C-4576

PRELIMINARY INPUT TO THE SPACE SHUTTLE REACTION CONTROL SUBSYSTEM FAILURE DETECTION AND IDENTIFICATION SOFTWARE REQUIREMENTS (UNCONTROLLED)

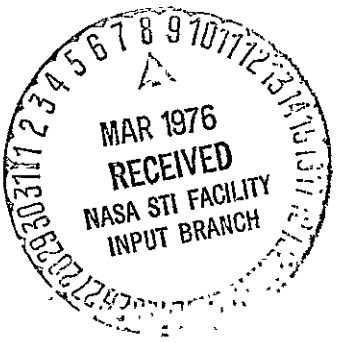
by

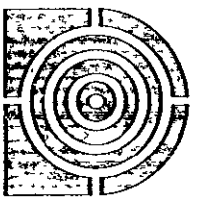
E. Bergmann

January 1976

Space Shuttle Orbiter
Orbital Flight Test
Level C
Functional Subsystem
Software Requirements Document

Part D
Redundancy Management





The Charles Stark Draper Laboratory, Inc.

Cambridge, Massachusetts 02139

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ACKNOWLEDGEMENT

This report was prepared by The Charles Stark Draper Laboratory, Inc., under contract NAS9-13809 with the Johnson Space Center, National Aeronautics and Space Administration. Design of the software algorithm was by Edward Bergmann under the supervision of Steven Croopnick, both of the C. S. Draper Laboratory, Inc., in cooperation with Kenneth Lindsay and Edward Kubiak of the National Aeronautics and Space Administration. Data regarding sensor procurement and RCS implementation was supplied by Don Blevins, and design of the CRT display was by Glen Watkins, both of the National Aeronautics and Space Administration. Rockwell International was responsible for the MDM channelization and procurement. Overall integration of the concept and design was by Kenneth Lindsay, National Aeronautics and Space Administration.

ABSTRACT

The current baseline method and software implementation of the Space Shuttle reaction control subsystem failure detection and identification (RCS FDI) system is presented. This algorithm is recommended for inclusion in the redundancy management (RM) module of the Space Shuttle Guidance, Navigation and Control System. Supporting software is presented, and recommended for inclusion in the system management (SM) and display and control (D&C) systems.

RCS_FDI uses data from sensors in the jets, in the manifold isolation valves, and in the RCS fuel and oxidizer storage tanks. A list of jet failures and fuel imbalance warnings is generated for use by the jet selection algorithm of the on-orbit and entry flight control systems, and to inform the crew and ground controllers of RCS failure status. Manifold isolation valve close commands are generated in the event of failed on or leaking jets to prevent loss of large quantities of RCS fuel.

FOREWORD

The system description is as complete and detailed as current development allows.

Reference 1 presents rationales for the design, a description of hardware sensor devices, and descriptions of nominal operation of RCS FDI.

Section 1 of this report describes the functional requirements of the method. It contains a statement of the objective of RCS FDI, a list of assumptions governing design of the algorithm, the input-output requirements, and a brief functional description of the software.

Section 2 presents the software formulation of RCS FDI. First, a model executive for FDI is given, followed by the eight functional modules of RCS FDI. An assessment is made of core and timing requirements.

Section 3 contains a glossary of variable names in the software.

Supporting data is included in the appendices.

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SECTION 1

SOFTWARE FUNCTIONAL REQUIREMENTS

1.1 Overview

The Flight Control (FC) module controls the attitude and translation of the space shuttle orbiter during the on-orbit mission phase and early in the entry phase by utilizing as effectors the Reaction Control Subsystem (RCS) and/or thrust vector control of the Orbital Maneuvering System (OMS).

In a normal RCS jet firing, the following sequence and delays can be expected:

(1) Turn on

- (a) Issuance of on command by Jet Select.
- (b) Transport to driver - TBD milliseconds.
- (c) Opening of solenoids - < 10 milliseconds.
- (d) Thrust buildup to steady state - ∿20 milliseconds.
- (e) Steady-state thrust.

(2) Turn off

- (a) Issuance of off command by Jet Select.
- (b) Transport to RCS driver - TBD milliseconds.
- (c) Closure of solenoid valves - < 10 milliseconds.
- (d) Thrust tailoff to zero - ∿20 milliseconds.

Several possibilites exist for anomalous behavior in either of these sequences leading up to failure. These include:

- (1) Communication failures.
- (2) Solenoid failures both opening, closing.
- (3) Failure to achieve normal chamber pressure.
- (4) Leakage.

Based on these considerations, failure types are broken up into two groupings, on failures and off failures. Although several subgroupings of these by cause exist, there are but two major types of FDI response; one for all on failures and another for all off failures.

An on failure occurs any time a jet is producing thrust or consuming propellant when not commanded or leaking. Since, in the strictest sense, this would include normal thrust tailoff, an on failure condition must consistently exist for a minimum period of time longer than that of normal thrust tailoff. On failures, then, may include failure of solenoids to close in response to off commands, excessively long tailoffs, or leaks. The current algorithm identifies on failures within 3 seconds.

Off failures are defined as a failure of an RCS thruster to develop thrust in response to an on command from the Jet Select. This could result from communication faults, accidental closure of isolation valves, jamming of either or both of the solenoids in the closed position, or a thruster structural failure. This current method detects off failures and identifies the failed jet in 120 milliseconds.

Nominal chamber-pressure and chamber-temperature histories have been obtained for the RCS jets in vacuum conditions. Changes in these conditions due to atmospheric effects during entry have not yet been determined, so that some parameter modifications in the FDI algorithm may be necessary.

The RCS FDI module will be contained primarily in the RM module, with interacting modules in the SM and D&C modules. Figure 1 shows the relationship of these modules to other GN&C major modules, and to sensors, effectors, controls, and displays.

These modules are scheduled by the Moding, Sequencing, and Control (MSC) software via the Flight Computer Operating System (FCOS).

RCS FDI is accomplished by two procedures in RM, with monitoring of manifold isolation valve positions, fuel/oxidizer ratios in the RCS tanks, and RCS command and feedback data path failures performed by three modules within SM, and crew interaction handled with two modules in D&C.

It is inaccurate, at this time, to refer to the RCS FDI executive as a module, as it is merely a conceptual model of the scheduling of the various RCS FDI modules. In fact, this scheduling will be accomplished by executives for the RM, SM, and D&C modules. However, it is presented here, as design requirements of RCS FDI dictate certain constraints on these executives, which are embodied in the RCS FDI executive.

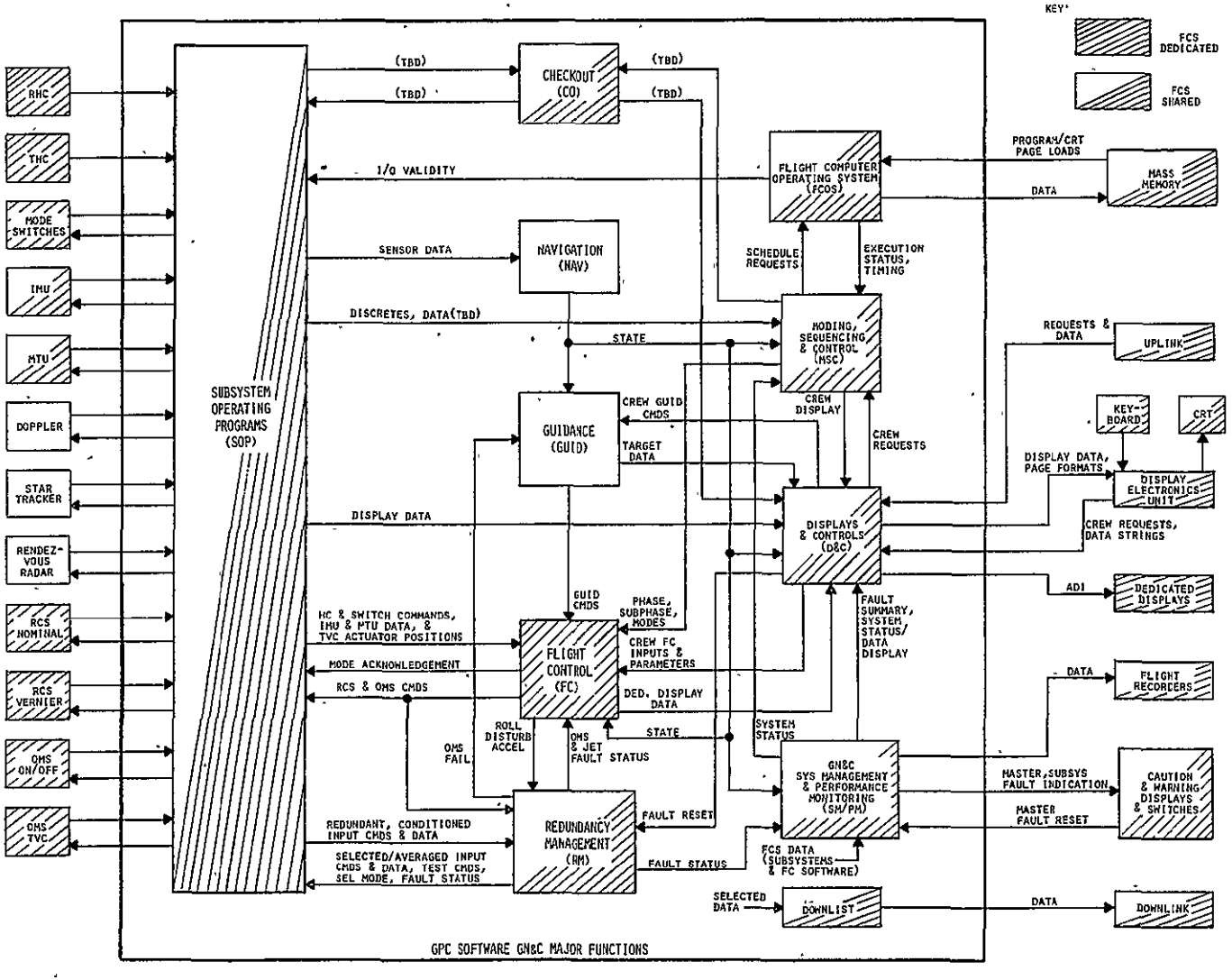


Figure 1. Relation of RM, SM, GN&C, and DC to other flight software and hardware.

The interaction between RCS FDI, other modules, and the flight hardware are shown in Figure 2, and described in some detail in Reference 1.

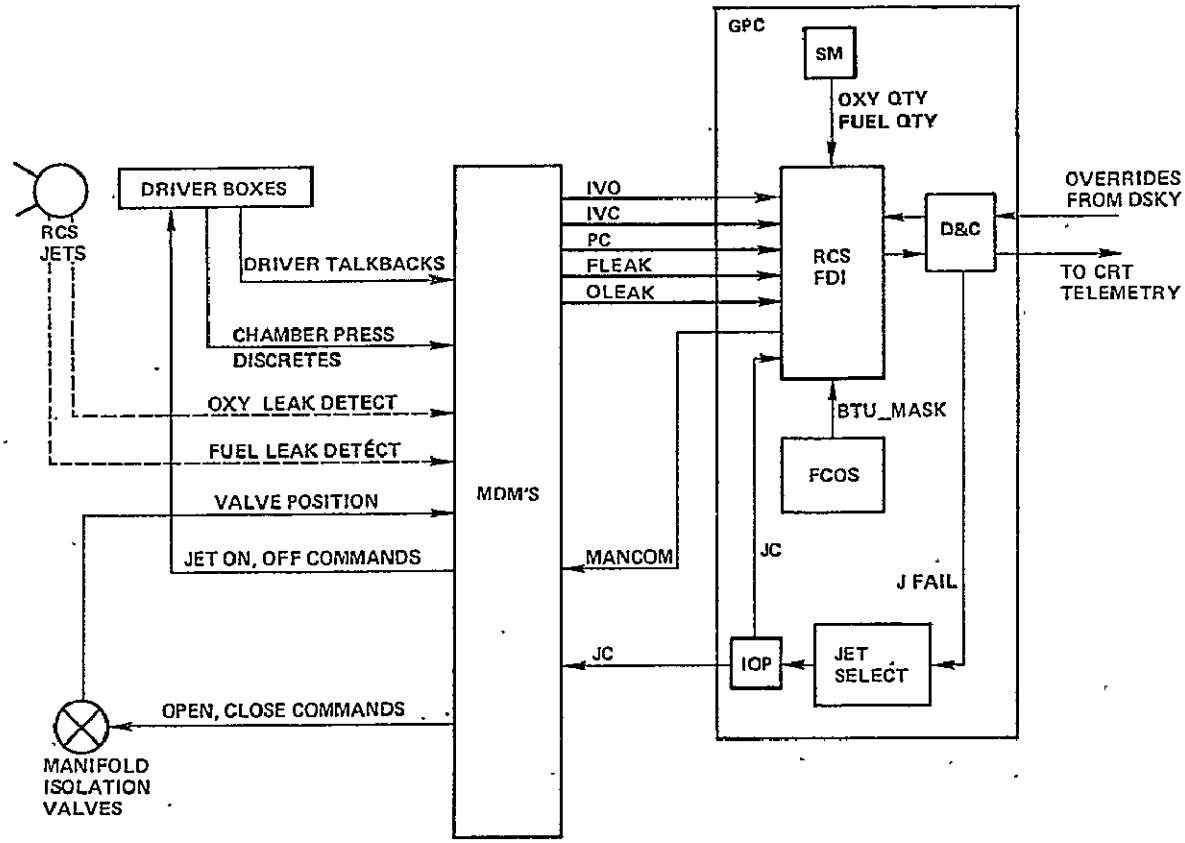


Figure 2. Interaction of FDI with other modules and hardware.

1.2 RCS FDI Executive

The RCS FDI executive, as herein described, is a model for segments of the RM, SM, and D&C executives which will schedule RCS FDI. It is not intended that this be a specific software module, and it must be emphasized that it is presented for engineering purposes only. Actual implementation of software to schedule the various RCS FDI modules will be accomplished as part of the design of the RM, SM, and D&C executives.

In each minor cycle (and major cycle, as major cycles will coincide with each 25th minor cycle), the executive calls MONITOR_BTU_MASK, OFFAIL, and MANIFOLD_CHECK. OFFAIL is scheduled on a minor cycle basis because it is quite fast, and such scheduling enables the most rapid possible detection of off failed RCS jets. MANIFOLD_CHECK is scheduled each minor cycle to meet the requirement that no RCS jet on a given manifold be fired 80 milliseconds after the closure of that manifold's isolation valves. Because of an uncertain lag in valve closure, and because the GPC has no other way of sensing manual manifold closure checks, MANIFOLD_CHECK cannot predict the closure times, and must therefore be executed each minor cycle. Running MONITOR_BTU_MASK each minor cycle prevents the other procedures run each minor cycle from acting on erroneous data by disabling them within a minor cycle of detecting a communication failure.

STORE_FDI_INIT_DATA, OVERRIDE_UPDATE, ONFAIL, and FUEL_IMBALANCE are each run no more frequently than every major cycle to minimize computer burden.

The tradeoff is that STORE_FDI_INIT_DATA provides initialization data which may be as stale as one major cycle, manual interactions with RCS FDI will take one major cycle to be implemented, and on failures of RCS jets will exist for two major cycles before detection. It is held that the first two penalties are readily ignored, and that the cost of running ONFAIL each major cycle (rather than each minor cycle) will be an acceptably small loss of RCS propellant.

Since the rate of depletion of the RCS propellant tanks is so small during normal RCS activity or leaks, FUEL_IMBALANCE can safely be run each major cycle, and it may be safe to execute it at a lower frequency if timing considerations so dictate.

In the presence of a communication fault, the FDI executive inhibits STORE_FDI_INIT_DATA to maintain the initialization data stored on the last major cycle before the communication failure. The executive also inhibits OVERRIDE_UPDATE except on those major cycles when the D&C SOP indicates a new override, inhibit, or enable command has been keyed in. The procedure RECHECK_ONFAILS is only scheduled when ONFAIL indicates a jet is newly on failed and requires checking.

1.3 RCS FDI

1.3.1 Objective

The RCS FDI detects and identifies RCS failures and off-nominal performance, and takes appropriate action. This action consists of sending a list of failed jets to the RCS jet selection algorithm, closing manifold isolation valves where a leak is detected, and informing the crew and ground controllers of RCS performance.

1.3.2 Assumptions

The following assumptions are made about inputs to RCS FDI:

(1) Driver talkbacks, jet commands, chamber-pressure talkbacks, and manifold isolation valve commands and talkbacks will be packed discretes channelized as in Appendix A and available to FDI in the concatenated form shown in Appendix A.

(2) RCS leak detector talkbacks will be available in 16-bit fixed-point format as in Appendix B, and can be treated as bit strings, i.e., operated upon by logical AND.

(3) Inputs from D&C will be packed as described in Appendix A, and preceded by appropriate flags (Section 2.3.3).

The following assumptions are made about RCS FDI output:

(1) Jet fail lists will be produced in packed form, bit assignments jet by jet being as those for jet commands.

(2) Manifold isolation valve commands are packed as in Appendix A.

(3) Interfacing software will be developed to reformat RCS FDI* data for crew display and telemetry.

It is further assumed that the sensors and actuators used by RCS FDI are completely reliable, pending further study.

* This software may be included in a later revision of this document.

1.3.3 Input/Output Requirements

Table 1 lists the interface requirements for RCS FDI.

1.3.3.1 Inputs

Inputs to RCS FDI are:

(1) Copies of packed RCS jet commands concatenated as in Reference 2.

(2) Packed chamber pressure discretes.

(3) Packed driver talkback discretes.

(4) Packed isolation manifold discretes.

(5) Packed manual overrides, inhibits, enables.

(6) RCS fuel and oxidizer tank quantities.

1.3.3.2 Outputs

Outputs of RCS FDI are:

(1) Jet fail lists packed the same way as the input jet commands.

(2) Manifold isolation valve automatic close commands.

(3) Fuel imbalance warning flags.

1.3.4 Functional Description

The RCS FDI algorithm compares packed discretes representing jet commands, jet chamber pressures and jet driver talkbacks, and integers representing jet fuel injector and jet oxidizer injector temperature, to arrive at a list of failed jets. In the event of leaks, it can automatically close manifold isolation valves to prevent the loss of fuel and oxidizer.

1.3.4.1 MONITOR_BTU_MASK

MONITOR_BTU_MASK checks eight discretes which indicate failure status of critical cards in the MDM used to control the RCS jets. When one of these discretes goes on, MONITOR_BTU_MASK inhibits the Jet Select from using the jets commanded via that data path, and issues a close command to the manifold controlled via that card. The state of RCS FDI at the last major cycle before the failure is kept for use in reinitializing FDI after the data path failure. When the flags are all down, reinitialization of RCS FDI using that data is commanded by MONITOR_BTU_MASK.

Table 1. RCS FDI interface requirements.

COMPUTER NAME	SOURCE OR DESTINATION	DESCRIPTION	UNITS	VALUE OR RANGE	SAMPLE RATE (Hz)
INPUTS					
JETCOMA JETCOMB JETCOMC JETCOMD	JET_SELECT	RCS jet commands (packed)	-	ON/OFF	25
MANUAL_OVER-RIDE_A MANUAL_OVER-RIDE_B MANUAL_OVER-RIDE_C MANUAL_OVER-RIDE_D	D&C	Request flags to reenable but inhibit further FDI on certain RCS jets (packed)	-	ON/OFF	1
INHIBIT_A INHIBIT_B INHIBIT_C INHIBIT_D	D&C	Request flags to disable certain RCS jets (packed)	-	ON/OFF	1
AUT_OVER-RIDE_A AUT_OVER-RIDE_B AUT_OVER-RIDE_C AUT_OVER-RIDE_D	D&C	Request flags to reenable and continue FDI on certain RCS jets (packed)	-	ON/OFF	1
CHANGE_OVERRIDE_STATUS	D&C	Flag indicating new crew requests to override, inhibit, or reenable certain jets	-	ON/OFF	1
IVOA, IVOB IVOC, IVOD	Hardware*	Manifold isolation valve OPEN talkbacks	-	ON/OFF	25
FLEAK	Hardware*	RCS fuel leak detector outputs	°F	TBD	1
OLEAK	Hardware*	RCS oxidizer leak detector outputs	°F	TBD	1
DRIVERA DRIVERB DRIVERC DRIVERD	Hardware*	RCS jet driver talkbacks (packed)	-	ON/OFF	1
PRESSA PRESSB PRESSC PRESSD	Hardware*	RCS chamber pressure sensor talkbacks (packed)	-	ON/OFF	25

*Pending design of IOPs

Table 1. RCS FDI interface requirements (Cont.)

COMPUTER NAME	SOURCE OR DESTINATION	DESCRIPTION	UNITS	VALUE OR RANGE	SAMPLE RATE (Hz)
MINOR_CYCLE	MS&C	Flag indicating minor cycle	-	ON/OFF	25
MAJOR_CYCLE	MS&C	Flag indicating major cycle	-	ON/OFF	25
OXY_QUANTITY	RCS SM	RCS oxidizer quantity remaining in tanks each module	Percent	0-109	1
FUEL_QUANTITY	RCS SM	RCS fuel quantity remaining in tanks each module	Percent	0-109	1
BTU_FF01_13 BTU_FF01_05 BTU_FF02_13 BTU_FF02_05 BTU_FA01_10 BTU_FA01_02 BTU_FA03_10 BTU_FA03_02	FCOS	Flags indicating failure of various MDM data paths	-	ON/OFF	25
INIT_OVER-RIDE_UPDATE	MS&C, MONITOR_BTU_MASK	Initialization flag for override update	-	ON/OFF	1
INIT_OFFAIL		Initialization flag for OFFAIL	-	ON/OFF	25
INIT_ONFAIL		Initialization flag for ONFAIL	-	ON/OFF	1
OUTPUTS					
MANCOMA MANCOMB MANCOMC MANCOMD	Hardware*	Automatic manifold close commands	-	ON/OFF	1
JFAILA JFAILB JFAILC JFAILD	Jet Select	RCS jet failure list	-	ON/OFF	25
MIN_QUANTITY	CRT SOP	Lesser of fuel, oxidizer quantities each RCS module	Percent	0-109	1
FUEL_IMBALANCE_FLAG	CRT SOP	Flag indicating fuel/oxidizer ratio out of spec each RCS module	-	ON/OFF	1

*Pending design of IOPs.

1.3.4.2 STORE_FDI_INIT_DATA

STORE_FDI_INIT_DATA snapshots the failure list, the overrides from crew input, and the automatic manifold isolation valve close commands each major cycle, for use in reinitializing RCS FDI after an MDM card failure. Since it is inhibited in the presence of the failure, the data it provides for reinitialization will not reflect any errors in RCS FDI due to data errors caused by the failure.

1.3.4.3 OVERRIDE_UPDATE

OVERRIDE_UPDATE receives crew requests to inhibit, reenable, and manually override RCS fail status. It ensures that mutually exclusive requests are not implemented, and builds a list of which jets are to be added to the fail list, and which are to be deleted due to crew requests.

1.3.4.4 OFFAIL

OFFAIL detects failures of jets to fire in response to on commands from the jet selection software. It compares these on commands with chamber pressure discretes generated by pressure sensors and level detection equipment in the hardware. When a jet is commanded on but shows no chamber pressure for three consecutive minor cycles, OFFAIL adds it to the fail list, unless it is manually overridden by the crew.

1.3.4.5 ONFAIL

ONFAIL detects leaks in RCS jets, and jet firings occurring in the absence of jet on commands (i.e., failures to shut off). ONFAIL first compares the temperature of the fuel and oxidizer injectors with a 30°F threshold. If either temperature is below this valve, or if the driver talkback is on and the jet command is off, for two consecutive major cycles, ONFAIL adds the jet to the fail list, and flags it for recheck.

1.3.4.6 RECHECK_ONFAILS

One major cycle after ONFAIL flags jets, they are checked for driver on talkbacks or leaks by RECHECK_ONFAILS. If those jets continue to show leaks or drivers on, RECHECK_ONFAILS issues a command to close the isolation valve on the manifold feeding fuel and oxidizer to those jets.

1.3.4.7 MANIFOLD_CHECK

MANIFOLD_CHECK examines the manifold isolation valve open talkbacks each minor cycle. If one such talkback was on (open) but goes off indicating partial or total closure of the valve, MANIFOLD_CHECK copies the failure status of the jets on that manifold, then adds all the jets on that manifold to the fail list. If one such talkback goes from off (closed) to on, MANIFOLD_CHECK deletes from the fail list those jets on the manifold that were not failed prior to manifold closure.

1.3.4.8 FUEL_IMBALANCE

FUEL_IMBALANCE checks the percentage of fuel and oxidizer remaining in the tanks of each of three RCS modules. If the difference between the fuel percentage remaining and the oxidizer percentage remaining exceeds 1.6, FUEL_IMBALANCE sets a warning flag for that RCS module which is displayed to the crew. The procedure then picks the lesser of fuel or oxidizer in each module and provides it as the critical quantity to the crew display.

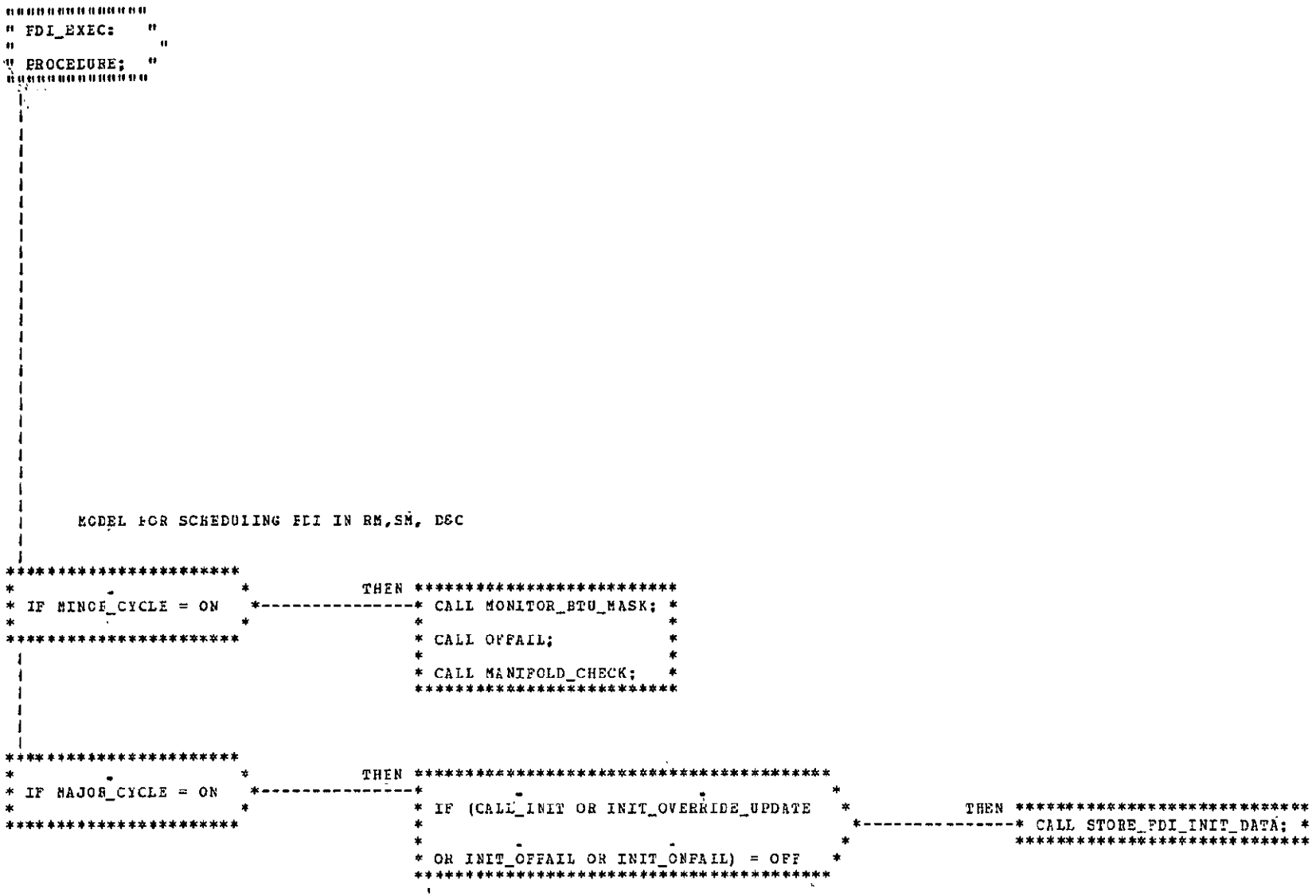
SECTION 2

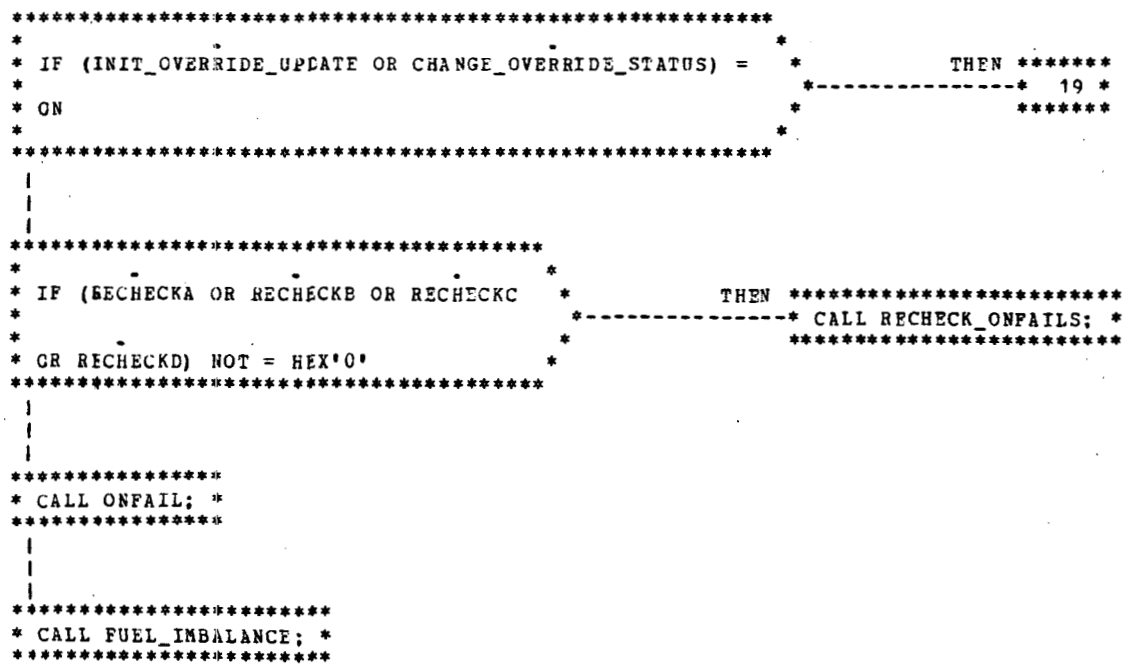
SOFTWARE FORMULATION

2.1 RCS FDI EXECUTIVE (see automatic flowchart)

The software herein described is only a working model for software in the RM, SM, and D&C executives and is only presented as a conceptual model.

The FDI EXECUTIVE will either be executed each minor cycle, or will check a flag which will trigger it each minor cycle. The latter is implemented for generality. On a minor cycle, the FDI EXECUTIVE calls MONITOR_BTU_MASK, OFFAIL, and MANIFOLD_CHECK. A flag indicating a major cycle is next checked. On a major cycle, STORE_FDI_INIT_DATA and OVERRIDE_UPDATE are called, subject to conditions described in Section 1.2. FUEL_IMBALANCE is called every major cycle.



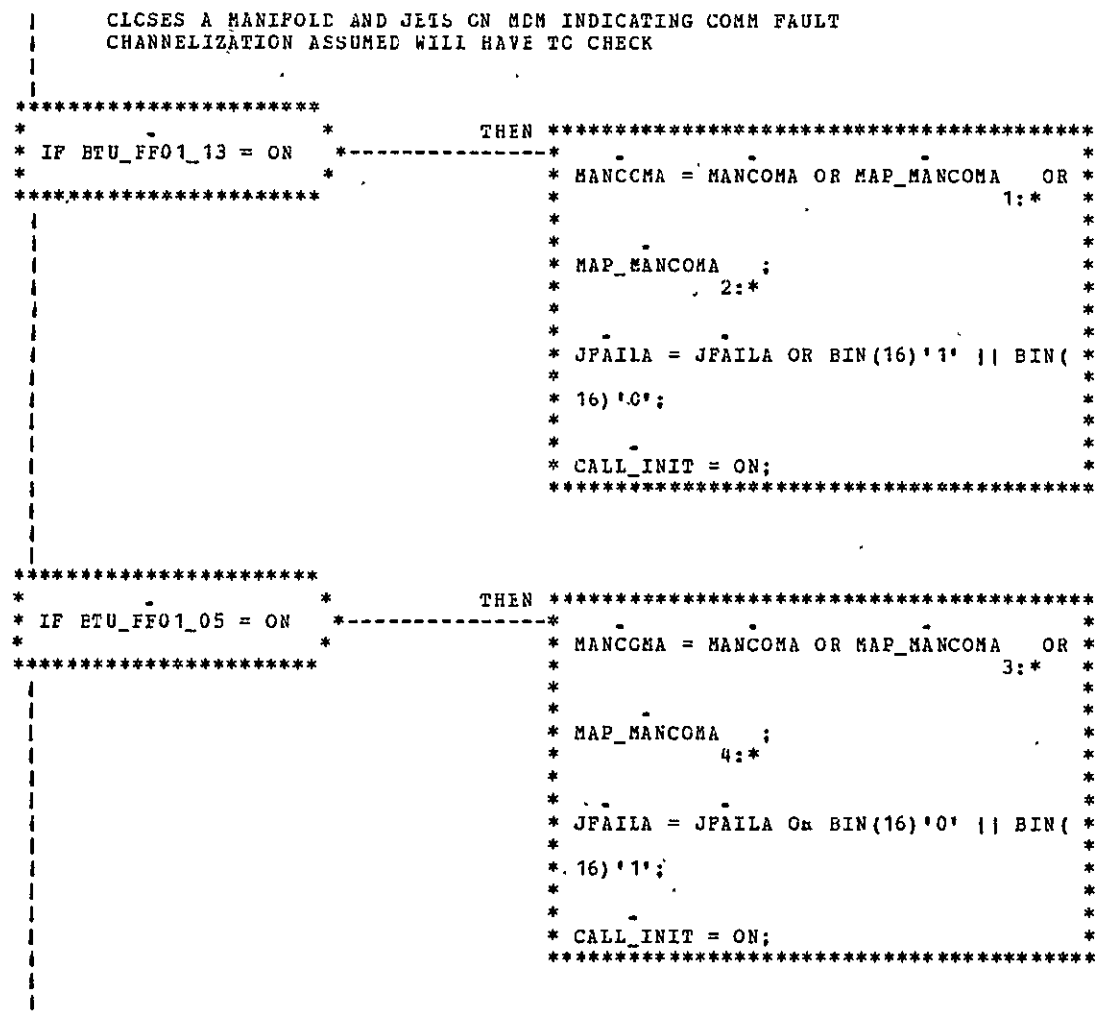

IF (INIT_OVERRIDE_UPDATE OR CHANGE_OVERRIDE_STATUS) =
ON
THEN
19
IF (RECHECKA OR RECHECKB OR RECHECKC
OR RECHECKD) NOT = HEX'0'
THEN
CALL RECHECK_ONFAILS;
CALL ONFAIL;
CALL FUEL_IMBALANCE;

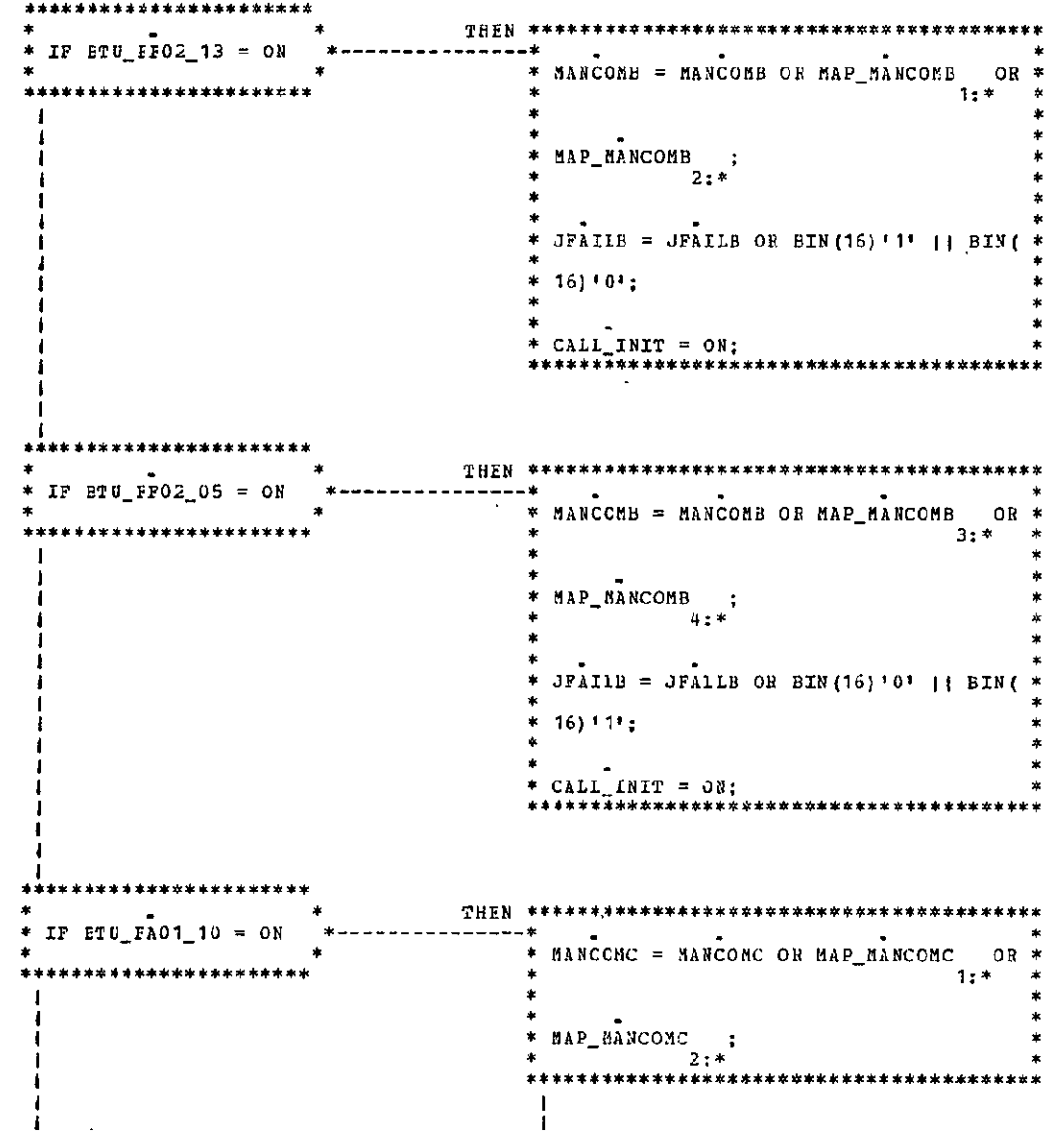
2.2 RCS FDI

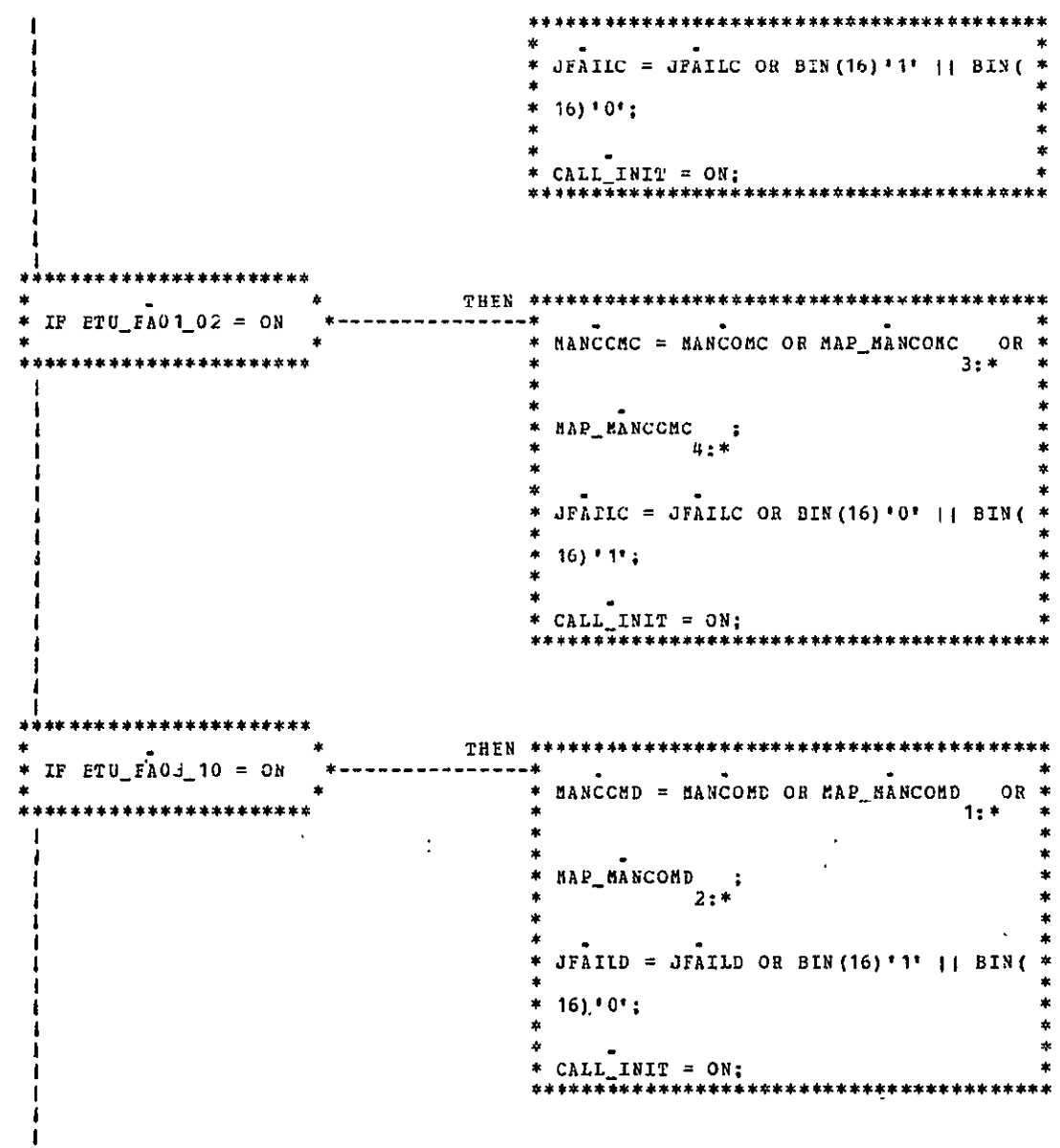
2.2.1 MONITOR_BTU_MASK (see automatic flowchart)

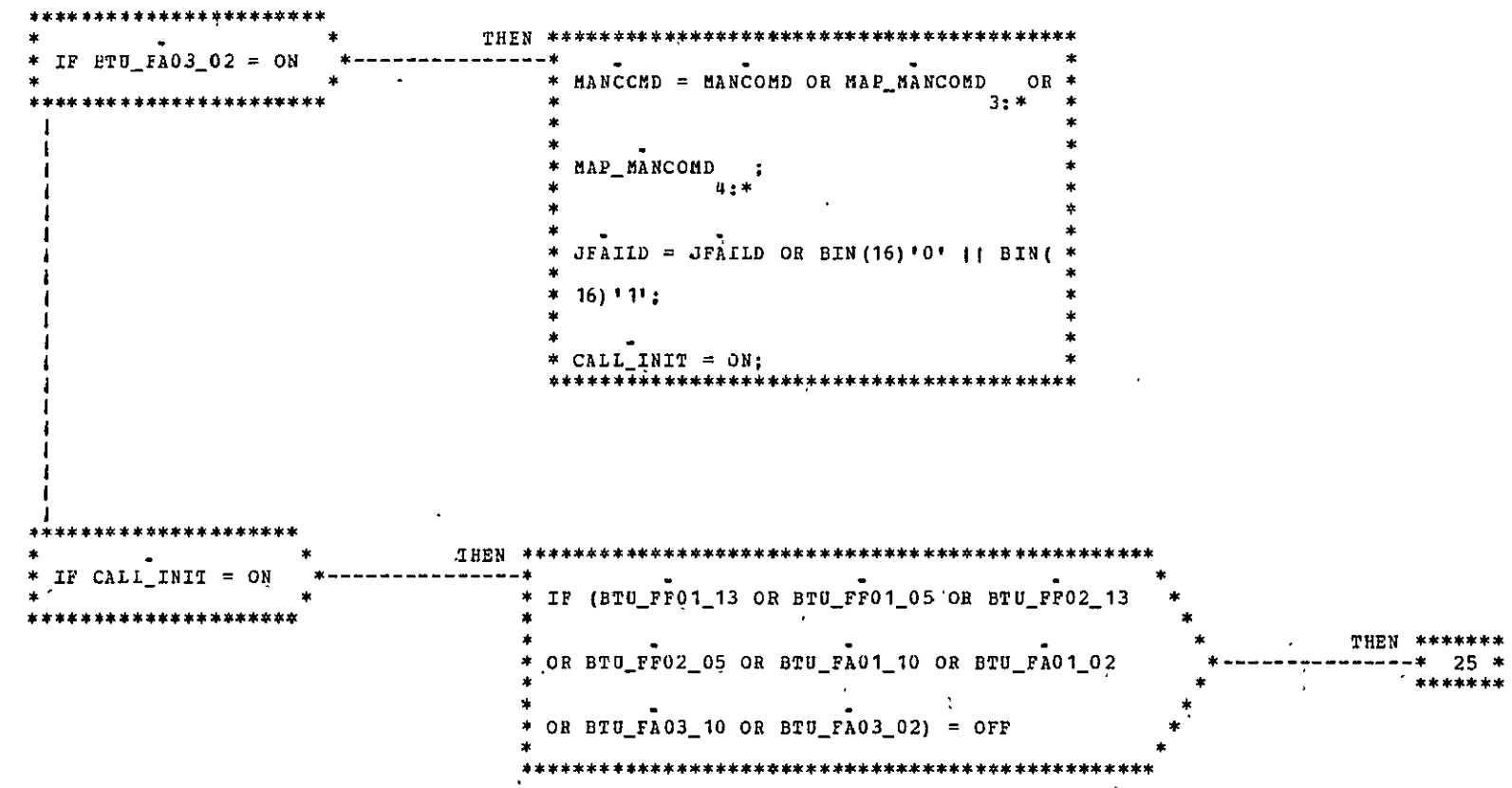
MONITOR_BTU_MASK checks eight flags called BTU_MASKs, which indicate failures in the hardware communication paths between the GPC and the RCS hardware. Each flag corresponds to an MDM, and if it is on, is assumed to indicate failure of all data paths on that MDM.

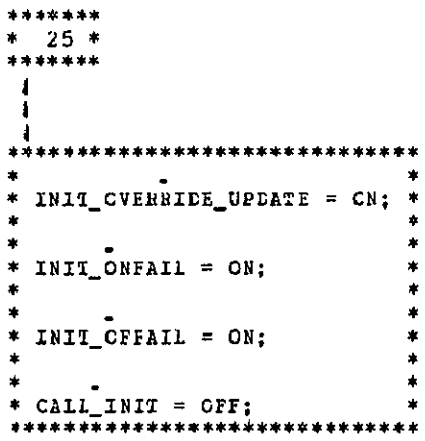
When a BTU_MASK goes on, the procedure adds the jets commanded through that MDM to the fail list, and issues a close command to the manifold isolation valve controlled through that MDM. The temporary flag CALL_INIT is set on. MONITOR_BTU_MASK then checks CALL_INIT. If it is on, the procedure checks the eight BTU_MASKs. When all eight are again off, the procedure sets initialization flags for OVERRIDE_UPDATE, ONFAIL, and OFFAIL, and sets CALL_INIT off.


CLOSES A MANIFOLD AND JETS ON MDM INDICATING COMM FAULT
CHANNELIZATION ASSUMED WILL HAVE TO CHECK
IF BTU_FF01_13 = ON
THEN
MANCOMA = MANCOMA OR MAP_MANCOMA 1:
OR
MAP_MANCOMA ; 2:
JFAILA = JFAILA OR BIN(16)'1' || BIN(16)'0';
CALL_INIT = ON;
IF BTU_FF01_05 = ON
THEN
MANCOMA = MANCOMA OR MAP_MANCOMA 3:
OR
MAP_MANCOMA ; 4:
JFAILA = JFAILA OR BIN(16)'0' || BIN(16)'1';
CALL_INIT = ON;



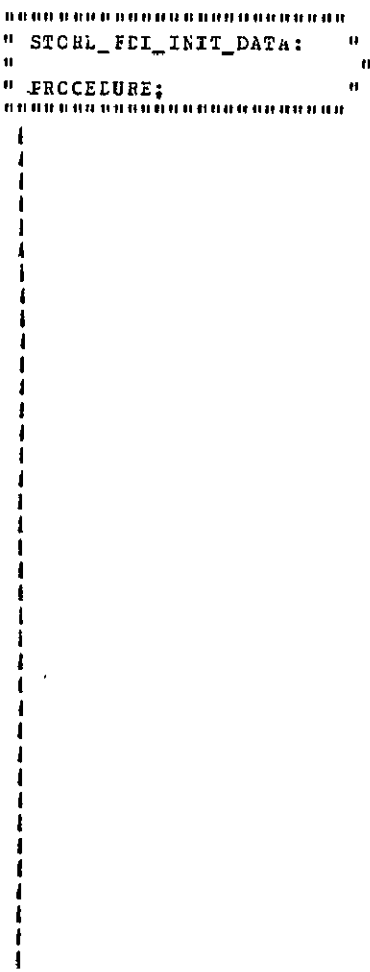

JFAILC = JFAILC OR BIN(16)'1' || BIN(
16)'0';
CALL_INIT = ON;
IF ETU_FA01_02 = ON
THEN
MANCCMC = MANCOMC OR MAP_MANCOMC OR
3:*
MAP_MANCOMC ;
4:*
JFAILC = JFAILC OR BIN(16)'0' || BIN(
16)'1';
CALL_INIT = ON;
IF ETU_FA03_10 = ON
THEN
MANCCMD = MANCOMD OR MAP_MANCOMD OR
1:*
MAP_MANCOMD ;
2:*
JFAILD = JFAILD OR BIN(16)'1' || BIN(
16)'0';
CALL_INIT = ON;

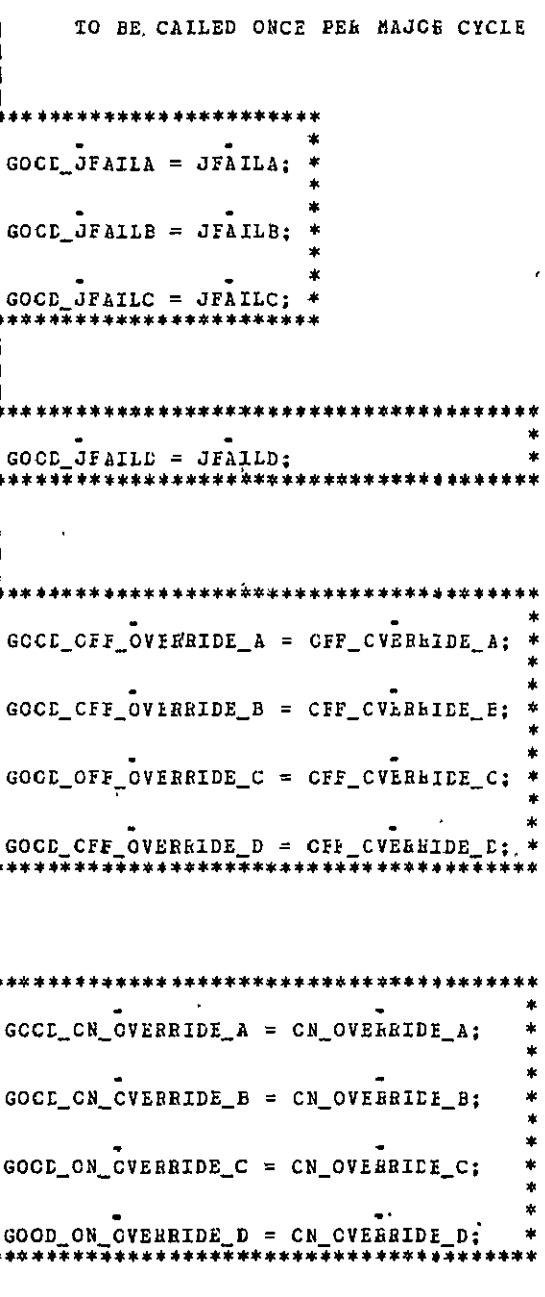

IF BTU_FA03_02 = ON
THEN
MANCCMD = MANCOMD OR MAP_MANCOMD OR 3:*
MAP_MANCOMD ;
4:*
JFAILD = JFAILD OR BIN(16)'0' || BIN(*
16)'1';
CALL_INIT = ON;
IF CALL_INIT = ON
THEN
IF (BTU_FF01_13 OR BTU_FF01_05 OR BTU_FF02_13
OR BTU_FF02_05 OR BTU_FA01_10 OR BTU_FA01_02
OR BTU_FA03_10 OR BTU_FA03_02) = OFF
THEN
25

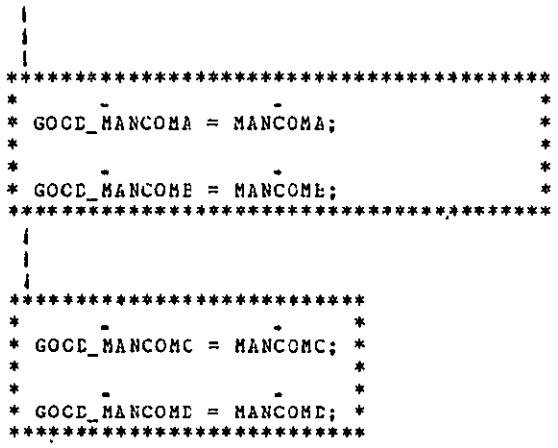

25
INIT_OVERRIDE_UPDATE = ON;
INIT_ONFAIL = ON;
INIT_OFFAIL = ON;
CALL_INIT = OFF;

2.2.2 STORE_FDI_INIT_DATA (see automatic flowchart)

STORE_FDI_INIT_DATA maintains a record of the jet failure list, the overrides, and the automatic manifold isolation valve close commands. Each time it is called, the procedure copies these items into separate storage locations, used only for initialization of the RCS FDI software.


STORE_FDI_INIT_DATA:
PROCEDURE;




GOOD_MANCOMA = MANCOMA;
GOOD_MANCOMB = MANCOMB;
GOOD_MANCOMC = MANCOMC;
GOOD_MANCOMD = MANCOMD;

2.2.3 OVERRIDE_UPDATE (see automatic flowchart)

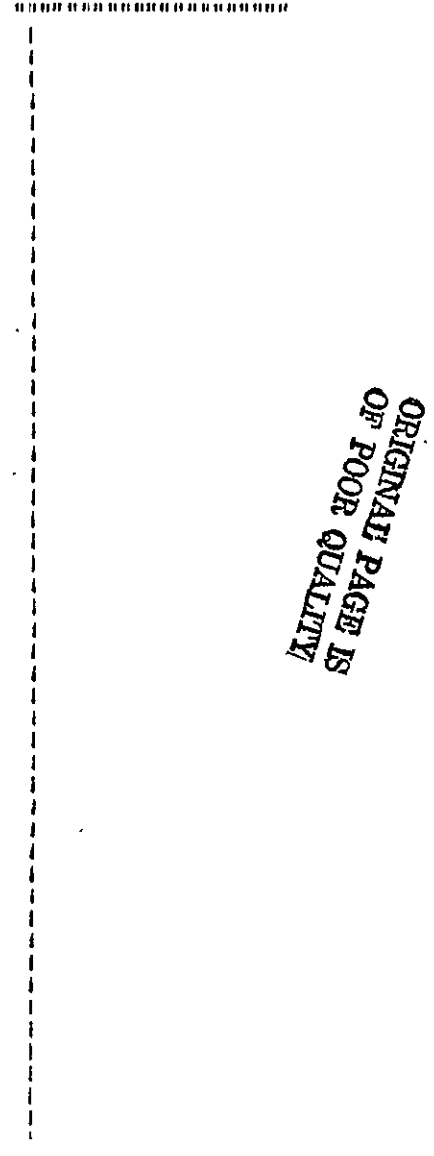
This procedure implements crew inputs to inhibit, override, and reenable RCS jets.

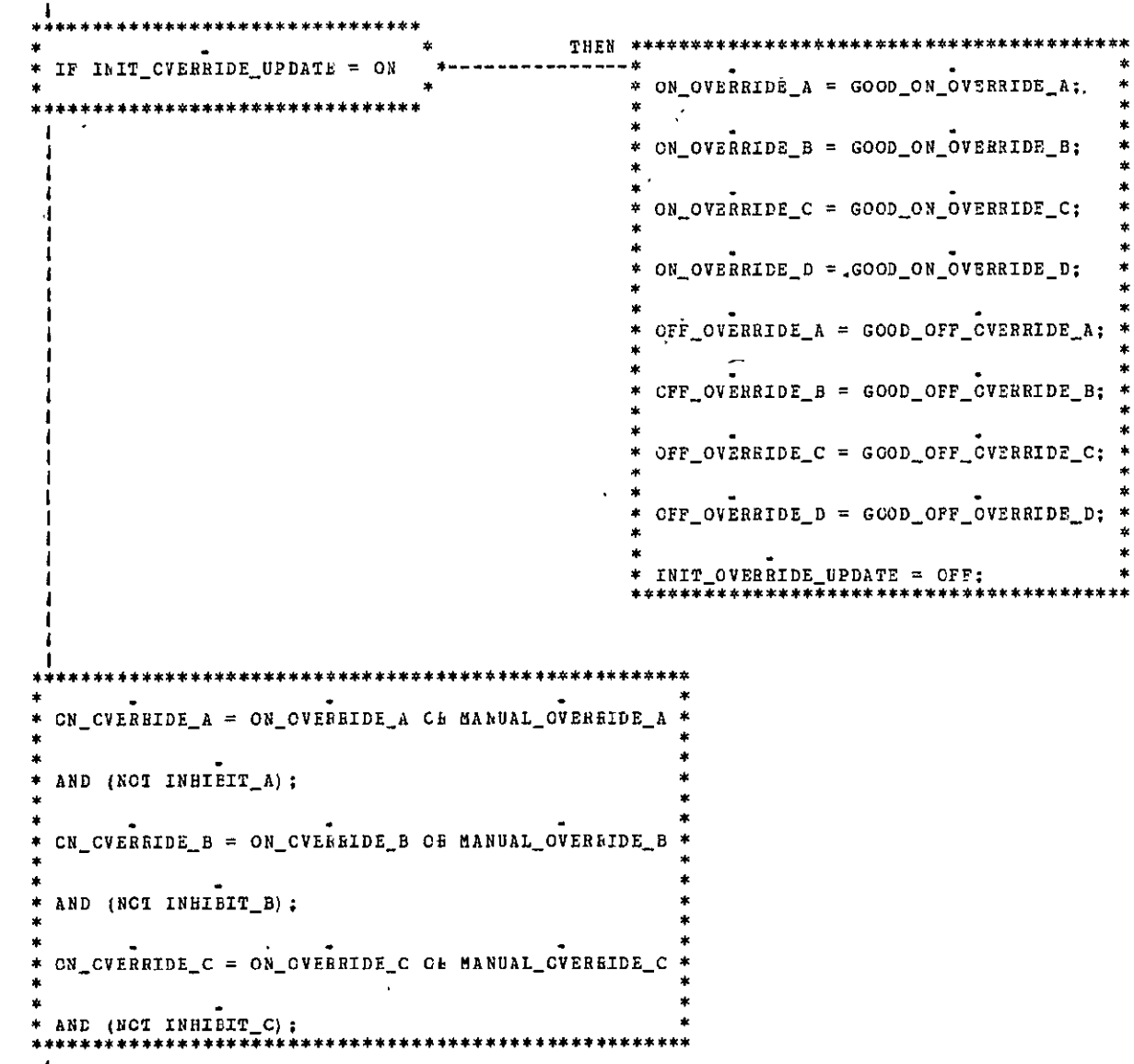
Initialization of this procedure consists of replacing the current override lists with copies of the lists provided by STORE_FDI_INIT_DATA.

Each time it is called, the procedure generates the lists ON_OVERRIDE and OFF_OVERRIDE for use by other RCS FDI software, and modifies the fail list to include temporary enables. ON_OVERRIDE _A, _B, _C, and _D are updated by ORing ON_OVERRIDE with the requests to reenable jets (NEW_ON_OVERRIDE) regardless of FDI, then ANDing the result with the complement of the inhibit requests (NEW_OFF_OVERRIDE), thus including the new requests to reenable jets, and preventing a conflict with the new requests to inhibit jets.

Similarly, OFF_OVERRIDE _A, _B, _C, and _D are updated by ORing OFF_OVERRIDE with the requests to inhibit jets, then ANDing the result with the complement of requests to reenable jets, thus including new inhibits, and preventing conflicts with new reenables.

JFAIL is then modified to incorporate requests to reenable jets, while still performing FDI on them. This is done by ORing JFAIL with these requests (TEMP_ON_OVERRIDE).




IF INIT_OVERRIDE_UPDATE = ON
THEN
ON_OVERRIDE_A = GOOD_ON_OVERRIDE_A;
ON_OVERRIDE_B = GOOD_ON_OVERRIDE_B;
ON_OVERRIDE_C = GOOD_ON_OVERRIDE_C;
ON_OVERRIDE_D = GOOD_ON_OVERRIDE_D;
OFF_OVERRIDE_A = GOOD_OFF_OVERRIDE_A;
OFF_OVERRIDE_B = GOOD_OFF_OVERRIDE_B;
OFF_OVERRIDE_C = GOOD_OFF_OVERRIDE_C;
OFF_OVERRIDE_D = GOOD_OFF_OVERRIDE_D;
INIT_OVERRIDE_UPDATE = OFF;
CN_OVERRIDE_A = ON_OVERRIDE_A OR MANUAL_OVERRIDE_A
AND (NOT INHIBIT_A);
CN_OVERRIDE_B = ON_OVERRIDE_B OR MANUAL_OVERRIDE_B
AND (NOT INHIBIT_B);
CN_OVERRIDE_C = ON_OVERRIDE_C OR MANUAL_OVERRIDE_C
AND (NOT INHIBIT_C);

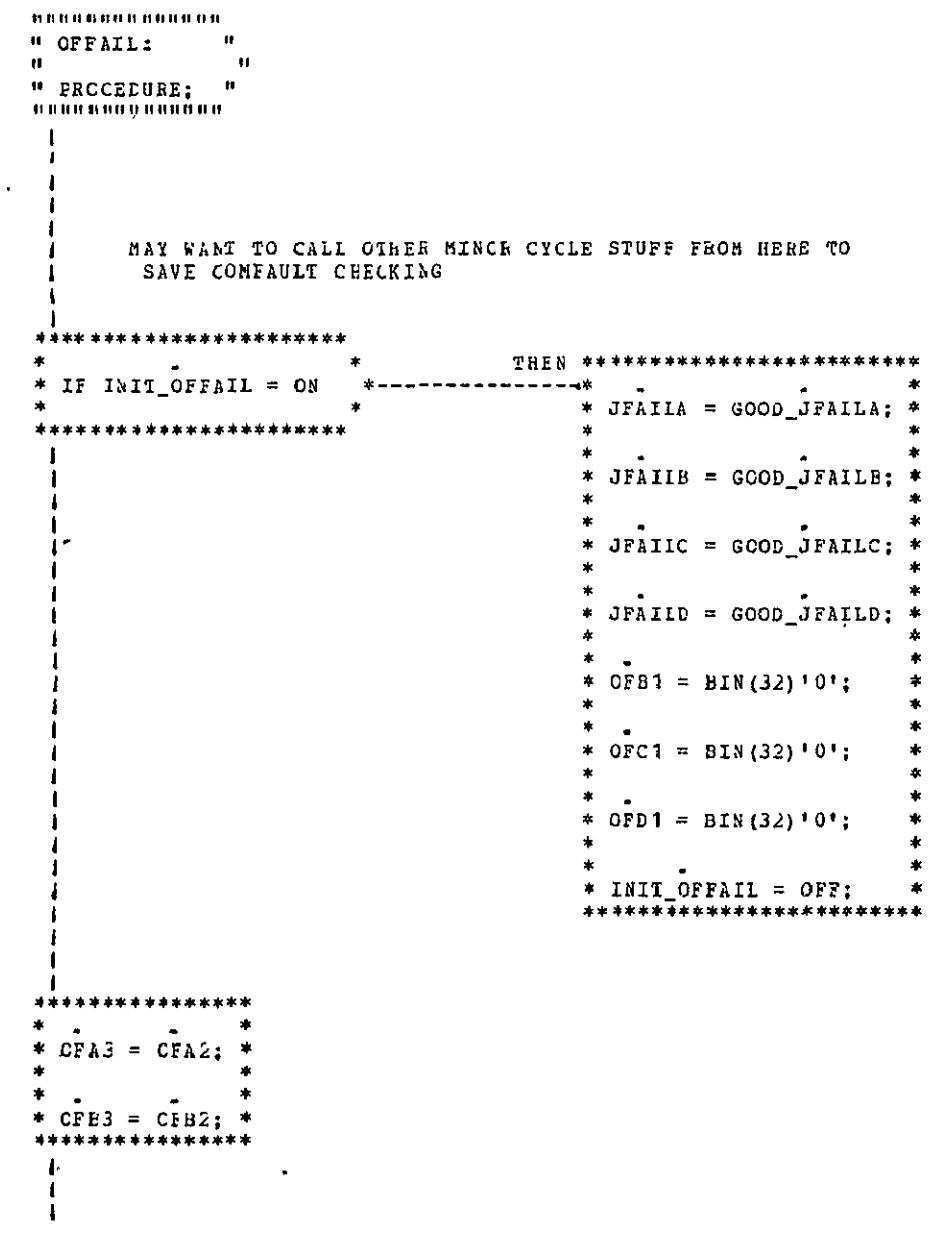
```
*****************************************************
*                                                   *
* ON_OVERRIDE_D = ON_OVERRIDE_D OR MANUAL_OVERRIDE_D *
*                                                   *
*                                                   *
* AND (NOT INHIBIT_D);                              *
*                                                   *
*                                                   *
* OFF_OVERRIDE_A = OFF_OVERRIDE_A OR INHIBIT_A      *
*                                                   *
*                                                   *
* AND (NOT MANUAL_OVERRIDE_A);                      *
*                                                   *
*                                                   *
* OFF_OVERRIDE_B = OFF_OVERRIDE_B OR INHIBIT_B      *
*                                                   *
*                                                   *
* AND (NOT MANUAL_OVERRIDE_B);                      *
*                                                   *
*                                                   *
* OFF_OVERRIDE_C = OFF_OVERRIDE_C OR INHIBIT_C      *
*                                                   *
*                                                   *
* AND (NOT MANUAL_OVERRIDE_C);                      *
*                                                   *
*                                                   *
* OFF_OVERRIDE_D = OFF_OVERRIDE_D OR INHIBIT_D      *
*                                                   *
*                                                   *
* AND (NOT MANUAL_OVERRIDE_D);                      *
*                                                   *
*                                                   *
* JFAILA = JFAILA AND (NOT AUT_OVERRIDE_A);         *
*                                                   *
*                                                   *
* JFAILB = JFAILB AND (NOT AUT_OVERRIDE_B);         *
*                                                   *
*                                                   *
* JFAILC = JFAILC AND (NOT AUT_OVERRIDE_C);         *
*                                                   *
*                                                   *
* JFAILD = JFAILD AND (NOT AUT_OVERRIDE_D);         *
*                                                   *
*                                                   *
* CHANGE_OVERRIDE_STATUS = OFF;                     *
*****************************************************
```

2.2.4 OFFAIL (see automatic flowchart)

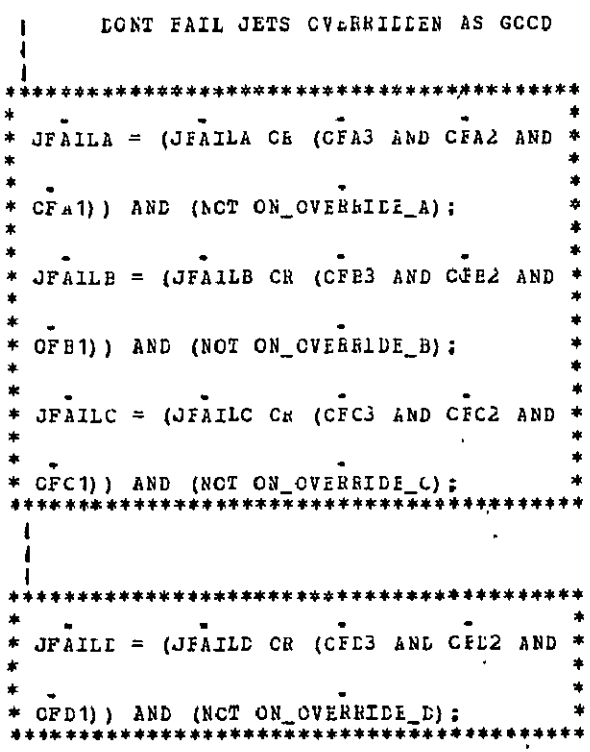
OFFAIL detects failures of jets to fire in response to "ON" commands from the GPC.

Upon initialization, OFFAIL replaces the jet fail list with the fail list stored by STORE_FDI_INIT_DATA, and zeroes the first slot in its pushdown list.

Each time it is called, OFFAIL first advances its three-level pushdown lists OFA, OFB, OFC, and OFD. That is, the jets in the second slot are moved into the third slot, and those in the first slot are moved into the second. OFFAIL then moves into the first slot those jets which are commanded on but whose pressure transducer talkbacks are off. OFFAIL adds to the jet fail list those jets which appear in all three slots by ORing those three slots with the fail list. Finally, OFFAIL implements the reenable command by ANDing the jet fail list with the complement of ON_OVERRIDE.



```
*****************************************
*  .     .                                *
* CFC3 = CFC2;                            *
*                                         *
*  .     .                                *
* OFD3 = CFD2;                            *
*                                         *
*  .     .                                *
* CFA2 = CFA1;                            *
*                                         *
*  .     .                                *
* CFB2 = CFB1;                            *
*                                         *
*  .     .                                *
* CFC2 = CFC1;                            *
*                                         *
*  .     .                                *
* CFD2 = CFD1;                            *
*                                         *
*  .     .           .                    *
* CFA1 = JETCCMA AND (NCT PRESSA);        *
*                                         *
*  .     .           .                    *
* OFB1 = JETCCMB AND (NCT PRESSB);        *
*                                         *
*  .     .           .                    *
* CFC1 = JETCCMC AND (NCT PRESSC);        *
*                                         *
*  .     .           .                    *
* OFD1 = JETCCMD AND (NCT PRESSD);        *
*****************************************
```


DONT FAIL JETS OVERRIDDEN AS GOOD
JFAILA = (JFAILA OR (CFA3 AND CFA2 AND CFA1)) AND (NOT ON_OVERRIDE_A);
JFAILB = (JFAILB OR (CFB3 AND CFB2 AND CFB1)) AND (NOT ON_OVERRIDE_B);
JFAILC = (JFAILC OR (CFC3 AND CFC2 AND CFC1)) AND (NOT ON_OVERRIDE_C);
JFAILD = (JFAILD OR (CFD3 AND CFD2 AND CFD1)) AND (NOT ON_OVERRIDE_D);

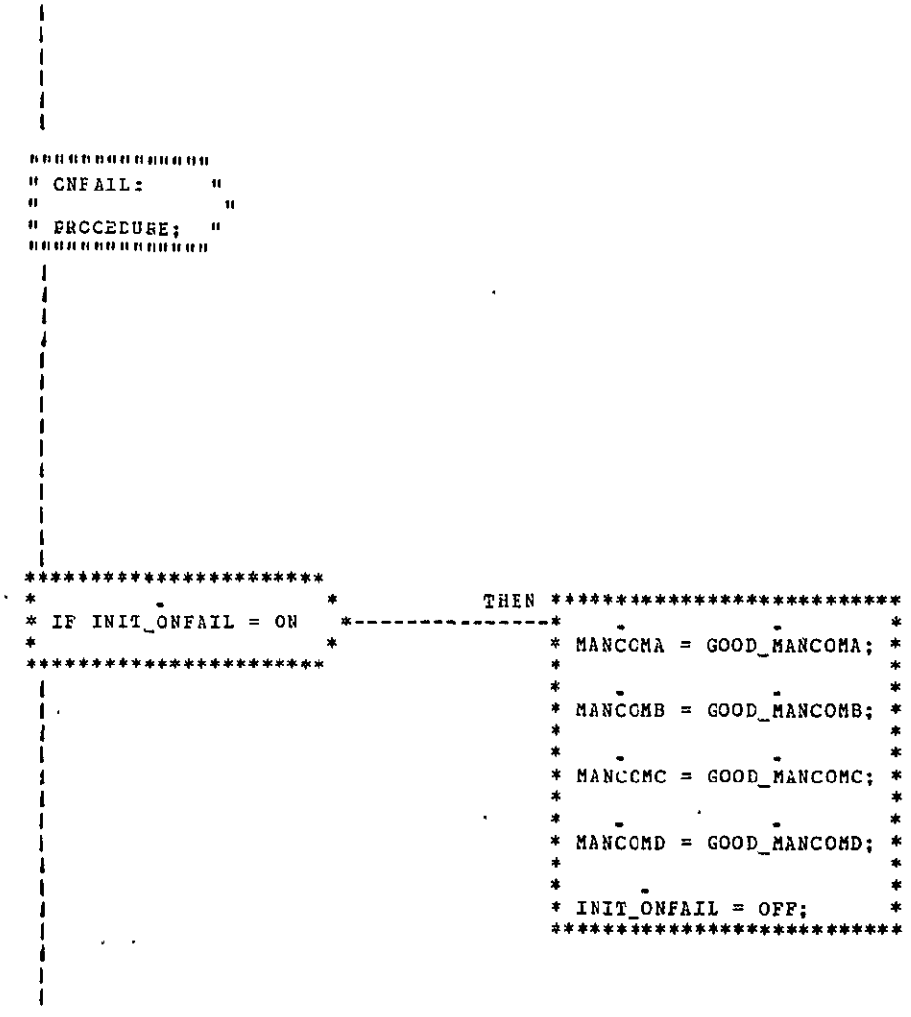
2.2.5 ONFAIL (see automatic flowchart)

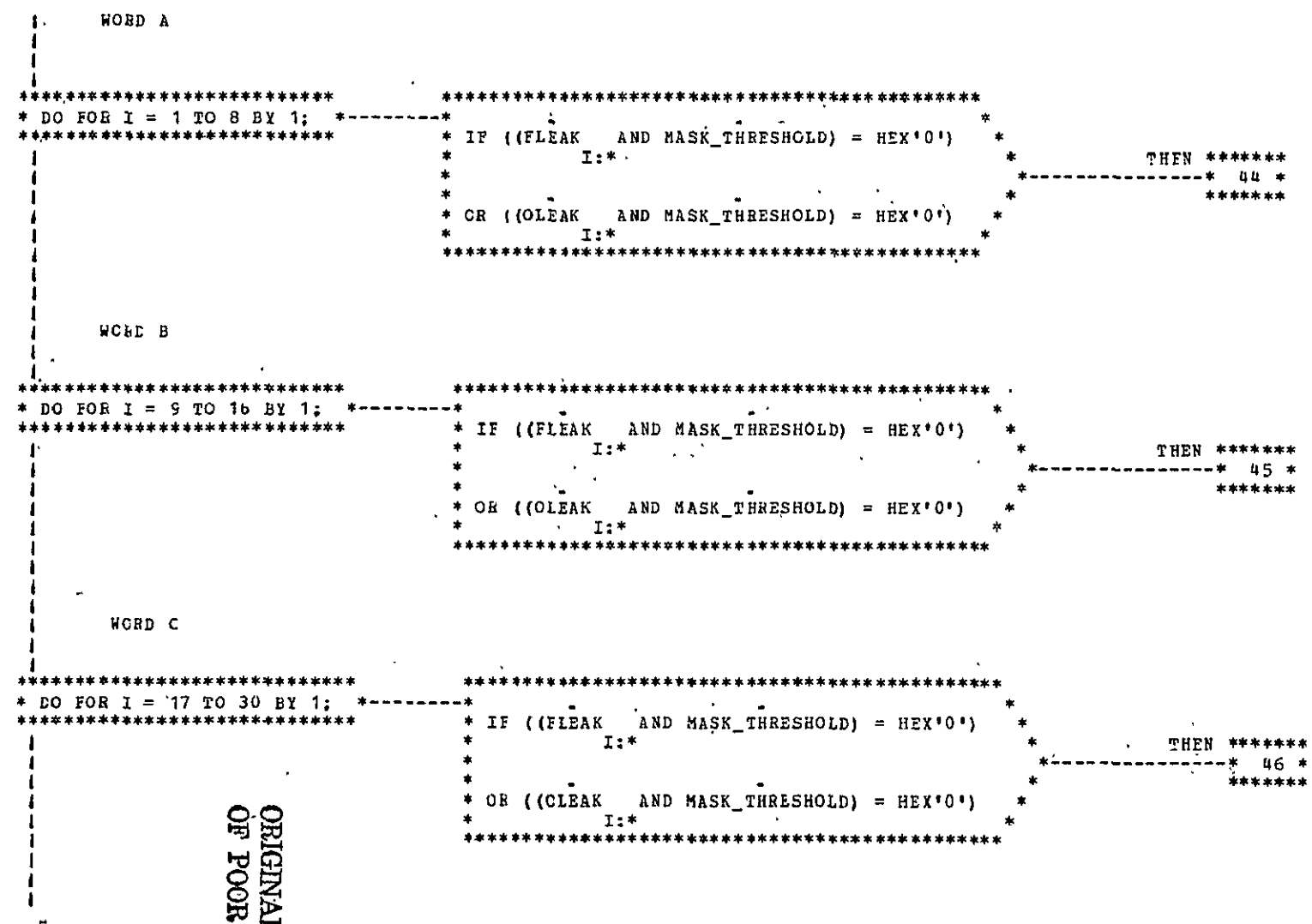
ONFAIL detects failures of jets to shut off in response to off commands, spurious RCS firings, and RCS fuel and oxidizer leaks within the jets.

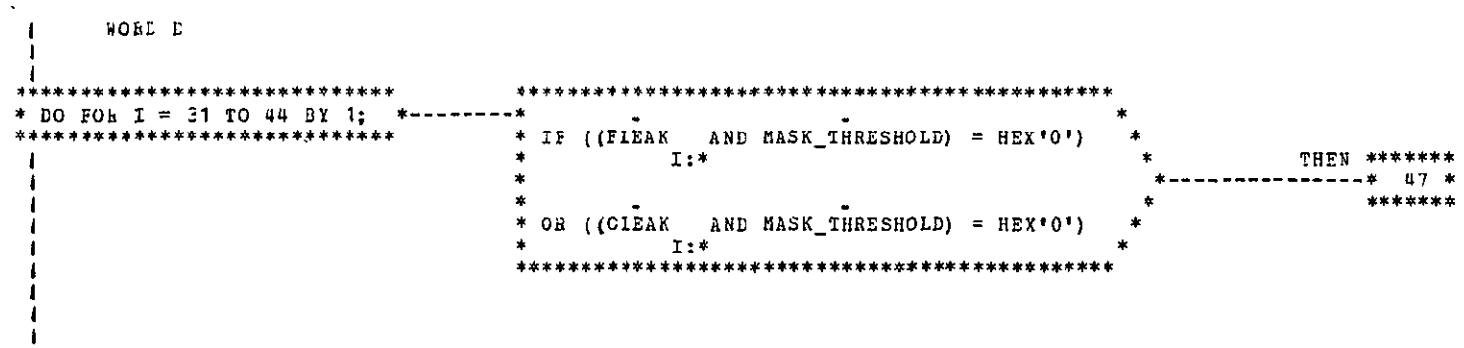
Upon initialization, ONFAIL sets the automatic manifold isolation valve close commands equal to the good copies from STORE_FDI_INIT_DATA.

Each pass, ONFAIL checks leak detector outputs, combines them with driver talkbacks, checks for failed on jets, and flags such jets for rechecking.

To check leak detector output, ONFAIL treats each output as a string of 16 bits. It ANDs each output with a mask representing the logical complement of a 31°F output (BIN '1111111111000000'). Since the transition from 30°F to 31°F occurs in the bit strings as BIN '0000000000111111' to BIN '0000000001000000', the result will be BIN '0000000000000000' if the indicated temperature is below 31°F, the condition for a leak. If this occurs for either the fuel or oxidizer injector temperature sensor, ONFAIL sets the software copy of the driver talkback to on (or leaves it on if it is already so). Having completed this, ONFAIL loads into the first slot of its pushdown list (NEWFAIL) those jets not commanded on, but whose driver talkbacks are on and which have not been previously failed by ONFAIL, by ANDing the driver talkbacks with the logical complement of the jet commands ORed with the previous fail data. ONFAIL then adds to the fail list, and flags for recheck, those jets which are in both slots of the pushdown list. Finally, ONFAIL advances its pushdown list for the next pass, by loading entries from the first slot into the second slot.


ONFAIL:
PROCEDURE;
IF INIT_ONFAIL = ON
THEN
MANCOMA = GOOD_MANCOMA;
MANCOMB = GOOD_MANCOMB;
MANCOMC = GOOD_MANCOMC;
MANCOMD = GOOD_MANCOMD;
INIT_ONFAIL = OFF;

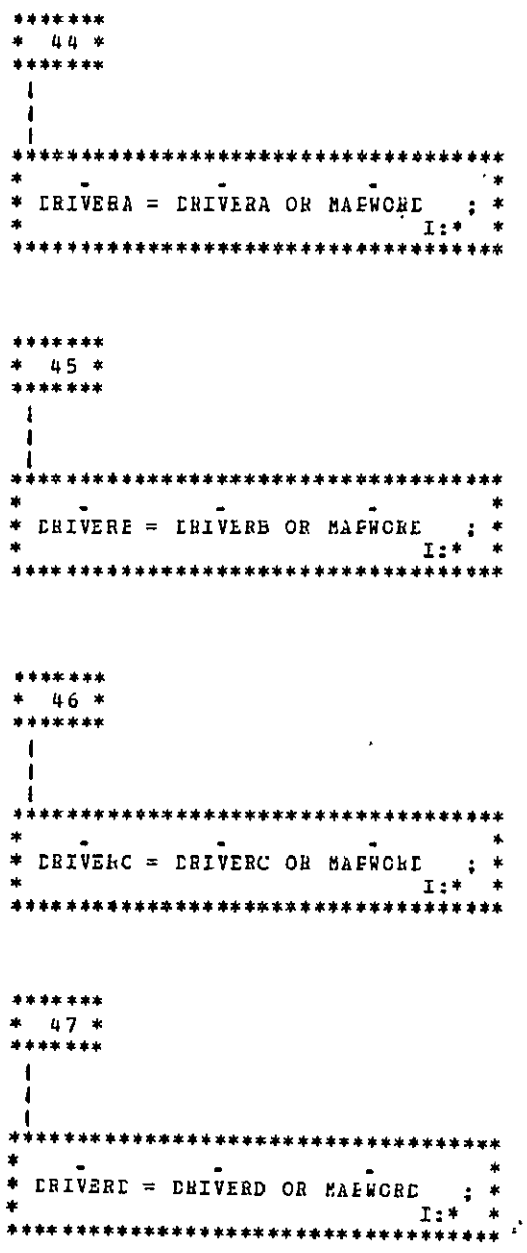



WORK D
DO FOR I = 31 TO 44 BY 1;
IF ((FLEAK I: AND MASK_THRESHOLD) = HEX'0')
OR ((CLEAK I: AND MASK_THRESHOLD) = HEX'0')
THEN
47

```
*****************************************
*                                       *
* NEWFAILA = DRIVERA AND NOT (JETCCMA OR *
*                                       *
*                                       *
* PREV_FAILA);                          *
*                                       *
*                                       *
* NEWFAILB = DRIVERB AND NOT (JETCCMB OR *
*                                       *
*                                       *
* PREV_FAILB);                          *
*                                       *
*                                       *
* NEWFAILC = DRIVERC AND NOT (JETCCMC OR *
*                                       *
*                                       *
* PREV_FAILC);                          *
*                                       *
*                                       *
* NEWFAILD = DRIVERD AND NOT (JETCCMD OR *
*                                       *
*                                       *
* PREV_FAILD);                          *
*                                       *
*                                       *
* RECHECKA = NEWFAILA AND OLDFAILA;     *
*                                       *
*                                       *
* RECHECKB = NEWFAILB AND OLDFAILB;     *
*                                       *
*                                       *
* RECHECKC = NEWFAILC AND OLDFAILC;     *
*                                       *
*                                       *
* RECHECKD = NEWFAILD AND OLDFAILD;     *
*****************************************
```

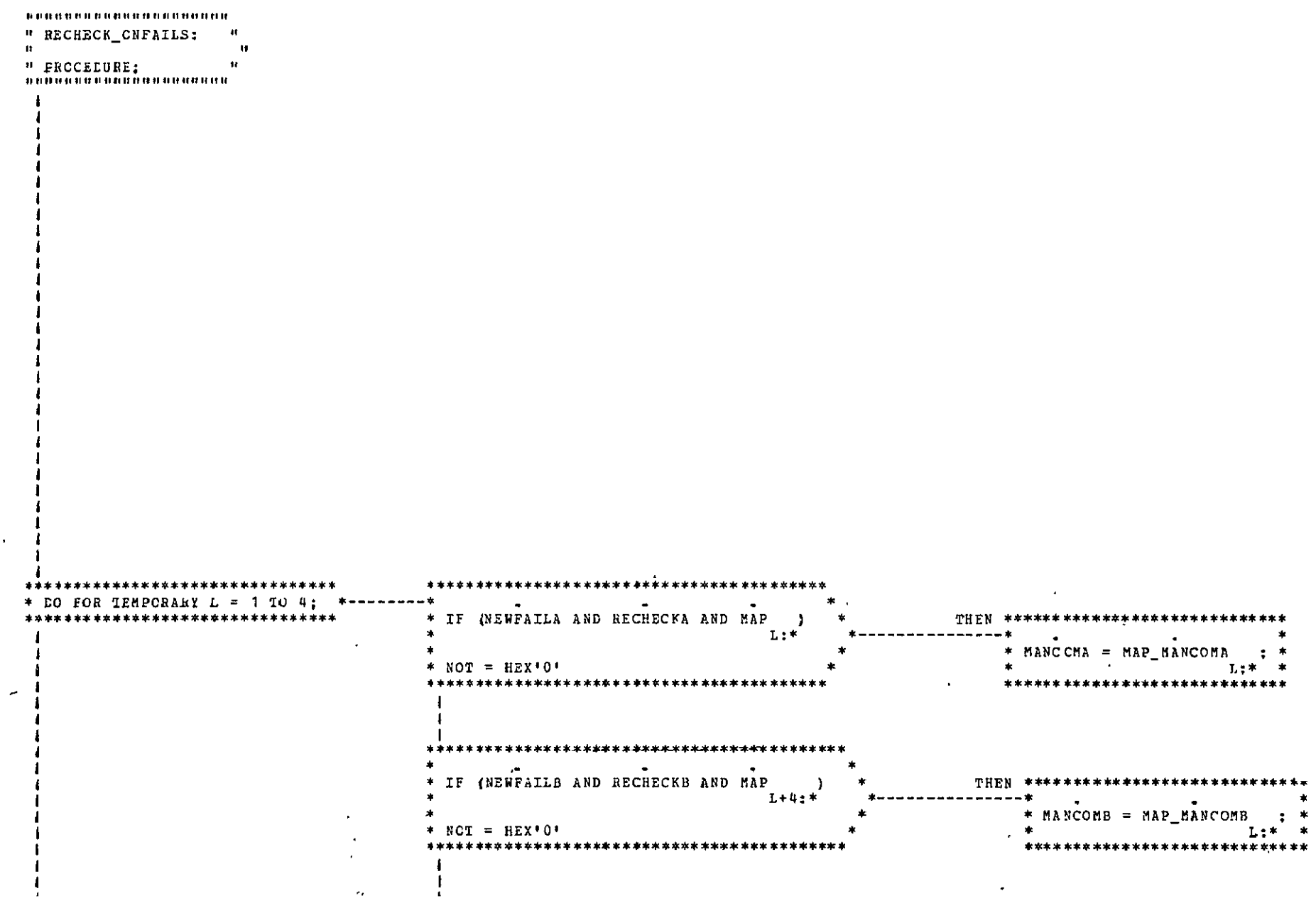
```
*********************************
*                               *
* JFAILA = JFAILA OR RECHECKA;  *
*                               *
*                               *
* JFAILB = JFAILB OR RECHECKB;  *
*                               *
*                               *
* JFAILC = JFAILC OR RECHECKC;  *
*********************************
```

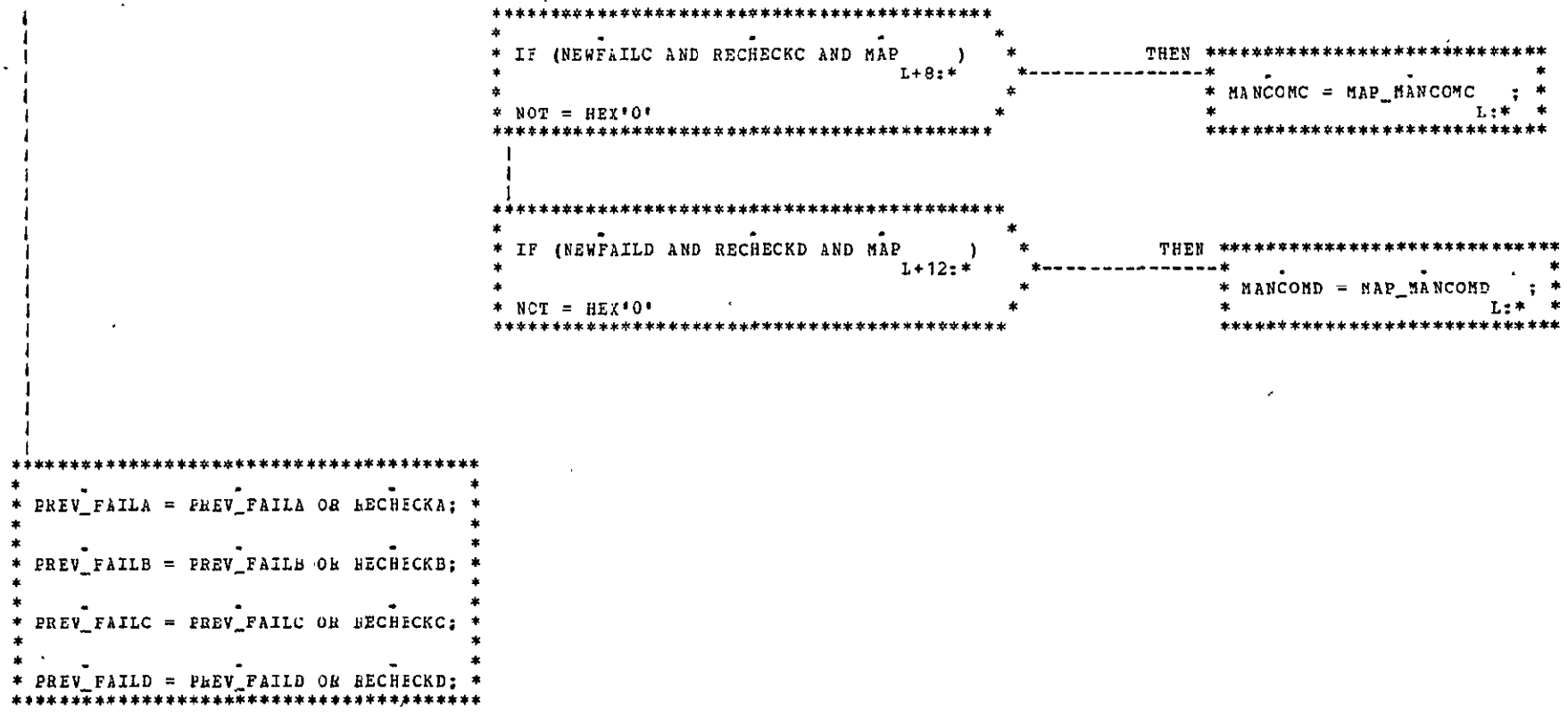
```
*************************************************
*                                               *
* JFAILD = JFAILD OR RECHECKD;                  *
*                                               *
*                                               *
* OLDFAILA = NEWFAILA AND (NOT ON_OVERRIDE_A);  *
*                                               *
*                                               *
* OLDFAILB = NEWFAILB AND (NOT ON_OVERRIDE_B);  *
*                                               *
*                                               *
* OLDFAILC = NEWFAILC AND (NOT ON_OVERRIDE_C);  *
*                                               *
*                                               *
* OLDFAILD = NEWFAILD AND (NOT ON_OVERRIDE_D);  *
*************************************************
```



2.2.6 RECHECK_ONFAILS (see automatic flowchart)

RECHECK_ONFAILS examines those jets which have been added by ONFAIL to the jet fail list on the previous major cycle, and closes the manifold isolation vlaves for those jets which still indicate leaks, or whose driver talkbacks remain on. The procedure then flags as previously rechecked, those jets currently flagged for rechecking, by ORing PREV_FAIL and RECHECK.


" RECHECK_CNFAILS: "
" "
" PROCEDURE; "
DO FOR TEMPORARY L = 1 TO 4;
IF (NEWFAILA AND RECHECKA AND MAP L:*
NOT = HEX'0'
THEN
MANCCMA = MAP_MANCOMA ; *
L:*
IF (NEWFAILB AND RECHECKB AND MAP L+4:*
NOT = HEX'0'
THEN
MANCOMB = MAP_MANCOMB ; *
L:*

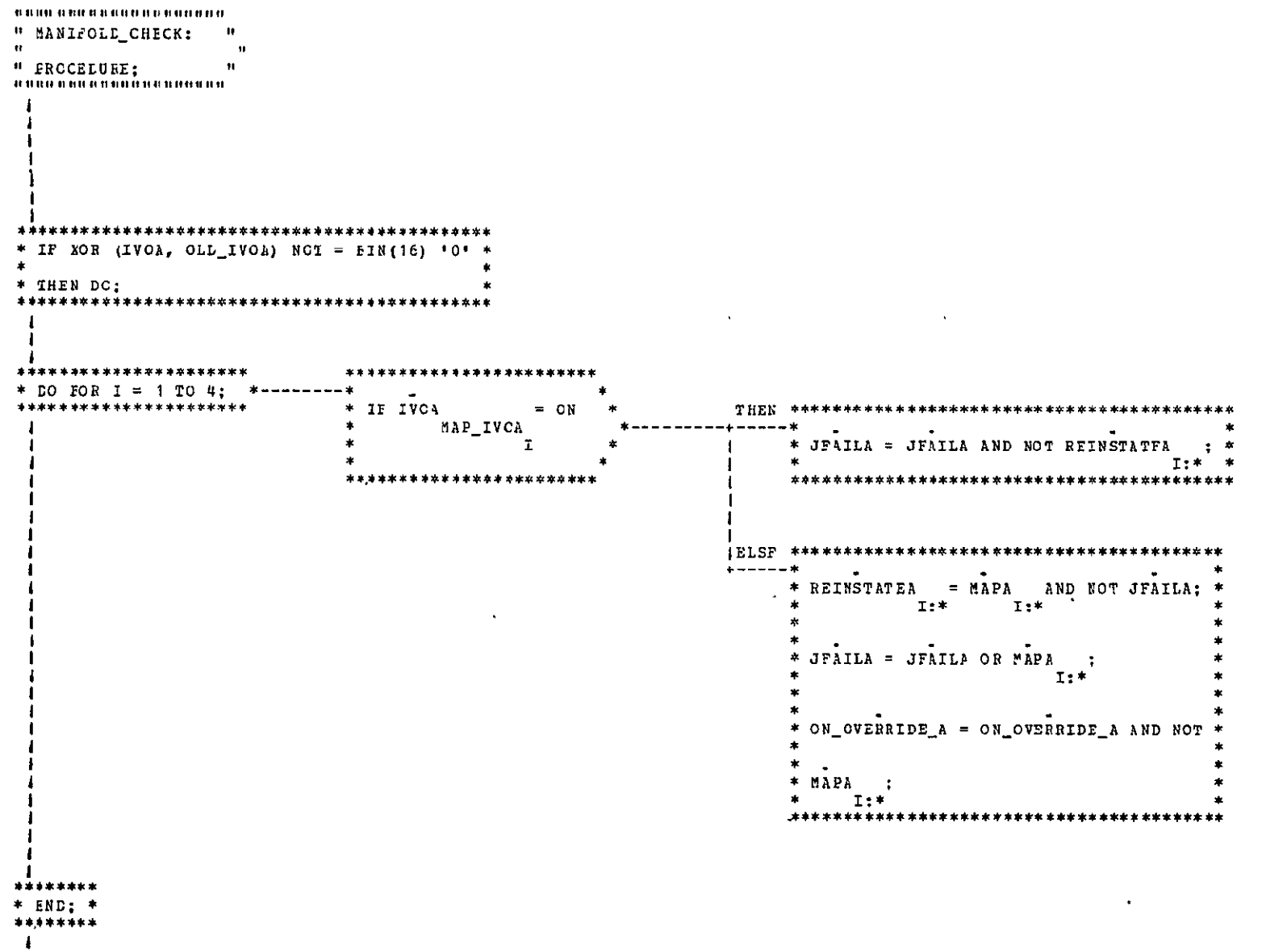

IF (NEWFAILC AND RECHECKC AND MAP L+8:* NOT = HEX'0'
THEN
MANCOMC = MAP_MANCOMC L:* ;
IF (NEWFAILD AND RECHECKD AND MAP L+12:* NOT = HEX'0'
THEN
MANCOMD = MAP_MANCOMD L:* ;
PREV_FAILA = PREV_FAILA OR RECHECKA;
PREV_FAILB = PREV_FAILB OR RECHECKB;
PREV_FAILC = PREV_FAILC OR RECHECKC;
PREV_FAILD = PREV_FAILD OR RECHECKD;

2.2.7 MANIFOLD_CHECK (see automatic flowchart)

MANIFOLD_CHECK compares the manifold isolation valve OPEN talkbacks with their values on the last pass through MANIFOLD_CHECK. If a manifold isolation valve OPEN talkback changes from OFF to ON, the jets on that manifold not failed prior to valve closure are deleted from the jet fail list, by ANDing JFAIL and the complement of REINSTATE for this manifold.

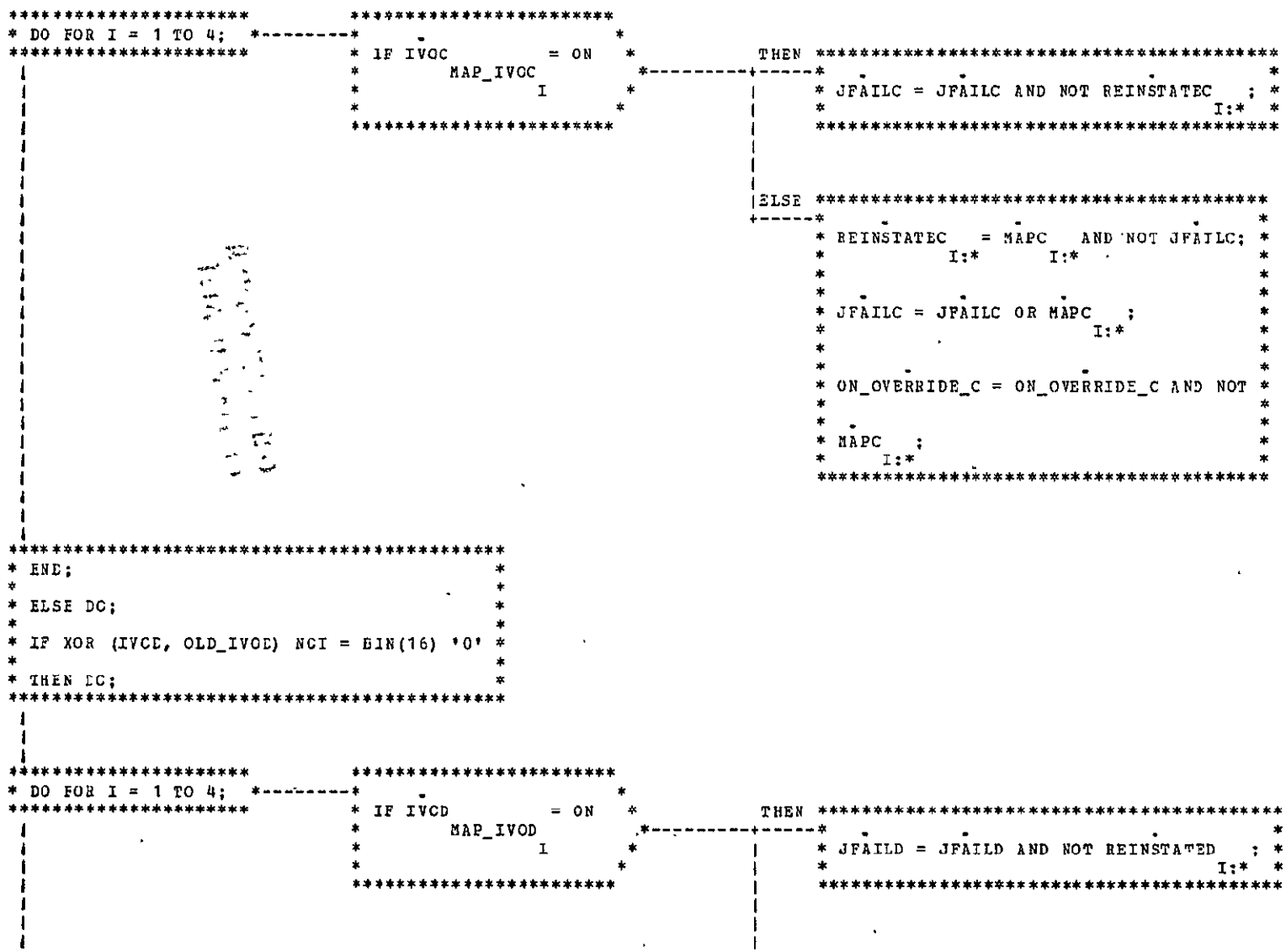
If a manifold isolation valve OPEN talkback changes from ON to OFF, MANIFOLD_CHECK does the following. First, a record of the jets on the manifold which are not failed at the time of manifold closure is made by ANDing the complement of the jet fail list with a map of the jets on this manifold. Next, the map of the jets on this manifold is ORed with the jet fail list to add those jets to the fail list. Finally, the complement of the map of jets on this manifold is ANDed with ON_OVERRIDE_A to prevent RCS FDI deleting those jets from the fail list while the manifold isolation valve is closed.

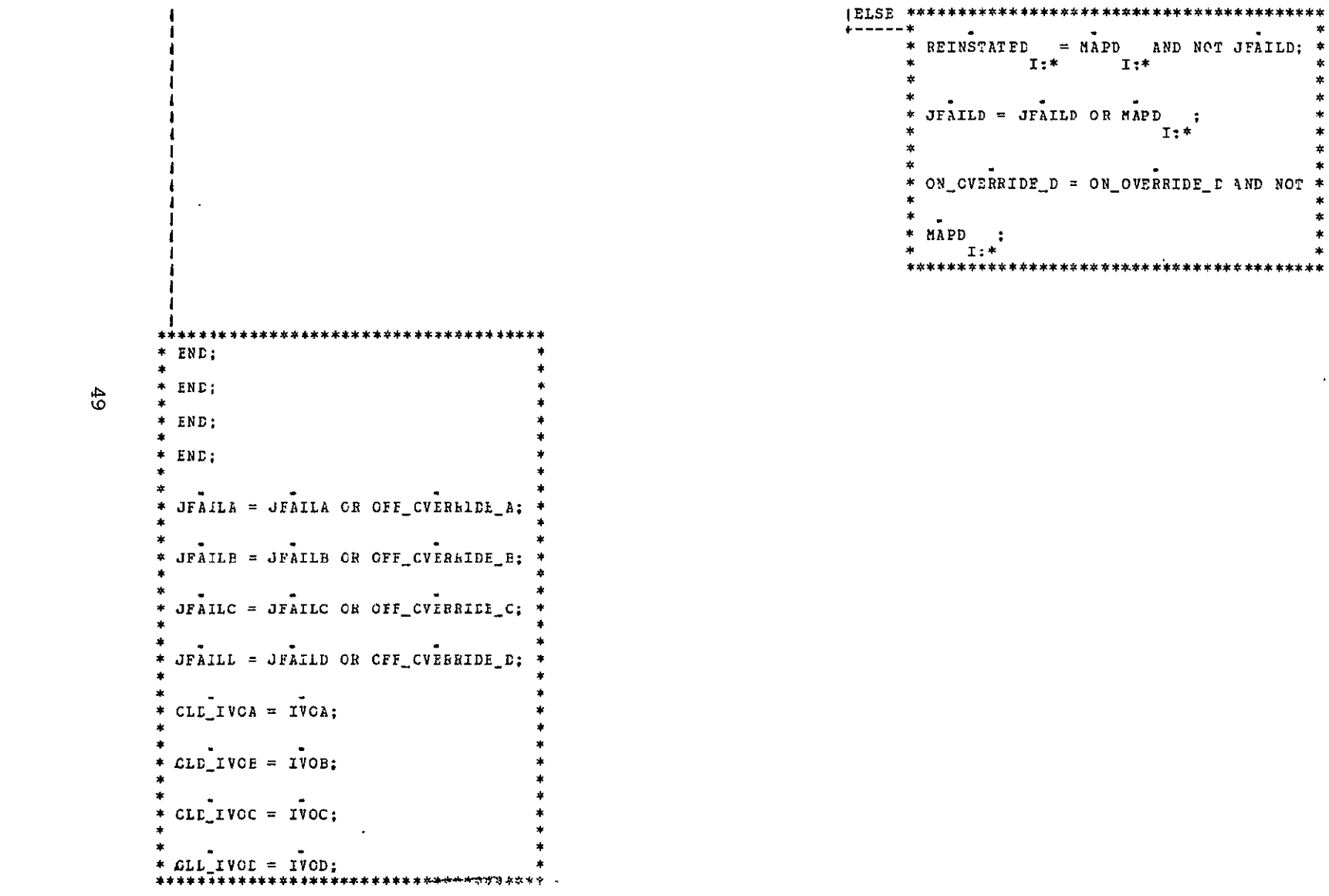
MANIFOLD_CHECK then ORs the OFF_OVERRIDEs with the fail list to implement the crew inhibit function. Finally, a copy of the current manifold isolation valve OPEN talkbacks is stored for use on the next pass.


" MANIFOLD_CHECK: "
" PROCEDURE; "
IF XOR (IVOA, OLD_IVOA) NOT = BIN(16) '0'
THEN DO;
DO FOR I = 1 TO 4;
IF IVOA I = ON MAP_IVOA
THEN
JFAILA = JFAILA AND NOT REINSTATFA ;
ELSE
REINSTATEA = MAPA AND NOT JFAILA;
JFAILA = JFAILA OR MAPA ;
ON_OVERRIDE_A = ON_OVERRIDE_A AND NOT
MAPA ;
END;

```
********************************************
* ELSE DO;                                 *
*                                          *
* IF XOR (IVCB, OLD_IVCB) NOT = BIN(16) '0' *
*                                          *
* THEN DO;                                 *
********************************************
 |
 |
 |
*********************       ***********************
* DO FOR I = 1 TO 4;  *---------*         .             *
*********************       * IF IVCB        = ON   *        THEN ******************************************
 |                          *        MAP_IVCB          *---------+-----*  .        .            .            *
 |                          *                I        *         |     * JFAILB = JFAILB AND NOT REINSTATEB    ; *
 |                          *                         *         |     *                  .            I:*  *
 |                          ***********************         |     ******************************************
 |                                                            |
 |                                                            |
 |                                                            |ELSE ****************************************
 |                                                            +-----*         .          .             .      *
 |                                                                  * [REINSTATEB] = MAPB   AND NOT JFAILB; *
 |                                                                  *                  I:*                   *
 |                                                                  *                                        *
 |                                                                  *  .         .        .                  *
 |                                                                  * JFAILB = JFAILB OR MAPB   ;            *
 |                                                                  *                      I:*               *
 |                                                                  *                                        *
 |                                                                  *       .             .                  *
 |                                                                  * ON_OVERRIDE_B = ON_OVERRIDE_B AND NOT *
 |                                                                  *                                        *
 |                                                                  *  .                                     *
 |                                                                  * MAPB   ;                               *
 |                                                                  *     I:*                                *
 |                                                                  ****************************************
 |
********************************************
* END;                                     *
*                                          *
* ELSE DO;                                 *
*                                          *
* IF XOR (IVCC, OLD_IVCC) NOT = BIN(16) '0' *
*                                          *
* THEN DO;                                 *
********************************************
 |
 |
 |
```

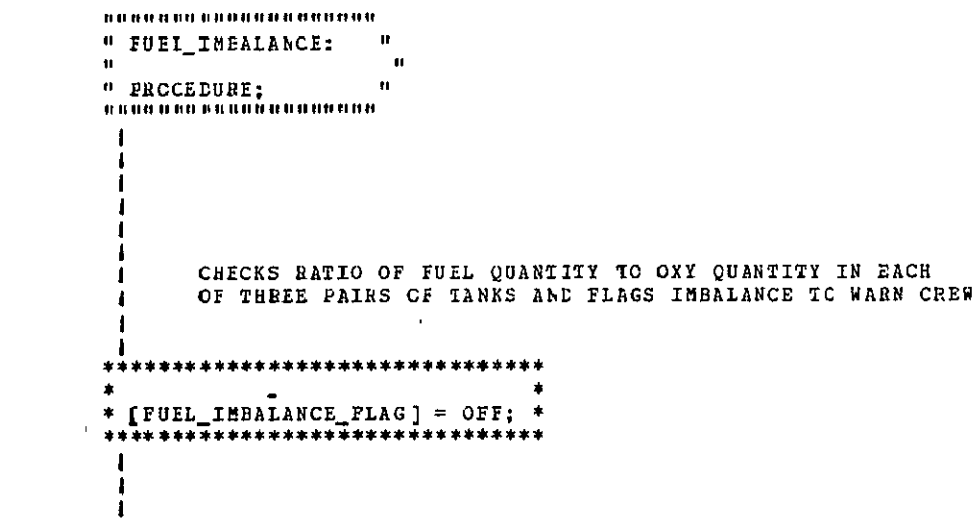
ORIGINAL PAGE IS
OF POOR QUALITY

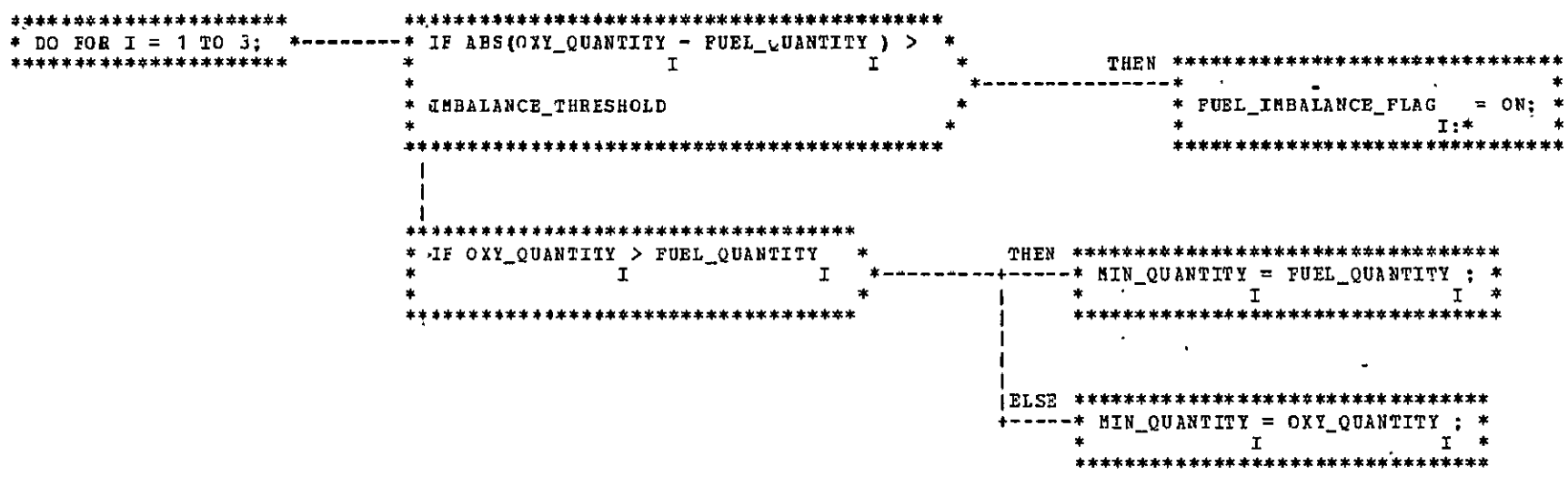

DO FOR I = 1 TO 4;
IF IVOC = ON
MAP_IVOC
I
THEN
JFAILC = JFAILC AND NOT REINSTATEC ;
ELSE
REINSTATEC = MAPC AND NOT JFAILC;
JFAILC = JFAILC OR MAPC ;
ON_OVERRIDE_C = ON_OVERRIDE_C AND NOT
MAPC ;
END;
ELSE DO;
IF XOR (IVCD, OLD_IVOD) NOT = BIN(16) '0'
THEN DO;
DO FOR I = 1 TO 4;
IF IVCD = ON
MAP_IVOD
I
THEN
JFAILD = JFAILD AND NOT REINSTATED ;


ELSE
REINSTATED_D = MAPD AND NOT JFAILD;
I:
I:
JFAILD = JFAILD OR MAPD ;
I:
ON_OVERRIDE_D = ON_OVERRIDE_D AND NOT
MAPD ;
I:
END;
END;
END;
END;
JFAILA = JFAILA OR OFF_OVERRIDE_A;
JFAILB = JFAILB OR OFF_OVERRIDE_B;
JFAILC = JFAILC OR OFF_OVERRIDE_C;
JFAILL = JFAILD OR OFF_OVERRIDE_D;
CLD_IVOA = IVOA;
CLD_IVOB = IVOB;
CLD_IVOC = IVOC;
CLD_IVOD = IVOD;

2.2.8 FUEL_IMBALANCE (see automatic flowchart)

FUEL_IMBALANCE receives fuel quantities and oxidizer quantities in the RCS tanks in each of the three RCS modules. These quantities are expressed as percent of tank capacity. The procedure compares the quantities, and also compares their difference to a preset threshold. If the magnitude of the difference between the percentages is greater than 1.6, an imbalance flag is set. FUEL_IMBALANCE then decides whether the remaining oxidizer in each module is less than the fuel quantity remaining in that module. If so, it flags the oxidizer as the lesser quantity, and provides it for display. Otherwise, it flags the fuel quantity and makes it similarly available.




DO FOR I = 1 TO 3;
IF ABS(OXY_QUANTITY - FUEL_QUANTITY) >
IMBALANCE_THRESHOLD
THEN
FUEL_IMBALANCE_FLAG = ON;
IF OXY_QUANTITY > FUEL_QUANTITY
THEN
MIN_QUANTITY = FUEL_QUANTITY ;
ELSE
MIN_QUANTITY = OXY_QUANTITY ;

2.2.9 Core Requirements and CPU Time

The timing and core requirements (Table 2) for RCS FDI are estimates based on results of compilation by the HAL/S and HAL/F compilers (HAL/S release 14.0 of 16 Dec. 75, HAL/F release 10.0 of 16 Dec. 75). They are not to be taken as final values, as studies of code and timing optimization are still in progress, and requirements levied on RCS FDI are in a state of flux.

Table 2. Approximate RCS FDI CPU times and burden (minor cycle = 0.04 s, major cycle = 1.0 s).

Procedure	Portion	Case	Time (μs)	%CPU
FDI_EXEC		minor cycle	22.8	0.057
		major cycle, worst	66.1	0.165
MONITOR_BTU_MASK		no BTU_MASKs on	103.0	0.258
		worst	296.9	0.742
STORE_FDI_INIT_DATA		all	81.4	0.0081
OVERRIDE_UPDATE	init		40.6	0.0041
	all but init	each pass	122.6	0.012
OFFAIL	init		34.9	0.087
	all but init	each pass	114.3	0.286
RECHECK_ONFAILS		one fail, close manifold	308.3	0.03083
ONFAIL	init		26.2	0.00262
	all but init	one leak	924.8	0.0925
MANIFOLD_CHECK		one change, longest path through code	350.1	0.876
FUEL_IMBALANCE		worst	151.2	0.01512
Total worst case (no inits)				2.235

Core requirements

Program	575 whole words
Data	285 whole words

SECTION 3

GLOSSARY

Table 3 describes all variables and constants used in RCS FDI. The entries are listed alphabetically by computer name.

Table 3. RCS FDI glossary.

Computer Name	Type/ Attribute	Description	Units	Value Range	Declared In	Assigned In	Referenced In
ON_OVERRIDE_A ON_OVERRIDE_B ON_OVERRIDE_C ON_OVERRIDE_D	Bit(32)	List of jets to be deleted from fail list by crew	—	TBD	COMPOOL	HDWRE/IOP	ONFAIL
OXY_QUANTITY	Array(3)/ Integer	Oxidizer remaining in RCS tanks	percent	0-109	COMPOOL	RCS_PVT	FUEL_IMBALANCE
PRESSA PRESSB PRESSC PRESSD	Bit(32)	Packed jet chamber pressure sensor talkbacks	—	ON/OFF	COMPOOL	HDWRE/IOP	OFFAIL
PREV_FAILA PREV_FAILB PREV_FAILC PREV_FAILD	Bit(32)	Record of jets previously rechecked	—	ON/OFF	COMPOOL	RECHECK_ONFAIL	ONFAIL
RECHECKA RECHECKB RECHECKC RECHECKD	Bit(32)	List of failed jets flagged for recheck	—	ON/OFF	COMPOOL	ONFAIL	RECHECK_ONFAILS
REINSTATEA REINSTATEB REINSTATEC REINSTATED	Array(4)/ Bit(32)	List of jets on each manifold failed prior to isolation valve closure	—	ON/OFF	MANIFOLD_CHECK	MANIFOLD_CHECK	MANIFOLD_CHECK

Table 3. RCS FDI glossary (Cont.).

Computer Name	Type/ Attribute	Description	Units	Value Range	Declared In	Assigned In	Referenced In
GOOD_JFAILA GOOD_JFAILB GOOD_JFAILC GOOD_JFAILD	Bit(32)	Copies of RCS fail list stored for initialization	—	ON/OFF	COMPOOL	STORE_FDI_INIT_ DATA	OFFAIL
GOOD_MANCOMA GOOD_MANCOMB GOOD_MANCOMC GOOD_MANCOMD	Bit(32)	Copies of manifold isolation valve automatic close commands stored for initialization	—	ON/OFF	COMPOOL	STORE_FDI_INIT_ DATA	ONFAIL
GOOD_OFF_OVERRIDE_A GOOD_OFF_OVERRIDE_B GOOD_OFF_OVERRIDE_C GOOD_OFF_OVERRIDE_D	Bit(32)	Copies of off overrides stored for initialization	—	ON/OFF	COMPOOL	STORE_FDI_INIT DATA	OVERRIDE_UPDATE
GOOD_ON_OVERRIDE_A GOOD_ON_OVERRIDE_B GOOD_ON_OVERRIDE_C GOOD_ON_OVERRIDE_D	Bit(32)	Copies of on overrides stored for initialization	—	ON/OFF	COMPOOL	STORE_FDI_INIT DATA	OVERRIDE_UPDATE
I	Integer	Counter	—	1, 2, 3, 4	COMPOOL		
IMBALANCE_THRESHOLD	Integer	1/2 range of acceptable RCS tank fuel/oxidizer quantities	—	TBD	FUEL_IMBALANCE	Initialization (Mission Constant)	FUEL_IMBALANCE
INHIBIT_A INHIBIT_B INHIBIT_C INHIBIT_D	Bit(32)	Packed requests to inhibit use of certain RCS jets	—	ON/OFF	COMPOOL	D&C SOP	OVERRIDE_UPDATE
INIT_OFFAIL	Bit(1)	Initialization flag for OFFAIL	—	ON/OFF	COMPOOL	MS&C, MONITOR_ BTU_MASK	OFFAIL

Table 3. RCS FDI glossary (Cont).

Computer Name	Type/ Attribute	Description	Units	Value Range	Declared In	Assigned In	Referenced In
INIT_ONFAIL	Bit(1)	Initialization flag for ONFAIL	—	ON/OFF	COMPOOL	MS&C, MONITOR_ BTU_MASK	ONFAIL
INIT_OVERRIDE_UPDATE	Bit(1)	Initialization flag for OVERRIDE_ UPDATE	—	ON/OFF	COMPOOL	MS&C, MONITOR_ BTU_MASK	ONFAIL
IVOA IVOB IVOC IVOD	Bit(16)	Manifold isolation valve OPEN talkbacks	—	ON/OFF	COMPOOL	HDWRE/IOP	MANIFOLD_CHECK
JETCOMA JETCOMB JETCOMC JETCOMD	Bit(32)	RCS jet commands	—	ON/OFF	COMPOOL	JET_SELECT	ONFAIL, OFFAIL
JFAILA JFAILB JFAILC JFAILD	Bit(32)	RCS fail list	—	ON/OFF	COMPOOL	ONFAIL, OFFAIL, MANIFOLD_CHECK, OVERRIDE_UPDATE, MONITOR_BTU_MASK	JET_SELECT, D&C SOP
MAJOR_CYCLE	Bit(1)	Major cycle flag	—	ON/OFF	COMPOOL	FCOS	FDI_EXEC
MANCOMA MANCOMB MANCOMC MANCOMD	Bit(32)	Manifold isolation valve automatic close commands	—	ON/OFF	COMPOOL	ONFAIL, MONITOR_ BTU_MASK	HDWRE/IOP
MANUAL_OVERRIDE_A MANUAL_OVERRIDE_B MANUAL_OVERRIDE_C MANUAL_OVERRIDE_D	Bit(32)	Request to reenable and inhibit FDI on certain jets	—	ON/OFF	COMPOOL	D&C SOP	OVERRIDE_UPDATE

Table 3. RCS FDI glossary (Cont).

Computer Name	Type/ Attribute	Description	Units	Value Range	Declared In	Assigned In	Referenced In
MAP_IVOA MAP_IVOB MAP_IVOC MAP_IVOD	Array(4)/ Integer	Bit assignments of packed manifold isolation valve talkback discretes	—	ON/OFF	MANIFOLD_CHECK	Initialization (Mission Constant)	MANIFOLD_CHECK
MAP_MANCOMA MAP_MANCOMB MAP_MANCOMC MAP_MANCOMD	Array(4)/ Integer	Bit assignments of packed manifold isolation valve automatic close commands	—	ON/OFF	COMPOOL	Initialization (Mission Constant)	MONITOR_BTU_MASK, RECHECK_ONFAILS
MAPA MAPB MAPC MAPD	Array(44)/ Bit(32)	Bit assignments of jet commands by manifold	—	ON/OFF	MANIFOLD_CHECK	Initialization (Mission Constant)	MANIFOLD_CHECK
MAPWORD	Array(44)/ Bit(32)	Masks of driver talkbacks by jet	—	ON/OFF	ONFAIL	Initialization (Mission Constant)	ONFAIL
MASK_THRESHOLD	Bit(16)	Internal mask for THRESHOLD temperature of fuel/oxidizer	—	BIN(10)'1' || BIN(6)'0'	ONFAIL	Initialization (Mission Constant)	ONFAIL
MIN_QUANTITY	Array(3)/ Integer	Lesser of oxidizer/fuel quantity in each RCS module	percent	0-109	COMPOOL	FUEL_IMBALANCE	D&C SOP
MINOR_CYCLE	Bit(1)	Flag indicating minor cycle	—	ON/OFF	COMPOOL	FCOS	FDI_EXEC
NEWFAILA NEWFAILB NEWFAILC NEWFAILD	Bit(32)	First slot in ONFAIL pushdown list	—	ON/OFF	ONFAIL	ONFAIL	ONFAIL, RECHECK_ ONFAILS

Table 3. RCS FDI glossary (Cont).

Computer Name	Type/ Attribute	Description	Units	Value Range	Declared In	Assigned In	Referenced In
OFA1 OFB1 OFC1 OFD1	Bit(32)	First slot in OFFAIL pushdown list	—	ON/OFF	OFFAIL	OFFAIL	OFFAIL
OFA2 OFB2 OFC2 OFD2	Bit(32)	Second slot in OFFAIL pushdown list	—	ON/OFF	OFFAIL	OFFAIL	OFFAIL
OFA3 OFB3 OFC3 OFD3	Bit(32)	Third slot in OFFAIL pushdown list	—	ON/OFF	OFFAIL	OFFAIL	OFFAIL
OFF_OVERRIDE_A OFF_OVERRIDE_B OFF_OVERRIDE_C OFF_OVERRIDE_D	Bit(32)	List of jets to be added to fail list by crew request	—	ON/OFF	OVERRIDE_UPDATE	OVERRIDE_UPDATE	STORE_FDI_INIT_DATA OVERRIDE_UPDATE MANIFOLD_CHECK
OLD_IVOA OLD_IVOB OLD_IVOC OLD_IVOD	Bit(16)	List of manifold isolation valve talkbacks from prior pass	—	ON/OFF	MANIFOLD_CHECK	MANIFOLD_CHECK	MANIFOLD_CHECK
OLDFAILA OLDFAILB OLDFAILC OLDFAILD	Bit(32)	Second slot in ONFAIL pushdown list	—	ON/OFF	ONFAIL	ONFAIL	ONFAIL
OLEAK	Array(44)/ Bit(16)	Output of jet oxidizer injector temperature sensors	°F	TBD	COMPOOL	HDWRE/IOP	ONFAIL

Table 3. RCS FDI glossary (Cont.).

Computer Name	Type/ Attribute	Description	Units	Value Range	Declared In	Assigned In	Referenced In
AUT_OVERRIDE_A AUT_OVERRIDE_B AUT_OVERRIDE_C AUT_OVERRIDE_D	Bit(32)	Packed requests to reenable and continue FDI on certain jets	—	ON/OFF	COMPOOL	D&C SOP	OVERRIDE_UPDATE
BTU_FA01_02 BTU_FA01_10 BTU_FA03_02 BTU_FA03_10 BTU_FF01_05 BTU_FF01_13 BTU_FF02_05 BTU_FF02_13	Bit(1)	Flags indicating MDM data path failures	—	ON/OFF	COMPOOL	FCOS	MONITOR_BTU_MASK
CALL_INIT	Bit(1)	Internal flag denoting MDM failure has occurred	—	ON/OFF	MONITOR_BTU_MASK	MONITOR_BTU_MASK	MONITOR_BTU_MASK
CHANGE_OVERRIDE_STATUS	Bit(1)	Flag indicating a crew entry to OVERRIDE_UPDATE	—	ON/OFF	COMPOOL	D&C SOP	OVERRIDE_UPDATE
DRIVERA DRIVERB DRIVERC DRIVERD	Bit(32)	Packed jet driver talkbacks	—	ON/OFF	COMPOOL	HDWRE/IOP	ONFAIL
FLEAK	Array (44)/ Bit(16)	Output of jet fuel injector temperature sensors	°F	TBD	COMPOOL	HDWRE/IOP	ONFAIL
FUEL_IMBALANCE_FLAG	Array(3)/ Bit(1)	Flags indicating fuel imbalances in RCS tanks	—	ON/OFF	COMPOOL	FUEL_IMBALANCE	D&C SOP
FUEL_QUANTITY	Array(3)/ Integer	Fuel remaining in RCS tanks	percent	0-109	COMPOOL	RCS_PVT	FUEL_IMBALANCE

APPENDIX A

FORMAT OF FDI INPUT-OUTPUT DISCRETES

Certain of the input discretes and output discretes are packed for FDI processing in groups of four 32-bit strings, designated by the letter A, B, C, or D terminating the name (e.g., JETCOMA, JETCOMB, JETCOMC, JETCOMD). Those discretes which are so arranged include the following:

(1) Manifold isolation valve close commands

(2) Manifold isolation valve open talkbacks

(3) Lists of bit assignments

(4) Lists of manual override requests

(5) Lists of inhibit requests

(6) Jet commands

(7) Jet driver talkbacks

(8) Jet chamber pressure sensor talkbacks

(9) Jet fail list

(10) Jet reenable requests

(11) Previous fail flags

(12) Recheck flags

(13) Lists of jets failed prior to manifold isolation valve closure

The reason for so packing these discretes involves consideration of storage access and CPU time burdens.

One of the desirable properties of any flight code dealing with discretes generated in hardware is that minimal repacking of these discretes be performed. To realize this, the code should operate on strings of bits channelized as they are in the MDM.

It was found that this data would be in eight strings of 16 bits (one AP101 half word). Thus, an operation on all the jet commands, for instance, would be performed as eight half-word instructions. Since many such operations are performed, and since the difference in timing between a half-word instruction and whole-word instruction was small or zero, these eight half words were concatenated into four whole words and then processed. The tradeoff is the time required to perform four concatenations, against performing each operation on twice as many bit strings. Currently, the design favors concatenation, hence the representation of each set of discretes in four whole words.

These four whole words could be stored as an array, or stored in four independent locations as currently done. There is no difference in storage requirements. However, there is a tradeoff between writing code for the strings as DO loops on array members, and replicated code on four independent addresses. Clearly, less code is required for the DO loop, but the current implementation of array addressing makes this time-inefficient for small arrays. Thus, while there is a greater core penalty for the four replications of each instruction, there is a significant saving in execution time. Studies into this tradeoff are currently underway, and should be reflected in subsequent releases of this document.

The MDM channelization of these discretes may be found in either Reference 1 or Reference 2. In general, the assignments by jet for the four words obtained by concatenation are:

BIT	A	B	C	D	BIT	A	B	C	D
0	112	122	211	231	16	132	144	223	243
1	113	123	213	233	17	134	146	225	245
2	115	125	215	236	18	135	157	226	246
3	116	126	311	331	19	146	158	324	344
4			314	334	20			325	345
5			315	336	21			326	346
6					22			357	357
7					23			358	358
8					24				
9					25				
10					26				
11					27				
12					28				
13					29				
14					30				
15					31				

APPENDIX B

FORMAT OF LEAK DETECTOR OUTPUTS

Leak detection in the RCS jets is accomplished by measuring the temperature at the fuel and oxidizer injector of each jet and comparing them with a threshold temperature. As leaking RCS fuel and oxidizer would very quickly cool the injectors, a leak is indicated by the sensor output being below the threshold temperature. This data comes through the MDM as 9 bits of fixed-point data, padded to a 16-bit integer in the GPC registers.

While the HAL compiler has means of comparing the size of two numbers, it was believed quicker to mask the output with a threshold, and test the result as zero or nonzero.

This implies the format of these sensor outputs must be such that they can be treated as bit strings, and particularly can be operated upon by the logical AND. There is no conversion from integer format to bit string, so by assuming the data enters the GPL as integer, there is a great saving in code.

LIST OF REFERENCES

1. Bergmann, E., Space Shuttle Reaction Control Subsystem Failure Detection and Identification Algorithm Description, Charles Stark Draper Laboratory Report R-937, December 1975.

2. Functional Subsystem Software Requirements, System Interface, Vol. 6, SD74-SH-0120, Rockwell International, November 1975.

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