HUMAN RELIABILITY PROGRAM
FOR THE
SATURN V LAUNCH VEHICLE GROUND SUPPORT EQUIPMENT

October 1965

Prepared under
Contract NAS8-11087
National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama

Prepared by
Dr. Harald R. Leuba

N67-21168
(ACCESSION NUMBER)
33
(PAGES)
CR-83119
(NASA CR OR TMX OR AD NUMBER)
(THRU)
(CODE)
05
(CATEGORY)
FACILITY FORM 602

ARINC RESEARCH CORPORATION
a subsidiary of Aeronautical Radio, Inc.
Annapolis Science Center
Annapolis, Maryland 21401

Publication 294-25-34-539

Rq/42373

© 1965 ARINC Research Corporation

Prepared under Contract NAS8-11087
which grants to the U. S. Government a
license to use any material in this
publication for Government purposes.

ABSTRACT

This report is concerned with the prediction and evaluation of human reliability for the Saturn V Launch Vehicle Ground Support Equipment (GSE). It is divided into five major sections: (1) the purpose of the human reliability program, (2) a system description, (3) possible techniques for prediction and evaluation, (4) limitations of the study, and (5) recommended actions. The material presented does not solve human reliability prediction and evaluation problems, but it does describe those problems and provide quantitative recommendations on how they could be solved. Information requirements and alternative analytic procedures are listed.

TABLE OF CONTENTS

	Page
ABSTRACT	ii
1. PURPOSE OF THE HUMAN RELIABILITY PROGRAM	1
2. SYSTEM DESCRIPTION	2
3. POSSIBLE TECHNIQUES FOR PREDICTION AND EVALUATION	8
3.1 Introduction	8
3.2 General Evaluation	8
4. LIMITATIONS ON THIS STUDY	13
5. RECOMMENDED ACTIONS	15
REFERENCES	16
APPENDIX A - TASK ANALYSIS OF PNEUMATICS FUNCTIONAL TEST	18
APPENDIX B - DESCRIPTION OF THE DATA STORE	28

1. PURPOSE OF THE HUMAN RELIABILITY PROGRAM

Today's system design philosophy freely admits that some attention is due man as a system "component." When effectively integrated into the system development process, such human factor considerations can significantly contribute to the reliability and effectiveness of the end product. Insufficient attention in this area can result in degraded system performance or actual mission failure.

This viewpoint is true for systems in general, and it is true for the Saturn V Launch Vehicle Ground Support Equipment (GSE). Accordingly, some attention is due man as a system component in the GSE system.

The human reliability program initiated by the present study is designed to support the overall reliability management program. It includes several elements:

(1) A general surveillance of the proposed GSE design as it might affect, or be affected by, human factors.

(2) A preliminary assessment of the impact of man upon system reliability.

(3) A routine evaluation of the maintainability and human factors documentation that has been made available.

(4) A spot check of certain critical areas with respect to human factors; viz., the computer control console.

(5) Continued attention to the prediction of human reliability as a function of design maturation.

Each of these activities will contribute to the overall reliability program and will support the ultimate performance of the Saturn V system. Thus human reliability will be optimized, and the probability of total mission success will be improved.

2. SYSTEM DESCRIPTION

The "system" being considered is the ground support equipment-procedures and personnel required for the prelaunch checkout and launch of the Saturn V vehicle. Currently, the design of this system is in a nebulous state. Certain major pieces of equipment and a basic procedures pattern have been identified, but little detailed design has been established. While this makes a short-term system evaluation virtually meaningless, it does bode well for the usefulness of long-term efforts, for there is a genuine opportunity for human factor considerations to interact with system design while the design is taking shape.

Yet in order to make even a preliminary analysis of the potential for human error in this system, it is necessary to have a system description. Since the system configuration is not yet fixed, any such description is really a conjecture; that is, any present analysis of the potential for human error will have to be based on assumptions that the system will be configured "thus and so."

Presently, best engineering judgments suggest the statements concerning the system that follow. These statements may be viewed as assumptions, and the conclusions drawn later in this report are partially dependent upon the validity of these statements:

(1) The system provides for between 50 and 300 people

(2) These people are to be NASA and contractor personnel.

(3) They will be trained on and off the job.

(4) They will have varied levels of responsibility.

(5) The system will have perhaps 400 display and control racks with up to 2200 panels.

(6) There will be two RCA 110A computers.

(7) These men and this equipment will perform prelaunch checkout and launch operations, of an as yet unspecified nature, in three essentially redundant modes:

(a) Automatic computer control

(b) Man-selected computer control

(c) Man control *

(8) In general, the system is designed to operate in a fully automatic fashion, and with the men and the display racks performing only a monitoring function. When the equipment functions normally, one of the computers, located in the launch control center, automatically relays time-phased messages to the other computer, located in the mobile launch umbilical tower. These messages deal with the performance of required checkout and launch operations; e.g., "Read fuel pressure in tank 8", or "Close circuit for power to switch 694". The commands are relayed over a data link that can be up to six miles long, depending upon the position of the mobile launch umbilical tower. The computer in the launch umbilical tower receives the time-phased messages and relays them, as commands, through preprogrammed subroutines. Thus, under normal operations, the launch umbilical tower computer actually controls the performance of the prelaunch checkout and launch sequences. If the messages from the launch control center computer concern the monitoring of some particular system parameter, then the launch umbilical tower computer

* Further general description is available in Reference 1

commands the parameter to be monitored, receives the reading, and relays the reading back through the data link to the launch control center computer, and also to an appropriate panel on one (or more) of the equipment racks. The launch control center computer compares the reading with a preprogrammed standard, and then branches to the appropriate following step.

(9) If the launch umbilical tower computer malfunctions (it is programmed to detect this malfunction itself), then the launch control center computer can directly control prelaunch checkout and launch through the data link by the use of slave tape routines stored with the launch umbilical tower computer. If the launch control center computer fails to operate properly (it also is programmed with self-diagnostic routines), then it can reprogram itself or be worked manually through the data link to direct the operations of the launch umbilical tower computer. This latter process is the second of the three operating modes; it can also be used if both computers fail in certain prescribed ways.

(10) Under certain equipment failure conditions, it may be necessary to resort to the third operating mode: direct manual control of the prelaunch checkout and launch process.

(11) Man is essentially a redundant element in this design. Only if the equipment fails is he to take over. This role, however, is a continuous job. Each man in the system is assigned to one, or two, or three of the panels on the equipment racks. Each man is to monitor continuously, against a prearranged time-phased performance standard, the behavior of each indicator on his assigned panels. If any particular

indicator is off standard, the man is to report this to his "immediate superior", i.e., to the individual responsible for monitoring the next largest subsystem that contains the function in question. (There is a man at the top, or system level, but he does not directly monitor functions; instead he monitors whole subsystems and can check his indicators by going down the chain of command instead of up it.)

If the out-of-tolerance condition is verified by direct observation and an independent complaint from a related, but not equivalent, indicator, then the existence of an out-of-tolerance condition is relayed to the top of the chain of command. There a decision is made, and a control action may or may not be required. If a control action is required, it is relayed down the chain of command to the operator of the rack with the out-of-tolerance condition, or to some other rack man, or to the console operator at the launch control center computer. The required action then takes place and the prelaunch checkout and launch process continues.

Assumptions 1, 5, and 6 are required to dimension the system, i.e., to indicate the general magnitude of the man-machine interface. Assumptions 2, 3, and 4 relate to the job skill and motivation of the personnel, and they suggest that this system will not be too different from past systems. One may thus assume that there will be no new motivation problems. Assumptions 7, 8, 9, and 10 are required in order to structure the relative duties of man and machine in this system. Assumption 11 is a final summary of man's role in this design.

Logically, each of the three types of system failure -- hold, scrub, and vehicle loss -- can be due to the EQUIPMENT, the PROCEDURES, or the PERSONNEL. One is told to accept the fact that no errors will be generated by the procedures per se. This amounts to Assumption 12 and is a very strong assumption. It is made because the current design philosophy demands it, but the reader may note what subassumptions it implies:

(12.1) The computer program will be flawless.

(12.2) The equipment racks will be so well integrated that no vehicle malfunction will be undetectable.

(12.3) The monitoring process will be such that no operator can independently (by himself) cause an equipment failure.

(12.4) Maintenance procedures will guarantee that only good equipment is put in a ready status.

Given that the procedures are as fool-proof as claimed, there are only four ways in which man can generate a failure:

(1) The computers can fail, and the computer-controlled modes can become inoperative; then man can take over control, program incorrectly, and thus lead to a system failure.

(2) The computers can so fail as to fail to detect the existence of a real equipment malfunction; and then several men also fail to detect the malfunction on their equipment rack panels.

(3) The computers may be operating properly, or the system may be in the third mode, and several men may report that one of several critical, but actually nonexistent, equipment malfunctions has occurred.

(4) One man can, intentionally or otherwise, manipulate a control out of sequence and thus induce a system failure directly or through a subsequent equipment failure.

3. POSSIBLE TECHNIQUES FOR PREDICTION AND EVALUATION

3.1 Introduction

There are several possible techniques to predict the likelihood of a human error and to evaluate the human reliability associated with a particular system (References 2, 3, 4, 5, 6, and 7). Each of these techniques, however, essentially uses the same model.

In each technique the system is broken down into equipment, procedures, and personnel. System reliability is then the probability that these personnel will follow these procedures when using this equipment. The precision, but not necessarily the usefulness, of the final answer depends upon the amount of detailed personnel, procedures, and equipment information available. Even where it is not possible to describe the system in detail, it may be possible to identify the critical areas of the system with respect to human reliability.

In the GSE system it is necessary to work at several levels of detail if one hopes to gain a maximum improvement in human reliability with a moderate level of effort. There are enough data now available to work out the evaluation at the most general level.

3.2 General Evaluation

There are only four possible ways in which man can generate a failure in this system, and they were listed in the preceding section. This section will predict the relative likelihood of each source of error. In order to do this, it is necessary to have a notation for several probabilities:

Let

C be the probability of a computer failure; say it is < 0.10 per launch.*

E be the probability of a failure in the vehicle equipment; say it is < 0.20 per launch.

G be the probability of a failure in the GSE equipment racks; say it is < 0.20 per launch.

A be the probability that the computer will accept a manual command issued out of sequence without the computer having been taken off-line first.

n be the number of men who monitor one function; say it is ≤ 2.

P be the probability of an error in keyboard programming; a reasonable estimate of this would be ≈ 0.008 for a fairly complex panel.

D be the probability of one man improperly detecting a signal on his panel; a reasonable estimate of this would be ≈ 0.005 for a fairly complex panel.

I be the probability of an inadvertant manipulation of a control by a man; a reasonable estimate of this would be ≈ 0.0001 for a routine monitoring operation over a double shift.

Further, let

M be the number of panels to be monitored, say 2000.

T be the number of times each indicator is used in the 16-hour checkout and launch sequence, say 10.

---

* If we assume unreasonable numbers here, we will not be deluded into thinking that we have predicted human reliability, but we still will be able to evaluate the <u>relative</u> likelihood of these four types of failure.

F be the number of functions performed during checkout and launch, say 20,000.

N be the number of men monitoring panels, say 50.

Then the likelihood of the first type of human-induced error (the computers fail and the computer-controlled modes become inoperative, and a man makes an error in manually programming the computer) is:

$$(C \times C \times P)\ F/2 < 0.8 \text{ per launch.}$$

The likelihood of the second type of human-induced error (the computers fail, then fail to detect their own failure, then fail to detect a real equipment failure, and then several men fail to detect the malfunction on their equipment racks) is:

$$T/2\ (C \times C \times C \times C \times C \times E \times D^n) < 0.00000000025 \text{ per launch.}$$

The likelihood of the third type of human-induced error (several men report one of several critical, but nonexistent, equipment malfunctions) is:

$$T/2 \left[G^{n-1} D \text{ or } G^{n-2} D^2 \text{ or } \ldots GD^{n-1} \text{ or } D^n \right] < 0.005 \text{ per launch.}$$

The likelihood of the fourth type of human-induced error (one man manipulates a control out of sequence) is:

$$M \times I \times N + (C \times C + 1\text{-}C \times C\ A) < 0.1 + 9.9A$$
$$< 10 \text{ per launch}$$

From this analysis one quickly observes that the second type of error (man fails to detect a real failure) is highly unlikely, even with very conservative estimates of computer reliability. It would seem reasonable, therefore, to focus attention on the other sources of human error.

The most likely cause of system failure is the fourth (inadvertent operation). This source of failure can be largely precluded by designing the computer-data-link-computer system so that during the computer-controlled modes the system will not accept a manual control command. This will not totally prevent these failures, but it will reduce their likelihood by at least 99%. (This percentage reduction is equivalent to the probability of operating in a computer-controlled mode; the answer shown here is independent of all the other parameters.) The remaining error potential will have to be reduced by careful attention to the placement and selection of the controls on the equipment racks.

> Recommendation:
>
> Provide a relay device in the computer-data-link-computer control process that will relay manual commands only (a) if an override switch is pressed on the computer console, or (b) if the computers are not in command.

The third type of error (several men report a false alarm) can be reduced by:

(1) Improving the cross-checking arrangements

(2) Requiring a self-check on all observed out-of-tolerance conditions

(3) Or requiring independent "neighbor checks" on all observed out-of-tolerance conditions

If self-checking is a matter-of-course, and if an independent "neighbor" check is required before any control action is initiated, then the likelihood of this type of error is reduced to less than 0.0000006 per launch.

Clearly the only major source of system failures then will be in the computer control panel. This panel should be given a detailed human reliability analysis. Appendix A* illustrates the level of detail required for this sort of analysis. This detailed information must be obtained, and the control panel must be carefully designed.

---

* Taken from Reference 6

4. LIMITATIONS ON THIS STUDY

The study reported to date is limited by a shortage of design information and by several assumptions. The shortage of design information currently is not very important; the preceding gross-level analysis would have been required in any event. The shortage, however, will become important when the time comes to perform a detailed analysis of the computer control console.

On the other hand, the assumptions (Section 2) have importance throughout the proposed human reliability program. The most important of these assumptions is the one dealing with procedures. The procedures themselves have been assumed to be flawless; i.e., they will not contribute to system failures. It is believed that this is an invalid assumption, that the consequences of various alternative procedure designs need to be studied, and that the possible procedures then need to be evaluated. (The minor assumptions deal with the personnel variables, although it can be argued that these also deal with procedures.)

So far in this study, the following additional assumptions have been implicitly made:

(13) The monitoring personnel are not overloaded.

(14) The monitoring personnel are not tired.

(15) The monitoring personnel are able to view directly all of their assigned panels.

As the study matures, it may be wise to examine these assumptions closely.

Finally, the study will be limited by the quality of the equipment and human reliability data entered into its models. Conservative equipment reliability data was purposely chosen here in order to counteract any tendency a reader might have to "over-read" the human reliability data. Human performance reliability data are available (References 2 and 5) and they are reasonably adequate, but they are not reasonably accurate (a 300% error is not unlikely).

5. RECOMMENDED ACTIONS

Recommended actions fall into two groups: those dealing with an actual solution to a reliability problem, like adding the automatic manual control rejection circuit mentioned earlier; and those concerned with continued attention to the remaining reliability problems, like performing a detailed analysis at the computer console. The actions in the latter category are discussed here.

An adequate human reliability management program for the Saturn V GSE system can be conducted with a relatively slight manpower commitment. Such a program is recommended.

This program (a human factors effort) should be directed primarily at the computer control console, but it must also concern itself with the following:

(1) Defining the various roles for man in this system

(2) Identifying the controls in the system that require extra protection against inadvertent operation

(3) Reviewing human factors and maintainability documentation as it becomes available

(4) Evaluating the effect and extent of work loads on the men involved in monitoring and control

(5) Locating, interpreting, and applying relevant human reliability data

(6) Maintaining surveillance over the present status of the design and the predictions of a human reliability model

REFERENCES

1. Commons, T.; and Tilkelenberg, A. P.,"How Can Redundancy, Maintainability, and Personnel Activities be Considered in Reliability Predictions for Saturn V Launch Vehicle GSE?" Paper presented at the Second ARINC Research Technical Seminar, Santa Ana, California, 4-5 August 1965.

2. Munger, Sara J.; Smith, R. W.; and Payne, D., An Index of Electronic Equipment Operability: Data Store. Report AIR C43-1/62 - RP (1), American Institute for Research, Pittsburgh, Pa., 31 January 1962.

3. Irwin, I. A.; Levitz, J. J.; and Freed, A. M., "Human Reliability in the Performance of Maintenance." Paper presented at the E14 M-5.7 Symposium on the Quantification of Human Performance, Albuquerque, New Mexico, 17 August 1964.

4. Miller, G. E.; Maxwell, R. A.; Ferguson, L.; and Galba, C. J., Human Factors Aspects of Reliability. Aeronutronic Division, Philco Corp., Newport Beach, California, January 1964.

5. Meister, D., Human Reliability of Controls and Displays. Convair (Astronautics) Division, General Dynamics Corp., San Diego, California, May 1963 (Rpt. No. GDA - 63 - 0047).

6. Stave, A. M., The Quantification of Human Reliability. General Electric, Philadelphia, Pa., March 1965. (Rpt. No. TIS 655D216).

7. Swain, A. D., A Method for Performing Human Factors Reliability Analysis. Sandia Corp., Albuquerque, New Mexico, August 1963 (Rpt. No. SCR-685).

APPENDIXES

APPENDIX A*

TASK ANALYSIS OF PNEUMATICS FUNCTIONAL TEST**

The following material is a reproduction of the task analysis used in this study. To the left of each step can be found the calculated DATA STORE reliability for that step. Numbers indented from the left side are values for parts of a step. The value for the total step is usually obtained by multiplying the values for all parts of the step.

Reliability	Step
0.9960	1. Turn on power to oscillograph recorder (if not already on):
0.9987	a. Throw ON/OFF toggle switch up.
0.9973	b. Push red button on console (1 of 6 buttons).
0.9886	2. Connect test cables to the pressure transducers and solenoids (19 cable sets):
0.9989	a. Position test cables.
0.9994	b. Connect cables.
0.9722	3. Connect the nitrogen high-pressure-leak-rate system to the fill line.
0.9952	a. Short pneumatics line to Millapore filter:
0.9989	(1) Remove cap.
0.9988	(2) Put on seal ring.
0.9991	(3) Put pneumatics line over connection.
0.9996	(4) Start connection with fingers.
0.9988	(5) Tighten with two wrenches (7/8 inch, open-end).
0.9952	b. Millapore filter:
For reliability values, see step 3a.	(1) Remove cap on filter fitting.
	(2) Put on seal ring.
	(3) Put pneumatics line over connection.
	(4) Start connection with fingers
	(5) Tighten connection with two wrenches.

* This appendix is taken from Reference 6. It is included here as an excellent example of a detailed human performance prediction.

** This test is defined by Standing Instruction 238131, Section 3.3.

Reliability	Step
0.9952	c. Filter to floor (line about 5 feet long).
	Same as in step 3b.
0.9864	d. Pneumatics line to Schrader valve on vehicle (line about 15 feet long):
0.9944	(1) Attach the long line at the AGE end.
0.9972	(2) Purge the system:
0.9976	(a) Set the regulator at 100 psi.
0.9996	(b) Let gas flow through system for short period of time.
0.9948	(3) Attach the pneumatics line to the vehicle Shrader valve:
0.9993	(a) Remove the cap on the Shrader valve.
0.9992	(b) Remove the cap on the pneumatics line.
0.9963	(c) Proceed as described in steps 3a (2) through 3a (5).
0.9745	4. Open the nitrogen line valve:
0.9981	a. Check gauge to determine what pressure is in the source.
0.9863	b. Crack the nitrogen valve and watch the pressure mount on gauge to 5500 psi.
0.9977	5. Open the nitrogen shutoff valve:
0.9992	a. Check that the vent valve is closed.
0.9985	b. Open the nitrogen valve.
0.9985	6. Open the nitrogen high-pressure-leak-rate system shutoff valve:
	a. Crack the valve slowly, then open it (twist counterclockwise).
0.9991	7. Open the Shrader valve on the vehicle:
	a. Using open-end wrench, turn valve counterclockwise two and one-half turns.

Reliability	Step
0.9985	8. Open the leak-rate shutoff valve on the console in the test control room:
	a. Twist the valve counterclockwise.
0.9985	9. Open the nitrogen high-pressure-leak-rate system shutoff valve:
	a. Twist the valve counterclockwise.
0.9711	10. Set up the oscillograph recorder (to be done prior to each test requiring its use):
0.9990	a. Flip POWER ON toggle switch up. Allow one hour for warmup.
0.9978	b. Push the POWER ON indicator button. Check to see if the indicator next to it goes on. If not, repeat step 10a.
0.9990	c. Turn on the power supply:
	(1) Flip toggle switch up.
0.9827	d. Adjust power to 5 volts:
0.9995	(1) Adjust coarse potentiometer.
0.9832	(2) Check reading on meter.
0.9900	e. Check that the timing lines on the recorder are correct:
0.9982	(1) Set selector (4-position switch) on 1 line per second.
0.9929	(2) Run short record check to determine that one timing line per second is indicated:
0.9996	(a) Check manual toggle switch
0.9965	(b) Push 1 SEC ON/OFF button.
0.9968	(c) Turn off recorder.
0.9934	f. Set up the proper traces on the recorder:
0.9980	(1) Pull the recorder half way out of the cabinet.
0.9999	(2) Open the access door on top of the recorder box.

Reliability	Step	
0.9997	(3)	Check the listing of the light spots desired for functions to be read out.
0.9997	(4)	If not set up correctly, disconnect or connect proper pins with adjustment tool (maximum of four pins: two put in, two pulled out).
0.9993	(5)	Check location of spots of light on the record.
0.9999	(6)	If not correct, remove adjustment tool.
0.9983	(7)	Move lights to correct position on the chart.
0.9999	(8)	Move extra spots off chart.
0.9999	(9)	Replace adjustment tool.
0.9999	(10)	Close access door.
0.9980	(11)	Push box back into console.
0.9038	11.	Calibrate the recorder:
0.9993	a.	Check that the timing mark selector is set correctly (4-position selector).
0.9976	b.	Set up the desired pressure on the gauge.
0.9993	c.	Record pressure used on record paper.
0.9965	d.	Push 1 SEC button and ON/ OFF button to start record.
0.9968	e.	Push ON/ OFF button to stop record.
0.9999	f.	Check the record for proper pressure indication.
0.9309	g.	Return to step 11b and repeat steps 11b through 11f in 10-pound increments until the low-pressure regulator locks out; i.e., the line shows no change between the last pressure and the present reading. (Range of values should be from zero to 70 pounds pressure.)
0.9917	h.	When the low-pressure regulator locks out, switch Millipore filters:
0.9985	(1)	Lower all pressure in system to ambient by opening leak-rate valve until gauge reads zero.

Reliability	Step
0.9996	(2) Push one or two solenoid buttons at random to vent off any residual pressure in the system.
0.9936	(3) Switch the Millapore filter from the low-pressure to the high-pressure system:
0.9984	(a) Remove one fitting with two wrenches.
0.9952	(b) Fasten filter to bulkhead fitting.
0.9930	(c) Fasten new filter to high-pressure fitting (see step 3).
0.9930	(d) Fasten filter to pneumatics line to vehicle.
0.9799	i. Return to step 11b and continue calibration of the high-pressure regulator pressure in increments of 100 pounds until regulator locks out. Usually two readings are required: 400 psi and 500 psi.
0.9988	j. Check the record to ensure proper operation of the regulators.
0.9992	12. After calibration of the recorder, detach the record and store it.
	a. Rethread the paper in the recorder.
0.9900	13. Pressurize the system with nitrogen:
0.9976	a. Open the leak-rate high-pressure regulator.
0.9924	b. Observe the high pressure gauge.
0.9929	14. Check the pressure downstream of the regulators.
For reliability values, see step 10f(2)	a. Take an oscillograph reading to verify the pressure:
	(1) Push 1 SEC button.
	(2) Push ON/OFF button.
	(3) Push ON/OFF button again to stop record.
	b. Check the record to verify proper lockout pressures; i.e., no change in lockout lines.

Reliability	Step
0.9976	15. Turn on the high- and low-pressure stabilization control POWER ON switches:
0.9977	a. Flip two toggles switches up.
0.9999	b. Observe indicator going on above switch.
0.9865	16. Purge high- and low-flow nozzles:
0.9970	a. Press solenoid microswitches (16 switches) for no longer than a few seconds each.
0.9999	b. Observe indicator on each switch as it is pressed and listen for swish of gas.
0.9901	17. Pressurize the system to 3500 psi:
For reliability values, see step 11b, 11c.	a. Open the leak-rate high-pressure regulator.
	b. Watch pressure gauge rise until it reads 3500 psi.
	c. Observe traces on the recorder. Traces must rise above lockout levels:
	(1) Write pressure on the record.
	(2) Press 1 SEC button.
	(3) Press ON/ OFF button to start record.
	(4) Press ON/ OFF button to stop record.
0.9908	18. Set up the timers on the calibration panel (to be done twice during the test for regulators for solenoids):
0.9974	a. Check that paper supply on recorder is adequate.
0.9997	b. Check that delay timer is set for more than 0.15 second.
0.9990	c. Check that recorder timer is set to read more than 0.15 second.
0.9990	d. Check that solenoid timer is set to read more than 0.80 second.

Reliability	Step
0.9967	e. Check that the settings on record speed controls are correct:
0.9984	(1) Observe 4-position dial (set at 100).
0.9983	(2) Observe six-button complex (button for 16 inches should be depressed).
0.9990	19. Flip solenoid toggle switch to the timer position (down):
	a. Observe indicator going on.
0.9742	20. Check Standing Instruction 238131, Section 3.3 for proper combination of solenoid switches.
0.9845	21. Record combination of solenoids on record.
0.8996	22. Press combination of solenoid buttons specified in SI 238131 (Section 3.3) and hold them down.
0.9738	a. Input from SI.
0.9239	b. Press and hold buttons.
0.9703	23. Press TIMER START button (at times, two men are required to accomplish this task).
0.8119	24. Repeat steps 22 and 23 for all 20 combinations specified in the SI:
0.9698	a. Check that pressure remains at 3500 psi throughout testing.
0.8372	b. See steps 20 through 23.
0.9971	25. Vent the system pressure to 1000 psi:
0.9976	a. Close leak-rate high-pressure regulator.
0.9999	b. Press solenoids on high-pressure side.

Reliability	Step
0.9996	c. Observe pressure decay on gauge. When pressure is zero, release solenoid buttons.
0.9976	d. Adjust leak-rate regulator to build pressure up to 1000 psi.
0.8119	26. Repeat the sequence of solenoid tests (steps 20 through 25) for 20 sequences.
0.9971	27. Vent system to ambient:
0.9972	a. Open leak-rate valve.
0.9999	b. Press solenoids at random.
0.9975	28. Shift recorder speed to a slower rate:
0.9982	a. Move selector switch to 10 degrees (4-position switch).
0.9993	b. Use a pen to identify the record.
0.9930	29. Run off a short strip of record:
0.9965	a. Press ON/ OFF button to start the recorder.
0.9965	b. Press ON/ OFF button to stop the recorder.
0.9992	30. Remove the record and store it.
0.9991	31. Rethread a new record in the recorder.
0.9976	32. Repressurize the system to 3500 psi:
See step 3d(2) and 3d(9) for reliabilities	a. Open the regulator valve.
	b. Watch gauge until it reads 3500 psi.
	c. Adjust valve to hold this pressure.

Reliability	Step
0.9990	33. Check the position of the solenoid switch.
	a. Switch should be in the down position (on TIME position).
0.9994	34. Check and adjust the recorder channels (See steps 10e and 11g).
0.9991	35. Check SI 238131 for proper solenoid button.
0.9993	36. Record solenoid "A" number on recorder chart.
0.9996	37. Hold down proper solenoid button (these buttons do not follow in order of console placement).
0.9995	38. Press TIME START button on recorder console and release both buttons.
0.9964	39. Perform steps 35 through 38 for all 16 solenoids.
0.9998	40. When test is complete at high pressure, run recorder at slow speed to identify end of record:
0.9924	a. Reset speed dia (4-position dial).
0.9990	b. Flip toggle switch to MANUAL.
0.9994	c. Write identification on record.
0.9995	d. Press ON/ OFF button to start record.
0.9995	e. Press ON/ OFF button to stop record.
0.9947	41. Vent the system to 1000 psi:
For reliabilities see step 25	a. Close leak-rate high-pressure regulator.
	b. Check recorder to determine that it is in manual mode.
	c. Press solenoid buttons at random to speed venting of system.

Reliability	Step
	d. Observe decay of pressure on gauge.
	e. Adjust leak-rate regulator to provide 1000 psi in system.
	f. Check gauge reading for 1000 psi.
0.9968	42. Check to ensure that recorder is ready for low-pressure run:
0.9990	a. Toggle switch in timer mode.
0.9984	b. Speed setting on 64 lines per second.
0.9994	c. Identify run on record with pen.
[illegible].8859	43. Repeat testing of solenoids (steps 36 through 40) for 16 switches.
[illegible].9990	44. Put recorder toggle switch in MANUAL position.
0.9971	45. Vent system to ambient:
0.9976	a. Open leak-rate regulator valve.
0.9995	b. Press high-pressure solenoid buttons at random until gauge reads zero pressure.
[illegible].9992	46. Detach record and store it.

END OF TEST

APPENDIX B

DESCRIPTION OF THE DATA STORE

DATA STORE is an index of electronic equipment operability developed under the supervision of James W. Altman at the American Institute for Research. This index contains quantitative information on the time and reliability of performing various human tasks. The individual tasks are broken up into small segments of behavior that lend themselves to general use in any situation. Examples of small segments of behavior represented in DATA STORE might be: reading a circular scale, reading a label, connecting a cable, turning a crank, or positioning an object. For purposes of quicker evaluation, the tasks are broken down into three categories: input or sensing tasks, mediating or deciding tasks, and output or control tasks.

The numbers used in DATA STORE were gathered from a search of thousands of human engineering studies, most of which involved laboratory research. The error rates obtained from these laboratory studies seemed to be grossly high for a direct estimate of operational or field error rates. Apparently laboratory workers, in order to obtain more statistical confidence in their conclusions, designed tasks to get high error rates whereas, in the operational situation, design was aimed at obtaining the lowest error rate possible. To reconcile these differences, past field studies were examined, and a correction factor was generated that was then applied to all laboratory results to bring them more in line with field experience.

Since the tasks listed in the DATA STORE are not gross ones, they can be combined into units that will closely approximate almost any given task that is to be evaluated. Reliability scores obtained through use of the DATA STORE method are the product of individual reliability estimates. When using the method, one makes the basic assumption that all tasks are independent of each other.

The information obtained from a DATA STORE analysis can be used to pinpoint problem areas because it provides individual scores for all tasks and their elements, as well as a total score. With these data, one can examine the total task for those elements which contribute the greatest amount to unreliability so that corrective attention can be focused on them.

Once corrective actions are proposed, a DATA STORE can be performed on the changes to determine the alteration in task reliability to be expected from the proposed changes. For further information, see Munger, Smith, and Payne (Reference 2).