TIME = 0.
 40= MTEF = 15. 11222965657696955989186
 50= VARIATION = .1
 60= MEAN OF RELIABILITY = .999479498920957791552271811
 70= STD. DEV. OF RELIABILITY = .00000884243447765012650059173113
 80= MAX VALUE = .99950896882347207308557752
 90= MIN VALUE = .999448205083568751601537483

G/S CAPTURE TO APPROACH ARM

20= MEAN TIME = 30.
 30= STD. DEV. OF TIME = 0.
 40= MTEF = 14. 3440549608996800678151481
 50= VARIATION = .1
 60= MEAN OF RELIABILITY = .999447438901833410938267291
 70= STD. DEV. OF RELIABILITY = .00000875223069871343394466683671
 80= MAX VALUE = .999477421474920771691780689
 90= MIN VALUE = .999418690806811322048072891

APPROACH ARM TO LAND ARM (100 FEET)


```

20=
30= PROBABILITY = .000402483020627832899556671273
40= STD. DEV. = .00000919715014006288352692713866
50= MAX VALUE = .000436081240626628488008504805
60= MIN VALUE = .00037329263106370459427006855
70=
80=
90=
100= BACK-UP ROLLOUT MODE
110=
120= PROBABILITY = .00000439341746497146130365324996
130= STD. DEV. = 1.64624720861172233085458211E-7
140= MAX VALUE = .00000485517218210574658547033374
150= MIN VALUE = .00000397095126335711496475678089
160=
170=
180=
190= CRITICAL FAILURE TO SINGLE CHANNEL DURING ROLLOUT
200=
210= PROBABILITY = .0000133791301122276651866038988
220= STD. DEV. = 5.81052656756328295260765894E-7
230= MAX VALUE = .0000149495829991964320177624132
240= MIN VALUE = .0000119581376079850369757930882
250=
260=
270= LOCALIZER FAILURE AND SUCCESSFUL R/GA
280=
290= PROBABILITY = 3.57822721877802641257182591E-8
300= STD. DEV. = 2.66562126085419307273057795E-9
310= MAX VALUE = 4.66870715206867296390803925E-8
320= MIN VALUE = 2.67868862607366090325299207E-8
330=
340=
350= SAFETY HAZARD
360=
370= PROBABILITY = 5.00194336140559899470724014E-11
380= STD. DEV. = 3.85365314247369441540430333E-12
390= MAX VALUE = 6.05868291251784786362268266E-11
400= MIN VALUE = 4.00602364661616738471813125E-11
410=
420=
430= ATTENUATED SAFETY HAZARD (NO PILOT VISIBILITY)
440=
450= PROBABILITY = 2.31409224690063050580642635E-11
460= STD. DEV. = 1.64660746537452689360356998E-12
470= MAX VALUE = 2.80542492381032662302985417E-11
480= MIN VALUE = 1.83888858280581404789470322E-11
490=
500=
510= ATTENUATED SAFETY HAZARD (LIMITED PILOT VISIBILITY)
520=
530= PROBABILITY = 8.78635935899647011918071715E-12
540= STD. DEV. = 5.88578616514211944847734868E-13
550= MAX VALUE = 1.07336831659075259519243547E-11
560= MIN VALUE = 6.83901195206099879749643317E-12
570=
580=
590=
600=
610=
620=
630=
640=
650=
660=
670=
680=
690=
700=
710=
720=
730=
740=
750=
760=
770=
780=
790=
800=
810=
820=
830=
840=
850=
860=
870=
880=
890=
900=
910=
920=
930=
940=
950=
960=
970=
980=
990=
1000=

```

```

10=4E0R
110=1 CSB NOS/BE L414H ECS CYBR CMR3 R.D 14.18
120= 16.02.17. PATIAJO FROM /IA
130= 16.02.17. IF 00000256 WORDS - FILE INPUT , DC 00
140= 16.02.17. PATIAJO NOS/BE L414H ECS CYBR CMR3 R.D 14.18

```

Program Listing for Reliability/Safety Analysis
(Category III Adapter System Configuration)

AWLS2

7-20-77

AWLS2

XPER = 0%

σ - very

TACH. DECK

18

/

CYCLE NO. = 001

DECK, S

A

00=PAT(T25, 1050, CM100000, STC88) D760276, BUSSINGER, UD, 229-4238

10=ATTACH(L30, AWLS2BIN, CY=1)

20=MAP(PART)

30=LGO.

40=*EOR

50= \$AWLS NL=100, XPER=0., ANS=1\$

TCH, DECK, INPUT, HERE

} LISTING OF
DECK

XPER=0%.

LES

CAL FILES--

LS2	CARDS	*DECK	*INPUT	*OUTPUT
	AWLS3	*A3	*LGO	DUM1

NOTE INPUT FILES--

TIAFD

NOTE OUTPUT FILES--

TIAEI

LISTING OF AWLS2

XPER=0%

σ = vary

```

10= PROGRAM AWLS2 (INPUT,OUTPUT)
10= DOUBLE PRECISION NUMAX(8), NUMIN(8), MAXRTA, MAXRTT, MINRTA, MIN
10= DOUBLE PRECISION DIFRTM(10), DIF(8), SUMDIF(8), RTADIF, RTTDIF,
10= DOUBLE PRECISION RTTSD, DEV(8), DEVRTA, DEVRTT, EL1A, EL1B, EG1, E
10= DOUBLE PRECISION EXPL1, EXPL2, EL1, EL2, EL3, EL4, EL5, EL6, EL7, MT
10= DOUBLE PRECISION TIME(9), RT(8, 100), FMEAN(11)
10= DOUBLE PRECISION PDEV(11), PMAX(11), PMIN(11), SRT(8), MEAN(8)
10= DOUBLE PRECISION RTT(100), RTAA(100), XMTBF(8), SRTT, SRTAA, VIN
10= DOUBLE PRECISION TOP, BOTTOM, VTERM, ABSRN, SUM20A, SUM20B, SUM20
10= DOUBLE PRECISION SUM21, SUM22, SUM23, SUM24, SUM25, SUM26, SUM27,
10= DOUBLE PRECISION SUM28, RTAAMN, RTTMN, RLOC(8), RGS(8), RGRND(8)
10= DOUBLE PRECISION RT7N
10= REAL XMEAN(9), STDDEV(9), INS, MCC, NAVREC, NAVSEL, EQUIP(55)
10= INTEGER ANS
10= COMMON MTBF, EL1, EL2, EL3, EL4, EL5, EL6, EL7, TIME, SUM26, SUM27, SU
10= COMMON FMEAN, PDEV, PMAX, PMIN, N, NLOOP, RT6N, RT7N
10= NAMELIST/AWLS/NL, XPER, ANS
10= DATA NL, XPER, ANS/100, 0. 1/
10= NLOOP=NL
10= CALL RANSET(. 05)
10= READ AWLS
10= PRINT AWLS
10= DO 60 I=1, 8
10= SRT(I)=0.
10= 60 SUMDIF(I)=0.
10= SRTAA=0.
10= SRTT=0.
10= RTASD=0.
10= RTTSD=0.
10= ADI=103. 778
10= EQUIP(1)=ADI
10= CONTP=631. 305
10= EQUIP(2)=CONTP
10= COUP=165. 180
10= EQUIP(3)=COUP
10= AISERV=2732. 240

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30=      ELSERV=7936. 508
70=      EQUIP(5)=ELSERV
00=      RUSERV=425. 894
10=      EQUIP(6)=RUSERV
20=      AICOMP=360. 620
30=      EQUIP(7)=AICOMP
40=      ATC=716. 332
50=      EQUIP(8)=ATC
60=      CADC=41. 571
70=      EQUIP(9)=CADC
80=      CATIII=112. 423
90=      EQUIP(10)=CATIII
00=      ELCOMP=274. 650
10=      EQUIP(11)=ELCOMP
20=      FDCOMP=983. 284
30=      EQUIP(12)=FDCOMP
40=      FLCOMP=641. 849
50=      EQUIP(13)=FLCOMP
60=      GSREC=499. 251
70=      EQUIP(14)=GSREC
80=      HSI=343. 643
90=      EQUIP(15)=HSI
00=      INS=1033. 058
10=      EQUIP(16)=INS
20=      MCC=626. 566
30=      EQUIP(17)=MCC
40=      NAVREC=1474. 926
50=      EQUIP(18)=NAVREC
60=      NAVSEL=730. 994
70=      EQUIP(19)=NAVSEL
80=      PAGYRO=381. 534
90=      EQUIP(20)=PAGYRO
00=      PRGYRO=1538. 462
10=      EQUIP(21)=PRGYRO
20=      RADIND=493. 097
30=      EQUIP(22)=RADIND
40=      RADRT=234. 632
50=      EQUIP(23)=RADRT
60=      RRGYRO=1538. 462
70=      EQUIP(24)=RRGYRO
80=      RGACOM=341. 647
90=      EQUIP(25)=RGACOM
00=      RDR=183. 9
10=      EQUIP(26)=RDR
20=      TFLC=407. 830
30=      EQUIP(27)=TFLC
40=      VGYRO=381. 534
50=      EQUIP(28)=VGYRO
60=      YDCOMP=304. 044
70=      EQUIP(29)=YDCOMP
80=      EQUIP(30)=1072. 961
90=      EQUIP(31)=552. 792
00=      EQUIP(32)=2066. 116
10=      EQUIP(33)=127. 405
20=      EQUIP(34)=1474. 926
30=      EQUIP(35)=2617. 801
40=      EQUIP(36)=183. 9
50=      EQUIP(37)=10000.
60=      EQUIP(38)=10000.
70=      EQUIP(39)=10000000.
80=      EQUIP(40)=142857. 143
90=      EQUIP(41)=10000000.
00=      EQUIP(42)=100000.
10=      EQUIP(43)=500000

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0=      EQUIP(46)=10000000.
0=      EQUIP(47)=10000000.
0=      EQUIP(48)=10000000.
0=      EQUIP(49)=1888888.667
0=      EQUIP(50)=11671.335
0=      EQUIP(51)=49504.931
0=      EQUIP(52)=46685.341
0=      EQUIP(53)=12378.238
0=      EQUIP(54)=10000.
0=      EQUIP(55)=1250000.
0=      XMEAN(1)=210.
0=      XMEAN(2)=30.
0=      XMEAN(3)=30.
0=      XMEAN(4)=31.54
0=      XMEAN(5)=5.35
0=      XMEAN(6)=3.07
0=      XMEAN(7)=4.02
0=      XMEAN(8)=22.73
0=      XMEAN(9)=3.
0=      STDDEV(1)=0.
0=      STDDEV(2)=0.
0=      STDDEV(3)=0.
0=      STDDEV(4)=1.95
0=      STDDEV(5)=.42
0=      STDDEV(6)=.33
0=      STDDEV(7)=.33
0=      STDDEV(8)=.53
0=      STDDEV(9)=0.
0=      DO 40 N=1,NLOOP
0=      DO 10 I=1,55
0=      RN=RANF(DUMMY)
0=      MTEF(I)=((1.-XPER)*(EQUIP(I)))+(RN)*(2.*XPER)*(EQUIP(I)))
0= 10 CONTINUE
0=      DO 30 M=1,9
0=      RN=RANF(DUMMY)
0=      VINSID=(-2.)*ALOG(0.5)*(1.-ABS(1.-(2.*RN)))
0=      V=DSORT(VINSID)
0=      TOP=2.515517+(0.802853*V)+(0.010328*V*V)
0=      BOTTOM=1.+(1.432788*V)+(0.189269*V*V)+(0.001308*V*V*V)
0=      VTERM=V-(TOP/BOTTOM)
0=      ABSRN=(RN-0.5)/(ABS(RN-0.5))
0= 10 TIME(M)=(XMEAN(M)/3600.)+(ABSRN*(STDDEV(M)/3600.)*VTERM)
0=      SUM20A=(1./MTEF(1))+(1./MTEF(2))+(1./MTEF(3))+(1./MTEF(4))+
0=      1F(5))+(1./MTEF(6))
0=      SUM20B=(1./MTEF(7))+(1./MTEF(9))+(1./MTEF(10))+(1./MTEF(11)
0=      1F(12))+(1./MTEF(15))
0=      SUM20C=(1./MTEF(16))+(1./MTEF(18))+(1./MTEF(19))+(1./MTEF(2
0=      1F(24))+(1./MTEF(29))
0=      RT(1,N)=DEXP(-1.*(SUM20A+SUM20B+SUM20C)*TIME(1))
0=      XMTEF(1)=1./(SUM20A+SUM20B+SUM20C)
0=      SUM21=SUM20A+SUM20B+SUM20C+(1./MTEF(14))
0=      RT(2,N)=DEXP(-1.*SUM21*TIME(2))
0=      XMTEF(2)=1./SUM21
0=      SUM22=SUM21+(1./MTEF(8))+(1./MTEF(27))
0=      RT(3,N)=DEXP(-1.*SUM22*TIME(3))
0=      XMTEF(3)=1./SUM22
0=      SUM23=SUM22+(1./MTEF(17))+(1./MTEF(20))+(1./MTEF(22))+(1./M
0=      1F(26))+(1./MTEF(28))
0=      RT(4,N)=DEXP(-1.*SUM23*TIME(4))

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0=      AMTBF(13)=1./SUM24
0=      SUM25=SUM24
0=      SUM26=SUM25-(1./MTBF(14))
0=      RT(6,N)=DEXP(-1.*SUM26*TIME(6))
0=      XMTEF(6)=1./SUM26
0=      RT6N=RT(6,N)
0=      SUM27=SUM26
0=      RT(7,N)=DEXP(-1.*SUM27*TIME(7))
0=      XMTEF(7)=1./SUM27
0=      RT7N=RT(7,N)
0=      SUM28A=SUM27-(1./MTBF(3))-(1./MTBF(5))-(1./MTBF(11))-(1./MT
30=      SUM28=SUM28A-(1./MTBF(17))-(1./MTBF(22))-(1./MTBF(23))-(1./
80=      1)-(1./MTBF(12))
0=      RT(8,N)=DEXP(-1.*SUM28*TIME(8))
0=      XMTEF(8)=1./SUM28
0=      EL1A=(4./MTBF(41))+(4./MTBF(39))+(5./MTBF(45))+(5./MTBF(38)
/M
0=      1TBF(44))+(2./MTBF(53))+(2./MTBF(51))
0=      EL1B=(2./MTBF(49))+(6./MTBF(42))+(2./MTBF(50))+(2./MTBF(52)
/M
0=      1TBF(48))+(4./MTBF(47))+(1./MTBF(43))
0=      EL1=EL1A+EL1B
0=      EL2=(1./MTBF(45))+(1./MTBF(38))
0=      EL3=1./MTBF(53)
0=      EL4=1./MTBF(52)
0=      EL5=(1./MTBF(51))+(1./MTBF(49))
0=      EL6=(1./MTBF(45))+(1./MTBF(38))
0=      EL7=1./MTBF(50)
0=      EG1=(1./MTBF(53))+(8./MTBF(45))+(1./MTBF(46))+(1./MTBF(39))
/M
0=      1BF(54))+(4./MTBF(42))+(1./MTBF(47))+(1./MTBF(48))
0=      EG2=(1./MTBF(45))+(1./MTBF(54))
0=      DO 32 K=1,8
0=      EXPL1=(DEXP(-1.*TIME(K)*EL1))*((3.-(2.*(DEXP(-1.*TIME(K)*EL
1**
70=      12.))*(3.-(2.*(DEXP(-1.*TIME(K)*EL3))))*(3.-(2.*(DEXP(-1.*TIM
*EL
0=      14))))
0=      EXPL2=(3.-(2.*(DEXP(-1.*TIME(K)*EL5))))*(2.-DEXP(-1.*TIME(K
5))
0=      1*(3.-(2.*(DEXP(-1.*TIME(K)*EL7))))
0=      RLOC(K)=EXPL1*EXPL2
0=      RGS(K)=DEXP(-1.*TIME(K)*EG1))*((3.-(2.*(DEXP(-1.*TIME(K)*EG2
**4
0=      1.))
0=      RGRND(K)=RLOC(K)*RGS(K)
0=      32 RT(K,N)=RT(K,N)*RGRND(K)
0=      RTAA(N)=RT(4,N)*RT(5,N)*RT(6,N)*RT(7,N)*RT(8,N)
0=      RTT(N)=RT(1,N)*RT(2,N)*RT(3,N)*RTAA(N)
0=      IF(ANS.EQ.0)GOTO 210
0=      CALL SAFETY
0=      210 DO 70 I=1,8
0=      70 SRT(I)=RT(I,N)-SRT(I)
0=      SRTAA=RTAA(N)-SRTAA
0=      SRTT=RTT(N)-SRTT
0=      IF(ANS.EQ.1)GOTO 100
0=      DO 80 I=1,8
0=      80 NUMAX(I)=DMAX1(RT(I,N),NUMAX(I))
0=      MAXSTA=DMAX1(RTAA(N),MAXSTA)
0=      MAXSTT=DMAX1(RTT(N),MAXSTT)
0=      GOTO 110
0=      100 DO 90 I=1,8

```

129

```

0= PRINT*, " "
10= PRINT*, " TOTAL RELIABILITY FROM APPROACH ARM TO

10= PRINT*, " "
20= PRINT*, " MEAN OF RELIABILITY = ", RTAMN
30= PRINT*, " STD. DEV. OF RELIABILITY = ", DEVRTA
40= PRINT*, " MAX VALUE = ", MAXRTA
50= PRINT*, " MIN VALUE = ", MINRTA
60= PRINT*, " "
70= PRINT*, " "
80= PRINT*, " "
90= PRINT*, " "
100= PRINT*, " "
110= PRINT*, " TOTAL RELIABILITY FOR COMPLETE MODEL"
120= PRINT*, " "
130= PRINT*, " MEAN OF RELIABILITY = ", RTTMN
140= PRINT*, " STD. DEV. OF RELIABILITY = ", DEVRTT
150= PRINT*, " MAX VALUE = ", MAXRTT
160= PRINT*, " MIN VALUE = ", MINRTT
170= IF(ANS. EQ. 0)GOTO 220
180= PRINT*, " "
190= PRINT*, " "
200= PRINT*, " "
210= PRINT*, " "
220= PRINT*, " SAFETY ANALYSIS"
230= DO 195 I=1,11
240= PRINT*, " "
250= PRINT*, " "
260= PRINT*, " "
270= IF(I. EQ. 1)PRINT*, " SYSTEM OPERATIONAL"
280= IF(I. EQ. 2)PRINT*, " NON-CRITICAL FAILURE AND SUCCESSFUL R/GA"
290= IF(I. EQ. 3)PRINT*, " CRITICAL FAILURE TO SINGLE CHANNEL AND
300= 18FUL R/GA"
310= IF(I. EQ. 4)PRINT*, " WHEEL SPIN-UP NOT DETECTED AND SUCCESSFUL R/GA"
320= IF(I. EQ. 5)PRINT*, " NON-CRITICAL FAILURE DURING ROLLOUT
330= IF(I. EQ. 6)PRINT*, " BACK-UP ROLLOUT MODE"
340= IF(I. EQ. 7)PRINT*, " CRITICAL FAILURE TO SINGLE CHANNEL D
350= 10LLOUT"
360= IF(I. EQ. 8)PRINT*, " LOCALIZER FAILURE AND SUCCESSFUL R/GA
370= IF(I. EQ. 9)PRINT*, " SAFETY HAZARD"
380= IF(I. EQ. 10)PRINT*, " ATTENUATED SAFETY HAZARD (NO PILOT VI
390= 11Y)"
400= IF(I. EQ. 11)PRINT*, " ATTENUATED SAFETY HAZARD (LIMITED PIL
410= 18I
420= 18I
430= PRINT*, " "
440= PRINT*, " PROBABILITY = ", PMEAN(I)
450= PRINT*, " STD. DEV. = ", PDEV(I)
460= PRINT*, " MAX VALUE = ", PMAX(I)
470= PRINT*, " MIN VALUE = ", PMIN(I)
480= 195 CONTINUE
490= 200 STOP
500= END
510= SUBROUTINE SAFETY
520= DOUBLE PRECISION P40, RT6N, RT7N, PFAIL1, PFAIL2, PFAIL3, DEL(11)
530=
540= DOUBLE PRECISION EL18, RTEF(53), EL1, EL2, EL3, EL4, EL5, EL6, EL7,

```

```

      DOUBLE PRECISION SUM26, SUM27, SUM28, TIME, TIME(1), TIME(2)
      DOUBLE PRECISION PMIN(11), RGA(5), FED(3), PATH(46, 100), G(3),
      DOUBLE PRECISION EXPL2, LOCR(3), P(11, 100), AT(10), P1(10), PF1(
      DOUBLE PRECISION DFF(10), AT2(3), P2(3), PF2(3), SUMP(11), SUMDI
      DOUBLE PRECISION DIFF(11), RGA, FEDF, DTFP, DTT1, DTT2, DTT3, TDWS
      DOUBLE PRECISION TD2, TD3, TD4, TD5, PINS25, PINS1, PINS2, P27, P3H
      DOUBLE PRECISION P28A1, DFF2, DFF3, P28A2, P41(10), PF41(10)
      DOUBLE PRECISION DFF41(10), P41A1, P45A1, P41A(3), PF41A(3), DFF
      DOUBLE PRECISION DFF413, P41A2, P45A2, A1P40(10), A1CAT3(10)
      DOUBLE PRECISION A2P40(3), A2CAT3(3)
      COMMON MTEF, EL1, EL2, EL3, EL4, EL5, EL6, EL7, TIME, SUM26, SUM27, SU
      COMMON PMEAN, PDEV, PMAX, PMIN, N, NLOOP, RT6N, RT7N
      RGA=DEXP(-1. *(1. /MTEF(30))*TIME(9))
      RGA(1)=1. -(2. *RGA)+(RGA**2.)
      RGA(2)=(2. *RGA)-(2. *RGA*RGA)
      RGA(3)=RGA**2.
      RGA(4)=1. -RGA
      RGA(5)=RGA
      FEDF=DEXP(-1. *(1. /MTEF(30))*TIME(6))
      FED(1)=1. -DEXP(-1. *(SUM26-(2. *(1. /MTEF(30))))*TIME(6))
      FED(2)=2. *FEDF-(2. *(FEDF**2.))
      FED(3)=1. -(2. *FEDF)+(FEDF**2.)
      G(1)=TIME(6)
      G(2)=TIME(7)+(1. /3600.)
      G(3)=TIME(8)-(1. /3600.)
      DO 901 I=1, 3
      EXPL1=(DEXP(-1. *G(I)*EL1))*((3. -(2. *(DEXP(-1. *G(I)*EL2))))*
      1. -(2. *(DEXP(-1. *G(I)*EL3))))*(3. -(2. *(DEXP(-1. *G(I)*EL4))))
      EXPL3=(3. -(2. *(DEXP(-1. *G(I)*EL5))))*(2. -DEXP(-1. *G(I)*EL6)
      12 *(DEXP(-1. *G(I)*EL7))))
      901 LOCR(I)=EXPL1*EXPL2
      PATH(1, N)=FED(1)*RGA(1)
      PATH(2, N)=FED(1)*RGA(2)
      PATH(3, N)=FED(1)*RGA(3)
      PATH(4, N)=FED(2)*RGA(4)
      PATH(5, N)=FED(2)*RGA(5)
      PATH(6, N)=FED(3)
      PATH(7, N)=RT6N
      PFAIL1=1. -LOCR(1)
      PATH(30, N)=PATH(1, N)*PFAIL1
      PATH(31, N)=PATH(2, N)*PFAIL1
      PATH(32, N)=PATH(3, N)*PFAIL1
      PATH(33, N)=PATH(4, N)*PFAIL1
      PATH(34, N)=PATH(5, N)*PFAIL1
      PATH(35, N)=PATH(6, N)*PFAIL1
      PATH(36, N)=RT6N*RGA(1)*PFAIL1
      PATH(37, N)=RT6N*RGA(2)*PFAIL1
      PATH(38, N)=RT6N*RGA(3)*PFAIL1
      DTFP=DEXP(-1. *(1. /MTEF(30))*TIME(7))
      DTT1=1. -DEXP(-1. *(SUM27-(2. *(1. /MTEF(30))))*TIME(7))
      DTT2=(2. *DTFP)-(2. *(DTFP**2.))
      DTT3=1. -(2. *DTFP)+(DTFP**2.)
      PATH(8, N)=DTT1*RGA(1)
      PATH(9, N)=DTT1*RGA(2)

```

```

10= PATH(12,N)=DTT2*RRGA(5)
20= PATH(13,N)=DTT3
30= PATH(14,N)=RT7N
40= TDWSP=DEXP(-1.*(1./MTBF(30))+(1./3600.))
50= TD1=1.-DEXP(-1.*(SUM28-(2./MTBF(30))-(1./MTBF(31)))*(1./3600.))
60= TD2=(2.*TDWSP)-(2.*(TDWSP**2.))
70= TD3=1.-(1.*TDWSP)+(TDWSP**2.)
80= TD4=1.-DEXP(-1.*(1./MTBF(31))*(1./3600.))
90= TD5=DEXP(-1.*SUM28*(1./3600.))
100= PATH(15,N)=TD1*RRGA(1)
110= PATH(16,N)=TD1*RRGA(2)
120= PATH(17,N)=TD1*RRGA(3)
130= PATH(18,N)=TD2*RRGA(4)
140= PATH(19,N)=TD2*RRGA(5)
150= PATH(20,N)=TD3
160= PATH(21,N)=TD4*RRGA(1)
170= PATH(22,N)=TD4*RRGA(2)
180= PATH(23,N)=TD4*RRGA(3)
190= PATH(24,N)=TD5
200= PINS25=DEXP(-1.*(1./MTBF(32))*(TIME(8)-(1./3600.)))
210= PINS1=(2.*PINS25)-(2.*(PINS25**2.))
220= PINS2=1.-(2.*PINS25)+(PINS25**2.)
230= PATH(25,N)=1.-DEXP(-1.*(SUM28-(1./MTBF(33)))*(TIME(8)-(1./3600.)))
240= 1=PINS1+PINS2
250= PATH(26,N)=1.-DEXP(-1.*(1./MTBF(34))*(TIME(8)-(1./3600.)))
260= P27=DEXP(-1.*(1./MTBF(35))*(TIME(8)-(1./3600.)))
270= PATH(27,N)=(2.*P27)-(2.*(P27**2.))
280= PATH(28,N)=(1.-(2.*P27)+(P27**2.))+(1.-DEXP(-1.*(1./MTBF(36)
290= TIME(8)-(1./3600.))))
300= PATH(29,N)=DEXP(-1.*SUM28*(TIME(8)-(1./3600.)))
310= DO 902 I=1,7
320= 902 PATH(I,N)=PATH(I,N)*LOCR(1)
330= FFAIL2=1.-LOCR(2)
340= PATH(39,N)=FFAIL2*(1.-DEXP(-1.*(SUM28+(1./MTBF(18))-(1./MTBF(19))
350= 1*(TIME(8)-(1./3600.))))
360= P40=DEXP(-1.*((1./MTBF(35))+(1./MTBF(32)))*(TIME(8)-(1./3600.)))
370= PATH(40,N)=((2.*P40)-(2.*(P40**2.)))*FFAIL2
380= PATH(41,N)=((1.-(2.*P40)+(P40**2.))+(1.-DEXP(-1.*(1./MTBF(2)
390= TIME(8)-(1./3600.)))))*FFAIL2
400= PATH(42,N)=FFAIL2*DEXP(-1.*SUM28*(TIME(8)-(1./3600.)))
410= FFAIL3=1.-LOCR(3)
420= PATH(43,N)=LOCR(2)*FFAIL3*PATH(39,N)
430= PATH(44,N)=LOCR(2)*FFAIL3*PATH(40,N)
440= PATH(45,N)=LOCR(2)*FFAIL3*PATH(41,N)
450= PATH(46,N)=LOCR(2)*FFAIL3*PATH(42,N)
460= DO 700 I=8,14
470= 700 PATH(I,N)=PATH(I,N)*PATH(7,N)
480= DO 710 I=15,24
490= 710 PATH(I,N)=PATH(I,N)*PATH(14,N)
500= DO 720 I=25,29
510= 720 PATH(I,N)=PATH(I,N)*PATH(24,N)*LOCR(2)*LOCR(3)
520= DO 368 I=30,46
530= 368 PATH(I,N)=PATH(I,N)*PATH(24,N)
540= 901 DO 1 I IS THE INDEX FOR 11 DIFFERENT PROBABILITIES TO BE CO
550= PATH(1,N)=PATH(29,N)
560= PATH(2,N)=PATH(1,N)+PATH(3,N)+PATH(5,N)+PATH(10,N)+PATH(16,N)+

```

10-0 ATTENUATION FUNCTION WITH NO PILOT VISIBILITY

```

10=      P45A1=P41A1
20=      P(10,N)=PSH+(P28A1*PATH(24,N)*LOCR(2)*LOCR(3))+(P41A1*PATH(
) *P
30=      1FAIL2)+(P45A1*PATH(24,N)*LOCR(2)*FFAIL3)

```

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Reliability/Safety Analysis Results
(Category III Adapter System Configuration)

Run # 1

Did Not Vary Either Equipment MTBF
Or Segment Time Intervals

0=OXPEN = 0.0,
0=OANS = 1,
0=OSEND

XPER = 0%.
STD DEV. = 0.

RELIABILITY ANALYSIS

LOC CAPTURE TO ARM G/S

MEAN TIME = 210.
STD. DEV. OF TIME = 0.
MTEF = 14.082884571868752568475971
VARIATION = 0.
MEAN OF RELIABILITY = .99586270431890024978121212
STD. DEV. OF RELIABILITY = 0.
MAX VALUE = .99586270431890024978121212
MIN VALUE = .99586270431890024978121212

ARM G/S TO G/S CAPTURE

MEAN TIME = 30.
STD. DEV. OF TIME = 0.
MTEF = 13.696532445454989180450208
VARIATION = 0.
MEAN OF RELIABILITY = .999391225525913424011936182
STD. DEV. OF RELIABILITY = 0.
MAX VALUE = .999391225525913424011936183
MIN VALUE = .999391225525913424011936183

G/S CAPTURE TO APPROACH ARM

MEAN TIME = 30.
STD. DEV. OF TIME = 0.
MTEF = 13.0108070314495826035939506
VARIATION = 0.
MEAN OF RELIABILITY = .99935917887114048152942464
STD. DEV. OF RELIABILITY = 0.
MAX VALUE = .999359178871140481529424641
MIN VALUE = .999359178871140481529424641

APPROACH ARM TO LAND ARM(100 FT)

MEAN TIME = 81.54
STD. DEV. OF TIME = 0.
MTEF = 10.4794439232769909088732488
VARIATION = 0.
MEAN OF RELIABILITY = .997839513269738218015763749
STD. DEV. OF RELIABILITY = 0.
MAX VALUE = 99783951326973821801576375
MIN VALUE = 99783951326973821801576375

160=
170=
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TOTAL RELIABILITY FOR COMPLETE MODEL

MEAN OF RELIABILITY = .991681473263029751090244356
STD. DEV. OF RELIABILITY = 1.014828852130214488977916585E-28
MAX VALUE = .991681473263029751090244356
MIN VALUE = .991681473263029751090244356

SAFETY ANALYSIS

SYSTEM OPERATIONAL

PROBABILITY = .999349986460438154086598134
STD. DEV. = 0.
MAX VALUE = .999349986460438154086598134
MIN VALUE = .999349986460438154086598134

NON-CRITICAL FAILURE AND SUCCESSFUL R/GA

PROBABILITY = .000202707182995918363858424733
STD. DEV. = 0.
MAX VALUE = .000202707182995918363858424733
MIN VALUE = .000202707182995918363858424733

CRITICAL FAILURE TO SINGLE CHANNEL AND SUCCESSFUL R/GA

PROBABILITY = .00000418854950139494397927334372
STD. DEV. = 0.
MAX VALUE = .00000418854950139494397927334372
MIN VALUE = .00000418854950139494397927334372

WHEEL SPIN-UP NOT DETECTED AND SUCCESSFUL R/GA

PROBABILITY = 5.02405502387034171250830551E-7
STD. DEV. = 0.
MAX VALUE = 5.02405502387034171250830552E-7
MIN VALUE = 5.02405502387034171250830552E-7

NON-CRITICAL FAILURE DURING ROLLOUT

PROBABILITY = .000400762796976050400164912103
STD. DEV. = 0.
MAX VALUE = .000400762796976050400164912103
MIN VALUE = .000400762796976050400164912103

BACK-UP ROLLOUT MODE

PROBABILITY = .00000415003889771518015386149116

Run # 2

Only Varied Equipment MTBF

RELIABILITY ANALYSIS

APLR = 10%
STD. DEV. = 0.

LOC CAPTURE TO ARM G/S

MEAN TIME = 210.
STD. DEV. OF TIME = 0.
MTBF = 14. 3130805087208055892715133
VARIATION = .1
MEAN OF RELIABILITY = .995849430288740829371283368
STD. DEV. OF RELIABILITY = .0000682563237373974679622163624
MAX VALUE = .996088271415122642305602199
MIN VALUE = .99564901791339317027304148

ARM G/S TO G/S CAPTURE

MEAN TIME = 30.
STD. DEV. OF TIME = 0.
MTBF = 13. 9025863582393155369438416
VARIATION = .1
MEAN OF RELIABILITY = .99938913247542234357842908
STD. DEV. OF RELIABILITY = .00000980996067547401205019762645
MAX VALUE = .999422083269531805154568542
MIN VALUE = .999360821650236346367987265

G/S CAPTURE TO APPROACH ARM

MEAN TIME = 30.
STD. DEV. OF TIME = 0.
MTBF = 13. 1378723805566057175275343
VARIATION = .1
MEAN OF RELIABILITY = .999356987874982809649503768
STD. DEV. OF RELIABILITY = .0000100272740412622819033177332
MAX VALUE = .999390963572005008481337438
MIN VALUE = .999327403321186251252656931

APPROACH ARM TO LAND ARM(100 FT)

MEAN TIME = 81. 54
STD. DEV. OF TIME = 0.
MTBF = 10. 5854626831567483740110429
VARIATION = .1
MEAN OF RELIABILITY = .997831697050747739605186316
STD. DEV. OF RELIABILITY = .0000284644184122234094970237077
MAX VALUE = .9979458190081003192878947
MIN VALUE = .997732326592867483055265282

```

50=          FLARE ENGAGE (45 FT) TO DECRAB (20 FT)
70=
90=      MEAN TIME =                      3.07
90=      STD. DEV. OF TIME =                0.
90=      MTEBF =                      10.6340885497214814401324082
10=      VARIATION =                      .1
20=      MEAN OF RELIABILITY = .999918674108690615315188418
30=      STD. DEV. OF RELIABILITY = .00000106474855476465422378935295
40=      MAX VALUE = .999923016706548769664860134
50=      MIN VALUE = .999914897562825376859151599

```

```

00=          DECRAB (20 FT) TO TOUCHDOWN
10=
20=      MEAN TIME =          4.02
30=      STD. DEV. OF TIME =          0.
40=      MTEF =          10.6340885497214814401324082
50=      VARIATION =          .1
60=      MEAN OF RELIABILITY =          .999893509456658361319027732
70=      STD. DEV. OF RELIABILITY =          .00000139419617264964518107770683
80=      MAX VALUE =          .999899195715410066510583088
90=      MIN VALUE =          .999888564399708329500467327

```

```

40=          TOUCHDOWN TO STOP
50=
60=      MEAN TIME =          22.73
70=      STD. DEV. OF TIME =          0.
80=      MTBF =          13.8668929527995460397317803
90=      VARIATION =          .1
00=      MEAN OF RELIABILITY =          .999535238635083240729716539
10=      STD. DEV. OF RELIABILITY =          .00000793911473797534805627658489
20=      MAX VALUE =          .999562831558650830379405866
30=      MIN VALUE =          .999511831544802549123805509

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990=
1000=

```

TOTAL RELIABILITY FOR COMPLETE MODEL

```

MEAN OF RELIABILITY = .99165346471296351148717394
STD. DEV. OF RELIABILITY = .00017636956911181057695794895
MAX VALUE = .992115784257176636348917964
MIN VALUE = .991277300139597408108815358

```

SAFETY ANALYSIS

SYSTEM OPERATIONAL

```

PROBABILITY = .999347701382240539676815498
STD. DEV. = .0000103110162845245590028552109
MAX VALUE = .999385326759930832718572314
MIN VALUE = .999317890423429535028725854

```

NON-CRITICAL FAILURE AND SUCCESSFUL R/GA

```

PROBABILITY = .000203439264361473688141151257
STD. DEV. = .000002774646505416838334376672
MAX VALUE = .000212552077092695143641978792
MIN VALUE = .000192316518771254618926371114

```

CRITICAL FAILURE TO SINGLE CHANNEL AND SUCCESSFUL R/GA

```

PROBABILITY = .00000417249046378535928156260161
STD. DEV. = 1.75591364776798690903841232E-7
MAX VALUE = .00000464427238289566964750581241
MIN VALUE = .00000382186125579357320331940099

```

WHEEL SPIN-UP NOT DETECTED AND SUCCESSFUL R/GA

```

PROBABILITY = 5.00078451161759469392786155E-7
STD. DEV. = 2.09280985791200759479396946E-8
MAX VALUE = 5.57300365441025925770756842E-7
MIN VALUE = 4.59406093661158145404652143E-7

```

NON-CRITICAL FAILURE DURING ROLLOUT

```

PROBABILITY = .000402013505658495173869543764
STD. DEV. = .00000738132382946555002231056903
MAX VALUE = .000425624468293846710541656914
MIN VALUE = .000370764347104610959890844041

```

BACK-UP ROLLOUT MODE

```

PROBABILITY = .00000416422553802501914384482039

```

```

10=
20=
30= BACKUP ROLLOUT MODE
40=
50= PROBABILITY = .00000416422553802501914384482039
60= STD. DEV. = 1.85632431147120856271725223E-7
70= MAX VALUE = .00000460116022041149312424612218
80= MIN VALUE = .00000378570603948040369958903803
90=
100=
110=
120=
130=
140=
150= CRITICAL FAILURE TO SINGLE CHANNEL DURING ROLLOUT
160=
170= PROBABILITY = .00000460547295156560874999725938
180= STD. DEV. = 1.9697710605039414928933721E-7
190= MAX VALUE = .00000511738679841756783630954031
200= MIN VALUE = .00000419208293122133648485963778
210=
220=
230=
240=
250= LOCALIZER FAILURE AND SUCCESSFUL R/GA
260=
270= PROBABILITY = 3.57987739299515164127006377E-8
280= STD. DEV. = 1.24684292237001470151697109E-9
290= MAX VALUE = 3.91685677460843732491387993E-8
300= MIN VALUE = 3.28109586101517251512295135E-8
310=
320=
330=
340= SAFETY HAZARD
350=
360= PROBABILITY = .0000326809552540182496786279886
370= STD. DEV. = .00000139367580029720519611705339
380= MAX VALUE = .0000363753552060146981102576679
390= MIN VALUE = .0000299017036974261999855955662
400=
410=
420=
430=
440= ATTENUATED SAFETY HAZARD (NO PILOT VISIBILITY)
450=
460= PROBABILITY = .0000199205013078987443603832449
470= STD. DEV. = 8.49490453130225767693419468E-7
480= MAX VALUE = .0000221723355630043173046616065
490= MIN VALUE = .0000182264783295722934446895812
500=
510=
520=
530= ATTENUATED SAFETY HAZARD (LIMITED PILOT VISIBILITY)
540=
550= PROBABILITY = .00000920431691777003052931543882
560= STD. DEV. = 3.92521735454409709075531399E-7
570= MAX VALUE = .000010244826645233485701356131
580= MIN VALUE = .00000842155564345798154140280838
590= *EOR
60=1 CSE NOS/BE L414H ECS CYBR CMR3 R. D 14. 18
61= 14. 23 54. PATIAPN FROM /IA
62= 14. 23 54. IF 00000256 WORDS - FILE INPUT , DC 00
63= 14. 23 54. PAT(T25, 1050, CM100000, STCSB) D760276, BUS
64= 14. 23 54. BINGER, UD, 229-4238
65= 14. 24 03. ATTACH(LGO, AWL82BIN, CY=1)
66= 14. 24 04. MAP(PART)
67= 14. 24 05. LGO.
68= 14. 25 58. STOP
69= 14. 25 58. 2.907 CP SECONDS EXECUTION TIME
70= 14. 26 58. 00001664 WORDS - FILE OUTPUT , DC 40
71= 14. 26 58. MS 3584 WORDS ( 3584 MAX USED)
72= 14. 27 58. 3584 WORDS MAXIMUM

```

1000053427

Run # 3

Only Varied Segment Time Intervals

RELIABILITY ANALYSIS

AWK52

KPER = 0%

STDDEV = 1.000

100 CAPTURE TO ARM G/S

MEAN TIME = 210.
 STD. DEV. OF TIME = 0.
 MTBF = 14.082884571868752568475971
 VARIATION = 0.
 MEAN OF RELIABILITY = .99586270431890024978121212
 STD. DEV. OF RELIABILITY = 0.
 MAX VALUE = .99586270431890024978121212
 MIN VALUE = .99586270431890024978121212

ARM G/S TO G/S CAPTURE

MEAN TIME = 30.
 STD. DEV. OF TIME = 0.
 MTBF = 13.696532443454989180450208
 VARIATION = 0.
 MEAN OF RELIABILITY = .999391225525913424011936182
 STD. DEV. OF RELIABILITY = 0.
 MAX VALUE = .999391225525913424011936183
 MIN VALUE = .999391225525913424011936183

G/S CAPTURE TO APPROACH ARM

MEAN TIME = 30.
 STD. DEV. OF TIME = 0.
 MTBF = 13.0108070314495826035939506
 VARIATION = 0.
 MEAN OF RELIABILITY = .99935917887114048152942464
 STD. DEV. OF RELIABILITY = 0.
 MAX VALUE = .999359178871140481529424641
 MIN VALUE = .999359178871140481529424641

APPROACH ARM TO LAND ARM(100 FT)

MEAN TIME = 81.54
 STD. DEV. OF TIME = 1.95
 MTBF = 10.4784439132769909088732488
 VARIATION = 0.
 MEAN OF RELIABILITY = .997843630974400061673492567
 STD. DEV. OF RELIABILITY = .0000290421711130484758741990335
 MAX VALUE = .997850010514573209398432981
 MIN VALUE = .99773237319613753354579477

0= MEAN TIME = 5.35
 10= STD. DEV. OF TIME = .42
 20= MTEF = 10.3110950708482540115214577
 30= VARIATION = 0.
 40= MEAN OF RELIABILITY = .999853379461330767816082509
 50= STD. DEV. OF RELIABILITY = .00000720975937230332924814289794
 60= MAX VALUE = .999881990465313856713826823
 70= MIN VALUE = .999831790470495383665966684

FLARE ENGAGE (45 FT) TO DECRAB (20 FT)

0= MEAN TIME = 3.07
 10= STD. DEV. OF TIME = .33
 20= MTEF = 10.5285424104665592109403648
 30= VARIATION = 0.
 40= MEAN OF RELIABILITY = .999920547546234108541327782
 50= STD. DEV. OF RELIABILITY = .00000556878357694219237069695121
 60= MAX VALUE = .999939401092994245929606076
 70= MIN VALUE = .999903745342622390335023668

DECRAB (20 FT) TO TOUCHDOWN

0= MEAN TIME = 4.02
 10= STD. DEV. OF TIME = .33
 20= MTEF = 10.5285424104665592109403648
 30= VARIATION = 0.
 40= MEAN OF RELIABILITY = .999893901374475084722544419
 50= STD. DEV. OF RELIABILITY = .0000049806099218790561463420569
 60= MAX VALUE = .999914216781577947322713019
 70= MIN VALUE = .99987903374153604068331222

TOUCHDOWN TO STOP

0= MEAN TIME = 22.73
 10= STD. DEV. OF TIME = .53
 20= MTEF = 13.6422080100111709982156181
 30= VARIATION = 0.
 40= MEAN OF RELIABILITY = .999536048708488275827033334
 50= STD. DEV. OF RELIABILITY = .00000623793966163493295342306487
 60= MAX VALUE = .999557493590003968665974326
 70= MIN VALUE = .999516230763294734828804829

TOTAL RELIABILITY FROM APPROACH ARM TO STOP

0= MEAN OF RELIABILITY = .997053606363009723637702349
 10= STD. DEV. OF RELIABILITY = .0000450853101825930683035689661
 20= MAX VALUE = .997162066234342112894566897
 30= MIN VALUE = .99693949172223848375290235

104 MEAN OF RELIABILITY = .991688129051804024161272395
 105 STD. DEV. OF RELIABILITY = .0000448426911224847784753382563
 106 MAX VALUE = .991796005364469420592212125
 107 MIN VALUE = .991574628499896243554385208

SAFETY ANALYSIS

SYSTEM OPERATIONAL

108 PROBABILITY = .999350774952271023975756019
 109 STD. DEV. = .00000907077944234324929665674442
 110 MAX VALUE = .999387943511487787849035058
 111 MIN VALUE = .999309328572372815932094907

NON-CRITICAL FAILURE AND SUCCESSFUL R/GA

112 PROBABILITY = .000201116606648448434460779118
 113 STD. DEV. = .00000766952859535023668564037176
 114 MAX VALUE = .0002267217078406733040045356736
 115 MIN VALUE = .00017589169615192688186252561

CRITICAL FAILURE TO SINGLE CHANNEL AND SUCCESSFUL R/GA

116 PROBABILITY = .00000415670800695877710783014955
 117 STD. DEV. = 1.33541478950163207585677348E-7
 118 MAX VALUE = .00000466942320565931811069401839
 119 MIN VALUE = .00000365171434464133181891376089

WHEEL SPIN-UP NOT DETECTED AND SUCCESSFUL R/GA

120 PROBABILITY = 3.02406318019390926949268814E-7
 121 STD. DEV. = 3.95470188035376530321004725E-12
 122 MAX VALUE = 3.02419249835355746568201815E-7
 123 MIN VALUE = 3.02393187748003015488778519E-7

NON-CRITICAL FAILURE DURING ROLLOUT

124 PROBABILITY = .000401518698030303744875188195
 125 STD. DEV. = .00000571903380067268845236436235
 126 MAX VALUE = .000419464635522861329206810656
 127 MIN VALUE = .000382105632372945863031256378

EACH-OF ROLLOUT MODE

128 PROBABILITY = .0000041377438314833332799409464
 129 STD. DEV. = 5.83027831767268926901914359E-8
 130 MAX VALUE = .00000433963046541300178578106731
 131 MIN VALUE = .00000383952769184939143232153239

10= CRITICAL FAILURE TO SINGLE CHANNEL DURING ROLLOUT

10=

10= PROBABILITY = .00000461931334373595194588576368

10= STD. DEV. = 6.58080292076122737244533975E-8

10= MAX. VALUE = .00000482581541924355270563909147

10= MIN. VALUE = .000004395793266483882372613826322

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LOCALIZER FAILURE AND SUCCESSFUL R/GA

10= PROBABILITY = 3.50380107846044730330866148E-8

10= STD. DEV. = 2.39512362346170567433149764E-9

10= MAX. VALUE = 4.24358296815451982725053807E-8

10= MIN. VALUE = 2.67158161789222138200373996E-8

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SAFETY HAZARD

10= PROBABILITY = .0000328773534987503181335723578

10= STD. DEV. = 4.683737252052227320442144E-7

10= MAX. VALUE = .0000343470844966541519794351715

10= MIN. VALUE = .000031287490806042231633344332

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ATTENUATED SAFETY HAZARD (NO PILOT VISIBILITY)

10= PROBABILITY = .0000200643642684414819220526373

10= STD. DEV. = 4.68372836748107496205444095E-7

10= MAX. VALUE = .0000215339876933890654917841086

10= MIN. VALUE = .0000184744371571344861163289356

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ATTENUATED SAFETY HAZARD (LIMITED PILOT VISIBILITY)

10= PROBABILITY = .00000930406651358467627285692434

10= STD. DEV. = 4.68332139938023583564272151E-7

10= MAX. VALUE = .0000107734722091827825723627051

10= MIN. VALUE = .0000077142146751771906945960579

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10=1 JOB NOS/BE L414H ECS CYBR CMRS 05/30/77

10= 14.00.52. PATIAPD FROM /IA

10= 14.00.52. IF 00000258 WORDS - FILE INPUT , DC 00

10= 14.00.52. PAT(T25,1050,CM100000,ST05E) D760276,BUS

10= 14.00.52. SINGER,LD,129-4238

10= 14.00.54. ATTACH(LGO,RWLS2BIN,CY=1)

10= 14.26.00. MAP(PART)

10= 14.26.00. LGO

10= 14.27.33. STOP

10= 14.27.33. 2.850 OF SECONDS EXECUTION TIME

10= 14.27.33. OF 00001864 WORDS - FILE OUTPUT , DC 40

10= 14.27.33. MB 3584 WORDS (3584 MAX USED)

10= 14.27.33. EOM 100000 WORDS MAXIMUM

10= 14.27.33. TPA 3.822 SEC. 1.659 ADJ.

10= 14.27.33. IO 1.240 SEC. 1.620 ADJ.

10= 14.27.33. CM 123.904 KWS. 1.004 ADJ.

10= 14.27.33. CPU 3.284

10= 14.27.33. CORT 1.19

10= 14.27.33. ** 3.577 SEC. DATE 07/20/77

10= 14.27.33. ED END OF JOB, IA D760276.

Run # 4

Varied Both Equipment MTBF
and Segment Time Intervals

KPER = 10%
STD DEV = 2.2

LOC CAPTURE TO ARM G/S

MEAN TIME = 210.
STD. DEV. OF TIME = 0.
MTEF = 14. 3130805087208055892715133
VARIATION = .1
MEAN OF RELIABILITY = .995849430288740829371283368
STD. DEV. OF RELIABILITY = .0000682563237373974679622163624
MAX VALUE = .996088271415122642305602199
MIN VALUE = .99564901791339317027304148

ARM G/S TO G/S CAPTURE

MEAN TIME = 30.
STD. DEV. OF TIME = 0.
MTEF = 13. 9025863382393155369438416
VARIATION = .1
MEAN OF RELIABILITY = .99938913247542234357842908
STD. DEV. OF RELIABILITY = .00000980996067547401205019762645
MAX VALUE = .999422083269531805154568542
MIN VALUE = .999360821650236346367987265

G/S CAPTURE TO APPROACH ARM

MEAN TIME = 30.
STD. DEV. OF TIME = 0.
MTEF = 13. 1378723805566057175275343
VARIATION = .1
MEAN OF RELIABILITY = .999356987874982809649503768
STD. DEV. OF RELIABILITY = .0000100272740412622819033177332
MAX VALUE = .999390963572005008481337438
MIN VALUE = .999327403321186251252656931

APPROACH ARM TO LAND ARM(100 FT)

MEAN TIME = 81.54
STD. DEV. OF TIME = 1.95
MTEF = 10. 5654626831567483740110429
VARIATION = .1
MEAN OF RELIABILITY = .997837987285320253189506894
STD. DEV. OF RELIABILITY = .0000377874475158911153696438087
MAX VALUE = .997953278577888939340186873
MIN VALUE = .9978880668378820849695667

LAND ARM (100 FT) TO FLARE ENGAGE (45 FT)

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TOTAL RELIABILITY FOR COMPLETE MODEL

MEAN OF RELIABILITY = .991660218426789376414068666
STD. DEV. OF RELIABILITY = .000178519424040598226387911906
MAX VALUE = .992078231481461317970334367
MIN VALUE = .99126558004041251531148117

SAFETY ANALYSIS

SYSTEM OPERATIONAL

PROBABILITY = .999348461930387827640081317
STD. DEV. = .0000146496300483847113458413202
MAX VALUE = .999397553192035063581056199
MIN VALUE = .999299008442766922298054749

NON-CRITICAL FAILURE AND SUCCESSFUL R/GA

PROBABILITY = .000201347514481479267807883652
STD. DEV. = .00000205010225588591630637756329
MAX VALUE = .000228036415699239010303879175
MIN VALUE = .000174434757590670444026206213

CRITICAL FAILURE TO SINGLE CHANNEL AND SUCCESSFUL R/GA

PROBABILITY = .00000414214452432271369911502239
STD. DEV. = 2.52524700975513096763710426E-7
MAX VALUE = .00000501056265786199491860458421
MIN VALUE = .00000350537993594147182816317901

WHEEL SPIN-UP NOT DETECTED AND SUCCESSFUL R/GA

PROBABILITY = 5.00079302672483344889263895E-7
STD. DEV. = 2.09287991393052967406993831E-8
MAX VALUE = 5.57303135267269994129881264E-7
MIN VALUE = 4.5941249651570681488034695E-7

NON-CRITICAL FAILURE DURING ROLLOUT

PROBABILITY = .000402798934259630453381627348
STD. DEV. = .00000975219370644601285568167931
MAX VALUE = .00043682582723761833401016501
MIN VALUE = .000367430979077755926006974318

BACK-UP ROLLOUT MODE

PROBABILITY = .00000417202937972974006328512277
STD. DEV. = 1.94742164150453024096121137E-7
MAX VALUE = .0000047132363064626669331978578

04 CRITICAL FAILURE TO SINGLE CHANNEL DURING ROLLOUT

04
04 PROBABILITY = .00000441395352207721008010787186
04 STD. DEV. = 2.0551201113986038823059677E-7
04 MAX. VALUE = .00000319170199513333145409433632
04 MIN. VALUE = .00000412861098360290379500162523

04 LOCALIZER FAILURE AND SUCCESSFUL R/GA

04
04 PROBABILITY = 3.50949876180129591887277136E-8
04 STD. DEV. = 2.72621996073851981636721798E-9
04 MAX. VALUE = 4.40873842719240909743807979E-8
04 MIN. VALUE = 2.52943013608305457402452179E-8

TABLE

SENSITIVITY ANALYSIS RESULTS

SAFETY HAZARD

04
04 PROBABILITY = .0000327438166021570361101459344
04 STD. DEV. = .00000150198422787008280541168935
04 MAX. VALUE = .0000379455922942719968971047685
04 MIN. VALUE = .0000292595644561550105540838004

04 ATTENUATED SAFETY HAZARD (NO PILOT VISIBILITY)

04
04 PROBABILITY = .0000199333454810879511949723643
04 STD. DEV. = .00000100095181976870049564397842
04 MAX. VALUE = .0000237838471041538688639588685
04 MIN. VALUE = .0000175542796299228743688370081

04 ATTENUATED SAFETY HAZARD (LIMITED PILOT VISIBILITY)

04
04 PROBABILITY = .00000926716074562744832560886392
04 STD. DEV. = 6.33662839524527614425351817E-7
04 MAX. VALUE = .0000118907612696732920246567859
04 MIN. VALUE = .00000750290686946635884223821882

04=END

04=1 086 NOS/BE L414H ECS CYBER CMRS 05/30/77
04= 12.00.43 PATIASX FROM /IA
04= 12.00.43. IF 00000128 WORDS - FILE INPUT , DC 00
04= 12.00.43. PAT(T25,1050,CM100000,STCSE) D760276,BUS
04= 12.00.43. SINGER,UD,229-4238
04= 12.00.44. ATTACH, A,AWL32,CY=1.
04= 12.00.45. FTN, I=A,T,L=0.
04= 12.01.51. 14.719 CP SECONDS COMPILATION TIME
04= 12.01.51. MAP(PART)
04= 12.01.51. LGO.
04= 12.02.01. STOP
04= 12.02.01. 2.975 CP SECONDS EXECUTION TIME
04= 12.02.01. OF 00001792 WORDS - FILE OUTPUT , DC 40
04= 12.02.01. MB 32256 WORDS (32256 MAX USED)
04= 12.02.01. BCM 100000 WORDS MAXIMUM
04= 12.02.01. CFA 18.820 SEC. 3.169 ADJ.
04= 12.02.01. IO 6.343 SEC. 3.183 ADJ.
04= 12.02.01. CM 559.034 KWS. 4.793 ADJ.
04= 12.02.01. CRLE 16.146
04= 12.02.01. COST .96

1.000027566

Program Listing For Reliability/Safety Analysis
(STACC System Configuration)

3.548 OF SECONDS COMPILATION TIME
LOG/LGO, AWLS3BIN, RP=999

LISTING OF
AWLS3

CLE CATALOG
= D760276 PFN=AWLS3BIN
= 002 00004736 WORDS.
E(OM1, AWLS3BIN, CY=1

= D760276 PFN=AWLS3BIN
= 001 00004736 WORDS.
ME, LGO, AWLS3BIN, CY=1, RP=999

7-20-77

AWLS3

XPER=0

σ = vary

= D760276 PFN=AWLS3BIN
= 002 00004736 WORDS.
= D760276 PFN=AWLS3BIN
= 001 00004736 WORDS.
CH, CARDS

LS

CLE NO. = 001
RDS, S

=PAT(T25, I050, CM100000, STCSB) D760276, BUSSINGER, UD, 229-4238
=ATTACH(LGO, AWLS3BIN, CY=1)
=MAP(PART)
=LGO.
=R
= \$AWLS NL=100, XPER=0, ,ANS=1#
CH, CARDS, INPUT, HERE

LISTING OF
CALDS

XPER=0%

LS

AL FILES--

LS	*A3	*A2	AWLS3	AWLS2
	*INPUT	*OUTPUT	*LGO	DUM1

ITE INPUT FILES--

IAGL

ITE OUTPUT FILES--

IAEI PATIAFC

LISTING OF AWLS3

$\sigma = 2.24$
XPER = 0%.

AS

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5=      PROGRAM AWLS3 (INPUT, OUTPUT)
10=     DOUBLE PRECISION NUMAX(8), NUMIN(8), MAXRTA, MAXRTT, MINRTA, MIN
20=     DOUBLE PRECISION DIFRTM(10), DIF(8), SUMDIF(8), RTADIF, RTTDIF,
30=     DOUBLE PRECISION RTTSD, DEV(8), DEVRTA, DEVRTT, EL1A, EL1B, EG1, E
40=     DOUBLE PRECISION EXPL1, EXPL2, EL1, EL2, EL3, EL4, EL5, EL6, EL7, MT
50=     DOUBLE PRECISION TIME(9), SUM26, SUM27, SUM28, RT(8, 100), PMEAN(
60=     DOUBLE PRECISION PDEV(11), PMAX(11), PMIN(11), SRT(8), MEAN(8)
70=     DOUBLE PRECISION RTT(100), RTAA(100), XMTBF(8), SRTT, SRTAA, VIN
80=     DOUBLE PRECISION V, TOP, BOTTOM, VTERM, ABSRN, SUM20A, SUM20B, SUM
90=     DOUBLE PRECISION SUM21, SUM22, SUM23, SUM24, SUM25, SUM28A, RTAAM
100=    DOUBLE PRECISION RLOC(8), RGS(8), RGRND(8), RT6N, RT7N
110=    REAL XMEAN(9), STDDEV(9), INS, MCC, NAVREC, NAVSEL, EQUIP(52)
120=    COMMON MTBF, EL1, EL2, EL3, EL4, EL5, EL6, EL7, TIME, SUM26, SUM27, SU
130=    COMMON PMEAN, PDEV, PMAX, PMIN, N, NLOOP, RT6N, RT7N
140=    INTEGER ANS
150=    NAMELIST/AWLS/NL, XPER, ANS
160=    DATA NL, XPER, ANS/100, 0., 1/
170=    NLOOP=NL
180=    CALL RANSET(.05)
190=    READ AWLS
200=    PRINT AWLS
210=    DO 60 I=1, 8
220=    SRT(I)=0.
230=    60 SUMDIF(I)=0.
240=    SRTAA=0.
250=    SRTT=0.
260=    RTASD=0.
270=    RTTSD=0.
280=    ADI=103.778
290=    EQUIP(1)=ADI
300=    CONTF=631.305
310=    EQUIP(2)=CONTF
320=    AISERV=2732.240
330=    EQUIP(3)=AISERV
340=    ELSERV=7936.508
350=    EQUIP(4)=ELSERV
360=    RUSERV=425.894

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10=      A1COMP=399. 629
20=      EQUIP(6)=A1COMP
10=      ATC=718. 332
20=      EQUIP(7)=ATC
30=      CADC=41. 571
30=      EQUIP(8)=CADC
30=      ELCOMP=274. 650
30=      EQUIP(9)=ELCOMP
20=      GSREC=499. 251
30=      EQUIP(10)=GSREC
30=      HSI=343. 643
30=      EQUIP(11)=HSI
10=      INS=1033. 058
20=      EQUIP(12)=INS
30=      MCC=626. 566
30=      EQUIP(13)=MCC
30=      NAVREC=1474. 926
30=      EQUIP(14)=NAVREC
20=      NAVSEL=730. 994
30=      EQUIP(15)=NAVSEL
30=      PAGYRO=381. 534
30=      EQUIP(16)=PAGYRO
10=      PRGYRO=1538. 462
30=      EQUIP(17)=PRGYRO
30=      RADIND=493. 097
30=      EQUIP(18)=RADIND
20=      RADRT=234. 632
30=      EQUIP(19)=RADRT
30=      RRGYRO=1538. 462
30=      EQUIP(20)=RRGYRO
30=      RGACOM=341. 647
30=      EQUIP(21)=RGACOM
10=      RDR=183. 9
20=      EQUIP(22)=RDR
30=      STACC=197. 668
30=      EQUIP(23)=STACC
30=      TFLC=407. 830
30=      EQUIP(24)=TFLC
20=      VGYRO=381. 534
30=      EQUIP(25)=VGYRO
30=      YDCOMP=304. 044
30=      EQUIP(26)=YDCOMP
10=      EQUIP(27)=1072. 961
10=      EQUIP(28)=552. 792
10=      EQUIP(29)=259. 538
30=      EQUIP(30)=2066. 116
30=      EQUIP(31)=1472. 754
30=      EQUIP(32)=906. 618
10=      EQUIP(33)=10000.
30=      EQUIP(34)=10000.
20=      EQUIP(35)=10000000.
20=      EQUIP(36)=142857. 143
10=      EQUIP(37)=10000000.
10=      EQUIP(38)=200000.
30=      EQUIP(39)=500000.
10=      EQUIP(40)=200000.
30=      EQUIP(41)=1000000.
10=      EQUIP(42)=10000000.
10=      EQUIP(43)=10000000.
10=      EQUIP(44)=10000000.
10=      EQUIP(45)=166666. 667
10=      EQUIP(46)=11571. 335
10=      EQUIP(47)=49504. 951
10=      EQUIP(48)=46665. 341

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10=      RT(8,N)=DEXP(-1.*SUM28*TIME(8))
30=      XMTBF(8)=1./SUM28
30=      EL1A=(4./MTBF(37))+(4./MTBF(35))+(5./MTBF(41))+(5./MTBF(34))

30=      6(1./MTBF(40))+(2./MTBF(49))+(2./MTBF(47))
30=      EL1B=(2./MTBF(45))+(6./MTBF(38))+(2./MTBF(46))+(2./MTBF(48))

30=      7(1./MTBF(44))+(4./MTBF(43))+(1./MTBF(39))
30=      EL1=EL1A+EL1B
10=      EL2=(1./MTBF(41))+(1./MTBF(34))
20=      EL3=1./MTBF(49)
30=      EL4=1./MTBF(48)
40=      EL5=(1./MTBF(47))+(1./MTBF(45))
50=      EL6=(1./MTBF(41))+(1./MTBF(34))
60=      EL7=1./MTBF(46)
70=      EG1=(1./MTBF(51))+(8./MTBF(41))+(1./MTBF(42))+(1./MTBF(35))

30=      8(8./MTBF(50))+(4./MTBF(38))+(1./MTBF(43))+(1./MTBF(44))
30=      EG2=(1./MTBF(41))+(1./MTBF(50))
20=      DO 32 K=1,8
10=      EXPL1=(DEXP(-1.*TIME(K)*EL1))*((3.-(2.*(DEXP(-1.*TIME(K)*EL
)
20=      9**2.)*(3.-(2.*(DEXP(-1.*TIME(K)*EL3))))*(3.-(2.*(DEXP(-1.*
30=      1TIME(K)*EL4))))
40=      EXPL2=(3.-(2.*(DEXP(-1.*TIME(K)*EL5))))*(2.-DEXP(-1.*TIME(K
50=      2EL6)))*(3.-(2.*(DEXP(-1.*TIME(K)*EL7))))
50=      RLOC(K)=EXPL1*EXPL2
70=      RGS(K)=DEXP(-1.*TIME(K)*EG1))*((3.-(2.*(DEXP(-1.*TIME(K)*EG2
**4
75=      1.)
30=      RGRND(K)=RLOC(K)*RGS(K)
30=      32 RT(K,N)=RT(K,N)*RGRND(K)
30=      RTAA(N)=RT(4,N)*RT(5,N)*RT(6,N)*RT(7,N)*RT(8,N)
10=      RTT(N)=RT(1,N)*RT(2,N)*RT(3,N)*RTAA(N)
20=      IF(ANS.EQ.0)GOTO 210
30=      CALL SAFETY
40=      210 DO 70 I=1,8
50=      70 SRT(I)=RT(I,N)+SRT(I)
50=      SRTAA=RTAA(N)+SRTAA
70=      SRTT=RTT(N)+SRTT
30=      IF(N.EQ.1)GOTO 100
40=      DO 80 I=1,8
50=      80 NUMAX(I)=DMAX1(RT(I,N),NUMAX(I))
10=      MAXRTA=DMAX1(RTAA(N),MAXRTA)
20=      MAXRTT=DMAX1(RTT(N),MAXRTT)
30=      GOTO 110
40=      100 DO 90 I=1,8
50=      90 NUMAX(I)=RT(I,N)
50=      MAXRTA=RTAA(N)
70=      MAXRTT=RTT(N)
30=      IF(N.EQ.1)GOTO 120
40=      110 DO 130 I=1,8
50=      130 NUMIN(I)=DMIN1(RT(I,N),NUMIN(I))
10=      MINRTA=DMIN1(RTAA(N),MINRTA)
20=      MINRTT=DMIN1(RTT(N),MINRTT)
30=      GOTO 40
40=      120 DO 140 I=1,8
50=      140 NUMIN(I)=RT(I,N)
50=      MINRTA=RTAA(N)
70=      MINRTT=RTT(N)
30=      40 CONTINUE
40=      DO 150 I=1,8
50=      150 MEAN(I)=SRT(I)/FLOAT(NLOOP)

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[illegible]


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5=      DOUBLE PRECISION F41A(3), FF41A(3), DFF412, DFF413, F41A2, F45A2
6=      COMMON MTEF, EL1, EL2, EL3, EL4, EL5, EL6, EL7, TIME, SUM26, SUM27, SU

40=      COMMON PMEAN, PDEV, PMAX, PMIN, N, NLOOP, RT6N, RT7N
70=      RGA=DEXP(-1. *(1. /MTEF(27))*TIME(9))
80=      RRG(1)=1. -(2. *RGA)+(RGA**2. )
90=      RRG(2)=(2. *RGA)-(2. *RGA*RGA)
100=     RRG(3)=RGA**2.
110=     RRG(4)=1. -RGA
120=     RRG(5)=RGA
130=     FEDP=DEXP(-1. *(1. /MTEF(27))*TIME(6))
140=     FED(1)=1. -DEXP(-1. *(SUM26-(2. *(1. /MTEF(27))))*TIME(6))
150=     FED(2)=2. *FEDP-(2. *(FEDP**2. ))
160=     FED(3)=1. -(2. *FEDP)+(FEDP**2. )
170=     G(1)=TIME(6)
180=     G(2)=TIME(7)+(1. /3600. )
190=     G(3)=TIME(8)-(1. /3600. )
200=     DO 901 I=1,3
210=     EXPL1=(DEXP(-1. *G(I)*EL1))*(3. -(2. *(DEXP(-1. *G(I)*EL2))))*
*
220=     1(3. -(2. *(DEXP(-1. *G(I)*EL3))))*(3. -(2. *(DEXP(-1. *G(I)*EL4)))
*
230=     EXPL2=(3. -(2. *(DEXP(-1. *G(I)*EL5))))*(2. -DEXP(-1. *G(I)*EL6)
*
240=     12. *(DEXP(-1. *G(I)*EL7))))
250= 901 LOCR(1)=EXPL1*EXPL2
260=     PATH(1,N)=FED(1)*RRG(1)
270=     PATH(2,N)=FED(1)*RRG(2)
280=     PATH(3,N)=FED(1)*RRG(3)
290=     PATH(4,N)=FED(2)*RRG(4)
300=     PATH(5,N)=FED(2)*RRG(5)
310=     PATH(6,N)=FED(3)
320=     PATH(7,N)=RT6N
330=     PFAIL1=1. -LOCR(1)
340=     PATH(30,N)=PATH(1,N)*PFAIL1
350=     PATH(31,N)=PATH(2,N)*PFAIL1
360=     PATH(32,N)=PATH(3,N)*PFAIL1
370=     PATH(33,N)=PATH(4,N)*PFAIL1
380=     PATH(34,N)=PATH(5,N)*PFAIL1
390=     PATH(35,N)=PATH(6,N)*PFAIL1
400=     PATH(36,N)=PFAIL1*RT6N*RRG(1)
410=     PATH(37,N)=PFAIL1*RT6N*RRG(2)
420=     PATH(38,N)=PFAIL1*RRG(3)*RT6N
430=     DTTP=DEXP(-1. *(1. /MTEF(27))*TIME(7))
440=     DTT1=1. -DEXP(-1. *(SUM27-(2. *(1. /MTEF(27))))*TIME(7))
450=     DTT2=2. *DTTP-(2. *(DTTP**2. ))
460=     DTT3=1. -(2. *DTTP)+(DTTP**2. )
470=     PATH(8,N)=DTT1*RRG(1)
480=     PATH(9,N)=DTT1*RRG(2)
490=     PATH(10,N)=DTT1*RRG(3)
500=     PATH(11,N)=DTT2*RRG(4)
510=     PATH(12,N)=DTT2*RRG(5)
520=     PATH(13,N)=DTT3
530=     PATH(14,N)=RT7N
540=     TDWSP=DEXP(-1. *(1. /MTEF(27))*(1. /3600. ))
550=     TD1=1. -DEXP(-1. *(SUM28-(2. /MTEF(27))-(1. /MTEF(28)))*(1. /360
*
560=     TD2=(2. *TDWSP)-(2. *(TDWSP**2. ))
570=     TD3=1. -(2. *TDWSP)+(TDWSP**2. )
580=     TD4=1. -DEXP(-1. *(1. /MTEF(28))*(1. /3600. ))
590=     TD5=DEXP(-1. *SUM28*(1. /3600. ))
600=     PATH(15,N)=TD1*RRG(1)
610=     PATH(16,N)=TD1*RRG(2)

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0=      PATH(20,N)=TDS
0=      PATH(21,N)=TD4*RRGA(1)
0=      PATH(22,N)=TD4*RRGA(2)
0=      PATH(23,N)=TD4*RRGA(3)
0=      PATH(24,N)=TDS
0=      PINS25=DEXP(-1.*(1./MTBF(30))*(TIME(8)-(1./3600.)))
0=      PINS1=(2.*PINS25)-(2.*(PINS25**2.))
0=      PINS2=1.-(2.*PINS25)+(PINS25**2.)
0=      PATH(25,N)=1.-DEXP(-1.*(SUM28-(1./MTBF(29)))*(TIME(8)-(1./3
))
0=      1+PINS1+PINS2
0=      PATH(26,N)=1.-DEXP(-1.*(1./MTBF(31))*(TIME(8)-(1./3600.)))
0=      P27=DEXP(-1.*(1./MTBF(32))*(TIME(8)-(1./3600.)))
0=      PATH(27,N)=(2.*P27)-(2.*(P27**2.))
0=      PATH(28,N)=1.-(2.*P27)+(P27**2.)
0=      PATH(29,N)=DEXP(-1.*SUM28*(TIME(8)-(1./3600.)))
0=      DO 902 I=1,7
0=      902 PATH(I,N)=PATH(I,N)*LOCR(1)
0=      PFAIL2=1.-LOCR(2)
0=      PATH(39,N)=PFAIL2*(1.-DEXP(-1.*(SUM28+(1./MTBF(14))-(1./MTB
))
0=      1*(TIME(8)-(1./3600.))))
0=      P40=DEXP(-1.*(1./MTBF(52))*(TIME(8)-(1./3600.)))
0=      PATH(40,N)=PFAIL2*((2.*P40)-(2.*(P40**2.)))
0=      PATH(41,N)=PFAIL2*(1.-(2.*P40)+(P40**2.))
0=      PATH(42,N)=PFAIL2*DEXP(-1.*SUM28*(TIME(8)-(1./3600.)))
0=      PFAIL3=1.-LOCR(3)
0=      PATH(43,N)=LOCR(2)*PFAIL3*(1.-DEXP(-1.*(SUM28+(1./MTBF(14))
MT
0=      1BF(29)))*(TIME(8)-(1./3600.))))
0=      PATH(44,N)=LOCR(2)*PFAIL3*((2.*P40)-(2.*(P40**2.)))
0=      PATH(45,N)=LOCR(2)*PFAIL3*(1.-(2.*P40)+(P40**2.))
0=      PATH(46,N)=LOCR(2)*PFAIL3*DEXP(-1.*SUM28*(TIME(8)-(1./3600.

0=      DO 700 I=8,14
0=      700 PATH(I,N)=PATH(I,N)*PATH(7,N)
0=      DO 710 I=15,24
0=      710 PATH(I,N)=PATH(I,N)*PATH(14,N)
0=      DO 720 I=25,29
0=      720 PATH(I,N)=PATH(I,N)*PATH(24,N)*LOCR(2)*LOCR(3)
4=      DO 888 I=39,46
4=      888 PATH(I,N)=PATH(I,N)*PATH(24,N)
0=C      P(I,N): I IS THE INDEX FOR 11 DIFFERENT PROBABILITIES TO B

0=C      COMPUTED
0=      P(1,N)=PATH(29,N)
0=      P(2,N)=PATH(2,N)+PATH(3,N)+PATH(9,N)+PATH(10,N)+PATH(16,N)+
17
0=      1,N)
0=      P(3,N)=PATH(5,N)+PATH(12,N)+PATH(19,N)
0=      P(4,N)=PATH(22,N)+PATH(23,N)
0=      P(5,N)=PATH(25,N)
0=      P(6,N)=PATH(26,N)+PATH(39,N)+PATH(42,N)+PATH(43,N)+PATH(46,
TH
0=      1(40,N)+PATH(44,N)
0=      P(7,N)=PATH(27,N)
0=      PSH=PATH(1,N)+PATH(4,N)+PATH(6,N)+PATH(8,N)+PATH(11,N)+PATH
0+
0=      1PATH(15,N)+PATH(18,N)+PATH(20,N)+PATH(21,N)+PATH(30,N)+PATH
0=      1PATH(35,N)+PATH(36,N)
0=      P(8,N)=PSH+PATH(18,N)+PATH(41,N)+PATH(45,N)
0=      P(9,N)=PATH(31,N)+PATH(32,N)+PATH(34,N)+PATH(37,N)+PATH(38,

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APPENDIX C

EXTRACTS, C-141 AWLS OPERATIONAL FLIGHT TESTS

AFFDL-TR-77-39

This report presents the results of approximately 1200 approaches and landings of which 82 were accomplished in actual Category III weather conditions (RVR less than 1200 feet) including 14 landings in a reported RVR of zero. The tests were conducted with a C-141 aircraft flying only Category II or III ground ILS equipment on runways furnished with U. S. Standard ALSF-1 approach lighting and touchdown Zone Lighting (TDZL systems.) Since the step 4 approach light setting was considered optimum, it serves as the basis for evaluation for this test.

The conclusions of the test program were subjective in nature and based upon the experience of the project test pilot; however, a majority reflect the consensus of opinion of other participating pilots and test observers. Conclusions were as follows:

1. Basically four parameters comprise the landing/go-around decision criteria:
 - a. Aircraft position relative to glideslope and localizer.
 - b. Aircraft lateral and vertical rates
 - c. System integrity.
 - d. Aircraft attitude.
2. An automatic landing should be the primary mode for Category III landings.
3. A specific point of landing committal should be determined based upon aircraft performance characteristics.
4. Step 4 approach light setting is optimum.
5. Aircraft landing lights provide no assistance for the landing and produce undesirable reflections at altitude.
6. The strobe and approach lights are useful down to RVR's of approximately 300 feet.
7. Roll bars in the ALSF-1 lighting system were generally ineffective aids.

8. The runway threshold lights were very ineffective.
9. The touchdown zone lights were generally very effective and provided the primary cues for operation in RVR's less than 800 feet. The touchdown Zone (TDZ) lights were positively acquired at approximately 50 AGL (Absolute Ground Level) for an RVR estimated to be 200 feet.
10. Although visual verification of lateral position and rate were possible before touchdown (point of commitment for the test vehicle), The TDZ lights did not provide cues to complete a flare. Overall attitude and altitude information were lacking.
11. Based upon the test aircraft geometry, the lowest RVR which provides a se-to-land capability is 1000 feet reported RVR and then only if all flight conditions are optimum.
12. The runway edge lights were generally not a factor in the final visual field upon landing.
13. If lateral excursions from the runway centerline are kept within ± 30 feet, the centerline lights provide acceptable cues to complete visual takeoffs and landings for RVR as low as 200 feet estimated (based upon pilot eye height of approximately 15 feet above ground).
14. Major inadequacy of the runway lighting system is the lack of longitudinal information and corresponding taxiway turnoff definition for ground operation.
15. The onset of taxi/ground operation difficulties correlates to a reported RVR of approximately 600 feet.
16. Unacceptable localizer signal oscillations caused by overflight of the transmitter antenna by other aircraft.
17. Compared to normal instrument flight, the task involved with completely instrument landings demand considerably increased pilot precision and concentration and consequently greater overall workload.
18. Due to capability limitations in general cockpit management and restricted instrument crosscheck capability, manual approaches are not feasible as a primary operational mode.
19. The unique wing low decrab instrument maneuver was initially difficult to become accustomed to on instruments. Although some flexibility and touchdown point accuracy were gained, the tests provided no definite support for the re-

quirement of the wing low decrab technique as long as 10 KTS direct cross-wind was not exceeded.

20. Biomedical tests were inconclusive and yielded little difference in results compared to data taken during normal Category II approaches.

21. If the criteria for a satisfactory backup mode consists of providing only control task capability, the manual mode of operation qualifies throughout all phases of approach and landing. The manual mode is satisfactory as a primary technique for landing rollout and takeoff.

RECOMMENDATIONS

As a result of experience in this program, the project pilot offered a number of recommendations:

1. Runway threshold definition is critical and a major effort for improved effectiveness should be undertaken.
2. All Category III landings should be totally instrument landings at least to touchdown point.
3. Rows of lights perpendicular to the runway centerline, extending approximately 15 feet to either side, could be located directly abeam each useable taxiway turnoff. In addition to positive turnoff definition, these lights would provide longitudinal information.
4. The RVR breakdown for Category III should be aligned to the correlation between actual RVR and reported RVR. Based upon these test results, this correlation suggests a breakdown as follows:

Category IIIa - RVR 1200 ft to 600 feet

Autoland, visual rollout, visual taxi.

Category IIIb - RVR less than 600 feet

Category IIIb - RVR less than 600 feet

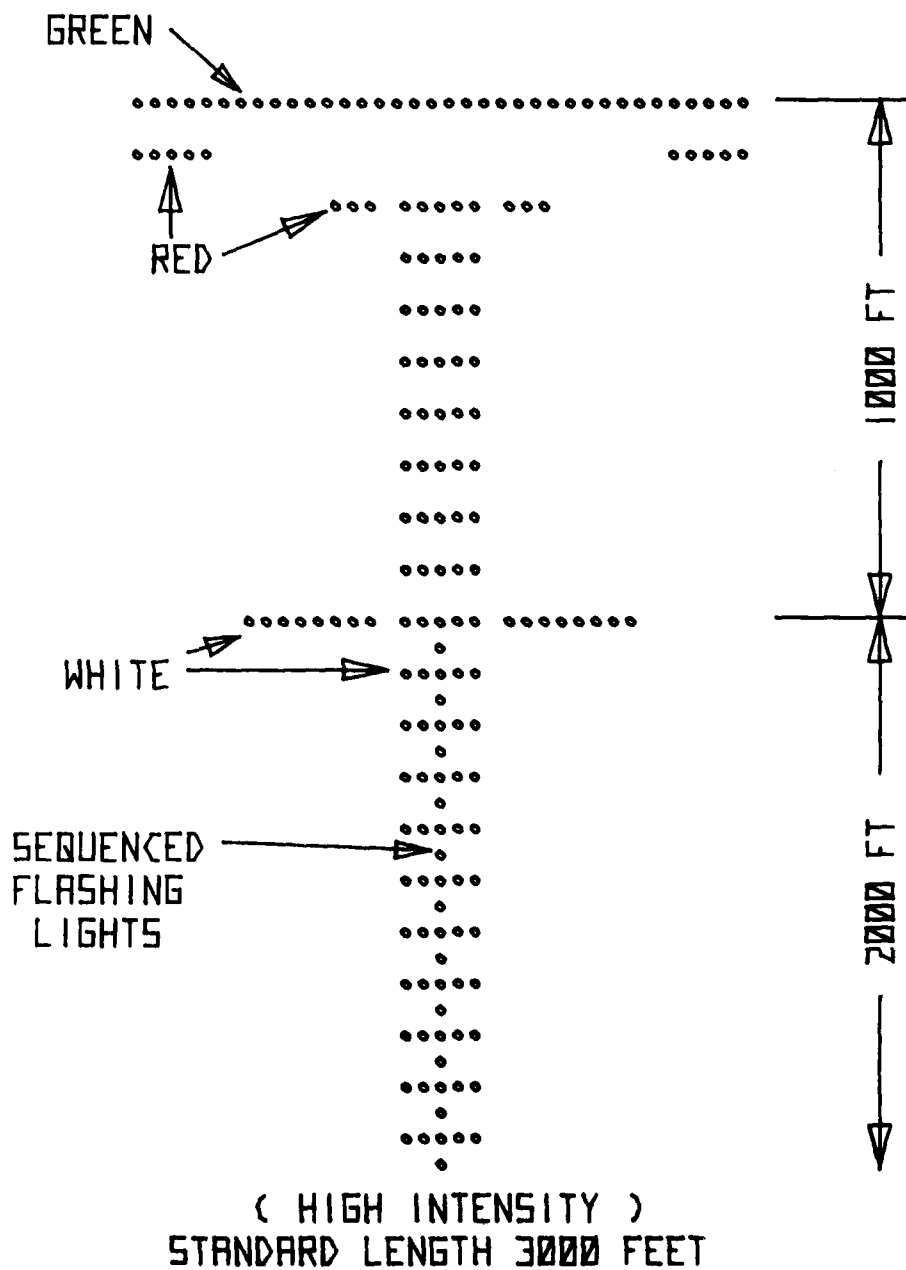
Autoland, auto-rollout, * auto-taxi**

* The assessment of conditions down to 200 feet estimated RVR indicates that visual rollout/takeoff could be conducted. Auto is specified to ensure capability based upon excellent instrument rollout results and also to include capability to actual zero visibility.

**** As suggested earlier, visual assistance, such as taxiway centerline lights may provide improvement sufficient to visually taxi in RVR conditions less than 600 feet reported.**

5. Improvements in instrument displays integrating failure warning and performance parameters with the control display could achieve feasibility for the manual mode to be a primary mode.

6. Considering the narrow bounds of pilot capability during manual approaches, the display integration process should focus upon representation of all the integrated parameters through flight director presentation.



TOUCHDOWN ZONE LIGHTING (TDZL)

