RESEARCH AND DEVELOPMENT FOR ONBOARD NAVIGATION (ONAV) GROUND BASED EXPERT/TRAINER SYSTEM

ONAV Entry Knowledge Requirements Specification Update

Deliverable G

Preface

This research was conducted under the auspices of the Research Institute for Computing and Information Systems by Daniel C. Bochsler of LinCom Corporation. Dr. Terry Feagin served as RICIS technical representative.

Funding has been provided by Mission Planning and Analysis Division, NASA/JSC through Cooperative Agreement NCC 9-16 between NASA Johnson Space Center and the University of Houston-Clear Lake. The NASA technical monitor for this activity was Robert Savely, Head, Artificial Intelligence Section, Technology Development and Applications Branch, Mission Support Directorate, NASA/JSC.

Research and Development for Onboard Navigation (ONAV)

Ground Based Expert/Trainer System

ONAV ENTRY KNOWLEDGE REQUIREMENTS SPECIFICATION UPDATE

(Deliverable G)

Prepared For:

Dr. Terry Feagin
Research Institute for Computing and Information Systems
University of Houston - Clear Lake

Prepared By:

Daniel C. Bochsler
LinCom Corporation
18100 Upper Bay Road, Suite 208
Houston, Texas 77058

Performed Under:

Project No. AI.8
Cooperation Agreement no. NCC9-16
Subcontract No. 005

March 1, 1988

87-FM-15

JSC-22657

Knowledge Requirements for the Onboard Navigation (ONAV) Console Expert/Trainer System

Entry Phase Specifications

~~Baseline Version 1.0~~ REVISED - VERSION 1.1

Mission Support Directorate
Mission Planning and Analysis Division

APRIL
~~FEBRUARY~~ 1988
~~October 1987~~

NASA
National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

~~87-FM-15~~ ?

~~JSC-22657~~ ?

SPACE STATION PROGRAM

Knowledge Requirements for the Onboard Navigation (ONAV) Console Expert/Trainer System

Entry Phase Specification
~~Baseline Version 1.0~~
REVISED — VERSION 1.1

By: The ONAV Expert System Working Group, Artificial Intelligence Section,
Technology Development and Applications Branch

Approved: Robert H. Brown
Robert H. Brown, Chief
Technology Development and Applications Branch

Approved: Edgar C. Lineberry
Edgar C. Lineberry, Chief
Mission Planning and Analysis Division

Mission Planning and Analysis Division

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas

~~October 1987~~
April 1988

ACKNOWLEDGMENTS

This document ~~is~~ was prepared by the Onboard Navigation (ONAV) Expert System Working Group which includes the following personnel:

Dan Bochsler/LinCom
Steve Desrosiers/RSOC
Angie Ferrell/RSOC
Glenn Goodrum/UNISYS
Maise Haynes/NASA-DM4
Lui Wang/NASA-FM7
Carol McConnell/Unisys
Lynn Morris/Unisys

CONTENTS

new page * after TTPINC is finished

New page #'s after TIPMS is finished

TABLES

new page #'s after TJ ink is finished

ACRONYMS

ACC	accelerometer
ADTA	air data transducer assembly
AIF	auto/inhibit/force
BFS	backup flight system
DT	delta time
GDO	Guidance Officer
GND	ground
GPC	general purpose computer
HSTD	high-speed trajectory determinator
IMU	inertial measurement unit
LRU	line replacement unit
MECO	main engine cutoff
MLS	microwave landing system
MSBLS	microwave scanning beam landing system
MVS	mid-value select
N/A	not applicable
NAV	navigation
n. mi.	nautical mile
OBH	onboard height
ONAV	onboard navigation
PASS	primary avionics software system
PFS	primary flight system
RM	redundancy management
RSS	root sum square
SPEC	specification
TACAN	tactical air navigation
TLM	telemetry

SECTION 1
SUMMARY

This document presents the ~~baseline~~ REVISED version of expert knowledge for the onboard navigation (ONAV) entry system. Included herein is some brief background information together with information describing the knowledge that the system ~~will~~ does contain.

SECTION 2
INTRODUCTION

2.1 BACKGROUND

Developing detailed requirements for an expert system involves a series of meetings with various combinations of development team and expert personnel. During these meetings, available information is reviewed and operations and functional processes of the proposed system are discussed.

Different issues are addressed in each meeting where relevant techniques and details are refined and documented. Broad areas are covered by early meetings with specific details being identified quickly. Information typically is captured in the form of rules, heuristics, or concepts along with associated background and functional specifications. As this information is refined and expanded, more detailed rules are formulated.

2.2 SCOPE OF THIS DOCUMENT

The target audience for this document is the knowledge domain expert. It ~~will be~~ is a reflection of "what the system knows" in a form as close as possible to the expert's language.

Required changes to this document are expected in the future. In particular, efforts to integrate this document into console operator training activities will subject the contents to the utmost scrutiny. Updates will be made as needed and in a timely manner. As such, this revised version of the baseline document represents the first of these expected changes.

SECTION 3
SYSTEM INFORMATION BASELINE

The following subsections detail the various subsystem rule baselines for the ONAV entry expert system. Each subsection is divided into five parts.

a. General Information

General information provides for background types of information or assumptions made in other parts. If no information is available or required to clarify general concepts and approaches, only the word -none- need be given. The intent is to provide any information that helps develop and clarify rules, concepts, or heuristics.

b. Inputs

Inputs should give descriptions of those data items or other information used to perform the processing conducted in part c. If possible, the information sources should be specified as well.

c. Rules/heuristics/concepts

Rules/heuristics/concepts give the specifications for the processing which must occur (or, in the case of rules, for the pieces of expertise which must be gathered). The content may be rules, but it also may consist of tables, figures, flowcharts, etc. as appropriate for specifying what is to be done.

d. Outputs

Outputs should indicate what information is generated and available as a result of the processing performed. Any available destination information also should be included.

e. Support Computations

Support computations make convenient the specification of repetitive computations/manipulations needed as part of the processing activity, but which are not integral elements of the rules, heuristics, and concepts information.

3.1 INITIAL CONDITIONS

a. General Information

The selected atmosphere model must be checked as part of the expert system's initial processing. Information about the atmosphere model comes both from the ONAV operator (as an input) and from the telemetry downlist giving the onboard atmosphere selected by the crew.

The primary avionics software system (PASS) and backup flight system (BFS) should be in Major Mode 304 after blackout. Ignore the major modes of systems that are not operating.

b. Inputs

(1) Major mode PASS
(2) Major mode BFS
(3) BFS engage
(4) Selected atmosphere
(5) Desired atmosphere (ONAV input)
(6) BFS NO GO (ONAV input)

(7) Commfault status PASS
(8) Commfault status BFS
~~(9) Redrics~~

c. Rules/heuristics/concepts

(1) Engaged System
IF
- The BFS is engaged is ON
THEN
- The BFS is the engaged system
ELSE
- The PASS is the engaged system.

(2) System Availability (Part 1) - bfs only
IF
- The BFS is engaged
THEN
- The BFS is the only system available.

(3) System Availability (Part 2) - pass only
IF
- The BFS is not engaged
- The BFS is NO GO
THEN
- The PASS is the only system available.

(4) System Availability (Part 3) - both
IF
- The BFS is not engaged
- The BFS is GO
THEN
- Both systems are available.

(5) Wrong Atmosphere Selected

IF

- The PASS is the engaged system
- The ONAV operator-desired atmosphere is not the same as the downlisted atmosphere

THEN

- Notify operator that crew has incorrect atmosphere selected.
- Recommend call to crew to select the desired atmosphere.

(6) Wrong Major Mode

IF

- For the available systems
- The major mode is not 304

THEN

- Notify the operator that the (system) is in the wrong major mode.
- Recommend call to crew to select Major Mode 304 in the (system).

d. Outputs

(1) PASS sequencing problem
(2) BFS sequencing problem
(3) Incorrect atmosphere selected
(4) System availability
(5) Engaged system

(6) String comm fault occurred/clear

e. Support Computations

~~Calculate desired~~ item entry to select the atmosphere correctly:

- Nominal (SPEC 51 item 37)
- Cold (SPEC 51 item 38)
- Hot (SPEC 51 item 39)

3.1A

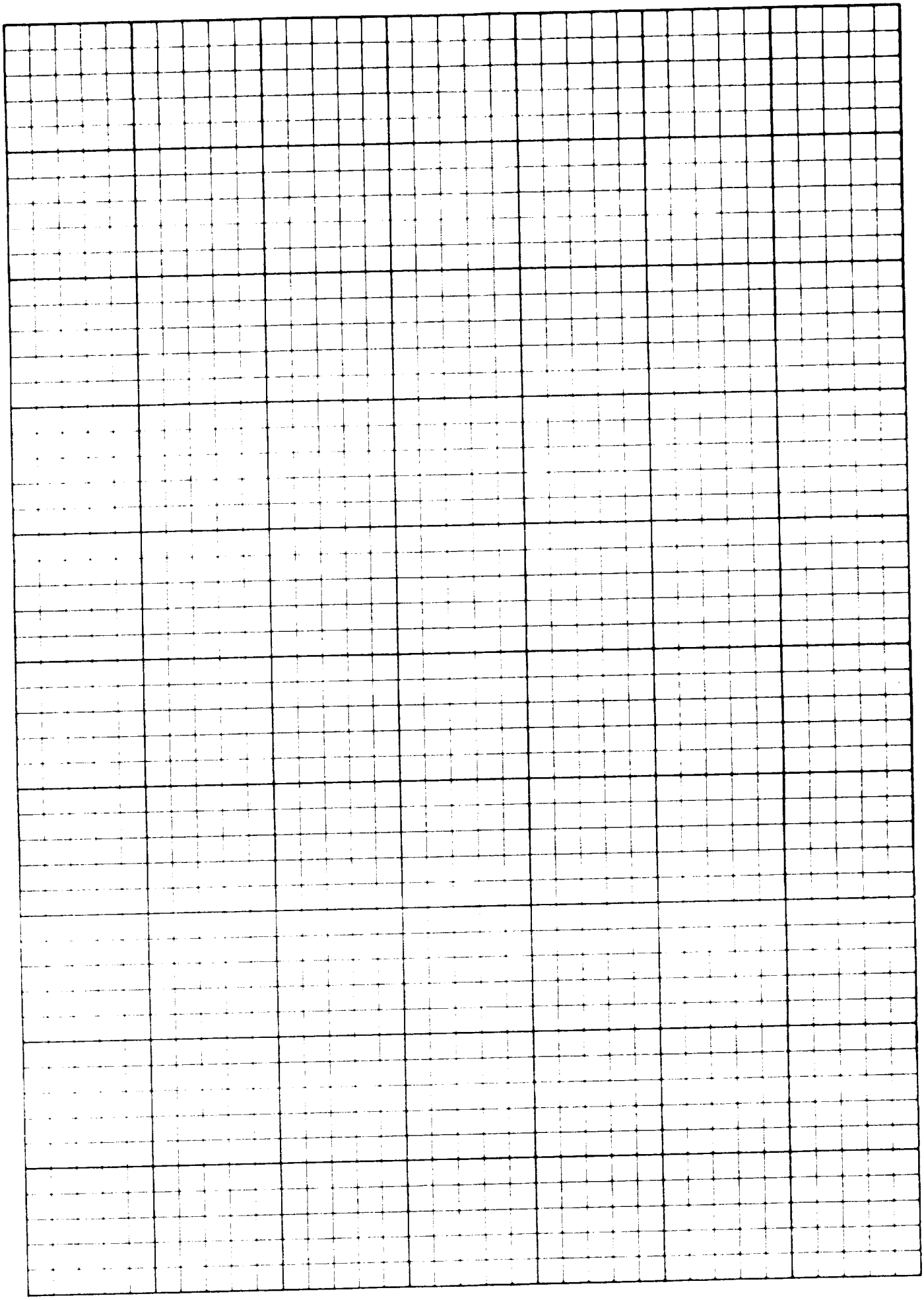
(6) CORRECT Atmosphere Selected

IF

- The desired atmosphere is the same as the downlisted atmosphere

THEN

- Notify operator that CORRECT atmosphere is selected.



3.1 B

(8) Commfaulted String in the PASS

IF
- A string is commfaulted in the PASS
- The string was not previously commfaulted

THEN
- Notify the operator that the string is commfaulted

(9) Commfaulted String in the BFS

IF
- A string is commfaulted in the BFS
- The string was not previously commfaulted

THEN
- Notify the operator that the string is commfaulted

(10) Clear String Commfault in the PASS

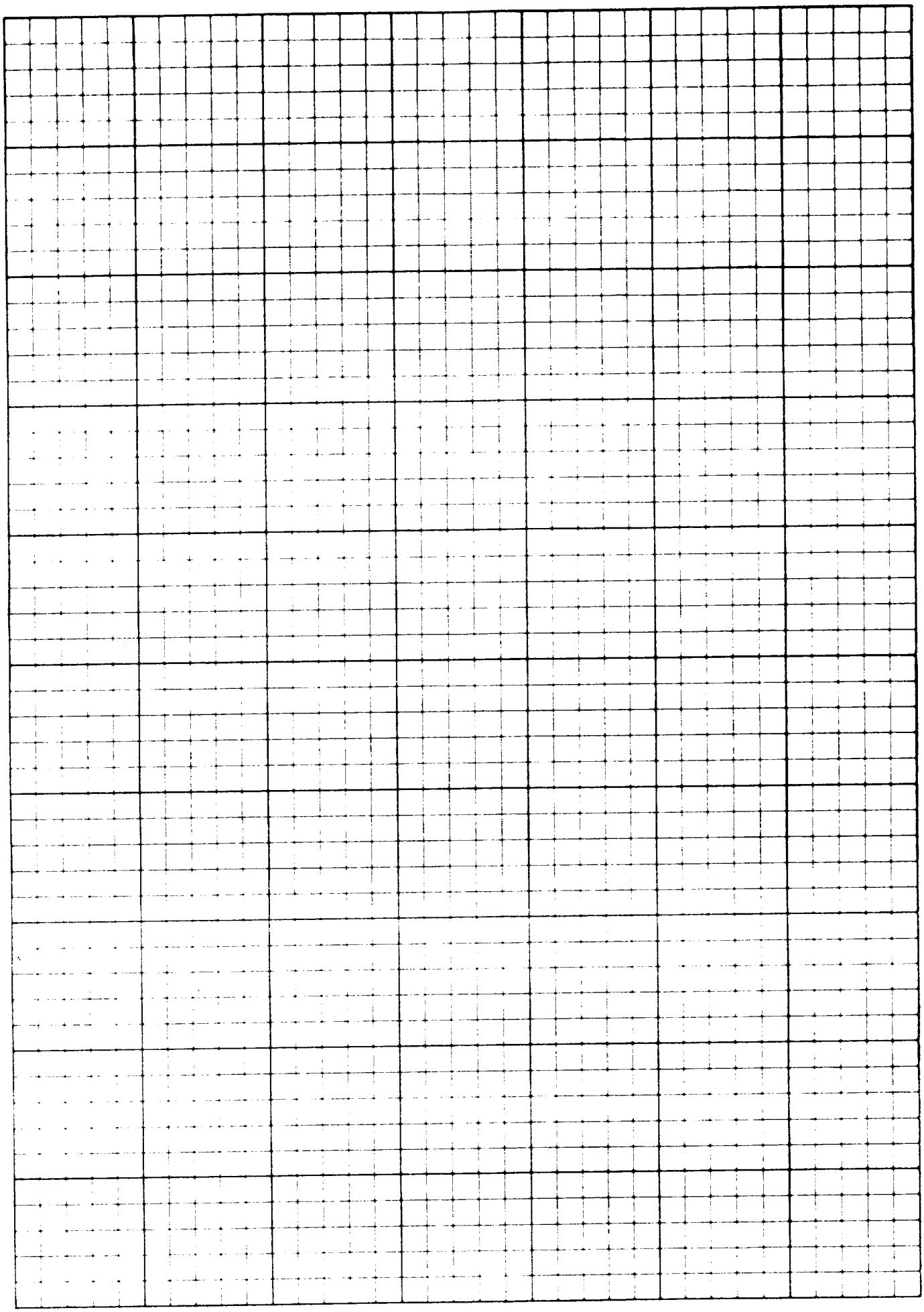
IF
- A string is not commfaulted in the pass
- The string was previously commfaulted

THEN
- Notify the operator that the commfault is clear

(11) Clear String Commfault in the BFS

IF
- A string is NOT commfaulted in the BFS
- The string was previously commfaulted

THEN
- Notify the operator that the commfault is clear



3.2 TELEMETRY STATUS

a. General Information

The telemetry (TLM) status tells the operator how much data is being downlisted. This is important since some variables are not available in low data rate.

b. Inputs

(1) Data available
(2) High data rate
(3) Low data rate

{No Rules specified at this time pending further details}

c. Rules/heuristics/concepts

Telemetry Status Change
IF
- The current status is not the same as the previous status
THEN
- Notify the operator of a telemetry status change.

d. Outputs

(1) TLM status (high, low, or none)
(2) Status change message

e. Support Computations

None.

3.3 ~~LANDING SITE~~ RUNWAY

a. General Information

It is important for the ground (GND) and onboard runways to match because delta state updates are computed in runway coordinates.

b. Inputs

(1) I-load runway names and slots
(2) Desired runway (name or slot number) (ONAV input)
(3) PASS runway (slot number)
(4) BFS runway (slot number)
(5) GND runway (name)
(6) System availability

c. Rules/heuristics/concepts

(1) Check GND Runway, Incorrect
IF
- The GND runway (name) is not the same as the desired runway (name)
THEN
- Notify operator that the selected GND runway is in error.
- Recommend call to Guidance Officer (GDO) to have trajectory change the GND runway.

(2) Check Onboard Runway, Incorrect
IF
- For the available systems
- The system runway (slot) is not the same as the desired runway (slot)
THEN
- Notify operator that the system has selected the wrong runway.
- Recommend call to crew to select proper runway.

3.3A

d. Outputs

(1) Runway selection error messages
(2) Item entry for area selection
(3) Item entry for primary/secondary runway
(4) Desired runway slot number

e. Support Computations

Calculate desired item entries to select the runways correctly.

For actual and desired runways in the same area,

Desired = primary - SPEC 50 item 3 (lower slot number)
Desired = secondary - SPEC 50 item 4 (higher slot number)

For actual and desired runways in different areas,

Desired = primary - SPEC 50 item 41 + area
Desired = secondary - SPEC 50 item 41 + area item 4

where area = (desired slot + 1)/2 truncated to an integer.

3.3 A

(3) Get desired RUNWAY from OPERATOR

IF
- The operator entered the desired RUNWAY slot number

THEN
- Conclude that the desired RUNWAY has that slot number

(4) Onboard RUNWAY CORRECT

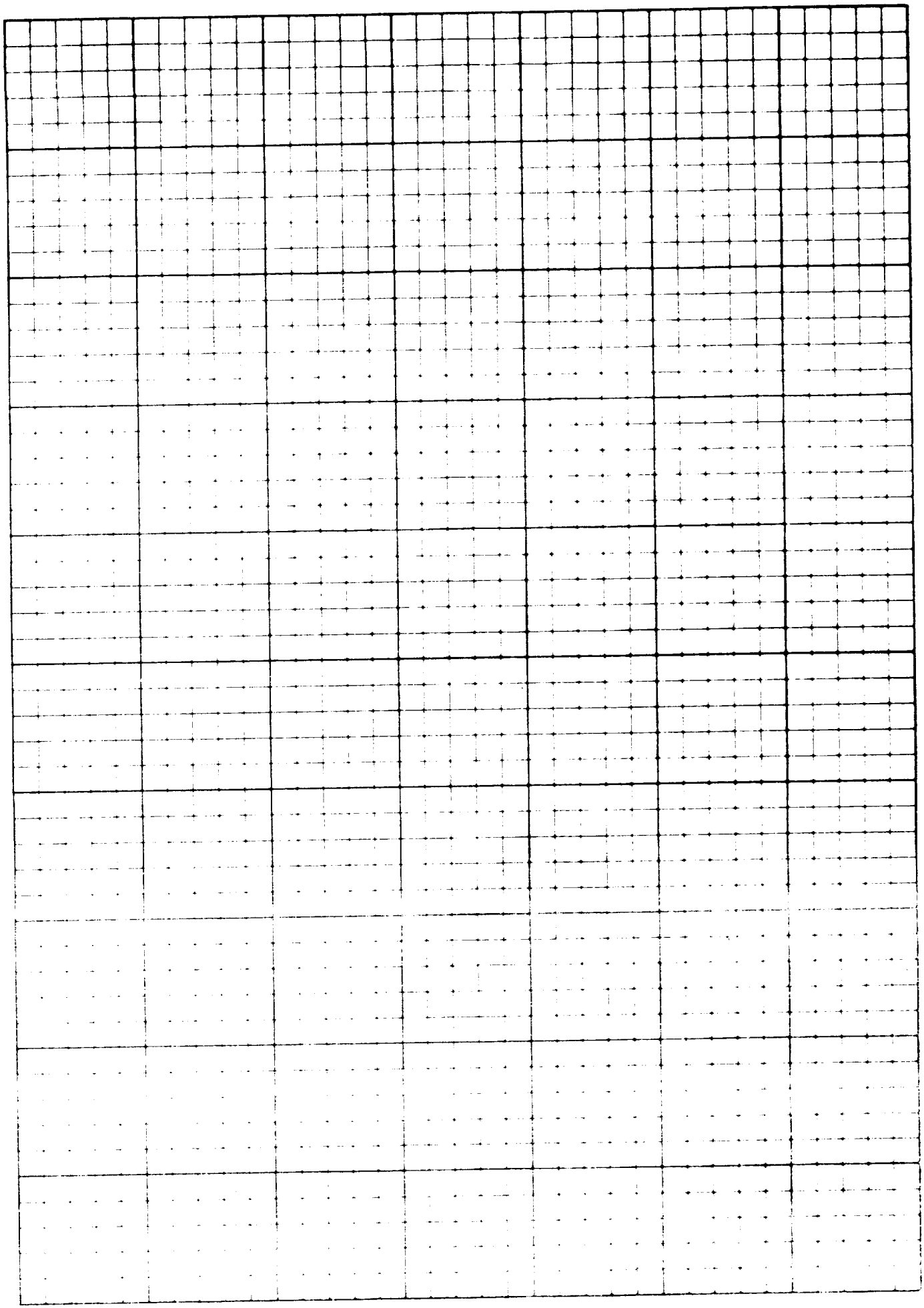
IF
- For the available SYSTEMS
- The selected runway in an onboard system is the same as the desired RUNWAY
- The runway STATUS of that system was previously UNKNOWN OR NO-GO

THEN
- Conclude that the runway status of the onboard system is go
- Notify the operator

(5) Onboard AREA INCORRECT

IF
- For the available SYSTEMS
- The selected runway in an onboard system is different from the desired RUNWAY
- The selected RUNWAY is not in the same area as the desired RUNWAY

THEN
- Notify operator that the correct area must be selected



3.4 INERTIAL MEASUREMENT UNITS (IMU's)

This section is divided into three major parts: availability, error growth, and recommended actions.

3.4.1 Availability

The purpose of this section is to determine which IMU's are available for use by navigation (NAV) or why an IMU is not available, and to note any changes in availability. Note that the check for good IMU's is to determine (1) how many IMU's can be used in the error detection and isolation sections, (2) if the IMU is independent of redundancy management (RM), and (3) if it is not a check of which IMU's are available.

3.4.1.1 PASS Availability

a. General Information

None.

b. Inputs

(1) IMU selection filter command
(2) Commfault flags
(3) String commfault flags
(4) RM failure flags
(5) Select/deselect flags
(6) BFS engage

c. Rules/heuristics/concepts

(1) IMU Commfault PASS
IF
- The PASS BFS is not engaged
- An IMU was not commfaulted in the PASS previously
- The commfault flag for that IMU is on in the PASS
THEN
- Notify operator that an IMU is commfaulted (unless the whole string is commfaulted).
- Conclude the IMU is unavailable to the PASS due to a commfault
- Conclude no IMU RM PREDICTION

(2) IMU Commfault Clear PASS (Part 1)
IF
- The PASS BFS is not engaged
- An IMU has been unavailable to the PASS due to commfault
- The commfault flag for that IMU is off in the PASS
- The fail flag or deselect flag for that IMU is on in the PASS
THEN
- Notify operator that the commfault has cleared (unless it was a string commfault).
- Conclude that the IMU is unavailable to the PASS due to failure or deselect, whichever flag is on.
- Conclude no IMU RM PREDICTION

(3) IMU Commfault Clear PASS (Part 2)
IF
- The BFS is not engaged
- An IMU has been unavailable to the PASS due to commfault.
- The commfault flag for that IMU is off in the PASS
- The fail flag for that IMU is off in the PASS
- The deselect flag for that IMU is off in the PASS

THEN
- Notify operator that the commfault has cleared (unless it was a string commfault).
- Conclude that the IMU is now available to the PASS.
- Conclude no IMU RM PREDICTION

(4) IMU Failed PASS
IF
- The BFS is not engaged
- An IMU has been available to the PASS
- The fail flag for that IMU is on in the PASS

THEN
- Notify operator of IMU failure.
- Conclude that the IMU is unavailable to the PASS due to failure.
- Conclude no IMU RM PREDICTION

(5) IMU Deselected PASS
IF
- The BFS is not engaged
- An IMU has been available to the PASS
- The deselect flag for that IMU is on in the PASS

THEN
- Notify operator of crew deselection.
- Conclude that the IMU is unavailable to the PASS due to deselect.
- Conclude no IMU RM PREDICTION

(6) IMU Reselected PASS
IF
- The BFS is not engaged
- An IMU has been unavailable to the PASS due to failure or deselect
- The fail flag for that IMU is off in the PASS.
- The deselect flag for that IMU is off in the PASS

THEN
- Notify operator of crew reselection.
- Conclude that the IMU is now available to the PASS.
- Conclude no IMU RM PREDICTION

(7) Three Good IMU's
IF
- The BFS is not engaged
- All three IMU's are not commfaulted in the PASS
- All three IMU's are good

THEN
- Conclude that three good IMU's are in the PASS.

(8) Two Good IMU's
IF
- The BFS is not engaged
- IMU A is not commfaulted in the PASS
- IMU A is good
- IMU B is not commfaulted in the PASS

- IMU B is good
- IMU C is commfaulted in the PASS or suspect

THEN

- Conclude that we have two good IMU's in the PASS.

(9) One Good IMU

IF

- The BFS is not engaged
- IMU A is not commfaulted in the PASS
- IMU A is good
- IMU B is commfaulted in the PASS or suspect
- IMU C is commfaulted in the PASS or suspect

THEN

- Conclude that we have one good IMU in the PASS.

(10) No Good IMU's

IF

- The BFS is not engaged
- All three IMU's are commfaulted in the PASS or suspect

THEN

- Notify operator of IMU shortage in the PASS.
- Conclude that we have no good IMU's in the PASS.

d. Outputs

(1) IMU good status
(2) IMU downmodes
(3) IMU upmodes
(4) IMU PREDICTION INDICATOR

e. Support Calculations

None.

3.4.1.2 BFS Availability

a. General Information

When the BFS is engaged, the expert system cannot keep track of IMU deselections and reselections except in certain situations.

b. Inputs

(1) Commfault flags
(2) String commfault flags
(3) Hardware failure flags
(4) BFS IMU
(5) BFS NO GO
(6) BFS engaged
(7) IMU deselect flag

c. Rules/heuristics/concepts

(1) IMU Commfault BFS
IF
- The BFS is available
- An IMU was not commfaulted in the BFS previously
- The commfault flag for that IMU is on in the BFS
THEN
- Conclude that the IMU is not available to the BFS due to commfault.
- Notify operator of IMU commfault (unless the whole string is commfaulted).

(2) IMU Commfault Clear BFS (Not Engaged)
IF
- The BFS is available
- The BFS is not engaged
- An IMU was unavailable to the BFS due to commfault
- The commfault flag for that IMU is off in the BFS
THEN
- Conclude that the IMU is available to the BFS (if the fail flag is off) or unavailable due to failure (if the fail flag is on).
- Notify operator that commfault has been cleared (unless the whole string is commfaulted).

(3) IMU Commfault Clear BFS (Engaged, Part 1)
IF
- The BFS is engaged
- An IMU has been unavailable to the BFS due to commfault
- The commfault flag for that IMU is off in the BFS
- The fail flag or deselect flag for that IMU is on in the BFS
THEN
- Notify operator that the commfault has cleared (unless it was a string commfault).
- Conclude that the IMU is unavailable to the BFS due to failure or deselect, whichever flag is on.

(4) IMU Commfault Clear BFS (Engaged, Part 2)
IF
- The BFS is engaged
- An IMU has been unavailable to the BFS due to commfault
- The commfault flag for that IMU is off in the BFS
- The fail flag for that IMU is off in the BFS
- The deselect flag for that IMU is off in the BFS
THEN
- Notify operator that the commfault has cleared (unless it was a string commfault).
- Conclude that the IMU is now available to the BFS.

(5) IMU Failed BFS
IF
- The BFS is available
- An IMU was available to the BFS
- The fail flag for that IMU is on in the BFS
THEN

- Conclude that the IMU is unavailable to the BFS due to failure.
- Notify operator of IMU failure in the BFS.

(6) IMU Deselected BFS (Not Engaged, Part 1)
IF the BFS is not engaged
- The BFS is available
- The BFS was mid-value selecting IMU's
- All IMU commfault flags are off in the BFS
- All IMU fail flags are off in the BFS
- The BFS is prime selecting an IMU

THEN
- Notify the operator that BFS has changed IMU status due to crew action.
- Notify the operator that BFS is now prime selecting an IMU

(7) IMU Deselected BFS (Not Engaged, Part 2)
IF
- The BFS is GO, available
- The BFS is not engaged
- The BFS was prime selecting an IMU
- The commfault flag for that IMU is off in the BFS
- The fail flag for that IMU is off in the BFS
- The BFS is now prime selecting a different IMU

THEN
- Notify operator that the formerly selected IMU has been deselected.
- Notify operator that BFS is now prime selecting a different IMU

(8) IMU Deselected BFS (Engaged)
IF
- The BFS is GO, available
- The BFS is engaged
- An IMU has been available to the BFS
- The deselect flag for that IMU is on the BFS

THEN
- Notify operator of crew deselection in the BFS.
- Conclude that the IMU is unavailable to the BFS due to deselection.

(9) IMU Reselection BFS (Engaged)
IF
- The BFS is engaged
- An IMU has been unavailable to the BFS due to failure or deselect
- The fail flag for that IMU is off in the BFS
- The deselect flag for that IMU is off in the BFS

THEN
- Notify operator of crew reselection.
- Conclude that the IMU is now available to the BFS.

(10) IMU Change BFS
IF
- The BFS is GO, available
- The fail flag or commfault flag for an IMU is on in the BFS
- That IMU was the prime selected IMU or the BFS was mid-value selecting

THEN
- Notify operator of a change in BFS IMU status due to commfault or failure.

d. Outputs

(1) BFS downmodes
(2) BFS upmodes
(3) Changes in selected IMU in the BFS

e. Support Calculations

None.

3.4.2 Error Growth

This section's purpose is to detect an IMU that is going bad, isolate which IMU is going bad, predict whether that IMU will fail in the next minute, and determine the magnitude of the IMU error.

3.4.2.1 Error Detection

The comparisons in this section can be done with an IMU that is not available for NAV. This is done only so that, if there is a problem at the two IMU level, the IMU not available to NAV can be used to help isolate the bad IMU in some circumstances. The term "valid" in the following sections means that an IMU can be used in comparisons with other IMU's; it does not refer to the overall health of an IMU or to its suitability for use in the onboard system.

All comparisons are either good, over half of the RM threshold, or over the RM threshold.

3.4.2.1.1 Velocity comparisons.-

a. General Information

None.

b. Inputs

(1) Velocity differences
(2) IMU status (PASS)
(3) BFS engage

c. Rules/heuristics/concepts

(1) Valid Velocity
IF PASS is engaged
- The BFS is not engaged
- An IMU is not commfaulted
- That IMU is good or is suspect due to drift
THEN
- Conclude that velocity comparisons with that IMU are valid.

(2) Invalid Velocity
IF PASS is engaged
- The BFS is not engaged
- An IMU is commfaulted or is suspect due to anything but drift
THEN
- Conclude that velocity comparisons with that IMU are invalid.

(3) Velocity Comparison (Part 1)
IF PASS is engaged
- The BFS is not engaged
- IMU A is not commfaulted
- IMU B velocity is valid
- Velocity comparison A-B is different from IMU A's earlier velocity comparison status
- IMU C velocity is invalid
THEN
- Change IMU A's velocity comparison status to current A-B comparison status.

(4) Velocity Comparison (Part 2)
IF PASS is engaged
- The BFS is not engaged
- IMU A is not commfaulted
- IMU B velocity is valid
- Velocity comparison A-B is some status (call it status-1)
- IMU C velocity is valid
- Velocity comparison A-C is some status (call it status-2)
- The smaller of status-1 and status-2 is different from IMU A's earlier velocity comparison status
THEN
- Change IMU A's velocity comparison status to the smaller of status-1 and status-2.

d. Outputs

Velocity miscompare indicators.

e. Support Computations

None.

3.4.2.1.2 Attitude comparisons.-

a. General Information

None.

b. Inputs

(1) Attitude differences
(2) IMU status (PASS)
(3) BFS engage
PASS

c. Rules/heuristics/concepts

(1) Valid Attitude
IF
- The BFS is not engaged
- An IMU is not commfaulted
- That IMU is good or is suspect due to accelerometer bias
THEN
- Conclude that attitude comparisons with that IMU are valid.

(2) Invalid Attitude
IF
- The BFS is not engaged
- An IMU is commfaulted or is suspect due to anything but bias
THEN
- Conclude that attitude comparisons with that IMU are invalid.

(3) Attitude Comparison (Part 1)
IF
- The BFS is not engaged
- IMU A is not commfaulted
- IMU B attitude is valid
- Attitude comparison A-B is different from IMU A's earlier attitude comparison status
- IMU C attitude is invalid
THEN
- Change IMU A's attitude comparison status to current A-B comparison status.

(4) Attitude Comparison (Part 2)
IF
- IMU A is not commfaulted
- IMU B attitude is valid
- Attitude comparison A-B is some status (call it status-1)
- IMU C attitude is valid
- Attitude comparison A-C is some status (call it status-2)
- The smaller of status-1 and status-2 is different from IMU A's earlier attitude comparison status
THEN
- Change IMU A's attitude comparison status to the smaller of status-1 and status-2.

d. Outputs

Attitude miscompare indicators.

e. Support Computations

None.

3.4.2.1.3 Accelerometer (ACC) comparisons.-

a. General Information

None.

b. Inputs

(1) ACC differences
(2) IMU availability (PASS)
(3) Reference IMU
(4) ACC delta-T
(5) PASS engaged

c. Rules/heuristics/concepts

(1) Valid to Use ACC Comparison
IF PASS
- The BFS is not engaged
- The ACC delta-T > 30 sec
THEN
- Valid to use ACC comparison.

(2) Valid ACC
IF the PASS is engaged
- An IMU is not commfaulted
- That IMU is good or is suspect due to resolver
THEN
- Conclude that ACC comparisons with that IMU are valid.

(3) Invalid ACC
IF the PASS is engaged
- An IMU is commfaulted or is suspect due to anything but resolver
THEN
- Conclude that ACC comparisons with that IMU are invalid.

(4) ACC Comparison (Part 1)
IF the PASS is engaged
- IMU A is not commfaulted
- IMU B ACC is valid
- Worst axis ACC comparison A-B is different from IMU A's earlier ACC comparison status
- IMU C ACC is invalid
THEN
- Change IMU A's ACC comparison status to current A-B comparison status.

(5) ACC Comparison (Part 2)
IF the PASS is engaged
- IMU A is not commfaulted
- IMU B ACC is valid
- Worst axis ACC comparison A-B is some status (call it status-1)
- IMU C ACC is valid
- Worst axis ACC comparison A-C is some status (call it status-2)
- The smaller of status-1 and status-2 is different from IMU A's

earlier ACC comparison status
THEN
- Change IMU A's ACC comparison status to the smaller of status-1 and status-2.

(6) Worst Comparison
IF the PASS is engaged
- Exactly two good IMU's are available
- Those two IMU's disagree in any way
THEN
- Conclude that two-level isolation must be used to determine which of the two IMU's has a problem.

d. Outputs

ACC miscompare indicators.

e. Support Computations

None.

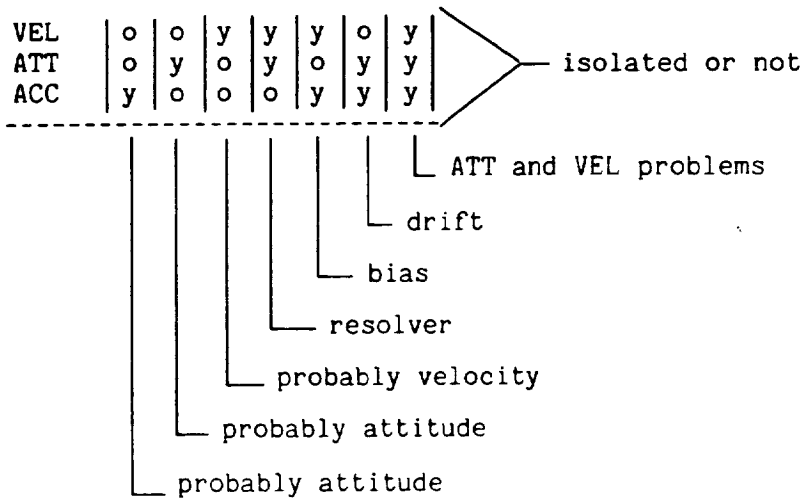
3.4.2.2 Error Isolation

3.4.2.2.1 Three-level isolation.-

a. General Information

At the three-level with no suspect IMU's, use the following fault matrix with a miscompare indicated for an IMU if it disagrees with both of the other IMU's.

A table drawn up to categorize the type of error that probably exists when problems have been isolated to a component is as follows:



NOTE: ACC means either ACC-x, ACC-y, or ACC-z.
o means okay; y means yes, there is a problem (i.e., an IMU miscompared with both other IMU's).

b. Inputs

(1) Velocity miscompare indicators
(2) Attitude miscompare indicators
(3) ACC miscompare indicators
(4) IMU availability (PASS)

c. Rules/heuristics/concepts

Three-level Component Isolation
IF
- The BFS is not engaged
- There are three good IMU's
- An IMU disagrees with the other two IMU's
THEN
- Use the fault matrix to determine the problem with the IMU.
- Notify operator of an IMU problem.

d. Outputs

IMU quality rating.

e. Support Computations

None.

3.4.2.2.2 Two-level isolation.-

a. General Information

When a miscompare exists between the two remaining good IMU's, four methods can be used to determine which IMU has the problem. The results of these methods is combined via a voting scheme.

- Method 1. Check A/GND and B/GND (where A and B are the two remaining IMU's) to see if exactly one is over the threshold. If so, vote 1 for that IMU; otherwise vote zero for both.

- Method 2. Check state vectors A and B to see if exactly one is bad. If so, vote 2 for that IMU; otherwise vote zero for both IMU's.

- Method 3. Let A be the reference IMU for the ACC comparison. If ACC miscompares are in the X-Y plane or in the Z axis (but not in both), vote 1 for A.

- Method 4. If IMU C is valid in velocity, attitude, or ACC, use valid comparisons with IMU C to check IMU's A and B. If exactly one IMU disagrees with C, vote 1 for that IMU. See section 3.4.2.1 for a definition of a valid comparison.

If either IMU outvotes the other by two or more, that IMU is declared suspect.

Once the IMU has been isolated, use comparisons with the other IMU and the fault matrix in section 3.4.2.2.1(a) to determine the problem with the bad IMU.

b. Inputs

(1) 1,2,3/GND IMU differences
(2) 1,2,3/GND state errors
(3) Velocity miscompare indicators
(4) ACC miscompare indicators
(5) IMU availability (PASS)
(6) Reference IMU
(7) IMU quality rating
(8) High-speed trajectory determinator (HSTD) status
(9) engaged system

c. Rules/heuristics/concepts

(1) Two-level GND Comparison
IF the PASS is engaged
- HSTD is good
- An error between IMU's A and B has been detected at the two-level
- Worst axis GND-IMU A comparison is some status (call it status-a)
- Worst axis GND-IMU B comparison is some status (call it status-b)
- GND-IMU comparison has not yet voted
THEN
- When status-a = status-b, vote zero for both IMU's.
- Otherwise, vote 1 for the IMU with the larger difference and zero for the other IMU.

(2) Two-Level GND Cannot Vote
IF the PASS is engaged
- An error between IMU's A and B has been detected at the two-level GND comparison
- The HSTD is not good
- GND-IMU comparison has not voted yet
THEN
- Vote zero for IMU's A and B.

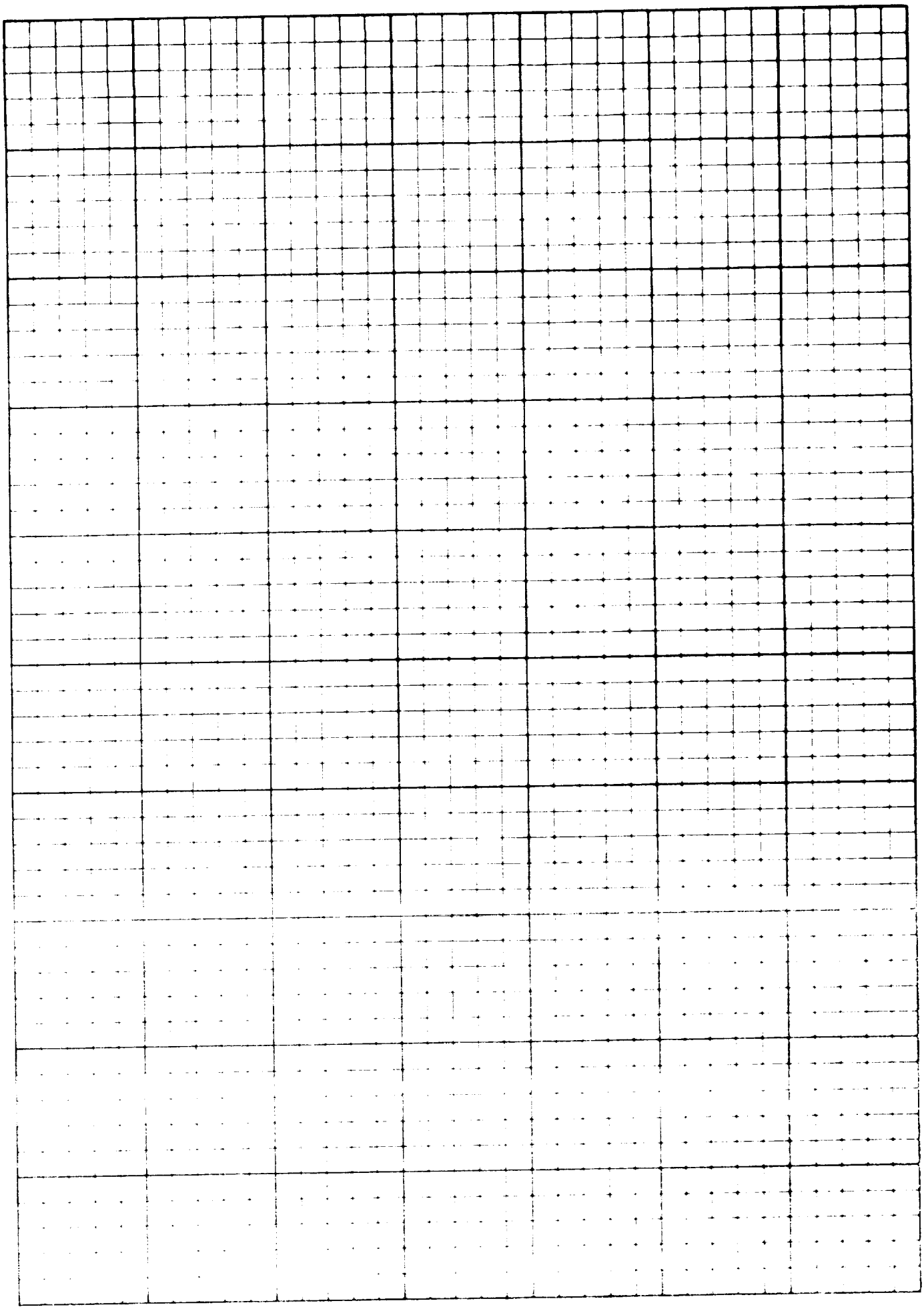
(3) Two-level State Comparison
IF the PASS is engaged - three state nav is active
- HSTD is good
- ~~Microwave scanning beam landing system (MSBLS) is not processing and never has processed~~
- An error between IMU's A and B has been detected at the two-level state comparison
- worst axis GND- State-A comparison is some status (call it status-a)
- State-B comparison is some status (call it status-b)
- State comparison has not voted yet
THEN
- When status-a = status-b, vote zero for both IMU's.

3.4A

(4) Two Level State Cannot Vote

IF
- The PASS is engaged
- The HSTD is NOT GOOD OR 3-state nav is inactive
- GND-state comparison has not voted yet

THEN
- Vote Ø for IMUs A and B



- Otherwise, vote 2 for the IMU with the larger difference and zero for the other IMU.

(4) Two-level ACC Comparison
5 IF the PASS is engaged
- An error between IMU's A and B has been detected at the two-level ACC comparison
- IMU A is the reference for ACC comparisons
- X-axis ACC comparisons A-B is some status (call it status-x)
- Y-axis ACC comparisons A-B is some status (call it status-y)
- Z-axis ACC comparisons A-B is some status (call it status-z)
- ACC comparison has not voted yet

THEN
- If status-x, status-y, and status-z indicate the error lies in the X-Y plane or Z-axis of IMU A, vote 1 for IMU A; otherwise, vote zero for IMU A.
- Vote zero for IMU B.

(5) Two-level ACC Cannot Vote
6 IF the PASS is engaged
- An error between IMU's A and B has been detected at the two-level ACC
- Neither A nor B is the ACC reference IMU
- ACC comparison has not voted yet

THEN
- Vote zero for both IMU's A and B.

(6) Partial IMU Velocity
7 IF the PASS is engaged
- An error between IMU's A and B has been detected at the two-level partial IMU velocity
- IMU C velocity is valid
- IMU A's velocity comparisons with IMU's B and C is some status (call it status-a)
- IMU B's velocity comparisons with IMU's A and C is some status (call it status-b)
- Partial IMU velocity comparison has not voted yet

THEN
- When status-a = status-b, vote zero for both IMU's A + B
- Otherwise, vote 1 for the IMU with the larger difference and zero for the other IMU.

(7) Partial IMU Attitude
8 IF the PASS is engaged
- An error between IMU's A and B has been detected at the two-level partial IMU attitude
- IMU C attitude is valid
- IMU A's attitude comparisons with IMU's B and C is some status (call it status-a)
- IMU B's attitude comparisons with IMU's A and C is some status (call it status-b)
- Partial IMU attitude comparison has not voted yet

THEN
- When status-a = status-b, vote zero for both IMU's A + B

- Otherwise, vote 1 for the IMU with the larger difference and zero for the other IMU.

(8) Partial IMU ACC
9 IF the PASS is engaged
- An error between IMU's A and B has been detected at the two-level partial IMU ACC
- IMU C ACC is valid
- IMU A's ACC comparisons with IMU's B and C are some status (call it status-a)
- IMU B's ACC comparisons with IMU's A and C are some status (call it status-b)
- Partial IMU acceleration comparison has not voted yet

THEN
- When status-a = status-b, vote zero for both IMU's.
- Otherwise, vote 1 for the IMU with the larger difference and zero for the other IMU.

(9) Partial IMU Cannot Vote
10 IF the PASS is engaged
- An error between IMU's A and B has been detected at the two-level partial IMU
- IMU C is invalid in velocity, attitude, and ACC
- Partial IMU comparison has not voted yet

THEN
- Vote zero for IMU's A and B.

(10) Two-level Vote Count
11 IF the PASS is engaged
- GND-IMU comparison rules have cast v1 votes for an IMU
- State comparison rules have cast v2 votes for that IMU
- ACC comparison rules have cast v3 votes for that IMU
- Partial IMU velocity comparison rules have cast v4 votes for that IMU

GND

THEN
- Compute vote total for the IMU as v1 + v2 + v3 + v4.
  - Partial IMU att comparison rules have cast v5 votes for that Imu
  - Partial IMU acc comparison rules have cast v6 votes for that Imu

+v5 + v6

(11) Two-level IMU Isolation
12 IF the PASS is engaged
- Votes for IMU A exceeded votes for IMU B by two or more

THEN
- Conclude that IMU A has an error.

(12) Two-level Component Isolation
13 IF the PASS is engaged
- An error between IMU's A and B has been detected at the two-level component isolation
- IMU A is the one with the problem

THEN
- Use the fault matrix to determine the problem with IMU A.
- Notify operator of the problem.
- Clear the miscompare indications for IMU B.

(~~13~~) Two-level Cannot Isolate
14 IF the PASS is engaged
- Votes for IMU A did not exceed votes for IMU B by two or more
- Votes for IMU B did not exceed votes for IMU A by two or more
THEN
- Notify operator that the IMU error cannot be isolated.

(~~14~~) Change IMU Quality
IF the Pass is engaged
15 - An IMU was diagnosed as having a problem previously
- That IMU's comparisons now indicate a different diagnosis
- The new indicated diagnosis is a bias, resolver, or drift, or if it is no problem at all
THEN
- Update the IMU's quality rating to reflect the new diagnosis.
- Notify the operator of the new diagnosis.

d. Outputs

IMU quality rating.

e. Support Computations

None.

3.4.2.3 Error Magnitude

a. General Information

It is desirable for notification messages to contain the following information: who, why, and magnitude. For example, "IMU# <who> has a <why> of <magnitude>; It <should/should not> fail." Magnitude information is used to make the "should/should not" determination.

Algorithms exist to do this, including using the largest compare (largest valid compare).

b. Inputs

(1) IMU quality rating
(2) Velocity differences
(3) Attitude differences

c. Rules/heuristics/concepts

(1) Bias Magnitude
IF the PASS is engaged
- IMU A has an accelerometer bias
- IMU B velocity is valid
- IMU C velocity is invalid or IMU C has a ~~lower number~~ A-C pairwise smallest difference than B's IMU A-B pairwise
THEN
- Compute the magnitude of the bias using the A-B pairwise velocity comparison.

- Notify operator of the magnitude of the bias.

(2) Resolver Magnitude
IF the PASS is engaged
- IMU A has a resolver error
- IMU B attitude is valid
- IMU C attitude is invalid or IMU C has a lower number than A-B compare smaller difference the IMU A-B comparison
THEN
- Compute the magnitude of the resolver error using the A-B pairwise attitude comparison.
- Notify operator of the magnitude of the resolver error.

3.4B

(3) Drift Magnitude
IF the PASS is engaged
- IMU A has a drift
- IMU B attitude is valid
- IMU C attitude is invalid or IMU C has a lower number than A-C compare smaller difference IMU A-B compare
THEN
- Compute magnitude of the drift using the A-B pairwise attitude comparisons, and the initial misalignment of A.
- Notify operator of the magnitude of the drift.

d. Outputs

(1) Accelerometer bias
(2) Drift rate
(3) Resolver error

e. Support Computations

For velocity (bias),
magnitude = 2023 * (add blank space)
(SQRT largest-valid-velocity-difference)
(units of micro-g's)

For attitude (resolver),
magnitude = deg/rad *
(SQRT largest-valid-attitude-difference)
(units in degrees)

For attitude (drift),
magnitude = sec/hour * (resolver-t - resolver-o) /
(t - t-o)
(units in deg/hr)
o is at some initial time (e.g., deorbit prep). Resolver-t and resolver-o are computed by the resolver magnitude equation above.

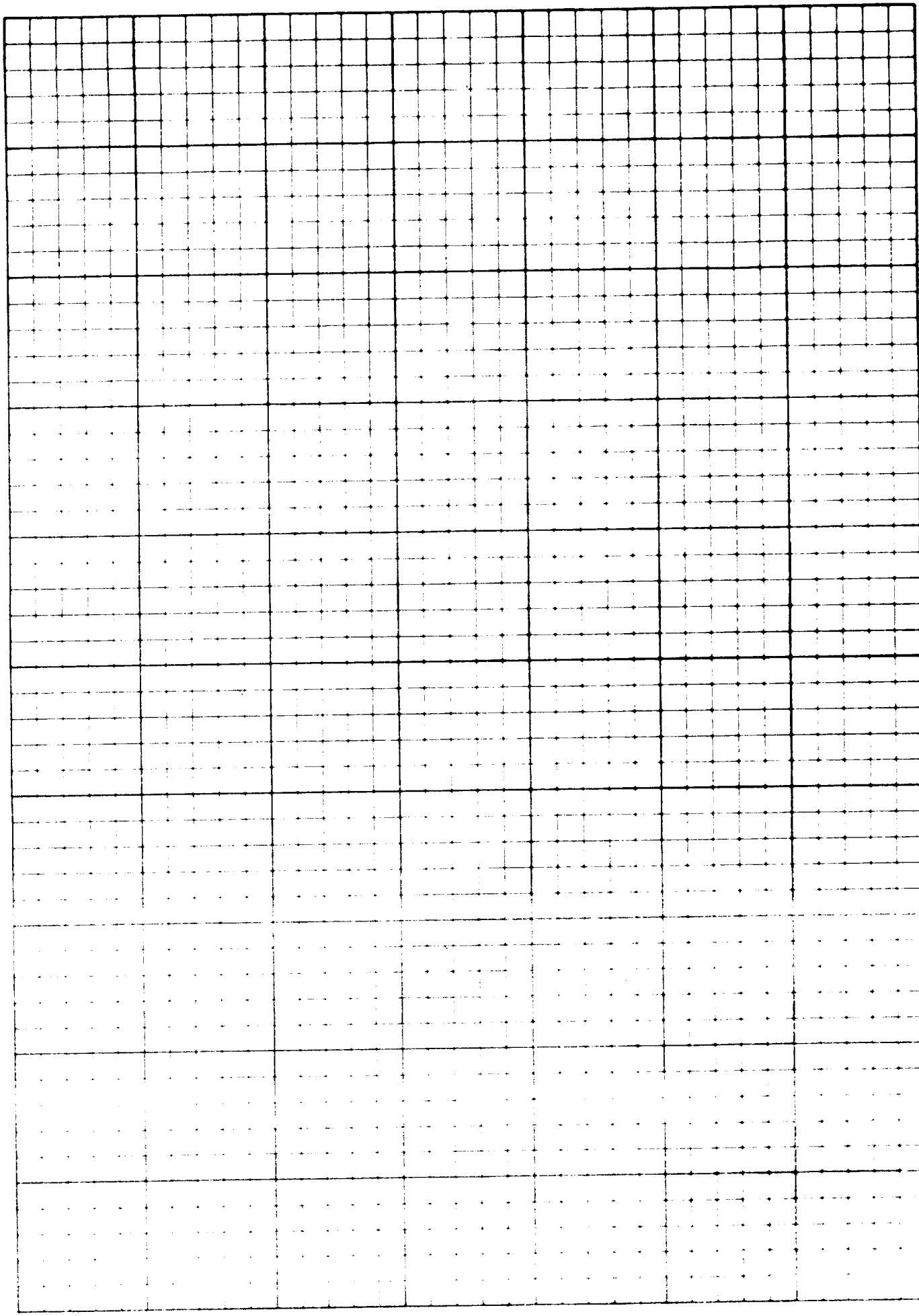
It should be noted that, at the two level, for example, if IMU 1 is failed, 2-3 is the compare to use.

3.4B

(4) Initial Misalignment

IF
- The PASS is engaged
- The initial misalignment for IMU A is unknown
- IMU B attitude is valid
- IMU C attitude is invalid OR IMU A-C compare has a lower difference than the IMU A-B comparison

THEN
- Compute the misalignment of IMU A using the A-B pairwise attitude comparison
- Save the computed misalignment for later drift calculations



3.4.2.4 Failure Prediction

a. General Information

Failure prediction is based on miscompares which exceed an RM threshold. Recall that error detection and isolation are based on miscomparisons exceeding half of an RM threshold.

b. Inputs

(1) IMU selection filter command
(2) Velocity differences
(3) Attitude differences

c. Rules/heuristics/concepts

(1) Three-level Failure Prediction
IF
- Onboard IMU RM is at the three-level failure prediction
- Exactly two pairwise differences exceed the fail threshold in either velocity or attitude
- A failure has not been predicted yet
THEN
- Predict RM will fail the IMU common to the two pairs that exceed the threshold. and notify operator

(2) Three-level No Failure Prediction
IF
- Onboard IMU RM is at the three level with no failure prediction
- All three pairwise differences in velocity or attitude exceed the fail threshold
- A failure has not been predicted yet
THEN
- Predict IMU RM will not take any action. and notify operator

(3) Two-level Failure Prediction
IF
- Onboard IMU RM is at the two level failure protection
- IMU A is available but not good
- IMU B is available and good
- IMU's A and B differ in velocity or attitude by more than some threshold
- A failure has not been predicted yet
THEN
- Predict an RM action and notify operator that ~~indicate~~ IMU A is the one that needs to be failed.

(4) Check Bite

When at two level and IMU A has bite and IMU B is bad, predict that RM will fail the wrong IMU. This must consider the possibility of needing a test on previous rules to know that IMU RM will do anything at all.

d. Outputs

Predicted IMU failure.

e. Support Computations

None.

3.4.3 Recommended Actions

3.4.3.1 PASS IMU ~~Actions~~ RECOMMENDATIONS

a. General Information

None.

b. Inputs

(1) IMU availability (PASS)
(2) IMU quality rating
~~(3) Attitude IMU~~

c. Rules/heuristics/concepts

(1) Reselect IMU with one OR Three State NAV
IF
- An IMU is unavailable to the PASS due to deselection
- That IMU is good
THEN
- Recommend that IMU be reselected (after zero delta state if three-state NAV is still active) OR recommend that Imu be reselected if 3-state Nav is not active.

(2) Help IMU Dilemma
IF
- IMU RM is in dilemma
- IMU A is available to the PASS and is good
- IMU B is available to the PASS and is not good
THEN
- Recommend deselecting IMU B to resolve Imu dilemma

(3) Cannot Help IMU Dilemma
IF
- IMU RM is in dilemma
- IMU A is available to the PASS
- IMU B is available to the PASS
- Either A and B are both good or A and B are both not good
THEN
- Notify operator that dilemma cannot be resolved.

(4) Incorrect IMU Failure
IF
- IMU A is unavailable to the PASS due to failure

- IMU A is good
- IMU B is available to the PASS
- IMU B is not good

THEN
- Notify operator of incorrect RM isolation and recommend switching to IMU A.

(5) Deselect Commfaulted IMU

IF
- An IMU is unavailable to the PASS due to commfault for some amount of time
- That IMU has not been deselected

THEN
- Recommend deselecting the IMU.

d. Outputs

PASS deselect/reselect messages.

e. Support Computations

None.

3.4.3.2 BFS IMU ~~Actions~~ RECOMMENDATIONS

a. General Information

A general rule for BFS IMU's is that an IMU should not be available in BFS if it is not available in PASS, unless it is the only one left in BFS. It should be noted that the ~~==~~ LRU number assigned to a given IMU ~~has some~~ is of importance for certain recommendations.

b. Inputs

(1) IMU availability (BFS)
(2) BFS IMU
(3) IMU quality rating

c. Rules/heuristics/concepts

(1) Deselect IMU in BFS

IF
- IMU A is not available to the PASS
- IMU A is available to the BFS
- IMU B is available to the BFS
- IMU B is good

THEN
- Recommend deselecting IMU A in the BFS.

(2) No BFS IMU's

IF
- The BFS is on IMU A
- IMU A is unavailable to the PASS
- Neither IMU B nor IMU C is available to the BFS

THEN
- Notify operator of IMU shortage in the BFS.

(3) Change BFS IMU (Part 1)
IF
- The BFS is on IMU A
- IMU A is not good
- IMU A is available to the PASS
- IMU B is available to the BFS
- IMU B is good
- Either IMU C is unavailable to the BFS or has a higher number than has IMU B

THEN
- Recommend deselect/reselect IMU A to put the BFS on IMU B.

(4) Change BFS IMU (Part 2)
IF
- The BFS is on IMU A
- IMU A is not good
- IMU B is available to the BFS and is good
- IMU C is available to the BFS but is not good
- IMU C has a lower number than has IMU B

THEN
- Recommend deselect/reselect IMU's A and C to put the BFS on IMU B.

d. Output

BFS deselect/reselect messages.

e. Support Computations

None.

3.5 STATE VECTORS

3.5.1 State Error Status

a. General Information

IF GROUND COMPARES AVAILABLE
Use this table [see note 3]

GND-PRI	GND-BFS	PFS-BFS	Call to Guidance
> UPDATE LIMIT	> XFER Limit	N/A	PASS has (error) [see note 1] BFS has (error) Need ST. VECTOR UPDATE; No XFER is required
"	> GAL	N/A	PASS has (error) BFS has (error) Need ST. VECTOR UPDATE; No XFER is required
"	IN Limits	N/A BFS is GO	PASS has (error) Need ST. VECTOR UPDATE; No XFER is needed
> GUIDE ADV.	> XFER Limit	>GAL	PASS has (error) [see note 1] BFS has (error) Need ST. VECTOR XFER
LIMIT (GAL)	"	<GAL	PASS has (error) [see note 2] BFS has (error) No XFER is needed
"	> GAL	N/A	PASS has (error) BFS has (error)
"	IN Limits	N/A	PASS has (error) BFS is GO
IN LIMIT	> XFER Limits	N/A	PASS is GO BFS has (error) Need ST. VECTOR XFER
"	> GAL	N/A	PASS is GO BFS has (error)
"	IN Limits	N/A	PASS and BFS ARE GO

NOTE 1: Unless the GND-PRI is about to violate the update criteria, the transfer will take out a significant amount of error in the BFS. Otherwise, it might be better to wait for the GND-PRI error to violate the update criteria and treat it appropriately.

NOTE 2: The error taken out by a transfer is not significant in this case.

NOTE 3: Prior to main engine cutoff (MECO)
DELTA STATE
Post MECO
WHOLE STATE

IF GROUND COMPARES NOT AVAILABLE
Use this table

PFS-BFS	IMU-Situation	Call to Guidance
> XFER LIMITS	Two IMU Level	(error) between PASS and BFS
	One BAD IMU BFS on Good One	BFS better than PASS so NO XFER needed [see note 4]
"	All	(error) between PASS and BFS
	Other Cases	Need state vector transfer
> GAL	N/A	(error) between PASS and BFS
IN LIMITS	N/A	PASS and BFS are TRACKING

NOTE 4: A transfer would make the BFS as bad as the PASS.

VERIFY STATE VECTOR UPDATE

when |GND-PRI->~0
|call "Guidance the update is onboard"

VERIFY STATE VECTOR TRANSFER

when |GND-BFS ~ GND-PRI or PFS-BFS ~ 0
|CALL "Guidance we see the transfer"

b. Inputs

(1) HSTD health
(2) GND-PASS
(3) GND-BFS
(4) PASS-BFS
(5) System availability

(6) Delta time (DT) (PASS-BFS state vector time tag difference)

c. Rules/heuristics/concepts

(1) State Error Change
IF
- For available systems
- The system worst axis error is different from what it was on the previous cycle
THEN
- Record the new worst axis status.

(2) Report State Error
IF
- More than 60 sec have elapsed since the last report
THEN
- Report the error on every axis whose status is the same as the worst axis.

(3) PASS and BFS Timing Problem
IF
- The HSTD is not good
- Both systems are available
- The DT is > |0.0003|
THEN
- There is a timing problem between the PASS and the BFS.

(4) PASS BFS Error Change
IF
- Both systems are available
- No timing problem exists between the PASS and the BFS
- The HSTD is not good
- The PASS-BFS worst axis error is different from what it was on the previous cycle
THEN
- Record the new worst axis status.

(5) Report PASS BFS Error
IF
- Both systems are available
- No timing problem exists between the PASS and the BFS
- The HSTD is not good
- More than 60 sec have elapsed since the last report of PASS-BFS errors
THEN
- Report the error on every axis whose status is the same as the worst axis.

d. Outputs

(1) State error messages
(2) Timing problem between the PASS and the BFS

e. Support Computations

The following table is valid for GND-PASS, GND-BFS, and PASS-BFS:

M50	UVW	OBH > 130K Suspect	OBH > 130K Update/ XFER	OBH < 130K and > 90K Suspect	OBH < 130K and > 90K Update/ XFER	OBH < 90K Suspect	OBH < 90K Update/ XFER
Z	U	6K	12K	3K	6K	1.5K	3K
X	V	24K	48K	3K	6K	3K	6K
Y	W	24K	48K	3K	6K	3K	6K
dZ	dU	50	75	50	75	50	75
dX	dV	50	75	50	75	50	75
dY	dW	50	75	50	75	50	75

Results from this table will be such that

GND-PASS = good/suspect/over
GND-BFS = good/suspect/over
PASS-BFS = good/suspect/over

All units are in ft and ft/sec.

3.5.2 Delta State Update

a. General Information

None.

b. Inputs

(1) HSTD status
(2) GND-PASS
(3) GND-BFS
(4) Engaged system
(5) Doing a delta state (ONAV input)
(6) Drag auto/inhibit/force (AIF) flag
(7) ~~Tactical air navigation~~ (TACAN) AIF flag
(8) ~~Air data transducer assembly~~ (ADTA) AIF flag

c. Rules/heuristics/concepts

(1) Need Delta State
IF the HSTD is good
- For the engaged system

- GND-system shows the system is above the update limits
THEN do that update
- A delta state is needed.

(2) Okay for Delta State
IF The HSTD is good
- A delta state is needed
- GND and engaged system runways are the same
THEN
- Recommend a delta state update.

(3) Not Okay for Delta State
IF the HSTD is good
- A delta state is needed
- The GND and engaged system runways are not the same
THEN
- Notify operator that a delta state is needed but that there is a runway mismatch.

(4) Inhibit Filter Processing
IF The HSTD is good
- Doing a position and velocity delta state
- For the engaged system
- The drag, TACAN, and/or ADTA flags are NOT inhibited
THEN
- Notify operator that (sensor) is not inhibited and needs to be inhibited before the delta state (include Item entries).

(5) Delta State Is in BFS
IF
- BFS is engaged
- Delta-state is in progress
- GND-system errors were not close to zero previously
- GND-system errors are now close to zero (within 200 ft.)
THEN
- Notify operator ~~Report~~ that state update ~~is in~~ has occurred in the BFS.

d. Outputs

(1) Delta-state recommendation
(2) Delta-state NO GO due to runway mismatch
(3) Inhibit measurement recommendation
(4) Delta state in

e. Support Computations

"Previously not close to zero" and "are now close to zero" refer to a comparison between the current measurement and previous measurement.

Item entry information: Specification numbers - BFS=40, PASS=51
TACAN inhibit = item 20
DRAG inhibit = item 23
ADTA inhibit = item 26

3.5.3 BFS Transfer

a. General Information

None.

b. Inputs

(1) HSTD status
(2) GND-BFS
(3) System availability
(4) PASS state error status
(5) PASS-BFS state error status
(6) PASS-BFS timing problem status
~~(7) Delta-state in progress~~

c. Rules/heuristics/concepts

(1) Need Transfer ~~(Part 1)~~
IF
- Good HSTD
- Both systems available
- GND-BFS > update limit
- PASS state error status is good
THEN
- Recommend a transfer to the BFS.

(2) Need Transfer (Part 2)
IF
- Good HSTD
- Both systems available
- GND-BFS > update limit
- PASS state error status is suspect
- No PASS-BFS timing problem
- PASS-BFS status is suspect or bad
THEN
- Recommend a transfer to the BFS.

(3) Need Transfer (Part 3)
IF
- The HSTD is good
- Both systems are available
- GND-BFS > update limit
- Delta-state is in progress
THEN
- Notify operator that a transfer will be needed after the state vector update.

(4) Do Not Do a Transfer (Part 1)
IF
- The HSTD is good
- Both systems are available

3.5 A

(2) Transfer In

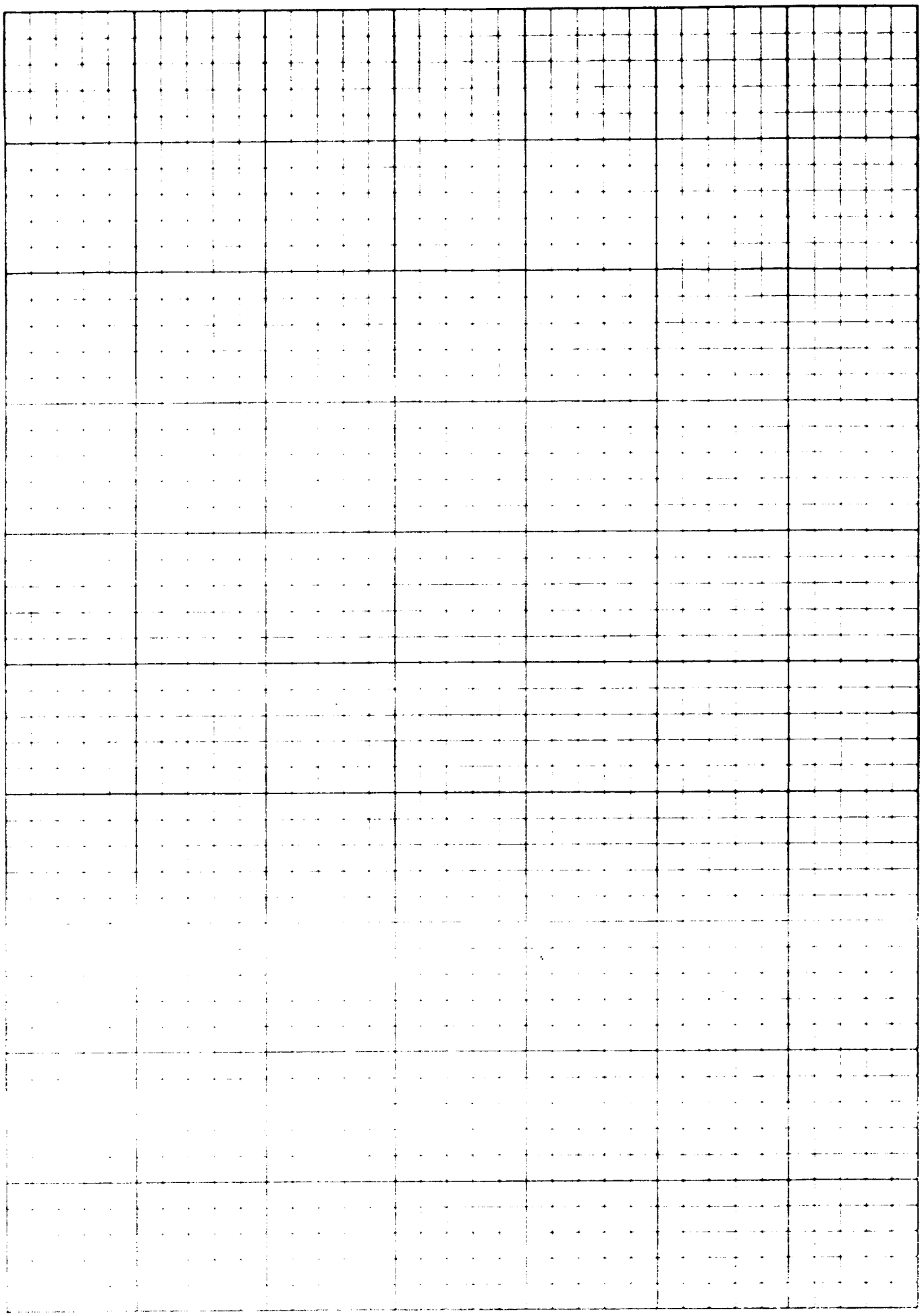
IF
- The PASS-BFS position differences are now close to zero
- The PASS-BFS position differences were not close to zero previously

THEN
- Notify operator that BFS transfer is in

(3) Update Previous pass BFS error differences

IF
- The PASS-BFS position differences are different from what they were on the previous cycle

THEN
- Update the previous PASS-BFS error differences



- GND-BFS > update limit
- PASS state error status is suspect
- PASS-BFS state error status is good

THEN

- Notify operator that no transfer is needed because it will not improve the BFS much.

(5) Do Not Do a Transfer (Part 2)

IF

- The HSTD is good
- Both systems are available
- GND-BFS > update limit
- PASS state error status is suspect
- There is a PASS-BFS timing problem

THEN

- Notify operator that NO transfer is needed because we are not sure how much it will improve the BFS vector.

(6) Transfer When No HSTD

IF

- The HSTD is not available
- Both systems are available
- PASS has at least one good IMU
- BFS prime selecting is bad or suspect IMU
- PASS-BFS error is bad
- No PASS-BFS timing problem

THEN

- Recommend a transfer to the BFS (any other situation could possibly corrupt the BFS with a transfer).

d. Outputs

(1) Transfer recommendation
(2) ~~Confirmation of~~ transfer status
(3) PASS-BFS error differences

e. Support Computations

None.

3.6 THREE-STRING STATE VECTORS

a. General Information

Three-string NAV is active when the number of microwave landing system (MLS) measurements processed by NAV is zero and the PASS is the engaged system.

THE FOLLOWING rules assume 3-state nav is active by default. There is CURRENTLY NO PROVISION for transitioning from 1-state to 3-state, after the 3→1 transition occurs.

b. Inputs

(1) HSTD health
(2) GND-1,2,3 state errors
(3) State differences
(4) IMU fail and commfault flags
(5) IMU health
(6) Delta state in

c. Rules/heuristics/concepts

(1) Ground-to-State Comparison

IF 3-state nav is active
- The HSTD is good
- A state vector had a certain quality rating previously
- Comparison with the ground indicates a different quality

THEN
- Change that state vector's rating to the quality indicated by the ground comparison.

(2) State-to-State Comparison (Part 1)

IF 3-state nav is active
- All three IMU's are ~~not commfaulted~~ available
- The HSTD is not good ~~or not available~~
- State A previously had a certain quality rating
- Comparison with states B and C indicates a different quality

THEN
- Change the quality rating of state A to that indicated by comparisons with states B and C. Use the best rating between states B and C. Do this check if an IMU is not available because it has been deselected. This will enable ONAV to check the state vector's health before the IMU can be reselected.

(3) State-to-State Comparison (Part 2)

IF 3-state nav is active
- Two IMU's are ~~not commfaulted~~ ~~good~~ available
- The HSTD is not good ~~or not available~~
- State A previously had the same rating as state B
- IMU A previously had the same rating as IMU B
- State A comparison with state B has a different rating

THEN
- Change the quality ratings of both states A and B. ~~Notify operator of inability to tell which state is going bad.~~
- notify operator of inability to tell which state is going bad.

(4) State-to-State Comparison (Part 3)
IF 3-state nav is active
- Two IMU's are ~~not commfaulted~~ available
- The HSTD is not good ~~or not available~~
- State A had the same rating as state B previously
- IMU A had a better rating than IMU B previously
- State A comparison with state B has a different rating
THEN
- Change state B's quality rating to the new one; leave state A's quality rating as it was.

(5) State-to-State Comparison (Part 4)
IF 3-state nav is active
- Two IMU's are ~~not commfaulted~~ available
- The HSTD is not good ~~or available~~
- State A had ~~a better~~ rating ~~than~~ state B previously
- State A comparison with state B has a different rating than state ~~B's rating~~
THEN
- Change state B's quality rating to the new one; leave state A's quality rating as it was.

(6) Zero Delta State Occurred
IF 3-state nav is active
- A delta state ~~is not in progress~~ has not been recommended
- All three pairwise state differences go to zero
THEN
- Notify operator that zero delta state occurred.

(7) Delta State Occurred
IF 3-state nav is active
- A delta state ~~is in progress~~ has been recommended
- All three pairwise state differences go to zero
THEN
- Notify operator that delta state ~~is in~~ has been performed

d. Outputs

(1) ~~three-string~~ state quality.
(2) delta state status
(3) 3-state nav status

e. Support Computations

Same as in section 3.5.1.5.

(8) 3-state nav has ended
IF
- 3-state nav is active
- A MSRU navigation report has been processed
THEN
- conclude that 3-state nav is no longer active.

3.7 DRAG ALTITUDE

3.7.1 Drag Flag Status

a. General Information

Drag altitude is used for limiting altitude errors. This group watches for changes in the drag filter flag.

b. Inputs

(1) Filter flags
(2) System availability

c. Rules/heuristics/concepts

(1) Drag Filter Flag Changed
IF
- For available systems
- The current value of the drag filter flag is different from its previous value

THEN
- Conclude that the value has changed.
- Notify the operator of the new value.

3.7A

d. Outputs

(1) Change in the drag filter flag
(2) New value of the drag filter flag

e. Support Computations

None.

3.7.2 Drag Recommendations

a. General Information

This group determines a recommended setting for the drag altitude AIF switch.

b. Inputs

(1) Edit ratio for drag
(2) Drag AIF flag
(3) Position and VEL delta state flag
(4) Onboard altitude
(5) System availability

c. Rules/heuristics/concepts

(1) Force Drag
IF
- For available systems
- The drag edit ratio is greater than one (1)
- Drag is not being forced
- Delta state has not been recommended
- The altitude is greater than 85,200 ft
THEN
- Recommend forcing drag.

(2) Auto Drag
IF
- For available systems
- The drag edit ratio is less than one (1)
- Drag is inhibited or forced
- Position and velocity delta state has not been recommended
- The altitude is greater than 85,200 ft
THEN
- Recommend that drag be placed in AUTO.

(3) Inhibit Drag
IF
- For available systems
- Drag is being forced
- The altitude is less than 85,200 ft
THEN
- Recommend drag be inhibited.

d. Outputs

(1) Drag altitude quality
(2) Recommended AIF setting

e. Support Computations

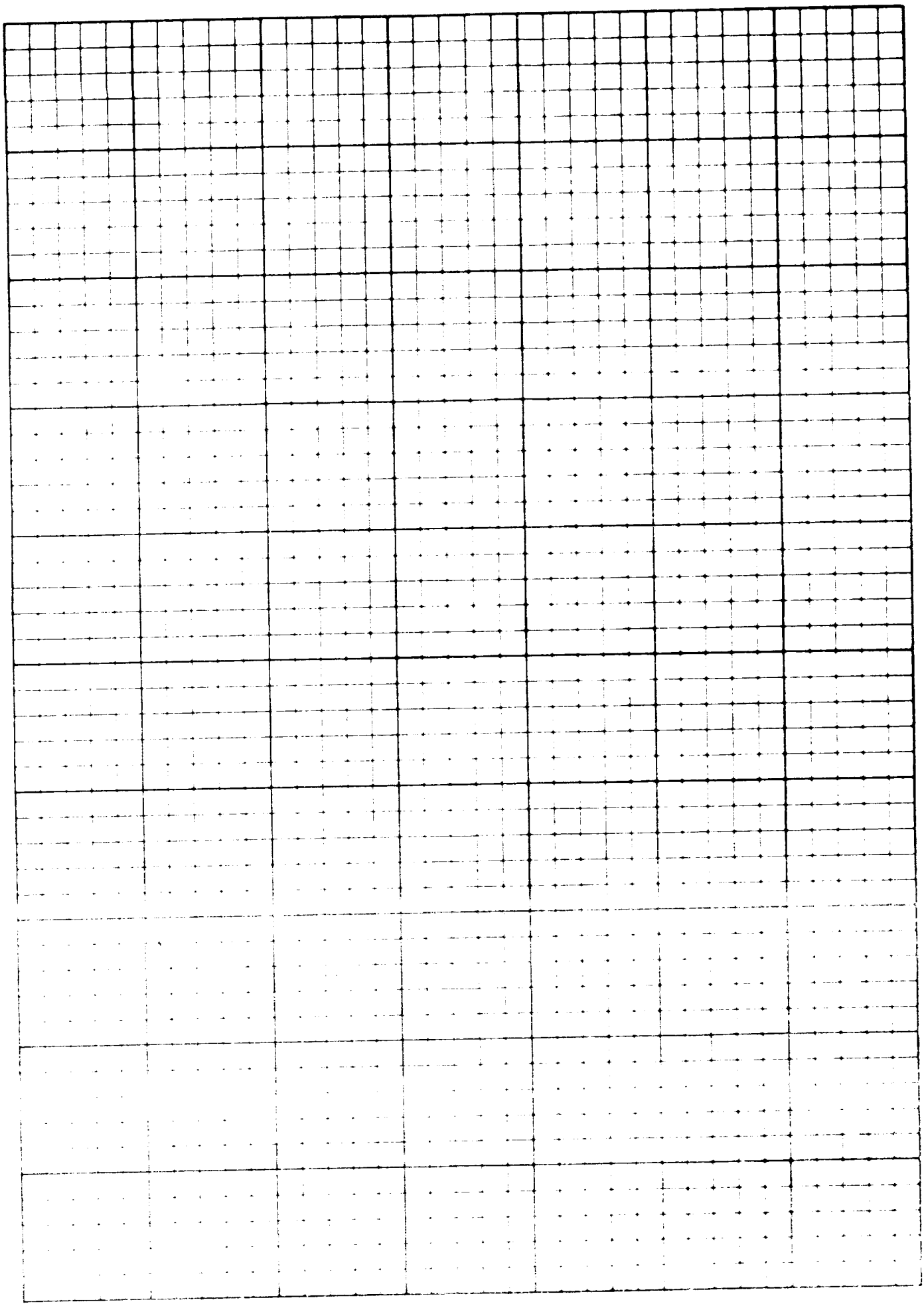
None.

3.7A

(2) End of Drag Processing

IF
- For available systems
- The current value of the drag filter flag is off
- The previous value is not off
- Either ~~the altitude is less~~
  - the altitude is less than 85.2k feet, or
  - Baro is being processed

THEN
- Notify operator that Drag processing has ended



3.8 TACTICAL AIR NAVIGATION

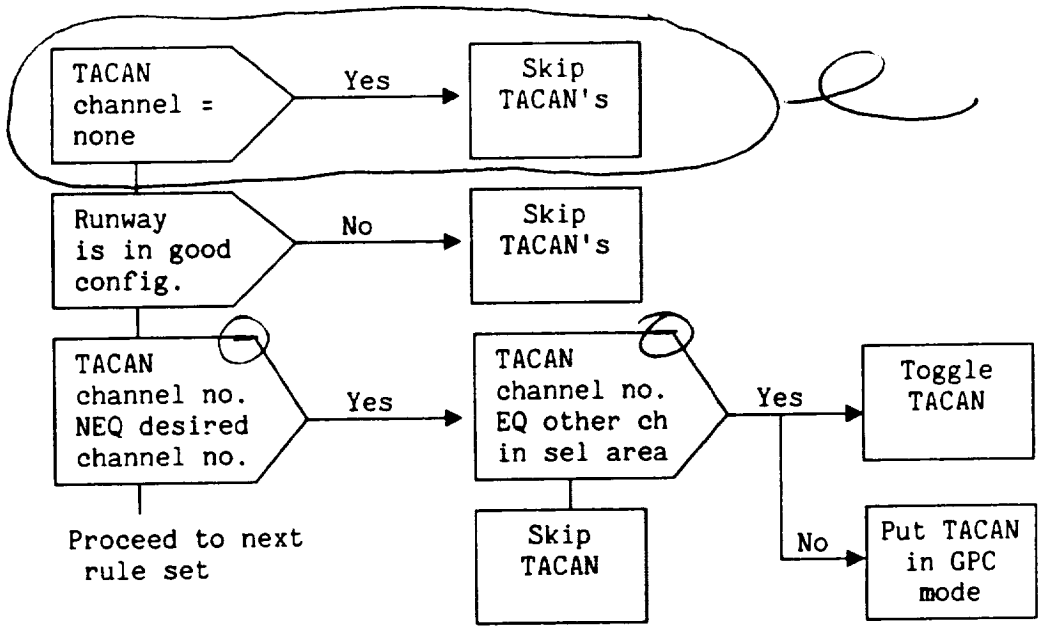
3.8.1 TACAN Configuration

a. General Information

This group makes sure that all line replacement units (LRU's) are tuned to the correct channel. The following ONAV inputs are assumed:

- Desired channel number (default is the PRIMARY in the selected runway area; other inputs are SECONDARY or NONE)
- Toggle capability status

The following flowchart gives an overall look at TACAN configuration information:



b. Inputs

(1) Engaged system
(2) Desired TACAN

c. Rules/heuristics/concepts

(1) Skip TACAN
IF
- The wrong runway is selected in the engaged system or desired TACAN channel = NONE

THEN
- Disable the rest of the TACAN checks.

(2) Channel Changed
IF
- All LRU's are tuned to a different channel than before
THEN Notify operator of the
- change in the selected channel.

(3) Toggle TACAN Due to wrong channel
IF FOR the engaged SYSTEM
- The selected channel is not the desired channel
- The selected channel is in the correct area of the site table
THEN
- Recommend toggle TACAN to get to the desired channel.
- Indicate that TACAN is no-go FOR the engaged SYSTEM

(4) General Purpose Computer (GPC) Mode
IF FOR the engaged SYSTEM
- The selected channel is not the desired channel
- The selected channel is not in the correct area of the site table
THEN
- Recommend that the TACAN's be put in GPC mode.
- Indicate that TACAN is no-go FOR the engaged SYSTEM

(5) Fix LRU Channel
IF FOR the engaged SYSTEM
- One LRU is not tuned to the desired channel
- At least one other LRU is tuned to the desired channel
THEN
- Recommend that the mistuned LRU be put in GPC mode.
- Indicate that TACAN is no-go FOR the engaged SYSTEM

3.8A

d. Outputs

(1) TACAN channel status.
(2) GPC mode Recommendations

e. Support Computations

None.

3.8.2 TACAN Availability

a. General Information

This group determines which LRU's are available in the engaged SYSTEM. It also determines why the unavailable LRU's are unavailable.

An LRU is available in range and/or bearing if it is

- Not commfaulted (LRU-level consideration)
- Not failed in range or bearing
- Not deselected (LRU-level consideration)
- Powered on (LRU-level consideration)

3.8A

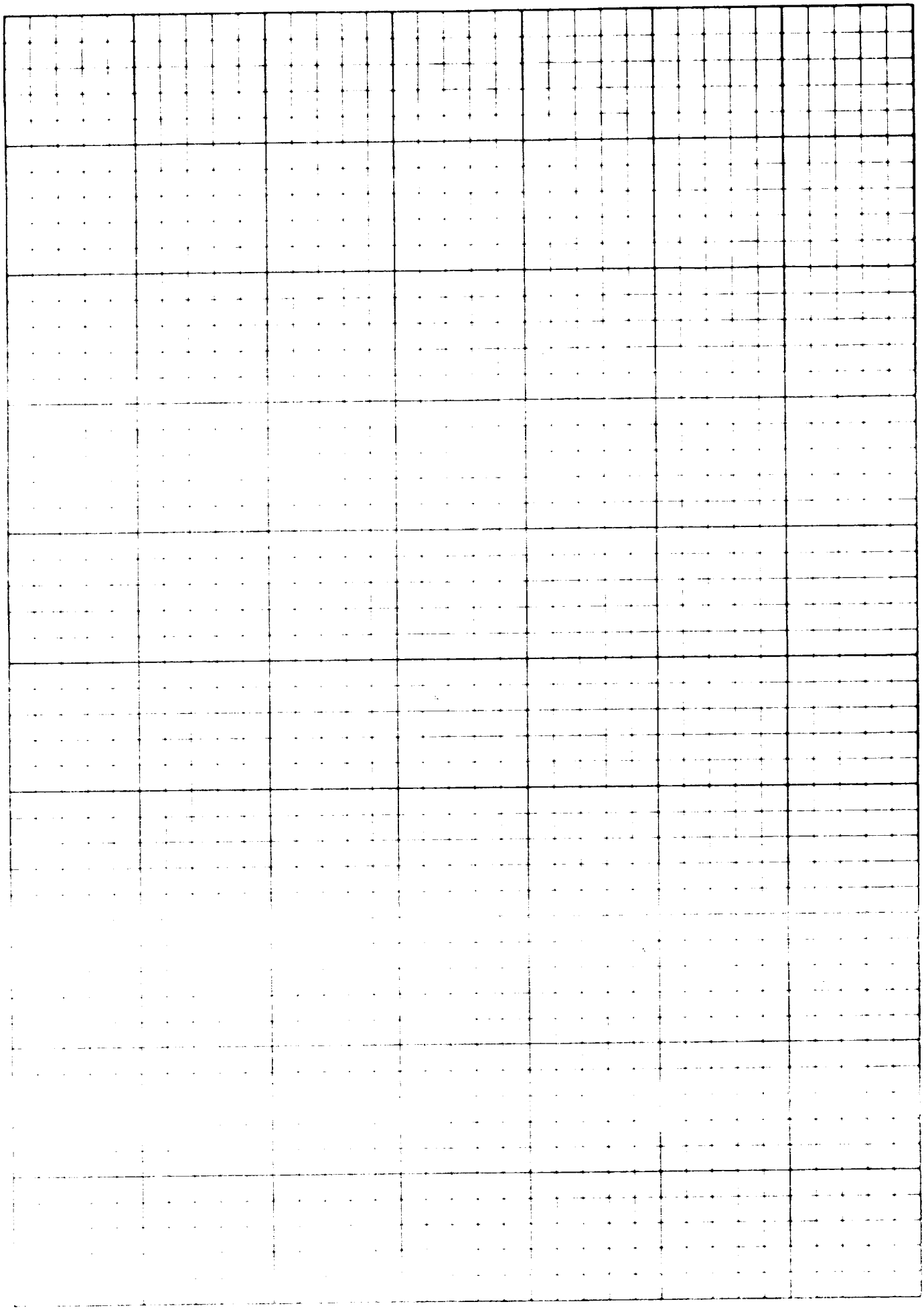
(6) Configuration is GOOD

IF

- For the engaged system
- All three LRU's are tuned to the desired channel

THEN

- Indicate that the TACAN configuration is good



Notify operator of changes in availability through the use of status lights. There is an overall total of six outputs - three for range and three for bearing.

b. Inputs

(1) Engaged system
(2) Commfault flag
(3) Deselect flag
(4) Power flag
(5) Fail flag
(6) Lockon flag

c. Rules/heuristics/concepts

(1) TACAN Commfault
IF
- For the engaged system
- A TACAN LRU was not commfaulted previously, nor powered down
- The commfault flag for that LRU is now on
THEN
- Notify the operator that the LRU is commfaulted (unless the whole string is down).
- Conclude that range and bearing from the LRU are no longer available to the PASS due to commfault.

(2) TACAN Commfault Clear
IF
- For the engaged system
- A TACAN LRU was commfaulted previously,
- The commfault flag for that LRU is now off
THEN
- Notify the operator that the commfault has cleared (unless the whole string is down).
- Conclude that the LRU has the status indicated by the fail and deselect indicators.

(3) TACAN Deselect
IF
- For the engaged system
- A TACAN LRU has been available in either range or bearing
- The deselect flag for that LRU is on
THEN
- Notify the operator of crew deselection.
- Conclude that the LRU is unavailable in range and bearing due to deselection.

(4) TACAN Power Off
If
- For the engaged system
- A TACAN LRU was powered on previously,
- The power indicator for that LRU is now off

THEN
- Notify operator that the LRU has lost power.
- Conclude that the LRU is not available due to loss of power.

(5) TACAN Power On
IF
- For the engaged system
- A TACAN LRU was powered off previously
- The power indicator for that LRU is now on
THEN
- Notify the operator that the LRU has been powered on.
- Conclude that the LRU has the status indicated by the fail and deselect indicators.

(6) TACAN Failed
IF
- For the engaged system
- A TACAN LRU measurement was available
- The fail flag for that measurement is on
THEN
- Notify the operator of the failure.
- Conclude that the measurement is no longer available due to failure.

(7) TACAN Reselected
IF
- For the engaged system
- A TACAN LRU has been unavailable due to failure or deselect
- The deselect flag for that LRU is off
- Both fail flags for that LRU are off
THEN
- Notify the operator of crew reselection.
- Conclude that the LRU is now available in range and bearing.

(8) TACAN Locked
IF
~~- For the engaged system~~
- No LRU's were locked on previously
- An LRU is locked on a measurement
THEN
- Notify the operator that TACAN is locking on.

(9) No TACAN Locked
IF
- An LRU was previously locked on a measurement
- ~~For the engaged system~~
- No LRU is locked on a measurement
THEN
- Notify the operator that TACAN lost lock.

d. Outputs

(1) LRU availability
(2) TACAN LRU lock status

e. Support Computations

None.

3.8.3 TACAN LRU Quality

a. General Information

This group checks LRU measurement errors to determine which LRU's have a problem and what the problem is.

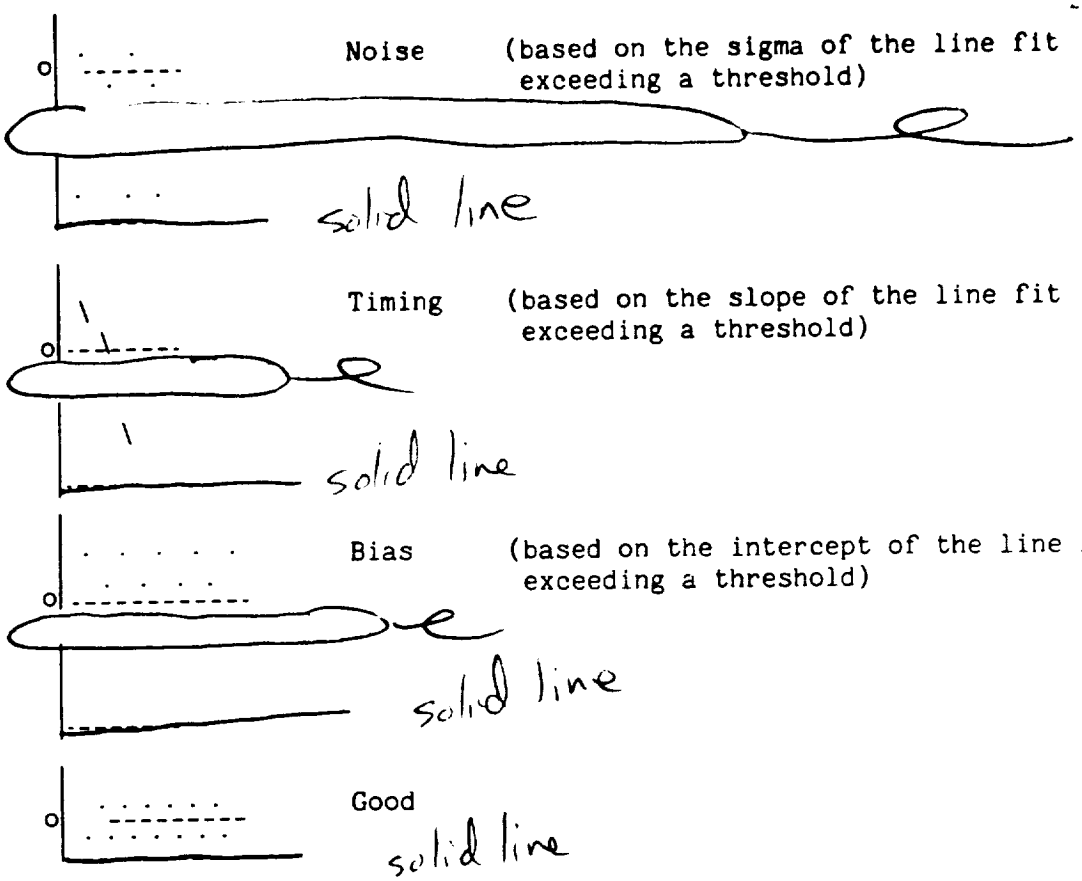
Six quality ratings are possible: three for range and three for bearing. Quality ratings are based on a line fit of the 10 most recent samples of the errors on each LRU. The line fit is computed with the least squares method, where time is an independent variable.

For comparison purposes, TACAN RM can fail one-half of an LRU (e.g., range or bearing), whereas IMU RM fails all of an LRU (i.e., there is no differentiation between VEL and attitude).

This section may need respecifying to enable the handling of

- Channel changes
- Lack of ground data (relative quality compares) using sigma, m (slope), and b (intercept)
- Use of raw TACAN data (NOTE: Holes in data preparation are implied; do not put raw TACAN data of any sort into the fact base currently)

The four quality types (noise, bias, timing, and good) are characterized as follows:



Bearing computations should be disabled within the cone of confusion (elevation is > 35 deg). Range processing can continue.

WHEN CHECKING BEARING PLOT

IF
- Any range asymptote > +0.2 nautical mile (n. mi.) [see note 1]
THEN
- Range is/are bias.

IF
- Any range form random pattern > +0.2 n. mi.
THEN
- Range is/are noise.
IF
- Any bearing asymptote > +1 deg
THEN
- Bearing is/are bias.

IF
- Any bearing forms random pattern > +2 deg

THEN
- Bearing is/are noise.

NOTE 1: Determines whether range/bearing problem is bias and/or noise.

Range Bearing [Note 2]	Bias	Noise	Good
BIAS	COMB	COMB	RBBN
NOISE	COMB	COMB	RBBN
GOOD	RBBN	RBBN	TAKE
			TACAN

NOTE 2: Uses matrix to determine which section to go to.

COMB = combination section
RBBN = PASS RANGE/BEARING BIAS/NOISE SECTION
TAKE TACAN = data good call "Take TACAN"

b. Inputs

(1) HSTD status
(2) GND-OB range errors
(3) GND-OB bearing errors
(4) Relative range errors
(5) Relative bearing errors
(6) LRU availability
(7) Cone-of-confusion status
(8) Raw range data
(9) Raw bearing data
(10) Engaged system

c. Rules/heuristics/concepts

Determine LRU quality while locked for range and bearing measurement. However, do not check bearing measurements while in the cone of confusion. Perform the checks in the following order for the engaged system:

(1) Cone of Confusion
IF
- In the cone of confusion
THEN
- Ignore bearing measurements.

(2) Use GND-OB Errors to Determine Status
IF
- The HSTD is good
THEN
- The selected errors for each measurement are the GND-OB errors.

(3) Use Relative Errors to Determine Status
IF
- The HSTD is not good
THEN
- The selected errors for each measurement are the relative errors.

(4) No Quality Rating (Part 1) - absolute
IF
- The HSTD is good - For the engaged system
- A TACAN LRU is ~~not available~~ commfaulted or is unlocked in the measurement
THEN
- Set temporary rating to NONE.

(5) No Quality Rating (Part 2) - relative
IF
- The HSTD is not good - For the engaged system
- Measurement A from LRU A is ~~not available~~ commfaulted or is unlocked ~~or measurement B is not available or unlocked~~
THEN
- Set temporary rating to NONE. - That same measurement from LRU B is commfaulted or unlocked

(6) Noise
IF
- The selected error's noise (spread) is greater than half that of the RM threshold
THEN
- Temporary rating = Noise.

(7) ~~Timing~~ Assign temporary Quality based on noise, bias + slope
IF An LRU has a particular rating based on considering selected errors of noise, bias, and slope
- ~~The selected error's slope is greater than the slope threshold~~
THEN
- ~~Set temporary rating = Timing~~ Conclude that the LRU has that rating

(8) Bias
IF
- The selected error's bias (offset) is greater than half that of the RM threshold
THEN
- Set temporary rating = Bias.

(9) Good
IF
- No temporary rating (not noise, timing, bias, or none) is given yet

3.8B

(3) No Quality due to channel change

IF
- An LRU is tuned to a different channel than it was previously

THEN
- That LRU has no quality rating for range or bearing

THEN
- Temporary rating = Good.

(10) Determine LRU Measurement Rating (Part 1)
8 IF
- HSTD is good
THEN conclude that
- Measurement rating = Temporary rating.
- Potential dilemma flag = OFF.

(11) Determine LRU Measurement Rating (Part 2)
9 IF For the engaged system
- The HSTD is not good
- All three measurements are available and locked
THEN conclude that
- A's measurement rating = Better rating (of good, suspect, or bad) between temporary ratings for AB's and AC's relative errors.
- Potential dilemma flag = OFF.

(12) Determine LRU Measurement Rating (Part 3)
10 IF For the engaged system
- The HSTD is not good
- Two measurements are available and locked
- Both measurements' previous ratings are equal
THEN conclude that
- Measurement rating for both measurements = Temporary rating for their relative error.
- Set potential dilemma flag to ON.

(13) Determine LRU Measurement Rating (Part 4)
11 IF For the engaged system
- The HSTD is not good
- Two measurements (A + B) are available and locked
- Measurement A's previous rating is better ~~(of good, suspect, or bad)~~ than measurement B's previous rating
THEN conclude
- ~~Set~~ measurement A rating = Previous measurement A rating.
- ~~Set~~ measurement B rating = Temporary rating for the AB relative error.
- Potential dilemma flag = OFF.

(14) Determine LRU Measurement Rating (Part 5)
12 IF For the engaged system
- The HSTD is not good
- Only measurement A is available and locked
- Measurement A's previous rating = NONE
- Measurement A's raw data noise (spread) is greater than half that of the RM threshold
THEN conclude that
- A's measurement rating = Noise.
- Potential dilemma flag = OFF.

(15) Quality Rating Change (Part 1)
IF
- A measurement rating has changed
- Potential dilemma flag = OFF
THEN
- Notify operator of change.

(~~15~~ 13) Quality Rating Change (Part 2)
IF
- A measurement rating has changed
- ~~Potential dilemma flag = ON~~
THEN
- Notify operator of the change and ~~that~~ the ~~expert system cannot determine which LRU caused the change.~~ potential dilemma condition based on the potential dilemma flag status

d. Outputs

(1) Quality rating change message.
~~Notify operator of changes in timing, bias, or noise (drives status lights and/or messages).~~

e. Support Computations

Noise, bias, and slope quantities are computed from a line fit computation. Take the last 10 data points when doing the fit. For data dropouts, either continue over skip or begin determining line fit over again. After a channel change, restart the line fit computation for the LRU whose channel changed.

3.8.4 TACAN Filter Flag Changes

a. General Information

This group watches for changes in the TACAN data good flags and filter flags.

b. Inputs

None.

c. Rules/heuristics/concepts

(1) TACAN Filter Flag Changed
IF
- For the engaged system
- The current value of ~~a TACAN filter~~ flag is different from its previous value (- The current value of a TACAN filter flag is anything but off)
THEN
- Note the new value.
- Notify the operator if the new value is "process."

3.8C

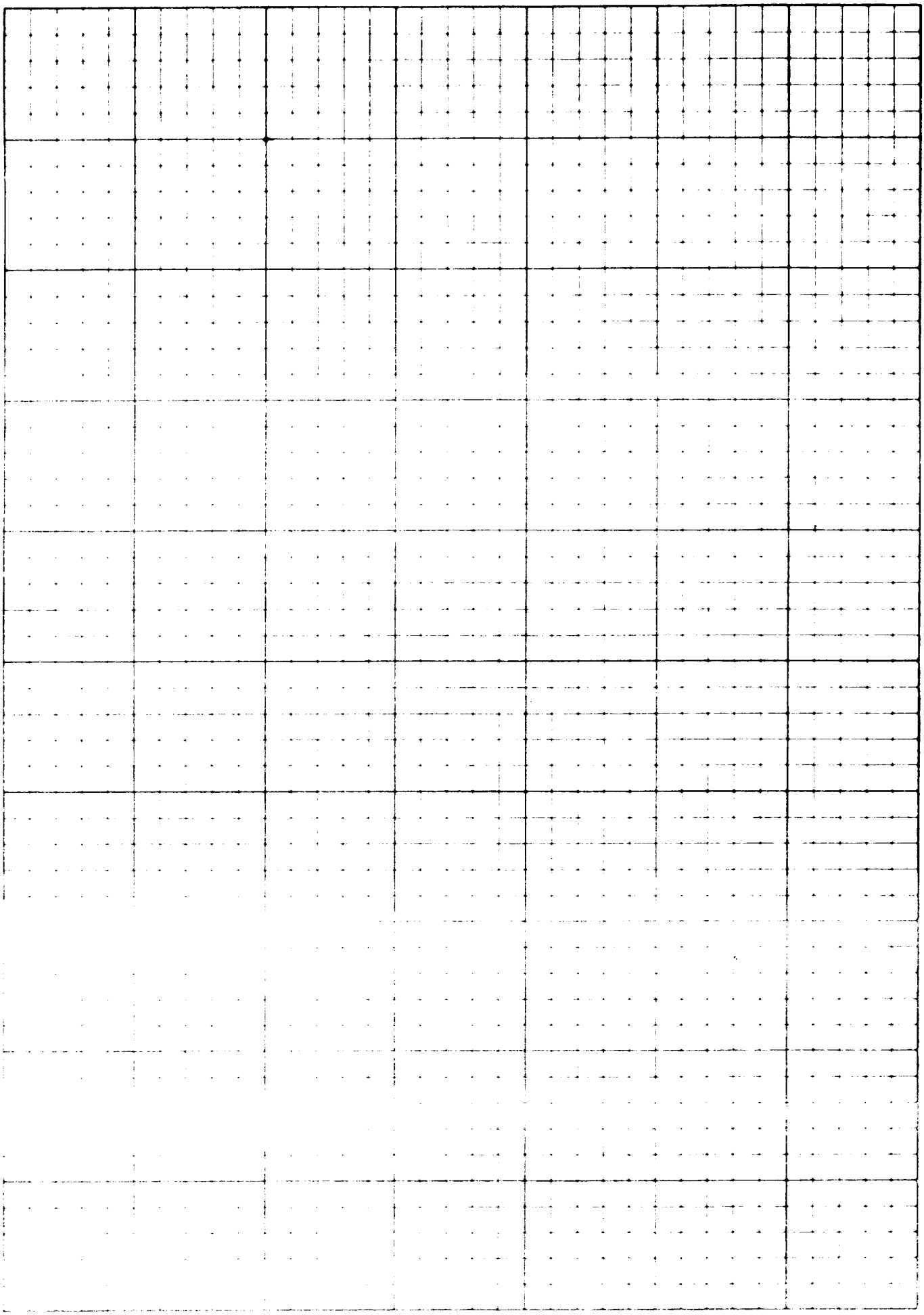
(2) END of TACAN measurement PROCESSING

IF

- For the engaged SYSTEM
- The current value of a TACAN filter flag is off
- The previous value of that TACAN filter flag is not off
- The corresponding data good flag is off, OR MSBLS is being processed

THEN

- Notify operator that the processing of the TACAN measurement has ended
- Indicate which measurement is off



(2) TACAN Data Good Flag Changed
3 IF
- For the engaged system
- The current value of a TACAN data good flag is different from its previous value

THEN
- Notify operator of the new value.

(3) TACAN Dilemma Occurred
4 IF
- For the engaged system
- TACAN dilemma flag is on for either measurement

THEN
- Warn the operator that a Tacan dilemma occurred

d. Outputs

(1) Notify operator of changes in the filter and in the data good and dilemma flags.

e, Support Computations

None.

3.8.5 TACAN Toggle Recommendations

a. General Information

This group determines whether or not the TACAN ground station has a problem. If it does and if a backup is available, toggling is recommended.

The following general comments should be embodied in the rules specified later:

If the same non-good quality rating exists on all locked LRU's (minimum of two) for either range or bearing, assume ground station is bad and request a toggle.

If only one LRU is locked, LRU has an error and is below 130K altitude.

If none locked over to be determined (TBD) sec below 130K ft, there may be a bad ground station.

b. Inputs

(1) Available LRU's
(2) Locked LRU's
(3) Toggle available
(4) Altitude
(5) LRU status flags

(6) Runway area
(7) Desired TACAN channel

c. Rules/heuristics/concepts

(1) Ground Station Problem (Part 1)
IF For the engaged system
- At least two LRU's are locked on to the same measurement
- All locked LRU's are exhibiting the same problem
THEN Notify operator
- ~~Conclude~~ that the ground station has a problem ~~and a toggle is needed.~~
- Conclude that a toggle is needed

NOTE: The above rule could be specified as two rules as follows:

(a) Three Locked
IF
- Number of LRU's available and locked is three
- At least two LRU's have same non-good quality (noise or bias)
- For bearing or range
THEN
- Request a toggle.

(b) Two Locked
IF
- Number of LRU's available and locked is two
- Both LRU's have same non-good quality (bias or noise)
- For bearing or range
THEN
- Request a toggle.

(2) Ground Station Problem (Part 2)
IF For the engaged system
- Only one LRU is available
- That one LRU is locked
- That one LRU has an error
THEN Notify operator
- ~~Conclude~~ that the ground station has a problem.
- Conclude a toggle is needed

(3) One LRU Locked Less Than 130K Altitude
IF
- Only one LRU is locked
- That one LRU has an error
- The altitude is less than 130 000 ft and greater than 5000 ft
THEN Notify operator
- ~~Conclude~~ that the ground station has a problem.
- Conclude a toggle is needed

NOTE: The following might be considered more specific than the preceding:

(a) One Locked LRU - Others Not Available
IF
- Number of LRU's locked is one
- That one LRU has a non-good quality rating (bias or noise)
- No other LRU's are available
- For bearing or range
THEN
- Request a toggle.

(b) One Locked LRU - Others Available
IF
- Number of LRU's locked is one
- That one LRU has a non-good quality rating (bias or noise)
- Other LRU's are available (one or two units)
- Altitude is less than 130 000 ft
THEN
- Request a toggle.

(4) None Locked at Less Than 130K Altitude
IF
- No LRU's are locked
- The altitude is less than 130 000 ft, and greater than 5000 ft.
THEN Notify operator
- ~~Conclude~~ that the ground station has a problem.
- Conclude a toggle is needed

NOTE: The following rule could be considered similar to the above rule:

Zero Locked LRU's
IF
- Number of LRU's locked is zero
- For greater than TBD sec
- Altitude is less than 130 000 ft
THEN
- Delay error checking for transitory changing of lock.

(5) Incorrect Channel for Runway Area
IF
- Runway area is correct
- TACAN channel is not correct for that area
THEN
- Recommend call to crew to put TACAN on correct channel.

(~~6~~ 5) Do a Toggle
IF
- A toggle is needed
- Toggle capability is available
THEN Recommend that operator
- Change the desired TACAN channel to the other channel in the current area.

(7) Do Not Do a Toggle
6 IF
- A toggle is needed
- Toggle capability is not available
THEN
- Do not do the toggle.

d. Outputs

(1) Toggle Requests - Suspending toggle requests when in an operational situation does not permit the toggle to be handled also.

(2) TACAN measurement status messages

e. Support Computations

None.

3.8.6 TACAN Deselect Recommendations

Because of the large number of inputs (deselects, fail flags, commfaults, lockon flags, measurement errors, etc.), it is impractical to try to enumerate all possible states requiring a deselect. Instead, the deselect recommendations are based on a generate-and-test method. For a given state, appropriate combinations of LRU's are proposed for deselection. Each combination is then evaluated based on predicted impact on navigation and the "best" combination is chosen for recommendation to the operator.

3.8.6.1 LRU's for Deselect

a. General Information

This group looks at problems with the LRU's to determine which LRU's might need to be deselected. If none, quit.

b. Inputs

(1) TACAN dilemma
(2) TACAN quality ratings
(3) TACAN availability
(4) TACAN lock status
(5) Altitude
(6) TACAN data good
(7) TACAN fail flag
(8) Go for TACAN
(9) Two lock flags

c. Rules/heuristics/concepts

(1) TACAN Dilemma
IF for the engaged system
- TACAN RM is in dilemma

- One LRU is known to be bad
- Another LRU is known to be good

THEN conclude that
- ~~Try~~ deselecting the bad LRU should be tried

(2) Two LRU's Against One

IF
- Two LRU's have a problem
- The third LRU is good
- The problem with the two bad LRU's is such that TACAN RM may fail the good LRU

THEN conclude that
- ~~Try~~ deselecting the two bad LRU's should be tried

(3) Not Two LRU's Locked

IF For the engaged SYSTEM
- Two LRU's are not locked
- One LRU is locked and good
- The data good flag is off
- The altitude is less than 130 000 ft and greater than 5000 ft.

THEN conclude that
- ~~Try~~ deselecting the two unlocked LRU's should be tried

(4) Noisy LRU

IF
- An LRU has excessive noise

THEN conclude that
- ~~Try~~ deselecting that LRU should be tried

(5) RM Failed Wrong LRU

IF For the engaged SYSTEM
- One LRU has a problem
- Another LRU is good
- TACAN RM has failed the good one

THEN conclude that
- ~~Try~~ deselecting the bad one should be tried

(6) Deselect the LRU Due to NOGO

IF
- The selected measurement from RM is not good enough to "GO for TACAN"
- Deselecting an LRU will remedy the situation

THEN conclude that
- ~~Recommend~~ deselection of the LRU should be TRIED

(7) Deselect Two LRU's

IF
- Below 130K
- Have not met the two-lock requirement in range

THEN
- Deselect the two bad LRU's.

NOTE: If faced with either a bad range or a bad bearing measurement, choose a bad bearing.

d. Outputs

(1) Possibility of requesting a deselection of TACAN.

e. Support Computations

None.

3.8.6.2 Deselect Configurations

a. General Information

Based on results from section 3.8.6.1, determine all reasonable deselection combinations. Each combination is proposed as a separate configuration. There are up to seven possible combinations.

The following is background information that should be contained in the rules:

If one LRU is recommended for deselection, try all of the following combinations of deselects:

- No LRU's (i.e., wait)
- Only the recommended LRU
- The recommended LRU with each of the other LRU's that is not commfaulted, not deselected, and powered on

If two LRU's are recommended for deselection (a and b), try all of the following:

- No LRU's
- a only
- b only
- a and b
- a and c (if c is not commfaulted, not deselected, and powered on)
- b and c (if c is not commfaulted, not deselected, and powered on)

If three LRU's are recommended for deselection, try all - zero, one, and two LRU combinations - involving LRU's that are not commfaulted, not deselected, and powered on (seven possible combinations).

b. Inputs

(1) Possibility of deselection.

c. Rules/heuristics/concepts

(1) Try Zero Deselects
IF
- Any LRU's have been proposed for deselection
THEN
- Propose a configuration where no LRU's are deselected (i.e., the onboard configuration is left as is).

(2) Try One Deselect
IF
- An LRU has been proposed for deselection
THEN
- Propose a configuration where that LRU is the only one that is deselected.

(3) Try Two Deselects
IF For the engaged system
- An LRU has been proposed for deselection
- Another LRU is not commfaulted, deselected, or powered off
THEN
- Propose a configuration where both LRU's are deselected.

d. Outputs

(i) Proposed deselections.

e. Support Computations

None.

3.8.6.3 Predicted Availability

a. General Information

For each configuration in section 3.8.6.2, compute the predicted availability of the three LRU's or how TACAN RM will respond to a proposed deselection configuration.

An LRU is predicted to be <u>available</u> if

- It is available in the real configuration
- It is not deselected in the hypothetical configuration; otherwise, it is predicted to be unavailable

b. Inputs

(1) TACAN availability
(2) TACAN lock status
(3) Data good flags

(4) Two lock flags
(5) Relative errors

c. Rules/heuristics/concepts

(1) Predict Available
IF For the engaged system
- An LRU is not deselected in a proposed configuration
- That LRU is available in the real world
THEN
- Predict that the LRU will be available in the proposed configuration.

(2) Predict Not Available (Part 1)
IF
- An LRU is deselected in a proposed configuration
THEN
- Predict that the LRU will not be available in the proposed configuration.

(3) Predict Not Available (Part 2)
IF For the engaged system
- An LRU is not available in the real world
THEN
- Predict that the LRU will not be available in any proposed configuration.

d. Outputs

(1) Predicted availability.

e. Support Computations

None.

3.8.6.4 Compute Configuration Data

a. General Information

Compute the following for range and bearing within all configurations from section 3.8.6.2:

- Bias of selected measurement
- Noise of selected measurement
- Data good flag
- RM dilemma indicator

Each of the above items applies to range and bearing separately.

b. Inputs

(1) Predicted availability.

c. Rules/heuristics/concepts

(1) Predict Data Good Two Locked
IF
- Two LRU's are available in a proposed configuration
- Both LRU's are locked on to a measurement currently
THEN
- Predict that the data good flag for that measurement will be on in the proposed configuration.

(2) Predict Data Good One Locked
IF
- At least one LRU is available in a proposed configuration
- That LRU is locked on to a measurement
- The two-lock flag for that measurement is off
THEN
- Predict that the data good flag for that measurement will be on in the proposed configuration.

(3) Predict Data Good One Avail
IF
- Only one LRU is available in a proposed configuration
- That LRU is locked on to a measurement
THEN
- Predict that the data good flag for that measurement will be on in the proposed configuration.

(4) Predict Data Good Off
IF
- No rule has predicted that the data good flag for a measurement will be on in a proposed configuration
THEN
- Predict that the data good flag for that measurement will be off in the proposed configuration.

(5) Predict Dilemma
IF
- Exactly two LRU's are available and locked for a measurement in a proposed configuration
- ~~Both LRU's are locked on to that measurement~~
- The relative bias between the two LRU's exceeds the RM threshold
THEN
- Predict that the RM will declare a dilemma in the proposed configuration.

(6) Predict No Dilemma
IF
- Not rule has predicted that RM will declare a dilemma in the proposed configuration

THEN
- Predict that RM will not declare a dilemma in the proposed configuration.

(7) Predict Error One Level
IF
- The data good flag is on for a measurement in a proposed configuration
- One LRU is available and locked
- The other two LRU's are either unavailable or unlocked

THEN
- Predict that the selected measurement bias and noise is the same as that of the available LRU.

(8) Predict Error Two Level
IF
- The data good flag is on for a measurement in a proposed configuration
- Two LRU's are available and locked
- The other LRU is either unavailable or unlocked

THEN
- Predict that the selected measurement bias and noise is the average of the available LRU's.

(9) Predict Error Three Level
IF
- The data good flag is on for a measurement in a proposed configuration
- All LRU's are available and locked for that measurement

THEN
- Predict that the selected measurement bias and noise is the same as that currently selected by RM.

d. Outputs

(1) Predicted data good
(2) Predicted dilemma
(3) Predicted measurement bias and noise

e. Support Computations

For bias and noise

(1) Let mu-i, sigma-i = bias, noise on LRU i, i=1,2,3
mu-sel, sigma-sel = bias, noise on currently selected data
mu-p, sigma-p = predicted bias and noise for hypothetical configuration

(2) If configuration prime selects LRU i,
mu-p = mu-i
sigma-p = sigma-i

(3) If configuration averages LRU i and j,
mu-p = 1/2 (mu-i + mu-j)
sigma-p = 1/2 (sqrt ((sigma-i * sigma-i) + (sigma-j * sigma-j)))

(4) If configuration is (mid-value select) (MVS),
mu-p = mu-sel sigma-p = sigma-sel

Predicted data-good is ON if any of the following occurs:

- Two or three available and two locked
- Two or three available, one locked, two-lock flag is off
- Only one available and locked

Predicted dilemma is ON if all of the following occur:

- Two or three available
- Two locked
- Relative bias exceeds RM threshold

3.8.6.5 Configuration Acceptability

a. General Information

Determine which configurations are unacceptable. Of those, choose the "best" (i.e., based on state error performance where best means the smallest state error).

Range affects downtrack primarily; bearing affects crosstrack primarily.

Range error should be minimized (with some consideration for redundancy coverage) because range has a much larger effect on the STATE than does bearing.

b. Inputs

(1) Proposed configurations.

c. Rules/heuristics/concepts

(1) Do Not Want Dilemma
IF
- A proposed configuration will result in a dilemma in either measurement

THEN
- Veto that configuration.

(2) Need Range Data
IF
- A proposed configuration does not have range data
THEN
- Veto that configuration.

(3) Do Not Have Bearing
IF
- A proposed configuration does not have bearing data
THEN
- Assume that the crosstrack state error under the proposed configuration will be the same as the current crosstrack state error.

(4) Predict State Effect
IF
- A configuration has not been vetoed
THEN
- Predict the effect of the proposed configuration on the state error.

(5) Pick Smallest State Effect
IF
- One configuration has a smaller predicted state error than another
THEN
- Veto the configuration with the larger state error.

(6) Select a Configuration
IF
- All configurations that are going to be vetoed have been vetoed
THEN
- Select the only one left as the chosen configuration.

(7) Confirm a Deselect
IF
- An LRU is deselected in the chosen configuration
THEN
- Confirm the deselect suggestion.

(8) Deny a Deselect
IF
- The initial deselect determination suggested deselecting an LRU
- ~~An~~ LRU is not deselected in the chosen configuration
THEN
- Deny the deselect suggestion.

(9) Deselect Confirmed
IF
- A deselect suggestion has been confirmed
THEN
- ~~Send the~~ recommend~~ation~~ to the operator. the desired ACTION

(10) Deselect Shortcut
IF
- An LRU has been suggested for deselection
- That suggestion has been confirmed or denied already
THEN
- Withdraw the suggestion.

d. Outputs

(1) Configuration acceptability assessment results.

e. Support Computations

For crosstrack error

For each configuration without bearing, set

mu-(p-b) = W state error / Cbb
where mu-(p-b) is predicted mean of the bearing from W crosstrack ground-onboard comps.

For each configuration, compute "estimated state effect" as follows:

```
E = (SQRT (PLUS
                --- (SQ (TIMES Crb Mu-r))
  range effect /--- (SQ (TIMES Crn Sigma-r))
                --- (SQ (TIMES Cbb Mu-b))
 bearing effect/--- (SQ (TIMES Cbn Sigma-b))))
```

where, Crb = 1 ft
Crn = 1 ft
Cbb = 200 ft/deg
Cbn = 200 ft/deg

These constants represent the predicted STATE ERROR for each type of TACAN error.

Crn and Cbn could be reduced to account for the effect of filtering on measurement noise.

For each deselected LRU in a configuration, add TBD feet to E for that configuration. This represents a factor for LRU redundancy considerations and is based on the number of LRU's deselected in each configuration.

3.8.7 TACAN Reselect Recommendations

a. General Information

None.

b. Inputs

(1) TACAN availability
(2) TACAN locked status
(3) TACAN quality ratings
(4) TACAN fail flags
(5) TACAN deselect flags

c. Rules/heuristics/concepts

(1) Reselect a TACAN
IF FOR the engaged SYSTEM
- A TACAN LRU is unavailable in a measurement due to RM declared failure or deselect
- The LRU is locked and good in range
- The LRU is locked and good in bearing
THEN
- Recommend reselecting the LRU.

d. Outputs

(1) Reselection recommendation.

e. Support Computations

None.

3.8.8 TACAN AIF Change Recommendations

a. General Information

TACAN data should be taken if it will improve the NAV state.

TABLE 3.8-I.- CALL TO TAKE TACAN

GND-RO/B	GND-RO/B	Two-range Lock	No. of LRU Lock	Edit Ratio	Call
<0.5 n. mi.	<6 deg	ON	1	<1.0	Deselect unlocked LRU's (range); take TACAN
"	"	ON	1	>1.0	Deselect unlocked LRU's (range); force TACAN
"	"	ON	>1	<1.0	Take TACAN
"	"	ON	>1	>1.0	Force TACAN
"	"	OFF	N/A	<1.0	Take TACAN
"	"	OFF	N/A	>1.0	Force TACAN
"	>=6 deg	N/A	N/A	N/A	NO GO for TACAN
"	N/A	N/A	N/A	N/A	NO GO for TACAN

NOTE: Whenever the highest of GND-O/B R and GND-O/B B is equal to or less than 0.5 n. mi. and 6 deg, it is an indication that TACAN range and bearing are good and within TACAN RM's miscompare limits.

If the TACAN two-range locked flag is on, it can be overridden by deselecting the unlocked LRU's. When the unlocked LRU's lock on, they have to be reselected before TACAN RM can process the data.

If the onboard navigation state is bad (edit ratio greater than or equal to one), the TACAN measurement data have to be forced. After several TACAN measurement cycles, the TACAN AIF flag can be set to AUTO. Analysis shows that, for the edit ratio to be > 1.0, the TACAN measurement residual must be > 15K ft.

TABLE 3.8-II.- TACAN PROCEDURES SECTION - THREE LRU LEVEL

Number of LRU's having noise/bias	Calls
Three LRU's > toggle limit	All three LRU's show--range/or bearing bias/or noise; toggle limit we recommend toggle TACAN. After toggle TACAN, repeat. Verify TACAN data.
Three LRU's < RM limit	All three LRU's show--range/or bearing bias/or noise; RM limit we can take TACAN.
Three LRU's ≥ RM LIMIT	All three LRU's show range/or bearing, bias/or noise RM limit greater than RM limit; NO GO for TACAN
Two LRU's ≥ RM limit	LRU and show--range/or bearing bias/or noise, deselect RM limit LRU--AND--; Take TACAN.
Two LRU's < RM limit	LRU and show--range/or bearing bias/or noise, less than RM limit. Take TACAN.
One LRU ≥ RM limit	LRU shows--range/or bearing bias/or noise; TACAN RM will fail range/or bearing LRU--. We can take TACAN.
One LRU <	LRU shows--range/or bearing bias/or noise less than RM limit. Take TACAN.
Toggle limits	0.3 n. mi. range 2 deg bearing
RM limit	0.5 n. mi. range 6 deg bearing

NOTE: At initial acquisition, if all three LRU's show range/or bearing bias/or noise greater than toggle limit, toggle TACAN from primary to alternate TACAN station is recommended. If the noise/or bias at the alternate TACAN station is larger than the primary TACAN station, toggle TACAN back to the primary TACAN station is recommended. If all three TACAN range/or bearing noise/or bias less than RM limit, take TACAN.

If all three TACAN range/or bearing noise/or bias greater than RM limit, NO GO for TACAN.

In the two LRU cases, deselect any LRU which has bias/or noise greater than RM limit because TACAN RM will fail the good LRU. In the one LRU case, if bias/or noise greater than RM limit, TACAN RM will fail that particular LRU (range/or bearing only). Otherwise, TACAN RM will mid-value-select measurement data.

Note that, when an LRU is deselected, both range and bearing measurement data are eliminated from the TACAN RM.

TABLE 3.8-III.- TWO LRU LEVEL

Number of LRU's having bias/noise	Calls
Two LRU's >	Both LRU's show--range/bearing bias/noise greater toggle than toggle limit; we recommend toggle TACAN. Limit after toggle TACAN, repeat verify TACAN data.
Two LRU's ≥	Both LRU and show--range/bearing bias/or noise RM limit greater than RM limit; NO GO for TACAN.
Two LRU's ≤	Both LRU and show range/bearing bias/or noise less than RM limit; take TACAN.
One LRU ≥	LRU shows--range/bearing bias/or noise; TACAN--will RM limit go into self test. After self test is completed, take TACAN.
One LRU <	LRU shows--range/or bearing bias/or noise; TACAN RM will average the measurement. We can take TACAN.
Toggle limits	0.3 n. mi. range 2 deg bearing
RM limit	0.5 n. mi. range 6 deg bearing

NOTE: At initial acquisition, if both LRU's show range/or bearing bias/or noise greater than toggle limit, toggle TACAN from primary TACAN station to alternate TACAN station is recommended. If the noise/or bias at the alternate TACAN station is larger than the noise/or bias at the primary TACAN station, toggle TACAN back to the primary TACAN station is recommended.

If both LRU's have range/or bearing bias/or noise greater than RM limit, NO GO for TACAN.

If both LRU's have range/or bearing bias/or noise less than RM limit, take TACAN.

If one LRU has range/or bearing bias/or noise greater than RM limit (the other LRU has zero bias/or noise), TACAN RM will do a self-test on both LRU's. After self test, take TACAN.

If one LRU has range/or bearing bias/or noise less than RM limit, TACAN RM will average the measurement data, take TACAN.

NOTE: Self-test is done in the two LRU level only.

TABLE 3.8-IV.- ONE LRU LEVEL

Bias/noise	Calls
>toggle limit	LRU shows--range/or bearing bias/or noise, we recommend toggle TACAN. After toggle TACAN, repeat verify TACAN data.
< RM limit	LRU--shows range/or bearing bias/or noise less than RM limit; take TACAN.
> RM Limit	LRU--shows range/or bearing bias/or noise greater than RM limit; NO GO for TACAN.
Toggle limits	0.3 n. mi. range 2 deg bearing
RM limit	0.5 n. mi. range 6 deg bearing

NOTE: If bias/or noise is greater than toggle limit, toggle TACAN from primary to alternate TACAN station is recommended. After toggle TACAN, repeat verify TACAN data.

If alternate TACAN station has larger bias/or noise, toggle TACAN from alternate TACAN station to primary station is recommended.

If bias/or noise is less than TACAN RM limit, take TACAN; otherwise, NO GO for TACAN.

(Skip if TACAN toggled already.)

If all three range LRU plots > 0.3 n. mi. and all three bearing LRU plots > 2 deg [see note 1].

THEN:CALL: "Toggle TACAN, there is a bias in range and bearing."
After TACAN toggle, repeat verify TACAN data procedures.

If all three range LRU plots > 0.05 n. mi.,
THEN:CALL: "There is a range bias in all three LRU's in excess of the RM limit. We are NO GO for TACAN."

If all three bearing LRU plots > 6 deg,
THEN:CALL: "There is a bearing bias in all three LRU's in excess of the RM limit. We are NO GO for TACAN." [See note 2.]

NOTE 1: If range/or bearings have bias/no noise greater than toggle limit, toggle TACAN is recommended.

If the alternate TACAN station has larger bias/or noise than the primary TACAN station, toggle TACAN back to the primary TACAN station is recommended.

NOTE 2: If all three range/or bearing measurements have bias/or noise greater than RM limit, NO GO for TACAN.

b. Inputs

(1) Data good flags
(2) Selected range error
(3) Selected bearing error
(4) Edit ratios
(5) TACAN AIF flag
(6) NAV error status
(7) Engaged system

3.8D

c. Rules/heuristics/concepts

(1) Go to AUTO ~~(Part 1)~~
3 IF the PASS is engaged
- ~~For engaged system state errors~~
- Data good is on in range and bearing
- Selected range error is ~~less than V state error~~
- Selected bearing error is ~~less than W state error~~
- Range and bearing edit ratios are less than one
- TACAN is currently ~~was~~ inhibited ~~previously~~
THEN for operator that TACAN
- Recommend go to AUTO mode.

- No toggle has been REQUESTED
- No TACAN deselects have been recommended
- No delta-state is in work

acceptable

acceptable

(2) Go to AUTO ~~(Part 2)~~ ~~[illegible]~~ end FORCE
4 IF ~~the~~ Pass is engaged
- TACAN is in force mode
- Both edit ratios are less than one
THEN for operator that TACAN
- Recommend go to AUTO mode.

(3) Go to AUTO ~~(Part 3)~~ with no BEARING
5 IF the PASS is engaged
- ~~For engaged system state errors~~
- ~~No~~ bearing data good flag is ~~available~~ off
- Range data is good
- Range error is ~~less than V (downtrack positive error)~~
- Range edit ratio less than one
THEN for operator that TACAN is currently inhibited
- Recommend go to AUTO mode.

- No toggle has been REQUESTED
- No TACAN deselects have been REQUESTED
- No delta-state is in work

acceptable

(4) Go to AUTO After Delta State (Position and Velocity) Is Done
6 IF
- For the engaged system ~~state errors~~
- Data good is ON in range and bearing
- Delta state is in work
- Range error is ~~less than RM limit~~
- Bearing error is ~~less than RM limit~~
- TACAN is inhibited currently

- No toggle has been REQUESTED
- No TACAN deselects have been REQUESTED

acceptable

acceptable

THEN
- Recommend go to AUTO after delta state (position and velocity) is ~~done~~ complete.

(~~5~~ 7) Go to Inhibit
IF the PASS is engaged
- ~~For engaged system state errors~~
- State error is good or suspect
- Range edit ratio is greater than one
  OR bearing edit ratio is greater than one while vehicle is not in cone of confusion
- TACAN is not inhibited
THEN to operator's TACAN
- Recommend go to INHIBIT.

(~~6~~ 8) Go to Force
IF the PASS is engaged
- Data good is ON in range and bearing
- ~~For engaged system state errors~~
- ~~State is bad~~
- No delta state is in work
- Range error is ~~less than RM limit~~ selected acceptable
- Bearing error is ~~less than RM limit~~ selected acceptable
- Either edit ratio is greater than one (inclusive OR)
THEN to operator's TACAN
- Recommend go to FORCE.

- No toggle has been REQUESTED
- No tacan deselects have been REQUESTED

Range OR BEARING

- TACAN is NOT BEING forced

3.8E

d. Outputs

(1) TACAN AIF Recommendations.

e. Support Computations

~~None.~~
Edit ratios do not exist for BFS engaged situation.

3.8 D

(1) Selected TACAN is Acceptable

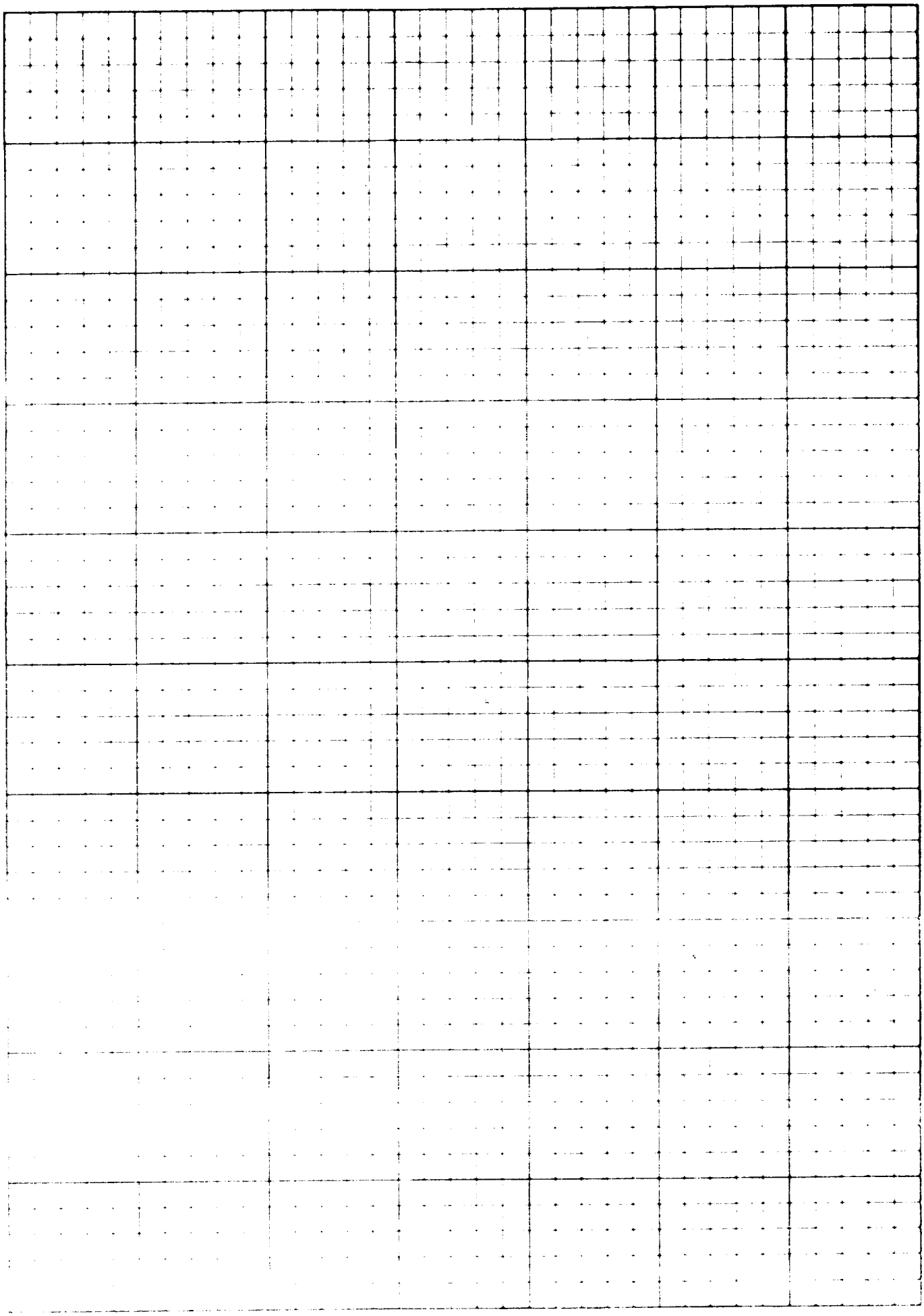
IF
- For the engaged SYSTEM
- The selected measurement was previously NO-go
- The measurement ERROR from every available and locked LRU is less than the CORRESPONDING state ERROR

THEN
- Change the selected measurement to "go"

(2) Selected TACAN is unacceptable

IF
- For the engaged SYSTEM
- The selected Tacan measurement was previously "go"
- The ERROR from any available and locked LRU is unacceptable

THEN
- Change the selected measurement to "NO-go"



3.8E

(9) CHECK ERROR Before TACAN [redacted]

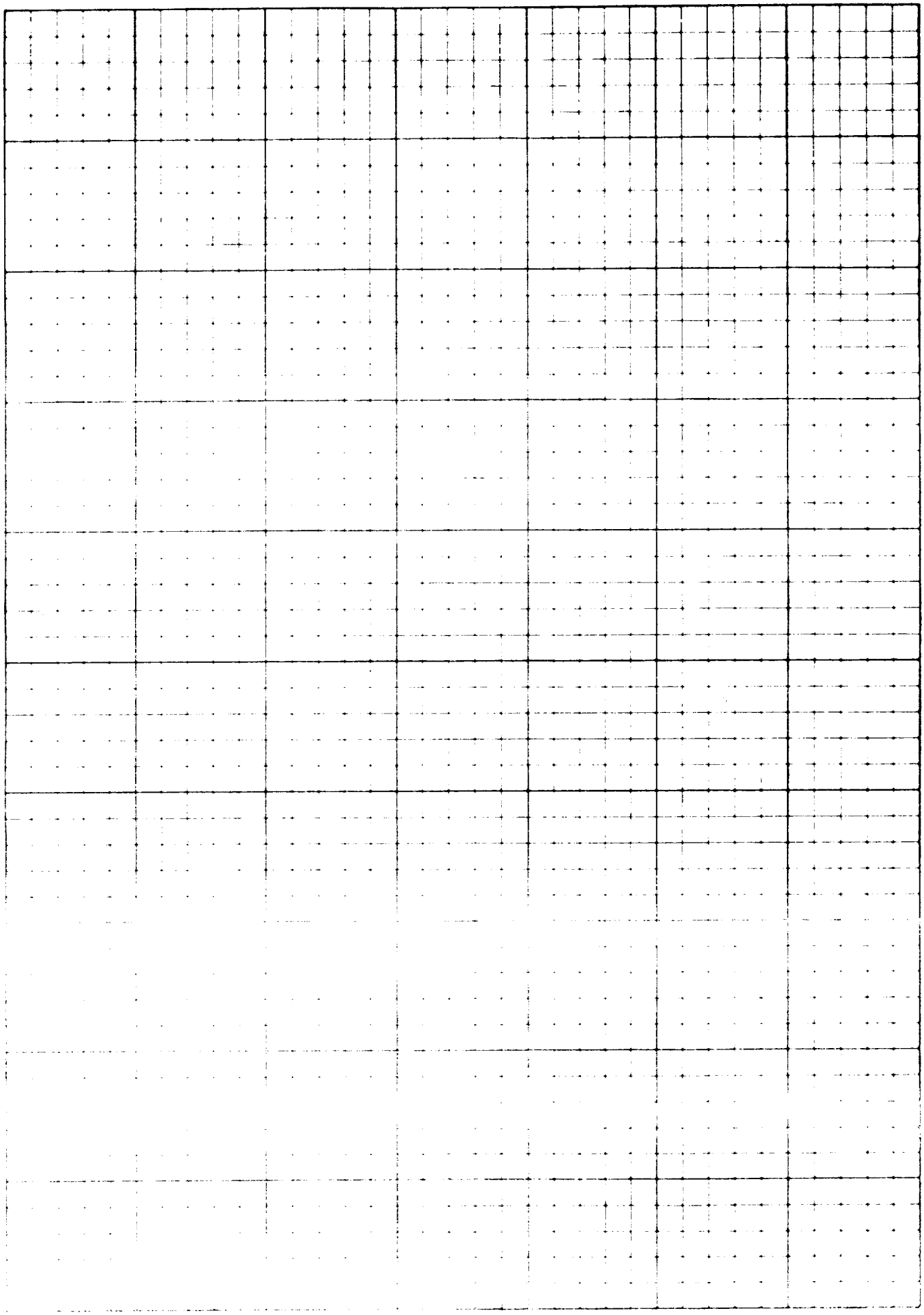
IF
- FOR the engaged SYSTEM
- At least one LRU is locked in range
- Neither range nor bearing is being processed
- The status of the state ERROR is different from what it was on the previous cycle

THEN
- Note the current status of the state error

(10) CHECK ERROR After TACAN

IF
- FOR the engaged SYSTEM
- TACAN is being processed
- The state error is worse now than before TACAN was processed

THEN
- Recommend to operator that TACAN be inhibited



3.9 BARO ALTITUDE

3.9.1 Baro Measurement Quality

a. General Information

This group of rules determines whether or not baro altitude measurements are good. If they are bad, the rules attempt to determine the reason.

The Mach jump region is generally Mach 1.6 to 1.1. Roll reversals are characterized by a roll rate greater than some threshold.

b. Inputs

(1) GND-O/B baro altitude
(2) HSTD status
(3) Role rate
(4) Mach jump indicator
(5) Engaged system

c. Rules/heuristics/concepts

(1) Okay to Perform Baro Checks
IF
- Mach is greater than 5 or in Mach jump region
THEN
- Do not perform any baro checking.

(2) Baro Is Good (Pass)
IF
- For ~~engaged system~~
- |delta sel| ≤ |delta Z| + 500
- Baro was not known to be good previously
- The HSTD is good
THEN
- Baro is good.

(3) Baro Is Bad (Pass)
IF
- For ~~engaged system~~
- HSTD is good
- |delta sel| > |delta Z| + 500
- Baro was good or unknown previously
- ~~Baro-GND is out of tolerance~~
THEN
- Baro is bad.

(4) Roll Reversal
IF
- Baro is bad

- The vehicle is executing a roll-reversal

THEN operator that
Notify
- Baro is bad because of roll-reversal.

3.9.1A

(5) Crew Call
IF
- HSTD is not good
THEN operator that
Notify
- ADTA is crew call.

d. Outputs

(1) Baro altitude quality
(2) ~~Mach jump region message~~ Crew call message
(3) Roll reversal message

e. Support Computations

delta sel = GH - sel measurement; delta-z means two different things depending upon what system is engaged. For the PASS, delta-z is a piece of data available for use. For the BFS, delta-z must be computed using the ground verses BFS "u" state vector component difference.

3.9.2 Baro Flag Status

a. General Information

This group watches for changes in the baro altitude filter flag. It also watches to see if the change is caused by entering or leaving the Mach jump region.

b. Inputs

(1) Baro filter flag
(2) Mach jump indicator

c. Rules/heuristics/concepts

(1) Enter Mach Jump
IF
- The vehicle was not in the Mach jump region previously
- The vehicle is now in the Mach jump region
THEN
- Notify the operator that the Mach jump region has been entered.

(2) Leave Mach Jump
IF
- The vehicle was in the Mach jump region previously
- The vehicle is now out of the Mach jump region
THEN
- Notify the operator that the Mach jump region has been exited.

(3) Baro filter flag changed
IF
- For the engaged system

3.9.1A

(6) BARO is Not Crew Call

IF
- HSTD is good

THEN
- Notify operator that ~~Baro~~ Air Data is NOT a Crew Call

(7) Baro is good in the BFS

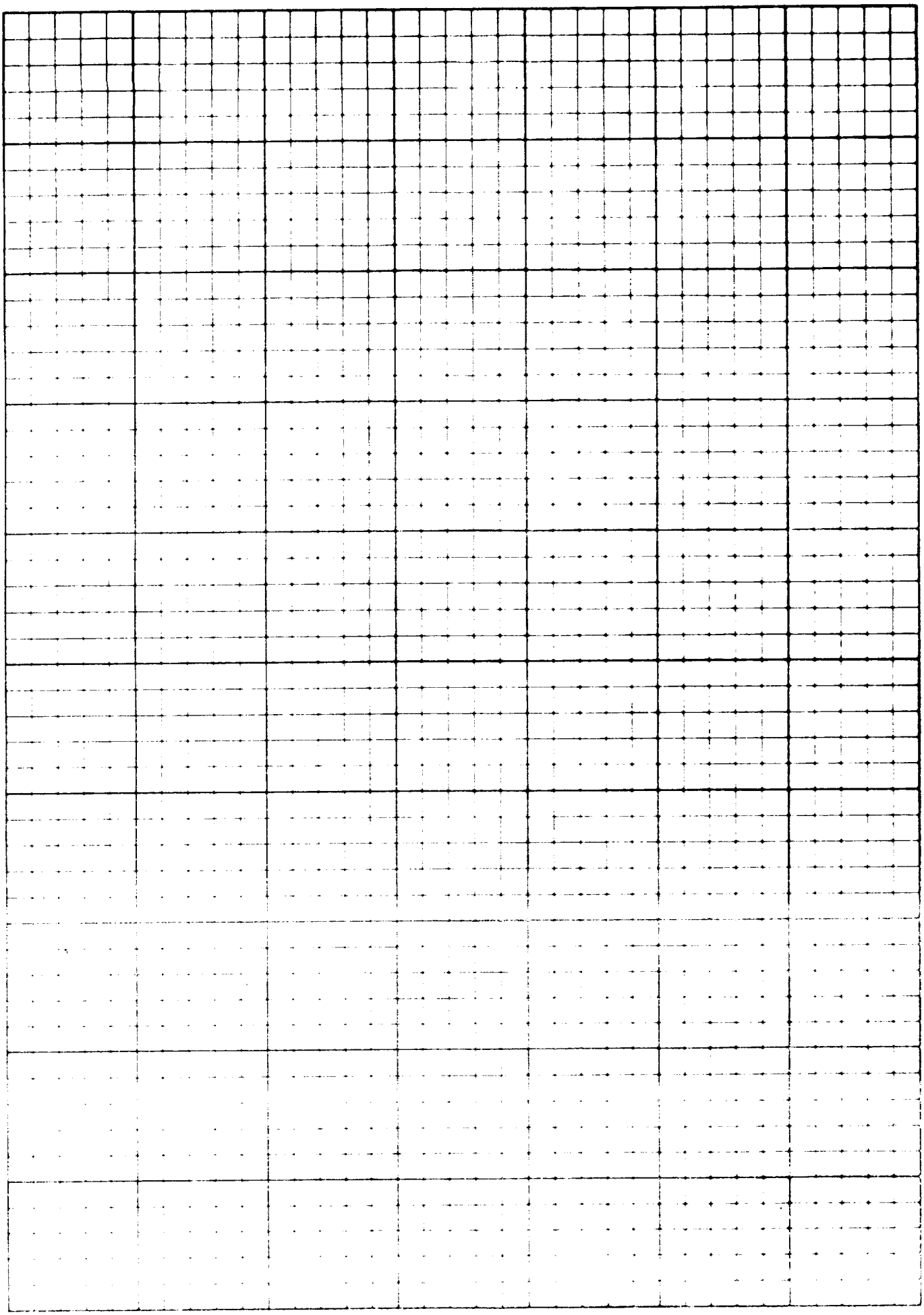
IF
- For the BFS system
- The HSTD is good
- Baro was previously not known to be good
- |delta-sel| <= |delta-z| + 500

THEN
- conclude that Baro is good

(8) BARO is Bad in the BFS

IF
- For the BFS system
- The HSTD is good
- BARO was previously good or unknown
- |delta-sel| > |delta-z| + 500

THEN
- Notify operator that Baro is bad



- The current value of the baro filter flag is different from its previous value

THEN
- Conclude that the value has changed
- Notify the operator if the new value ~~is "process."~~

d. Outputs

~~Status messages.~~ ← [(1) Baro filter flag value; (2) mach jump status]

e. Support Computations

None.

3.9.3 Baro Recommendations with Ground Available

a. General Information

This group recommends a setting for the AIF switch when the ground state is available.

b. Inputs

(1) Baro filter flag
(2) Baro AIF flag
(3) Baro altitude quality
(4) HSTD status
(5) Baro edit ratio (only available with PASS)
(6) TACAN range filter flag
(7) Engaged system

c. Rules/heuristics/concepts

(1) Baro to AUTO

IF for the Pass system
- Baro is good
- Baro edit ratio is less than one (1)
- Baro is inhibited

THEN notify operator that
- Baro is GO for NAV.

(2) Baro to Force

IF for the Pass system
- Baro is good
- Baro edit ratio is greater than one (1)
- Baro is not being forced

THEN
- Recommend forcing baro.

(3) End Baro Force

IF for the Pass system
- Baro is good

- Baro edit ratio is less than one (1)
- Baro is being forced

THEN

- Recommend returning baro to AUTO.

(4) Baro to Inhibit

IF For the engaged SYSTEM

- Baro is bad
- The vehicle is not in the Mach jump region
- Baro is not inhibited

THEN

- Recommend that baro be inhibited.

d. Outputs

Recommend ad AIF setting.

e. Support Computations

None.

3.10 THE MICROWAVE SCANNING BEAM LANDING SYSTEM

The first thing to be done in the MSBLS section overall should be to check the landing site data table. If the MLS is not available at that site, no part of the entire MLS rule set should be invoked. Also no MLS is in the BFS.

3.10.1 MSBLS Availability

a. General Information

Availability is determined by several values as follows:

- Not commfaulted
- Not failed
- Powered on

This group determines which LRU's are available. It also determines why the unavailable LRU's are unavailable.

b. Inputs

(1) Commfault flag
(2) Power flag
(3) Fail flag

c. Rules/heuristics/concepts

(1) MSBLS Commfault
IF
- The LRU is powered on
- An MLS LRU was not commfaulted previously
- The commfault flag for that LRU is now on
THEN
- Notify operator that the LRU is commfaulted (unless the whole string is down).
- Conclude that the LRU is no longer available due to commfault.

(2) MSBLS Commfault Clear
IF
- An MLS LRU was commfaulted previously
- The commfault flag for that LRU is now off
THEN
- Notify operator that the commfault for that LRU has cleared (unless the whole string was down).
- Conclude that the LRU has the status indicated by the fail flag.

(3) MSBLS Failed
IF
- An MLS LRU was available previously
- A fail flag for that LRU is now on

THEN
- Notify the operator of the LRU failure.
- Conclude that the LRU is no longer available due to RM failure.

(4) MSBLS Power Off
IF
- An MLS LRU was powered on previously
- The power indicator for that LRU is now off
THEN
- Notify operator that the LRU has lost power.
- Conclude that the LRU is not available due to loss of power.

(5) MSBLS Power On
IF
- An MLS LRU was powered off previously
- The power indicator for that LRU is now on
THEN
- Notify operator that the LRU has been powered on.
- Conclude that the LRU has the status indicated by the fail flag.

(6) MSBLS Availability
IF
- An LRU is powered on
- An LRU is not failed
- An LRU is not commfaulted
THEN
- The LRU is available.

(7) Three MSBLS's Available
IF
- All three MLS LRU's are available
THEN conclude that
- the number of available MLS LRU's is three.

(8) Two MSBLS's Available
IF
- MLS LRU A is available
- MLS LRU B is available
- MLS LRU C is not available ~~(where A, B, and C represent any of the three LRU numbers)~~
THEN conclude that
- the number of available MLS LRU's is two.

(9) One MSBLS Available
IF
- MLS LRU A is available
- MLS LRU B is not available
- MLS LRU C is not available ~~(where A, B, and C represent any of the three LRU numbers)~~
THEN conclude that
- the number of available MLS LRU's is one.

(10) No MSBLS Available
IF
- All MLS LRU's are not available
THEN conclude that
- the number of available MLS LRU's is zero.

d. Outputs

(1) MSBLS LRU availability.

e. Support Computations

None.

3.10.2 MSBLS Lockon Status

a. General Information

This group determines how many LRU's are locked on to range, azimuth, and elevation.

b. Inputs

(1) Estimated altitude
(2) MSBLS lockon flags
(3) LRU availability
(4) Runway state vector

c. Rules/heuristics/concepts

(1) Check Channel
IF
- At least one MLS LRU is available
- No LRU is locked on to one of the measurements (i.e., range, azimuth, or elevation)
- The vehicle is below an altitude of 13 000 ft
THEN if operator needs to
- ~~ask~~ that the MLS channel number be verified.

(2) Three MSBLS's Locked
IF
- All three LRU's are available
- All LRU's are locked on to a measurement ~~(i.e., range, azimuth, or elevation)~~
THEN conclude that
- the number locked for that measurement is three.
- If the number locked previously was zero, notify operator that MLS is locking on.

(3) Two MSBLS's Locked
IF
- LRU A is locked on to a measurement
- LRU B is locked on to the same measurement
- LRU C is not locked on to the measurement or not available ~~(measurement refers to range, azimuth, or elevation, and A, B, or C refers to any LRU number)~~
THEN conclude that
- the number of LRU's locked on to that measurement is two.
- If the number locked previously was zero, notify the operator that MLS is locking on.

(4) One MSBLS Locked
IF
- LRU A is locked on to a measurement
- LRU B is not locked on to the measurement or not available
- LRU C is not locked on to the measurement or not available ~~(measurement refers to range, azimuth, or elevation, and A, B, or C refers to any LRU number)~~
THEN conclude that
- the number of LRU's locked on to that measurement is one.
- If the number locked previously was zero, notify the operator that MLS is locking on.

(5) No MSBLS Locked
IF
- At least one LRU is available
- ~~MSBLS was locked on to a measurement previously~~ At least one MLS LRU was previously locked on to a measurement
- No LRU is locked on to that measurement ~~(measurement refers to range, azimuth, or elevation)~~
THEN conclude that
- the number of LRU's locked for that measurement is zero.
- Notify operator that the MLS lost lock.

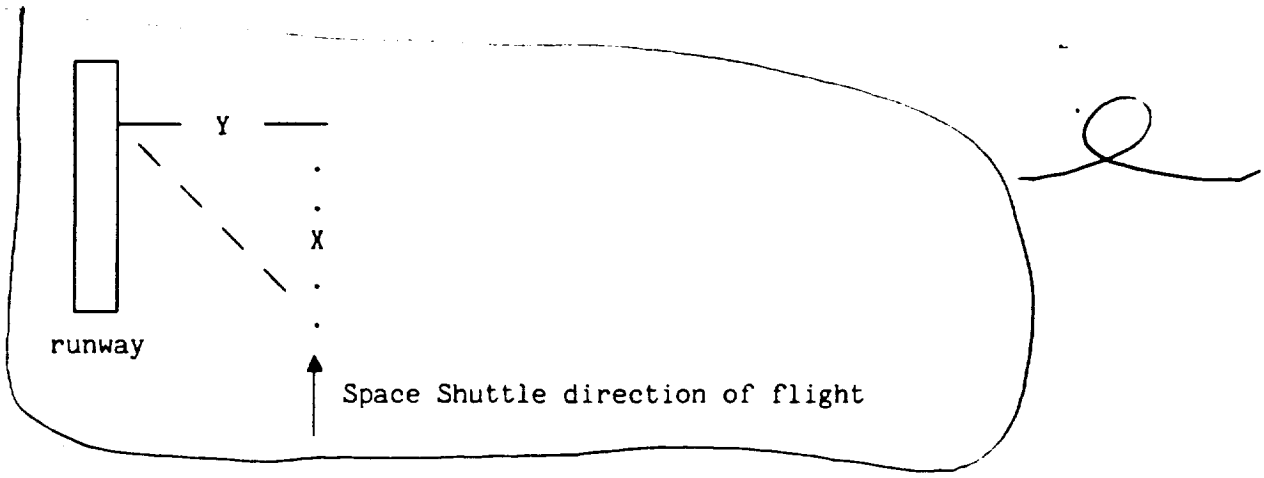
(6) Wide Landing
IF
- Y/X > tan 13.5 deg (as shown in figure following)
THEN
- Notify operator of possible "out of MLS cone" condition.

d. Outputs

(1) Number of MSBLS's locked.
(2) Lock status messages

e. Support Computations

None.



3.10.3 MSBLS Error Checks

a. General Information

Check plots. For each available and lock measurement, calculate b (y-intercept) and sigma (noise). Wait for about three points, then compare b and sigma verses the RM limits.

Range = 2000 ft
Azimuth = 0.5 deg
Elevation = 0.4 deg

IF the b or sigma is ≥ the RM limit
THEN that measurement's status = Bad

IF the b or sigma is ≥ 1/2 the RM limit and < the RM limit
THEN that measurement status = Suspect

IF the LRU is not available or not locked on
THEN that measurement status = None

This group checks measurement errors and determines the quality of the three LRU's.

b. Inputs

(1) MSBLS LRU lock flags
(2) MSBLS availability
(3) Quality ratings

3.10A

c. Rules/heuristics/concepts

(1) MSBLS Error Change
2 IF
- Either the noise or bias on a measurement has a different status than it did previously

THEN
- Notify the operator of the new status

(2) MSBLS LRU Quality (Part 1)
3 IF
- An MLS LRU is unavailable or unlocked in a measurement
THEN
- That LRU has no quality rating for that measurement.

(3) MSBLS LRU Quality (Part 2)
4 IF
- An MLS LRU is available
- The LRU is locked on a measurement
- The noise and bias ratings on the measurement indicate a quality rating different from the one given to the LRU previously
THEN conclude that there is a
- ~~Note the~~ new quality rating for the LRU.

d. Outputs

(1) MSBLS LRU quality.

e. Support Computations

None.

3.10.4 MSBLS Flag Status

a. General Information

Note any changes in data good flags and inform ONAV operator; i.e., good-to-bad or bad-to-good.

Print dilemma messages if dilemmas occur. Also note changes in processing flags, not-processing or processing. After start of processing, check state error (PASS). If error increases, force TACAN.

This group watches for changes in the MLS data good flags and filter flags.

b. Inputs

(1) MSBLS filter flags
(2) MSBLS data good flags
(3) MSBLS dilemma flags

c. Rules/heuristics/concepts

(1) MSBLS Filter Flag Changed
IF

3.10 A

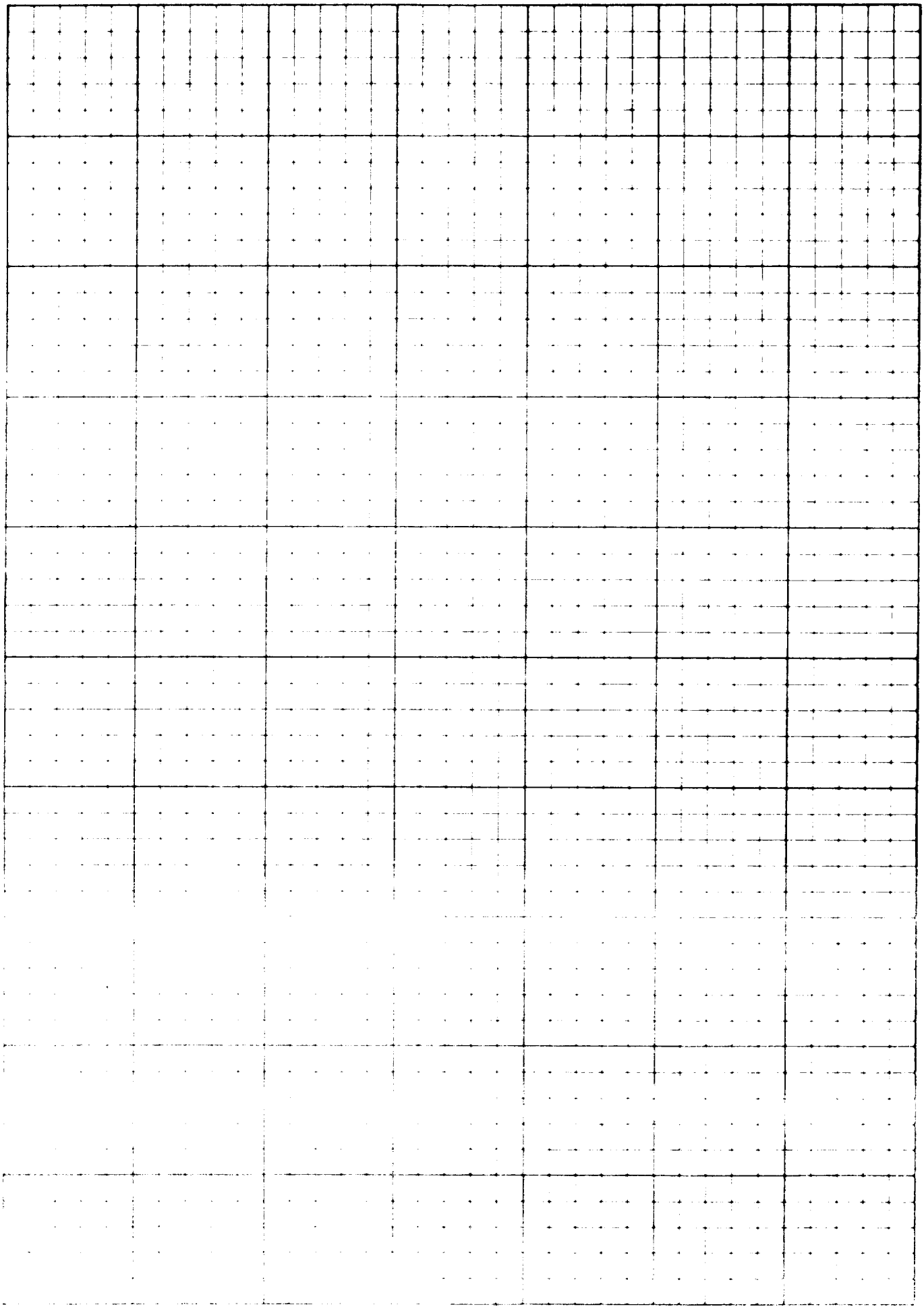
(1) Initial MSBLS Check

IF

- No quality statement has yet been made about a measurement
- The measurement bias is within tolerance
- the measurement noise is within tolerance

THEN

- Notify operator that the measurement is good



- The current value of a MLS filter flag is different from its previous value

THEN

- Conclude that the value has changed.
- Notify operator if the new value is "process."

(2) MSBLS Data Good Flag Changed

IF

- The current value of an MLS data-good flag is different from its previous value

THEN

- Notify operator of the new value.

(3) MSBLS Dilemma

IF

- MLS dilemma flag is on for any measurement

THEN Notify

- ~~Warn~~ the operator that the MLS measurement is in dilemma

d. Outputs

(1) MSBLS status messages.

e. Support Computations

None.

3.10.5 MSBLS Recommendations

a. General Information

For each measurement type, count the number of LRU's with noise or bias greater than the RM limits.

This group determines what actions need to be taken on the MLS to keep it from corrupting the NAV state.

No. available	No. locked	Count	Action
3	1	1	None
	2	1	Deselect bad LRU (power off or flip thumbwheel)
		2	Force TACAN
	3	1	RM will fail LRU
		2	Deselect bad LRU's
		3	Force TACAN
2	1	1	None
	2	1	Deselect bad LRU's
		2	Force TACAN
1	1	1	Force TACAN
N/A	N/A	0	Skip MSBLS section

Note that, with the preceding table, there is the possibility of redundant commands or of getting rid of all of the MLS data without forcing TACAN's. Other subsystem interactions and variations on response also are determined by flight rule: no navigation input will be used that will cause the NAV state to degrade.

b. Inputs

(1) MSBLS availability
(2) Number of MSBLS's locked
(3) MSBLS LRU quality

c. Rules/heuristics/concepts

(1) Three-level MSBLS Deselect 1
IF
- Three LRU's are available
- Two LRU's are locked on
- One LRU is bad
THEN
- Recommend deselecting the bad LRU.

(2) Three-level MSBLS Force TACAN 1
IF
- Three LRU's are available
- Two LRU's are locked on
- Two LRU's are bad in the same measurement
THEN
- Recommend forcing TACAN.

(3) Three-level MSBLS RM Fail
IF
- Three LRU's are available
- Three LRU's are locked on
- One LRU is bad
THEN
- Recommend deselecting (for a noise problem) or waiting for RM isolation (for a bias problem).

(4) Three-level MSBLS Deselect 2
IF
- Three LRU's are available
- Three LRU's are locked on
- Two LRU's are bad in the same measurement
THEN
- Recommend deselecting the bad LRU's.

(5) Three-level MSBLS Force TACAN
IF
- Three LRU's are available
- Three LRU's are locked on
- Three LRU's are bad on the same measurement

THEN
- Recommend forcing TACAN to the operator due to bad measurement on all LRU's

(6) Two-level MSBLS Deselect
IF
- Two LRU's are available
- Two LRU's are locked on
- One LRU is bad
THEN
- Recommend deselecting the bad LRU to the operator.

(7) Two-level MSBLS Force TACAN
IF
- Two LRU's are available
- Two LRU's are locked on
- Two LRU's are bad in the same measurement
THEN
- Recommend forcing TACAN to the operator.

(8) One-level MSBLS Force TACAN
IF
- One LRU is available
- One LRU is locked on
- One LRU is bad
THEN
- Recommend forcing TACAN to the operator.

(9) Do Not Force TACAN
IF
- Forcing TACAN is recommended
- ~~If TACAN is not GO (from TACAN section)~~ A selected TACAN measurement is no-go
THEN
- Cancel any force TACAN recommendations
- Recommend powering off MLS to the operator.

d. Outputs

(1) Recommended actions.

e. Support Computations

None.

3.10.6 MSBLS Effects on State Errors

a. General Information

This group checks to see if MSBLS processing makes the state error worse.

b. Inputs

(1) GND-O/B state error
(2) MSBLS filter flags

c. Rules/heuristics/concepts

(1) Error Before MSBLS
IF
- At least one LRU is locked on range
- No MLS is being processed
THEN
- Remember the current worst-axis state error.

(2) Error After MSBLS
IF
- MLS is being processed
- The current state error is worse than before MLS was processed
THEN
- Recommend to operator forcing TACAN due to state error growth from MLS

d. Outputs

(1) Recommended action.

e. Support Computations

None.

3.11 HIGH-SPEED TRAJECTORY DETERMINATOR MONITORING

a. General Information

These rules have the task of determining the status of the HSTD state vector and depend primarily on operator input. The rules can detect when the filter is stopped and some situations where the filter is not converged. In addition, the operator can indicate when the filter is bad. The operator must specify when the filter is good; the rules never do that automatically.

The overall rationale is that it is better to assume ground is bad and not make some recommendations rather than assume that ground is good and encounters bad recommendations. The issue is to keep consistency between ONAV expert system recommendations and ground status (which is available only over the "loop").

b. Inputs

(1) Operator input
(2) Ground NAV expert system (not yet available)
(3) Internal rules in the ONAV expert system

c. Rules/heuristics/concepts

(1) Start HSTD
IF
- The HSTD has not been running
- The "stopped" indicator is off
THEN
- Conclude that the HSTD is running but has not converged.

(2) HSTD Bad
IF
- The HSTD ~~was~~ IS good
- The operator entered the HSTD bad indicator
THEN
- Conclude that the HSTD is bad (not converged).

(3) HSTD Good
IF
- The HSTD ~~was~~ IS bad
- The operator entered the HSTD good indicator
- At least 10 sec have elapsed since last restart
THEN
- Conclude HSTD is good.

(4) HSTD Stopped
IF
- The HSTD is running
- The stopped indicator is on

THEN
- Conclude that the HSTD has been stopped.

(5) HSTD Editing
IF
- The HSTD ~~was~~ is good
- Less than three stations are being processed
- A given station is not being excluded
- Data is coming from that station
- At least one good measurement of a given type was available from that station
- All of the measurements of that type from that station were edited by the filter

THEN
- Conclude that the HSTD is bad.

(6) HSTD Prop
IF
- The HSTD ~~was~~ is good
- The prop flag is on

THEN
- Conclude that the HSTD is bad.

(7) HSTD Covariance
IF
- The HSTD ~~was~~ is good
- The root sum square (RSS) position or velocity covariance diagonals are too large

THEN
- Conclude that the HSTD is bad.

(8) HSTD Restart
IF the HSTD is available
- The HSTD restart flag is on

THEN
- Conclude that the HSTD is bad.
- Record the current time as the time of the last restart.

(9) No Ground Data
IF
- No ground data available

THEN
- Make a statement on NAV as it relates to BFS transfers.

d. Outputs

HSTD health (good, bad, not running, not available).

e. Support Computations

None.

SECTION 4
GENERAL ISSUES

a. What will ONAV expert system do when data is not available or when messages are not acted upon?

b. What are the ONAV operator interaction considerations?

SECTION 8 4
REFERENCES

1. "Guidelines and System Requirements For the Onboard Navigation (ONAV) Console Expert/Trainer System." NASA/Johnson Space Center, Mission Support Directorate, Mission Planning and Analysis Division. JSC-22433, December 1986.

2. Experience (Knowledge) Sources:

   (a) Stephen M. Desrosiers, Rockwell Shuttle Operations Co.
   (b) Angie Ferrell, Rockwell Shuttle Operations Co.
   (c) Glenn R. Goodrum, Unisys - Houston

3 "Knowledge Requirements for the Onboard Navigation (CNAV) Console Expert/Trainer System." NASA/Johnson Space Center, Mission Support Directorate, Mission Planning & Analysis Division. JSC-22657, October 1987.

DISTRIBUTION FOR JSC IN 87-FM-15

NASA - JSC
DM6/M. Collins
M. Haynes (5)
F. Lowes
FM/E. Lineberry
FM7/R. Brown
FM72/R. Savely
L. Wang (21)
JM2/Technical Library (3)
JM86/Distribution Operations (15 + extras)
JM88/Documentation (2)

BARRIOS - Houston
K. Hernandez

LINCOM - Houston
D. Bochsler (20)

MDAC - ES
K. Greiner (2)

OMNIPLAN - Houston
Editing
17226 Mercury
Houston, Texas 77058

RSOC - Houston
RS16/S. Desrosiers (2)
RS16E/A. Wylie

UNISYS - Houston
8C/L. Morris (5)