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Software Analysis and Management System

Intelligence/Electronic Warfare (IEW) Direction Finding and Fix Estimation Analysis Report

Volume 3 GUARDRAIL

December 1986

National Aeronautics and
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Jet Propulsion Laboratory
California Institute of Technology
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This report contains an analysis of the direction finding (DF) and Fix estimation algorithms in GUARDRAIL. The GUARDRAIL software analysed is old and not currently used in the field. However, the algorithms ~~here~~ analyzed are used in present GUARDRAIL software and in other current IEW systems. The report examines the underlying algorithm assumptions (including unmodeled errors) and their appropriateness for GUARDRAIL. Coding and documentation problems are then discussed. A detailed error budget is presented in Appendix B. An extensive bibliography on Fix estimation procedures is ~~contained in Appendix A.~~

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DIRECTION-FINDING AND FIX ESTIMATION ANALYSIS REPORT
VOLUME 3 GUARDRAIL

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ABBREVIATIONS AND ACRONYMS

ACM	Association for Computing Machinery
AGTELIS	Automated Ground Transportable Emitter Location and Identification System
BETA	Battlefield Exploitation and Target Acquisition
COMINT	Communication Intelligence
DF	Direction Finding
DOD	Department of Defense
EEP	Elliptical Error Probability
ELINT	Electronic Intelligence
EOB	Electronic Order of Battle
GR	GUARDRAIL
IPF	Integrated Processing Facility
ITEP	Interim Tactical ELINT Processor
JPL	Jet Propulsion Laboratory
LOB	Line-of-Bearing
LOP	Line-of-Position
MGR	Military Grid Reference System
QUICKLOOK	Airborne Non-Communication Emitter Location and Identification System
SNR	Signal to Noise Ratio
TB	TRAILBLAZER
TCATA	TRADOC Combined Arms Training Activity
USAICS	U. S. Army Intelligence Center and School
USAMS	USAICS Software Analysis and Management System
UTM	Universal Transverse Mercator

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SECTION 1
INTRODUCTION

1.1 PURPOSE

This analysis focuses on illuminating the logical and mathematical structure of the location estimating algorithms found in the GUARDRAIL V system, and identifying the assumptions that must hold for these algorithms to give valid results. GUARDRAIL V is one of several current U. S. Army direction-finding systems. These systems use several lines-of-bearing to estimate the location of an enemy emitter. Such a location estimate is often called a "fix." Several general methods for direction finding and fix estimations, some with more mathematically rigorous foundations, some frankly empirical, were discussed in Volume I. Although the designer of such an algorithm often has a specific mathematical structure in mind, the empirical nature of the algorithm often leaves the analyst several possible mathematical interpretations. This richness of interpretation increases the understanding of just how well the algorithms function in various environments and how compatible they are with algorithms found in other systems.

1.2 BACKGROUND

This algorithm analysis effort is being performed by the Jet Propulsion Laboratory (JPL) for the U. S. Army Intelligence Center and School as a research effort to increase the understanding of the hybrid mathematical/empirical algorithms found in intelligence processing systems. Algorithm results from one system are frequently used as input data for another system. Understanding both the assumptions under which the algorithms work, and the assumptions their results satisfy, is crucial to understanding the overall system. This view of a metasystem of intelligence processing systems (Figure 1-1) is central to this algorithm analysis effort.

For purposes of these studies, "algorithm" means a set of rules for carrying out a single conceptual operation on a set of data. There are many types of algorithms necessary to the operation of the metasystem shown in

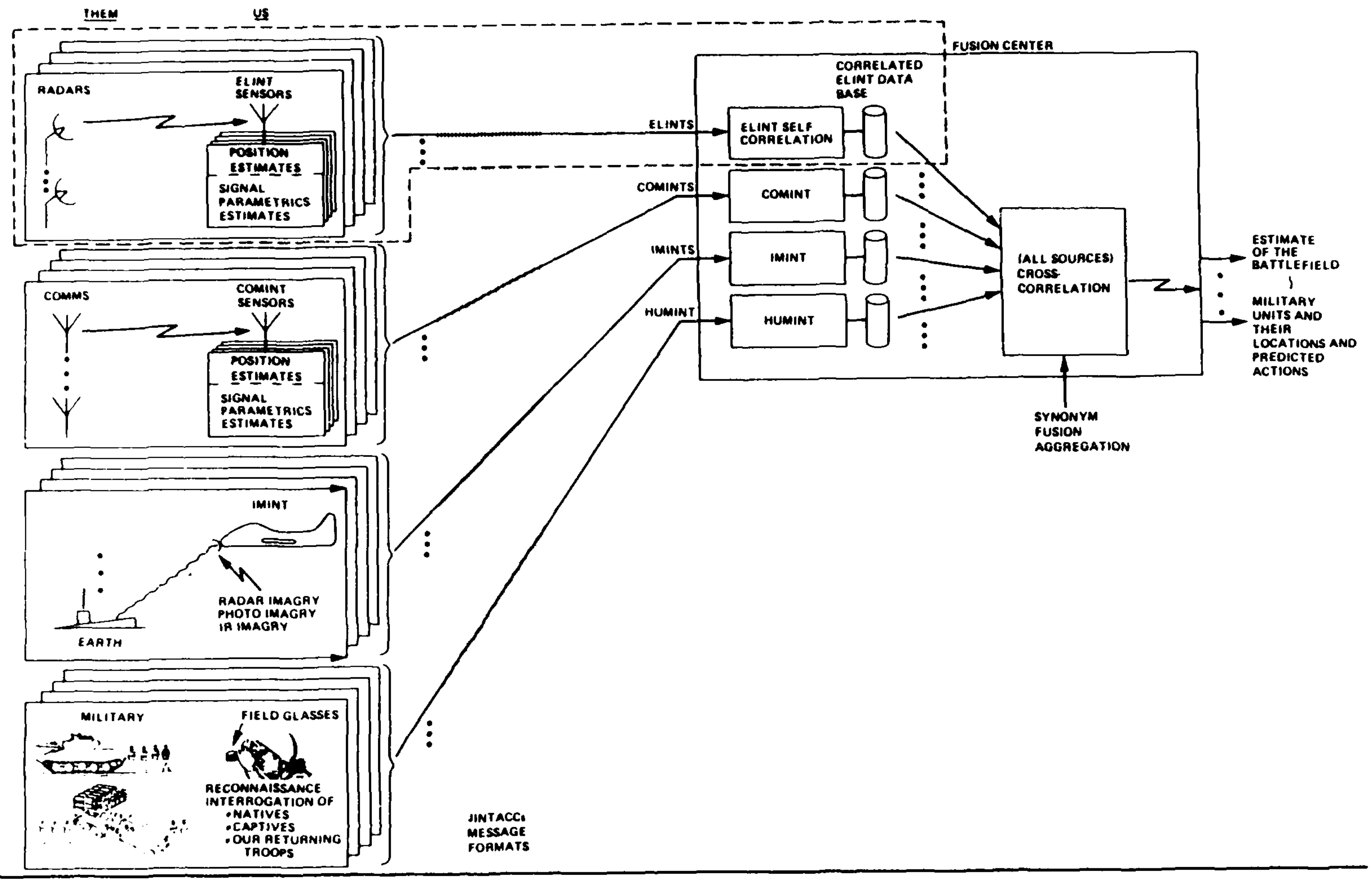


Figure 1-1. Overview -- From All Sources Through the Cross-Correlation Process

Figure 1-1. Analyses reported on so far, listed in Appendix F, have focused on four of these: geographical transformation algorithms, self and cross-correlation algorithms, and aggregation algorithms. Geographical transformation algorithms translate locations from one grid reference system to another. These algorithms appear in almost all systems, often as incoming data or report preparation functions. Self-correlation algorithms test if the entity referred to in a new report has already been recorded in the database that reflects the estimated enemy situation. Cross-correlation algorithms test if a sighted piece of equipment belongs to an already identified unit, or a lower echelon unit to a higher echelon one. Aggregation algorithms try to identify an artillery battery in a cluster of equipment, a division in a group of regiments, or like groupings. Several statistical issues, arising particularly in the correlation algorithms, are analyzed in a companion set of technical memoranda listed in Appendix F.

Looking once more at Figure 1-1, note that the same intelligence function, hence an algorithm performing that function, is often embedded in several intelligence processing systems. Some generic algorithms, such as the geographical transformation algorithms mentioned above, appear in almost all systems. Comparing these algorithms that perform the same function in different systems increases the understanding not only of what these algorithms actually do and how well they perform, but also increases the understanding of how a "good" algorithm would work and what it would look like. Such comparisons should lead to developing criteria for selecting algorithms for embedding in new or upgraded systems, and finally in the creation of a library of "good" algorithms from which the choice can be made. The development of these criteria and building such a library are two major goals of this algorithm analysis effort to which each analysis of an algorithm in an existing system contributes.

SECTION 2

ASSUMPTIONS, RESTRICTIONS, SCOPE

2.1 BRIEF DESCRIPTION OF RADIO DIRECTION-FINDING AND POSITION FIXING

The purpose of radio direction-finding is to estimate or fix the position of selected emitters. Usually, the position estimate is accompanied by a confidence region reflecting measurement errors, propagation errors, and modeling errors.

Radio direction-finding (DF) requires that an emitter be viewed from at least two DF stations spaced far enough apart that their look angles intersect as close to 90 degrees as possible. However, a 90-degree look angle is usually impossible under battlefield conditions. Figure 2-1 illustrates a simple situation of two DF stations.

The fix estimate is at the point of intersection of the two lines-of-bearing (LOBs) (see Figure 2-1). Since there is only one point of intersection, we have insufficient information to estimate the fix uncertainty due to measurement, propagation, and modeling errors.

In a multiple DF station configuration, there are many intersections (see Figure 2-2). A more accurate fix estimate may be obtained by evaluating the clustering of these intersections. Since each intersection is a simple fix estimate, the uncertainty can then be expressed as a confidence region surrounding this fix estimate. This uncertainty reflects:

(1) Random measurement errors in measuring the lines-of-bearing.

(2) Errors because of different radio propagation effects along the lines-of-bearing.

(3) Errors because of spherical or flat-Earth assumptions.

(4) Phantom or ghost intersections which resulted from the presence of multiple emitters or hidden emitter reflectors.

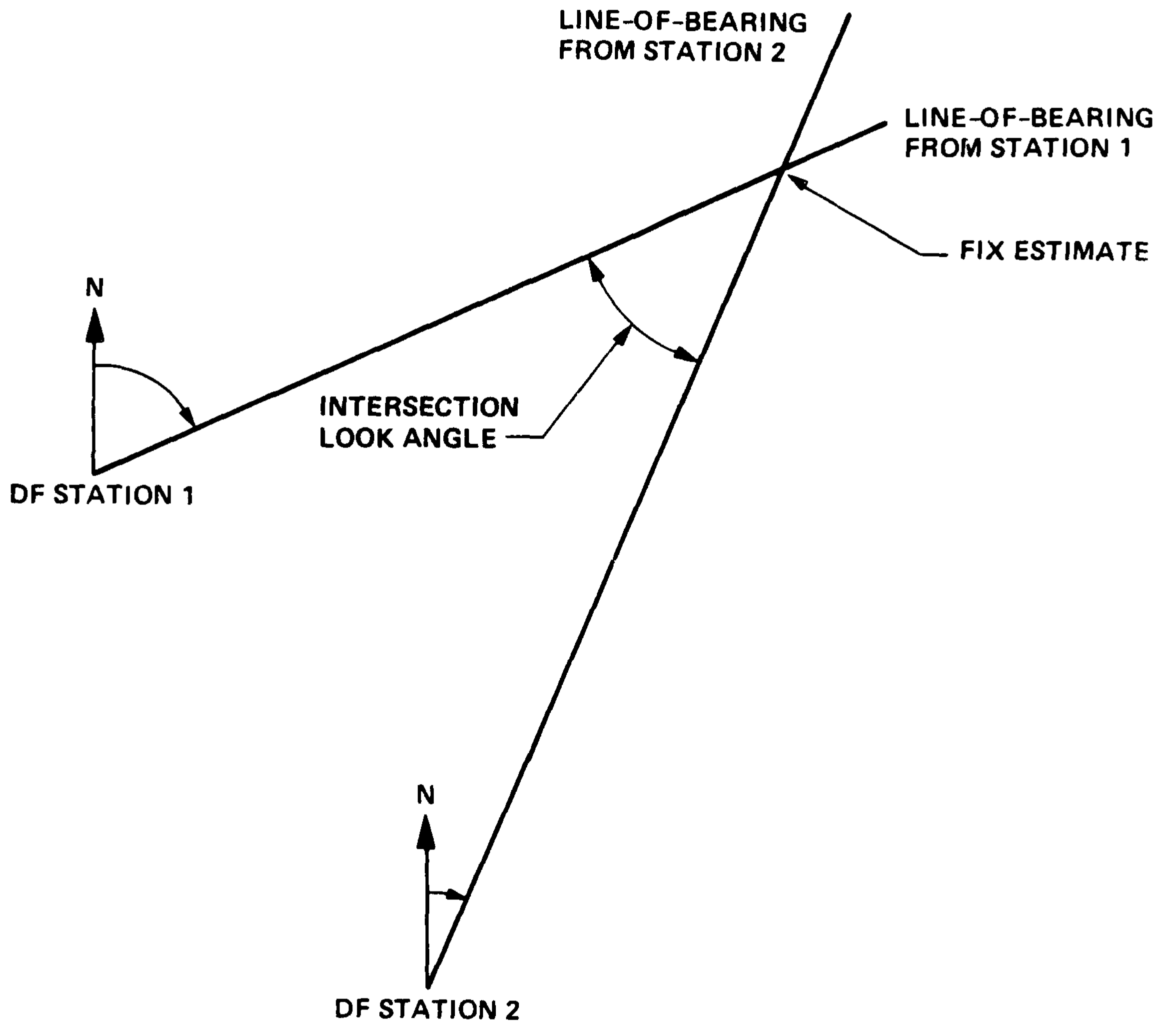


Figure 2-1. Relative Location of Two Direction-Finding Stations

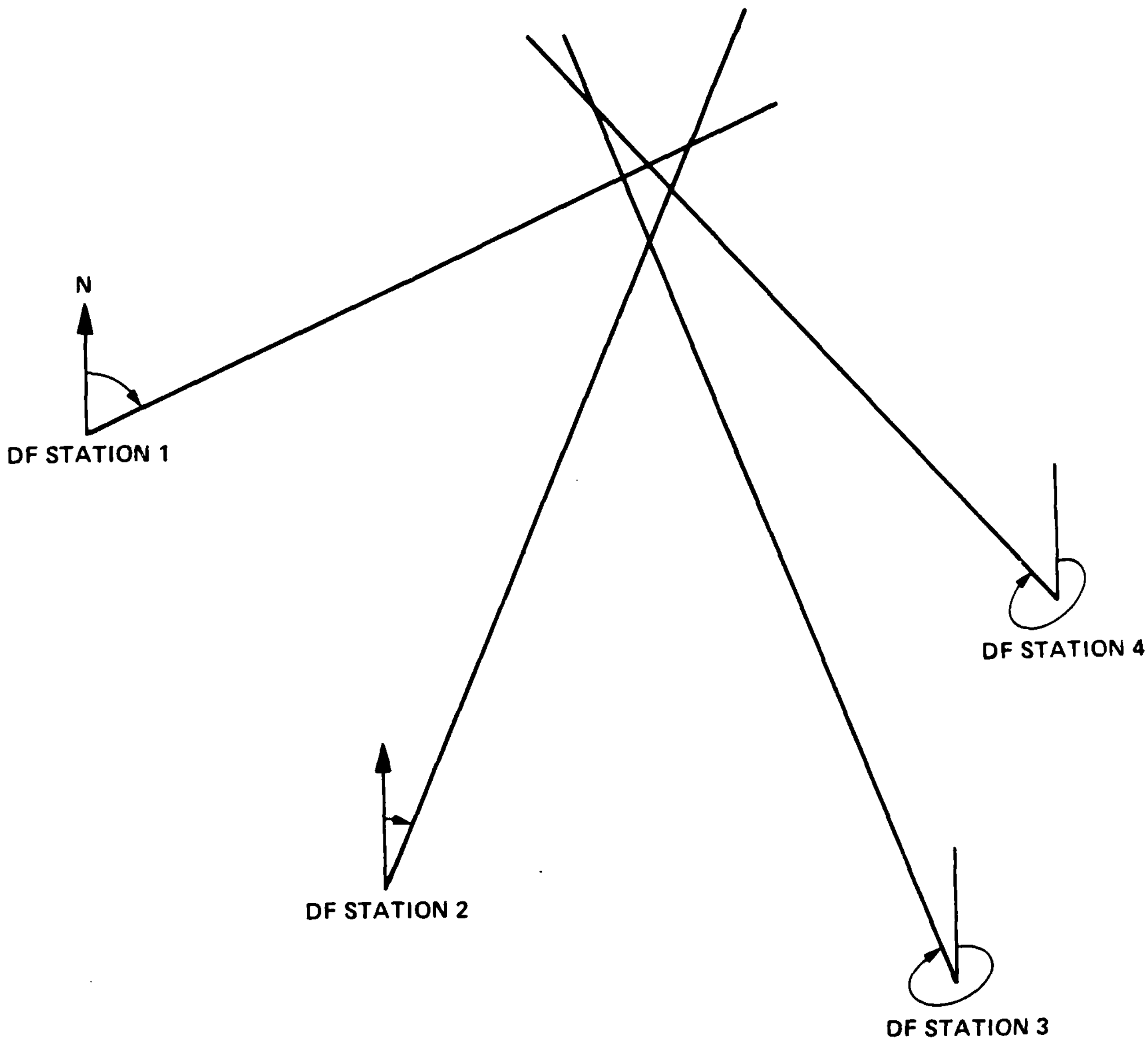


Figure 2-2. Relative Location of Several Direction-Finding Stations

2.2 ASSUMPTIONS

Some standard assumptions are made in the following analyses:

(1) The lines-of-bearing are straight.

(2) The errors in the separate lines-of-bearing are independent.

(3) The errors in the lines-of-bearing are Normally (Gaussian) distributed with zero mean and fixed estimable variance.

(4) The emitter location estimate error is distributed as a bivariate Normal distribution.

(5) The sensor positions are known exactly.

(6) The transmitter location is fixed during the period of DF fixing.

(7) The sensors are properly sited, calibrated, and operated.

Assumption #1 is reasonable for the systems considered in this report when the sensors are properly sited. However, this assumption is weak at frequencies below approximately 30 MHz because of the effects of atmospheric tilt.

Assumption #2 is reasonable because it is based on the systematic errors being accounted for in calibrations. This assumption is weak at frequencies below approximately 30 MHz when some stations are close enough to each other to be subjected to the same propagation effects.

Assumption #3 is usual when considering measurements which are subject to random measurement error. There are biases in the measurements from navigation errors, errors in the calibration tables, interference, depression angle effects, etc; these biases may be removed. In the absence of specific knowledge about these errors the Normal (Gaussian) assumption is reasonable. Distorting effects such as plinthing to account for wild bearings, skewedness because of low receiver signal-to-noise ratios, and distortions resulting from the sensors not uniformly surrounding the emitter can weaken or invalidate this assumption.

Assumption #4 is necessary to allow confidence levels about the estimated emitter position to be computed. The qualifications on assumption #3 also apply to #4.

Assumption #5 is reasonable, based on the fact that any such position errors can be added to the emitter estimate uncertainty, if they are significant.

Assumption #6 is necessary to the analyses of the systems considered in this report, and it is reasonable over the period required to obtain a single fix.

Assumption #7 is reasonable in the absence of contradictory information.

2.3 RESTRICTIONS

In addition to the assumptions discussed in Section 2.2, this report does not consider the following effects:

(1) Geographic transformation, map projection effects, and grid reference system conversions (see Analysis of Geographic Transformation Algorithms, July 9, 1982 in this series of algorithm analysis reports).

(2) Propagation effects.

(3) Centroid effects and susceptibility to deception (e.g., meaconing, gated signal parameter techniques, etc.).

(4) Special problems associated with low-probability-of-intercept emitters (low SNR, spread-spectrum, time-frequency diversity, frequency agility, etc).

(5) Numerical computation and normal truncation effects.

(6) Combination of lines-of-bearing, or emitter location estimates and their confidence ellipses from different systems (these problems will be the subject of a future report in this series of algorithm analysis reports).

(7) Elimination of wild bearings and ghost intersections using hardware/software processing of target message internals.

2.4 SCOPE

This report covers the GUARDRAIL V system based on the documentation detailed in Appendix A, Section A.5 of this report.

SECTION 3

GUARDRAIL V DF FIX ESTIMATION

This analysis of the GUARDRAIL V DF Fixing System (COMINT) is based on the GUARDRAIL V AN/TSQ-105, AN/USD-9, Technical Manual ESL-TM-928. These references include flow charts and some mathematical details. No applicable computer program code was available for this analysis. There are several versions of GUARDRAIL.

The GUARDRAIL V System is an airborne/ground remote controlled COMINT intercept and direction-finding (DF) system. The collection system (sensors) are integrated into specially modified RU-21H aircraft. The processing is done in the ground-based Integrated Processing Facility (IPF), AN/TSQ-105(U)3. GUARDRAIL's sensors obtain independent lines-of-position (LOPs) at a specified emitter frequency and downlinks them for processing at the information processing facility. Typical deployment is two sensor aircraft launched together, providing an optimum base line for direction-finding. Up to four aircraft can be deployed simultaneously.

This report considers only the DF Fixing algorithms used in the GUARDRAIL System. Algorithms for data-base handling, screen handling, geographic transformations, and aircraft calibrations are not considered.

3.1 GENERAL DISCUSSION OF GUARDRAIL V DF FIX ESTIMATION PROCESS

The GUARDRAIL V System normally operates sequentially, collecting lines-of-position (LOPs) according to time and using them to update the fix estimate. This sequential process leads to a fast-fixing algorithm which minimizes internal memory requirements and will be described in the next section. However, provisions exist to obtain fix estimates using a set of LOPs simultaneously. This provision will help get an initial fix estimate and refine sequentially obtained estimates. Initial fix estimates may also be introduced manually (seeded) by the operator. These manual estimates are based on other available intelligence information.

3.2 SIMPLIFIED DESCRIPTION OF THE GUARDRAIL V DF FIX ESTIMATION PROCESS

The following description is based on the mathematical/statistical procedures and results in Volume 1 of the Directing Finding and Fix Estimation Series of reports. This simplified description treats the overall GUARDRAIL system from the integrated analysis/algorithm viewpoint.

Based on preliminary intercept information, the analyst selects the frequency for which a fix estimate is desired. Each time the emitter is activated, LOPs are taken from each sensor. These LOPs may be directed to different emitters radiating at the same frequency. All LOPs collected are entered into a database. Anytime after three or more LOPs are collected on a single emitter, the fix estimation process may be initiated. For the initial fix estimate, all the LOPs in the data base become available to attempt a nonsequential fix. This nonsequential fix estimate may also be performed at any time after the initial fix estimate in an attempt to reduce bias effects.

After the initial fix estimate is made, subsequent LOPs (obtained by subsequent DF button depressions) become available for updating the fix estimate. Fix estimates are normally made sequentially using the additional LOPs to update earlier fix estimates. The analyst may, at any time, attempt a nonsequential fix using all the LOPs in the database. This makes all the LOPs available. This nonsequential fix estimating process is algorithmically the same as the initial fix estimate process. Thus GUARDRAIL involves two types of DF fixing algorithms, nonsequential and sequential algorithms based on the same mathematical/statistical method of weighted least squares. They are simply two different implementations of the same method.

The initial fix and nonsequential fix algorithms have a collection of LOPs available to be used simultaneously. These LOPs are first screened for wild bearings (rejecting those LOPs that are not closely clustered with the main body of the LOPs). However, this strategy is not without flaws; the "main body" of the LOPs may be poorly chosen, thus rejecting some valid bearings.

After the wild bearings have been edited from the collection of LOPs, a fix is estimated. The fixing process consists of minimizing the weighted sum of the squares of the angular differences between the LOPs and the estimated true bearing to the emitter. As discussed in Volume 1 of this series, the weights are inversely proportional to the distances between the sensor and emitter. These weights are also inversely proportional to angular instrumentation errors (standard deviation). The weighted least squares solution is obtained by using an iterative technique described below.

After obtaining a fix estimate, a confidence region surrounding the fix estimate is calculated at the 99 percent level. This confidence region contains the true emitter position 99 percent of the time for a large number of fix estimates under the same conditions. This confidence region is used on the statistical tests for the mean and unknown covariance using the Hotelling T^2 statistic and the F distribution which is described later in this section.

The sequential fix algorithm has the initial or most recent fix available for updating with subsequent valid LOPs. Each additional LOP is tested statistically at the 99% level to determine if it belongs to the same distribution as the previously accepted LOPs. If not, it is discarded as a wild bearing. Thus, an applicable bearing is rejected only 1% of the time. Remember that the 99% confidence is on no applicable bearings being rejected; the probability of inappropriate bearings being accepted depends on the power of the test, and can be significant. Acceptable bearings are used to recursively update the fix as discussed later in this section. Then the confidence region is applied as described in the previous paragraph. Sometimes the initial and sequential fixing processes do not lead to a good fix estimate. This is because the order in which the LOPs are processed determines the fix estimate. Some early LOPs can be biased and can pull off the fix estimate by causing some later valid LOPs to be rejected as wild bearings. There are two possible solutions to this problem. First, the sequentially obtained fix estimate may be deleted and then the remaining LOPs are used as in an initial fix, which in turn uses a different wild bearing rejection technique. Second, if other intelligence indicates a reliable estimate of the emitter's actual position, this position can be entered as a "seed" position from which all subsequent fix estimates are made.

3.3 DETAILED DISCUSSION OF GUARDRAIL V DF FIX ESTIMATION PROCESS

As discussed in Volume 1 of the Direction Finding and Fix Estimation Series of reports, there are four main steps in the DF fixing process. They are:

(1) Obtaining an initial fix estimate.

(2) Rejecting wild lines-of-position.

(3) Refining the fix estimate.

(4) Establishing a confidence region around the fix estimate.

In the GUARDRAIL V system these four steps are rather intertwined.

As seen in Figure 3-1, GUARDRAIL V has four main operating functions for the DF Fixing process. They are:

(1) Add a bearing (ADBEAR) - this introduces each new LOP to be added sequentially into the fix computation.

(2) Delete a bearing (DLBEAR) - this selects wild LOPs to be removed from the fix computation.

(3) Form a fix (FIX) - this causes an initial fix to be computed. A formed fix provides the basis for the sequential fixing process. This initial fix may be computed automatically from the LOPs in the unassigned LOP file or may be set manually (CONFIX) by the operator.

(4) Delete a fix (DELFIX) - deletes an existing fix and returns the involved LOPs to the unassigned LOP file, making them available for a subsequent fix estimate.

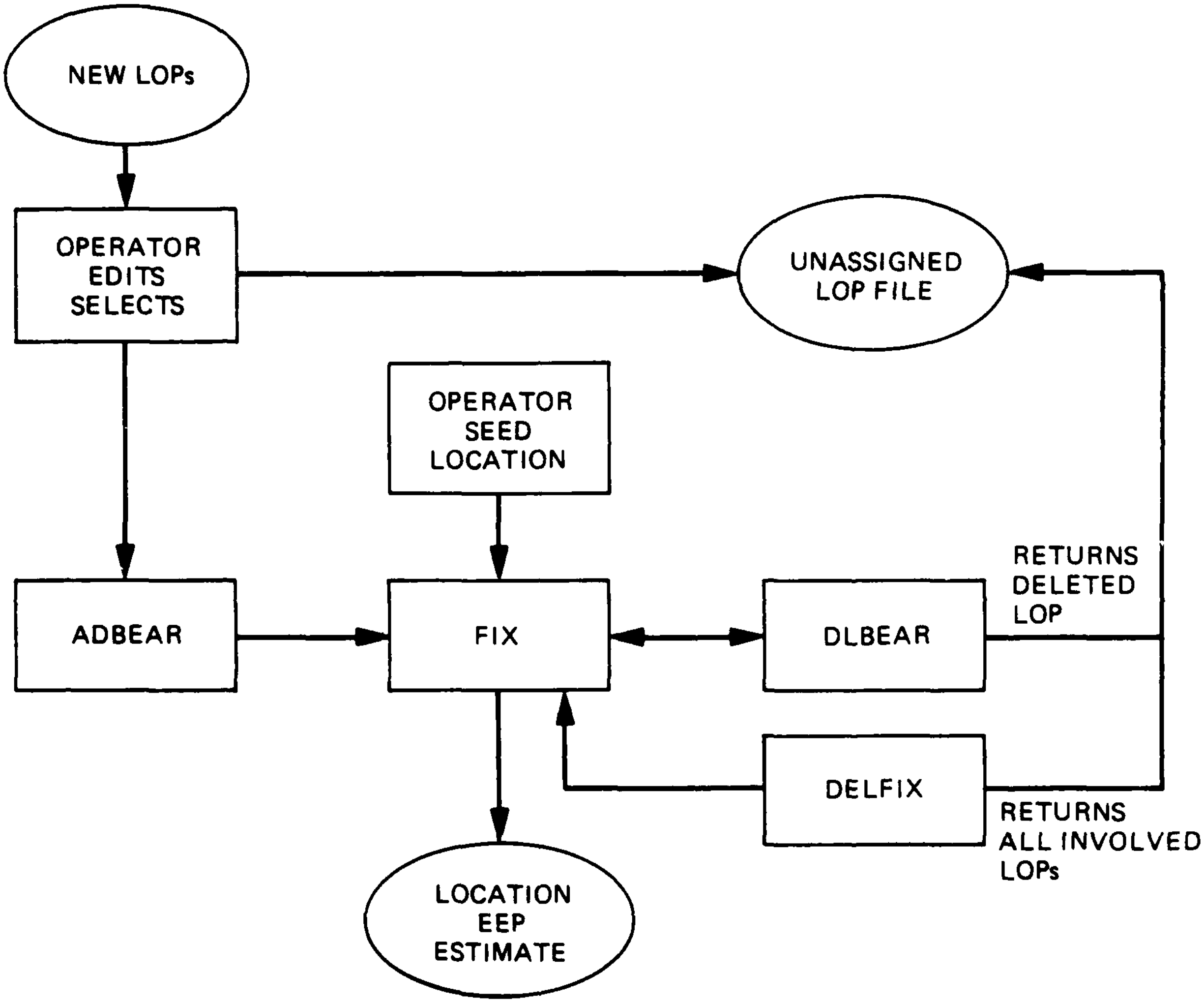


Figure 3-1. GUARDRAIL DF Fix Estimation Algorithm Flow

The general sequence of operations involved in the GUARDRAIL V DF fixing process is:

(1) Intercept the desired emitter signal.

(2) Add a LOP (ADBEAR) to the unassigned LOP file. Note: there must be three collected LOPs before attempting a fix.

(3) Attempt to obtain a fix (FIX) either:

(a) Automatically (AUTFIX) from the LOPs in the unassigned LOP file.

(b) Manually (MANFIX) using a "seed" fix location entered by using the crosshairs of the display.

(4) If the fix attempt is unsuccessful, more LOPs are obtained (ADBEAR) and another fix (FIX) is attempted.

(5) If the fix attempt is successful, the sequential fix updating process can proceed as follows:

- Add a bearing (ADBEAR) sequentially updating the fix estimate.

(6) If the result is satisfactory, i.e. not changing the fix estimate significantly, it is retained and the sequential updating process continued.

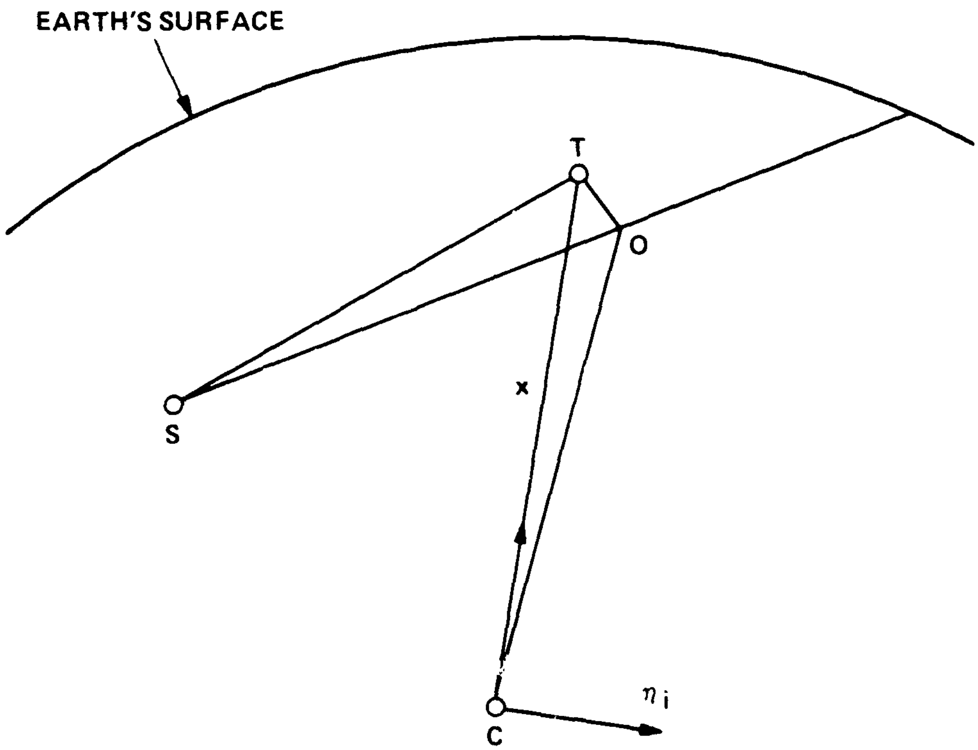
(7) If the result is unsatisfactory, the contribution of this LOP to the fix can be removed by the "remove a bearing" process (DLBEAR) which returns the LOP to the "unassigned" LOP file.

(8) Refined fixes are obtained (when biases are suspected) by deleting the sequentially obtained fix (DELFIX) and recomputing it using all available LOPs simultaneously (FIX/AUTFIX).

(9) Each elliptical confidence region is centered (error ellipse or elliptical probable (EEP)) about the fix estimate (COMPEL).

The GUARDRAIL V direction finding fix estimation process uses the statistical weighted least squares technique described in detail in Volume 1 of this series. It is important to remember that this fix algorithm is only an estimation process for which there is no exact solution. The weighted least squares estimate produces a maximum-likelihood statistical estimate of the emitter position based on at least three sensor LOPs.

The GUARDRAIL fix estimation algorithm is based on a spherical earth model which is a more accurate model than the planar model of the earth's surface. The emitter plane is defined as the plane through the emitter's true position (T), earth's center (C), and the sensor position (S). A bearing plane is defined as a plane containing the sensor's measured line-of-bearing (SO), earth's center (C), and the sensor position (S). The bearing plane and emitter plane will usually differ due to noise, involved in obtaining bearings (Figure 3-2). Bearing planes can be described by their unit normal vectors, η. The emitter's true x position can be represented as a unit normal vector from the earth's center along the line to the emitter's true position, **T**. If there are no measurement errors, the emitter plane and bearing plane coincide, then η and **x** vectors are orthogonal, and their inner-product is zero. If the bearing plane contains measurement noise, the two planes do not coincide, and the η, **x** inner product is in the range (0,1), increasing with increasing bearing measurement error. Therefore, the inner



C – CENTER OF THE EARTH
S – SENSOR POSITION
T – EMITTER'S TRUE POSITION
SO – MEASURED LINE-OF-BEARING
x – UNIT VECTOR FROM CENTER OF EARTH TOWARD EMITTER'S TRUE POSITION

Figure 3-2. Emitter Location Geometry

product of the unit normal to the bearing plane and the unit vector to the emitter provide an appropriate objective function to be minimized in obtaining a fix estimate. To obtain a fix estimate three or more bearing measurements must be made. This set of LOPs may be represented by the set of unit normal vectors, η_i. This set of m unit normals η_i = [x y x], i ∫ 3, may be represented by the mx3 matrix **A**. The measurement error in the i-th bearing measurement is the inner product 0 □ $\eta_i x^t$ □ 1. Then, the set of m measurement errors can be written as E = A x which is simply the mx1 vector E of the bearing measurement errors. The quadratic form $(\underline{x}^t\ \underline{A}^t)(\underline{A}\ \underline{x})$, which yields the sum of the squares of the measurement errors, E^2, would be appropriate for a simple least-squares objective function. However, in the fix estimation process the distance from the sensor to the estimated emitter position affects the value of the LOP. To compensate for the distance effect, each LOP is weighted by its distance to the estimated fix position, which will be denoted w_i. This set of weights can be represented by the mxm matrix,

$$\mathbf{W} = \begin{bmatrix} w_1^2 & & & 0 \\ & w_2^2 & & \\ & & \ddots & \\ 0 & & & w_m^2 \end{bmatrix}, \quad \text{where } w_i^2 = \frac{1}{d_i^2}$$

The weighted least squares objective function may be written as the quadratic form $E_m^2 = (\mathbf{x}^t\mathbf{A}^t)\mathbf{W}(\mathbf{A}\ \mathbf{x})$. Let $C = A^t\ \mathbf{WA}$, then $E_m^2 = x^t\ C\ x$ *is the function* to be minimized and will be referred to frequently in this section. The underlying mathematics are discussed in detail in Volume 1 of the Direction Finding and Fix Estimation Series of Reports.

The emitter location algorithm is recursive, which means that the estimate of emitter location can be updated as new bearings are obtained, without the need for storing all the actual data. It is necessary to store only the symmetric 3 x 3 C matrix = $A^t\mathbf{WA}$, and the first eigenvalue of the matrix.

Before a set of data can be accepted, there must be considerable confidence that the estimate of the emitter location obtained with that data is sufficiently accurate so that subsequent valid bearings will not be rejected. If the bearings are consistent, they are assumed to be associated with a single emitter. In this case the data may be discarded, and subsequent bearings used to update the C matrix.

There are four actual fix estimating processes. They are:

(1) Form an Automatic Fix (AUTOFIX) estimate from a set of unassigned LOPs (used for an initial fix and for refining an existing fix).

(2) Form a fix estimate based on a manually introduced initial fix estimate (MANFIX).

(3) Add subsequent LOPs to update a fix estimate (ADBEAR).

(4) Remove the previously introduced LOP's effect on a fix estimate (DELFIX) and return the involved LOP to the unassigned LOP file, making it available for a subsequent fix estimate.

One sequence of operations is common to all four of these fix estimating processes. This sequence calculates the weighted least squares fix estimate and the confidence region for that estimate. Since this sequence is common to all four fix estimating processes, it will be discussed before discussing each of the four processes individually.

The weighted least squares fix estimate is obtained as the eigenvector solution of equation $E(\mathbf{x})=\mathbf{x}^t\mathbf{A}^t\mathbf{W}\ \mathbf{A}\ \mathbf{x}$ which reduces the problem of minimizing the equation $\mathbf{C}=\mathbf{A}^t\mathbf{W}\ \mathbf{A}$. The first eigenvector minimizes $E(\mathbf{x})$ and the first (least) eigenvalue is equal to the minimum sum of the squared errors (Jennings, 1977). The ITERFL, ITERN, and CALC/EIGEN/RNGCK routines each produce such fix estimates operating under different conditions, depending on which one of the four estimating processes is involved. The underlying sequence in ITERFL and ITERN is actually the CALC/EIGEN/RNGCK sequence of routines.

The ITERFL and ITERN routines are used when forming a fix estimate from a pool of unassigned LOPs. ITERFL is used to automatically form an initial fix and to refine an existing fix. On the other hand, ITERN is used to form a fix estimate based on a manually inserted "seed" fix position. In each of these cases, the distance squared used in the weights is set to unity and may be improved upon by iteratively computing a fix estimate and updated distance. These routines iterate until the change in the distance squared between successive iterations is less than one-millionth or until the maximum for these iterations is exceeded.

The CALC routine updates the C matrix with the current LOP's contribution. Note that the contribution is weighted by the distance squared. The EIGEN routine calculates the normalized first eigenvector (emitter position vector estimate) from the C matrix and first eigenvalue. The RNGCK routine verifies that the emitter position vector is in the right direction by checking that the chord length between the emitter and sensor positions is small enough (distance-squared is □2) to indicate that the emitter and sensor positions are in the same hemisphere. If they are not in the same hemisphere, the sign of the eigenvector is reversed. The EIGEN process provides an estimate of the emitter position vector each time it is used.

The CALC/EIGEN/RNGCK sequence of routines is used in a noniterative way in the "delete and add a bearing" processes. These processes, CALC, EIGEN, and RNGCK remove or add a single LOP's effect from the C matrix (and first eigenvalue) so there is no need to iterate to improve the distance squared estimate.

Having formed the fix estimate in each of the above processes, each process still needs to calculate the confidence region around each estimate. The COMPEL routine forms this confidence region using the Hotelling T^2 statistic method (Morrison 1976). This method is derived from the probability density function of the fix estimate. Since the population variance is unknown, the sample variance must be used which makes the F-distribution the appropriate distribution for forming the confidence region.

The COMPEL routine computes the error ellipse defined by the latitude and longitude of the ellipse center (fix estimate), the semi-axes of the ellipse, and the semi-major axis angle with respect to true north.

The COMPEL routine calculates the third eigenvalue (by setting $\lambda=0$) from the deflated characteristic equation. This value is used in the EIGEN routine to obtain the third eigenvector. The second eigenvector is calculated as the cross-product of the first and third eigenvectors. The number of involved LOPs (n) and the first eigenvalue are used by the S2ANP2 routine to calculate sample variance and an approximation to the F distribution value for $F_{1-\alpha}$; 2,n-2. Finally, the semi-axes corresponding to the $1-\alpha$ confidence level are obtained in the S2ANP2 routine. Here, $\alpha = 0.05$.

Each of the four fix estimating processes uses the basic fix estimate/confidence level sequence of operations. The difference between them relates to the values of the first eigenvalue and distance-squared available upon entry to the fix estimate/confidence level sequence of routines.

The automatic initial fix (AUTFIX) (Figure 3-3) procedure forms an automatic fix estimate from a set of unassigned LOPs. This process results in either an initial fix estimate or a refining of an existing fix estimate. This process controls the automatic calculation of a fix, which utilizes all previous unassigned LOPs corresponding to a single intercept frequency.

The BLDIR routine establishes a directory of unassigned LOPs available for use in an initial fix attempt. This routine also initializes the C matrix and sets the range-squared value (weight) for each LOP to the start-up value of one. Since this set of LOPs may contain other fixes and wild bearings, it is necessary to find a subset of these LOPs that are consistent for the one fix being considered. This is done by the CONSIS routine, using a statistical jackknifing procedure (Efron, 1982; Kolata, 1984; Miller, 1974; Mosteller, 1977). First, the emitter location is calculated using the initial C matrix, and all LOPs more than $+90^{\circ}$ from the initial

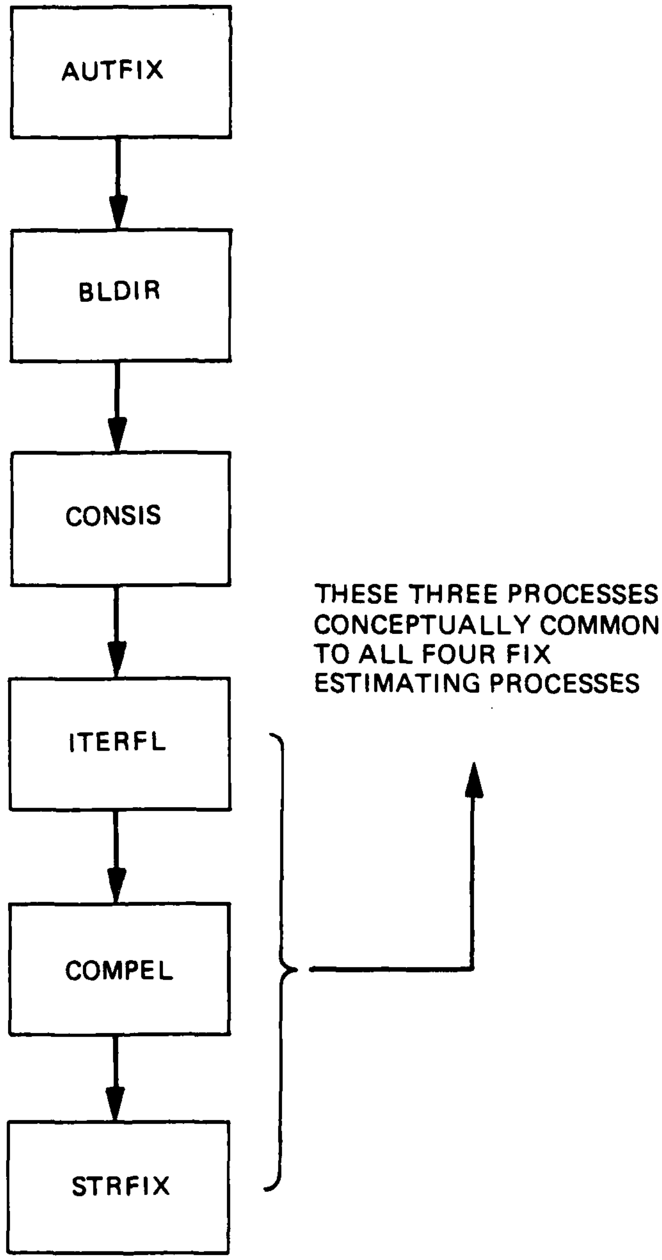


Figure 3-3. *GUARDRAIL V Automatic Fix Estimate Processing*

estimated location are rejected as wild bearings. Next, the jackknifing consistency test is performed. Given a set of n LOPs, a subset of n-1 LOPs can be defined in n different ways. An emitter location is estimated for each subset of n-1 LOPs and the miss distance between this emitter location and the omitted (nth) LOP is noted. The LOP causing the largest miss distance also is noted. If this LOP is within $+4.5^{o}$ of the other n-1 LOPs, then it is considered significant to the fix and the set of n-1 LOPs is considered consistent. Otherwise, it is deleted and the process is repeated on the n-1 set of LOPs. The result is a set of LOPs that cluster closely around their estimated emitter location.

Once a consistent set of LOPs has been constructed (chosen), the previously described fix estimate is called, namely, ITERFL/COMPEL/STRFIX. First, the distance of the squared weights is initialized to unity. Then the start-off value of the first eigenvalue is set to zero. These values and the fix estimate improve with the iterations of the ITERFL routine. The available LOPs are introduced to the C matrix one at a time until exhausted. Following an automatic fix estimate, additional LOPs may be added one at a time or removed, if necessary.

The Manual Fix (MANFIX) routine forms a fix estimate from a set of unassigned LOPs based on a manually input "seed" emitter position to guide an initial fix estimate. The manual fix estimate routine, flow-charted in Figure 3-4, controls the formation of a fix estimate starting from an initial "seed" position. This "seed" position is based on operator judgment and, perhaps, prior information such as the Electronic Order of Battle (EOB). The LOPs from the set of unassigned LOPs must be checked for wild bearings (miss angle ß 4.5^{o} or in the wrong direction) before being introduced into the C matrix and first eigenvalue calculation. When all the valid LOPs have been introduced, the fix estimate/confidence level sequence ITERN/COMPEL/STRFIX is initiated. The distance squared weights are calculated from the "seed" emitter position to the sensor. The first eigenvalue is calculated (this is the sum of the squares of the LOP miss angles). Due to the iterative nature of the ITERN routine, the distance of the squared weights and fix estimates are

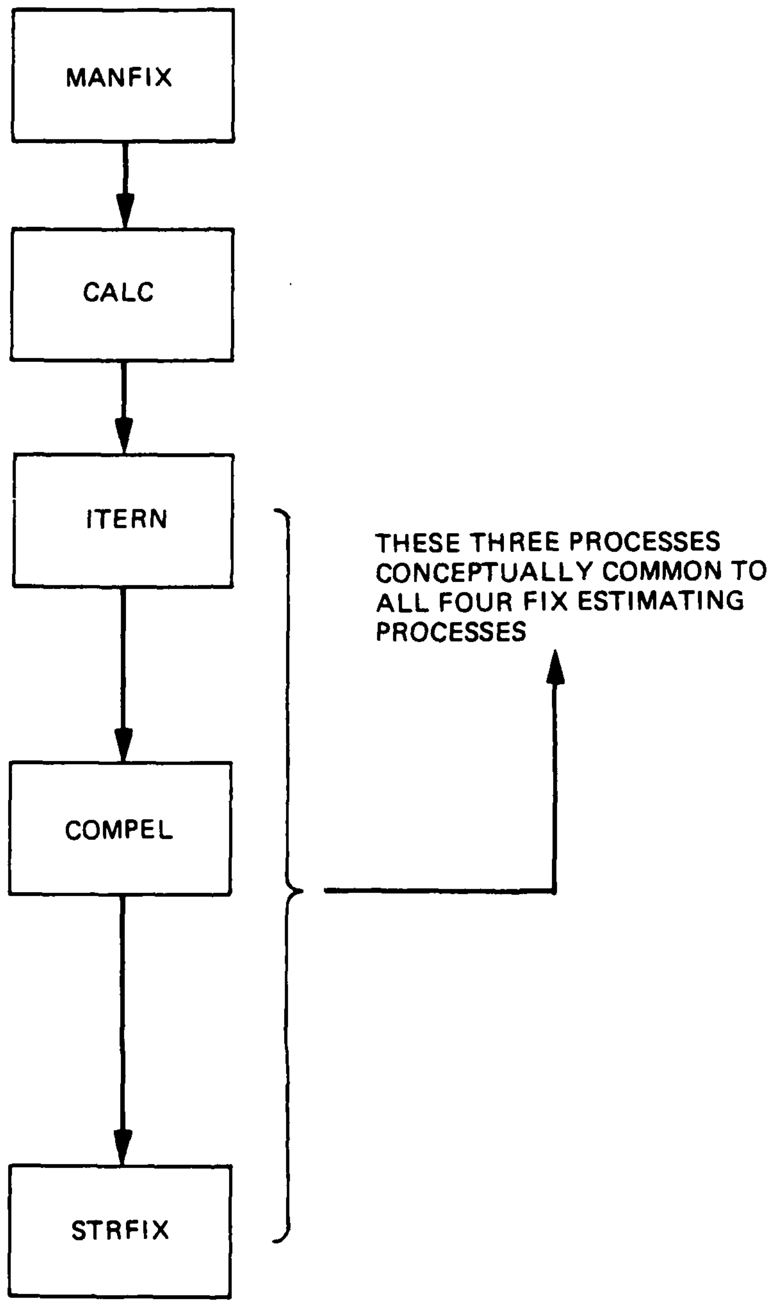


Figure 3-4. GUARDRAIL V Manual Fix Estimate Processing

improved. Following a manually "seeded" fix estimate, additional LOPs may be added one at a time or removed, as usual.

The DLBEAR routine removes the effects of any previously introduced LOP in the C matrix and in the first eigenvalue. First, the receiver, emitter position vectors, and the LOP miss angle are calculated. Then the first eigenvector is reduced by the value of the miss angle squared. Since this miss angle is not exactly equal to the miss angle when the LOP was introduced, a small error is introduced.

At the time the LOP to be deleted was introduced, the distance from the sensor to the emitter was stored to allow removal of the distance, when necessary, via the DLBEAR routine. This was needed because of the emitter position estimate, hence, the distance from the sensor to the emitter may vary considerably between the time of addition and the time of deletion of an LOP. The availability of the distance, its calculation, or use, does not appear on the flow charts. This is probably a documentation error, but if it is not, it could lead to significant error.

The fix estimate/confidence level sequence of operations CALC/EIGEN/RNGCK/COMPEL/STRFIX is initiated, then called upon. This process will compute the revised fix estimate and error ellipse. However, since we are removing the effects of the LOP to be deleted, its contribution is subtracted from the C matrix.

The ADBEAR routine adds the effects of a new LOP to the C matrix and first eigenvalue to generate an updated fix estimate. The candidate LOP must be checked against each of the existing fixes to determine which fix it is associated with and if it is a valid (non-wild) LOP with respect to that fix.

For an LOP to be acceptable to update a fix using ADBEAR, the LOP must pass the following "wild bearing test"

$$r\left|\Delta\theta\right| < Z_{\alpha}\sqrt{r^2\sigma^2 + \sigma_B^2}$$

where $\Delta\theta$ is the angle between the bearing plane and the emitter/receiver plane (miss angle), r is the sensor-emitter range, σ^2 is the variance in the measured bearing error, σ_B^2 is the variance in emitter position perpendicular to the emitter/sensor plane, and $Z\alpha$ is a confidence parameter.

If the LOP passes the wild bearing test, it is checked to make sure it is pointing in the direction of the emitter as described earlier. The LOP is tested, in the above manner, against all the fixes in the fix file. If the LOP passes the "wild tests" and "direction tests" for more than one fix, the fix where the LOP has the largest probability of occurring is chosen. For comparison purposes, a quantity which is proportional to the square of the probability is used in the code.

If an acceptable fix is found for the LOP, it is added to the fix as follows. The LOP's contribution to the eigenvalue is added in (λnew=λold + miss angle squared), and its contribution to the C matrix is added to the C matrix and weighted by the range to the current emitter location.

Using these values, a new emitter location is calculated using the CALC/EIGEN/RNGCK sequence of routines. The location calculation is iterated once again in order to refine the estimate. Finally, the ellipse and location parameters are calculated using the COMPEL routine, then stored.

APPENDIX A

A.1 ANNOTATED REFERENCE LIST

The references listed in this appendix fall into two categories: (1) books on general mathematics, and (2) books for the individual sections. The general mathematics books are included to better acquaint users with the necessary mathematical and technical background. They include Schaum's outline series which provides good examples, some introductory undergraduate level references, and more specialized and advanced text and references.

A.2 SCHAUM'S OUTLINE SERIES - SELECTED UNDERGRADUATE-LEVEL OUTLINES

These outlines are valuable for obtaining an overview of selected subjects quickly. Explanatory text is developed along with fully solved examples in stand-alone, easily referenced blocks. The most current edition is not always referenced. The publisher is McGraw-Hill, New York.

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A.5 MILITARY SYSTEMS AVAILABLE DOCUMENTATION

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QUICKLOOK II Operator Course, Description of QUICKLOOK II System, File No. F452/H01/AN/USM-393 Operating Programs, File F452/H02.

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APPENDIX B

ERROR BUDGET

CONTENTS

APPENDIX B

ERROR BUDGET

1.0 PURPOSE

The purpose of this appendix is to identify all of the various error components, in the most general case, when determining lines-of-bearings. These lines-of-bearing are used in subsequent fix estimations for emitters.

2.0 SCOPE

The essential assumptions of this document are: the emitter is not moving at the time the line-of-bearing is measured; the sensor may be in any position, from earthbound to a moving satellite.

The type of errors considered may be classified into several categories:

Sensor platform position and orientation errors
Sensor attitude
Antenna errors
Instrumentation errors
Time

The sensor platform position and orientation errors may be referred to as "positional errors."

Errors due to propagation effects, site selection, varying aperture versus aspect effects and operator errors are not considered in this document. Also, errors due to the choice of algorithms or numerical computations are not considered.

3.0 POSITIONAL ERRORS

These error sources may be broadly classified into errors in the frame of reference and errors in position measurement. The former include errors which will be present regardless of a sensor platform's actual location in establishing the frame of reference for exchange of position information. Position measurement errors are those due to error or uncertainty in the methods and equipment used to determine platform location within the selected frame of reference.

The geocentric coordinates and references are:

Latitude	ϕ	Phi
Longitude	λ	Lambda
Altitude	h	

Orientation of meridian plane (Direction of North)

These coordinates are best described by the diagram in Figure 1. The geographic latitude is measured positive from the equator towards the North Pole in degrees. The geographic longitude is measured positive from the prime meridian at Greenwich towards the East in degrees. The altitude is measured from the mean sea level (the geoid) in meters and is positive in a direction away from the center of the earth. The physical sources of errors in these parameters will depend largely on the source of the data used to determine them.

3.1 FRAME OF REFERENCE ERRORS

Establishment of a frame of reference for exchange of position information on the earth involves seven major processes, all of which may introduce some error of uncertainty into any position reference within the selected framework.

3.1.1 Geodetic Errors

Two of the seven processes are the province of geodesy, and involve measuring and representing the shape of the earth.

One process involves measurement of the actual shape of the earth, independent of local variations in topography. This is typically most closely represented by mean sea level, i.e., sea level independent of variations due to lunar tides and local gravitational anomalies. The resulting geometric figure, termed a geoid, becomes the basis for subsequent representations of the earth's surface. This figure is subject to error and uncertainty due to the measurement process and to changes in the actual shape of the earth over time.

The second process is the selection of a geometrical figure close to the geoid in shape, but simpler from the standpoint of mathematical and geometric manipulation; and this second process is to be used as the basis of the mapping process in a given part of the world. The figure is generally based on a very nearly spherical ellipsoid which, because of its nearness to spherical shape, is often called a spheroid. Different spheroids are in use for different parts of the world both for historical reasons and because slightly differing ellipsoids best approximate the geoid over different parts of the earth. Different spheroids are typically defined by giving the radius at the equator and the flattening. The latter is defined as the difference between the radius at the equator and that at the pole divided by the radius at the equator. Selection of a spheroid introduces errors as the selected figure is only an approximation to the geoid, and may vary from the geoid irregularly over the portion of the earth being mapped.

3.1.2 Geomagnetic Errors

Airborne platforms depend on a magnetic flux goniometer during initialization of the inertial platform. Field soldiers and mobile units often have to depend on magnetic compasses for determining bearings. Although this is one of the oldest means of taking bearings, it can be very inaccurate. The earth's magnetic field tends to align with the nearest magnetic pole. However, the magnetic poles are different even from the geographic poles. Furthermore, the two poles, North and South, are not even symmetrically placed. And to complicate this, there are local variations over all the earth's surface. This angle that the compass makes with the grid lines of a military map is called the "declination" of the compass. The magnetic lines of force are not parallel to the earth's surface, except along the indefinite circle called the magnetic equator. The angle the magnetic field makes with a horizontal plane is called the dip angle or the magnetic inclination.

The declination at any one location does not remain the same year after year and changes somewhat over long periods of time. Besides these so-called secular changes, there are variations within the year and also small changes of angle throughout the day. Large erratic variations occur during "magnetic storms." These storms are often concurrent with the appearance of sun-spots. Variations from storms are infrequent enough and the other variations are sufficiently slow that it is practical to publish maps of countries and other large areas showing the magnetic declination. On these maps, points of equal magnetic declination are connected by lines. Each wiggly line is labeled with the amount and direction of the magnetic declination. These lines are called isogonic lines. The isogonic line of zero magnetic declination is indicated by a heavy line and is called the agonic line. Maps of smaller areas indicate the magnetic declinatioı in their legend by an arrow pointing to the magnetic north and labeled with the value of the magnetic declination in degrees.

The National Space Technology Laboratory at the Naval Oceanographic Office in Bay Saint Louis has a world mathematical model of the earth's magnetic field. The model consists of an order 12 spherical harmonic series with time varying coefficients to take care of secular changes. The model is considered good for ± 5 years, and is updated every five years from new satellite and aircraft survey data. Local anomalies will normally deviate a few degrees of arc from the earth's main field direction, but can deviate by tens of degrees in areas where the mineral magnetite is abundant and in polar regions. For accurate orientation using the earth's magnetic field, there is no good substitute for a local survey.

3.1.3 Cartographic Errors

The remaining four processes introducing frame of reference errors fall into the province of cartography, i.e., the recording, measurement, and representation of geographic, topographic, and cultural features on the surface of the earth.

The first of these processes involves selection of one or more coordinate systems to be used to specify locations on the selected representation of a portion of the earth. In virtually all world reference systems, at least one of the coordinate frames used will apply to the selected spheroid, and the reference system used is in fact almost always the familiar geographic (latitude-longitude) coordinate system. Errors arise in this process due to errors in the measurements associated with selection of reference or registration points as bases of the coordinate system, as well as in the measurement and computation involved in extending the coordinate frame from the base points through the area to be mapped.

The second process involves, in those cases where the final representation will be planar, a projection of all or a portion of the selected spheroid onto a plane according to some well defined set of mathematical and geodetic conventions. This step will often be followed by another iteration of the first step to select a reference system suitable for measurement and computation in the Euclidean plane. Errors arise in this process due to the distortion involved in the projection from the spheroid to the plane as well as in any subsequent registration and extension of the associated planar coordinate system.

The third process consists of the recording and measurement of surface features within the selected coordinate system(s). The errors inherent to this process include those associated with measurement of the features themselves, their relative locations, and their locations with respect to the coordinate systems selected.

The fourth process consists of the rendering of recorded features and associated coordinate systems into one or more forms that can be interpreted by people with a modicum of training and experience. Errors arise in this process due to distortions and simplifications imposed by the scale and resolution available in the final product, which in turn are governed in part by the current technology and in part by the limitations of the human perceptual system. A highway 10 meters in width, for example, if represented to scale on a 1:250,000 map, would be 0.04 millimeters wide and all but invisible to the naked eye.

3.2 POSITION MEASUREMENT ERRORS

3.2.1 Inertial Navigation

The four coordinates of position can be maintained by a suitably designed inertial platform. There will be essentially four type of errors with such systems:

(1) Errors in measurement and setting of initial position.
(2) Errors in platform measurement of inertial change.
(3) Errors in precision of computation of position from inertial change.
(4) Cumulative error in position, i.e., drift.

The basic component of most modern inertial navigation systems is the gyroscope. In addition to the familiar function of referencing direction (gyro compass), gyroscopes may be designed to measure rotations, to seek the local vertical, and to act as accelerometers.

3.2.2 Reference Navigation

Referenced navigation systems are those that depend on beacons, or repeaters of known position or velocity. These may be classified by the geometry of the data processing:

(1) Hyperbolic (Decca, Loran, Omega, Satellite-Aided Navigation).

(2) Circular (Sextant, Satellite-Aided Navigation).

(3) Polar (TACAN).

The hyperbolic and the circular navigation systems are methods of triangulation. However, the hyperbolic method deals exclusively with the sides of the triangle while the circular method deals with two sides and an angle. The polar method gives both a range and azimuth from the reference station.

Decca is a low frequency (70-130 kHz) hyperbolic system that triangulates by measuring the phase difference between signals from a master/slave pair of reference stations. The master/slave separation is 60 to 120 nmi. The useful range is about 240 nmi over water. Loran A is a medium frequency (2 MHz) hyperbolic system that triangulates by measuring the time difference between receipt of pulses from two stations. The range of Loran A is several hundred miles over water, but much reduced over land. Loran C is a low frequency (90--110 kHz) version of Loran A with considerably more range. OMEGA is a very low frequency hyperbolic system that triangulates by comparing the phase of signals from two beacons separated by a baseline of 5,000 to 6,000 miles. The coverage is worldwide and may be used by submersibles.

Satellite-aided navigation has the most diverse possibility for use as a referenced system of navigation. The orbital elements and thus both the position and velocity of the satellite are accurately known. By combining such measurables as elevation angle, azimuth angle, ranges, difference in range, range sum, or doppler shift, fixes may be obtained that fit any of the listed categories in the first paragraph of this section. Methods that depend on measurement of the elevation angle of one or more satellites determine small circles on the earth's surface for fixes. Methods that determine distances lead to hyperbolic conic lattices for fixing.

TACAN is a UHF radio navigation system which provides both distance and bearing information of the aircraft relative to the selected ground beacon. The antenna system is the key to measuring the azimuth. The antenna system has a single central element for transmission and reception. The parasitic elements are mounted on two concentric cylinders which rotate at fifteen revolutions per second. The inner cylinder consists of a single parasitic element which causes a single cardioid polar pattern rotating at 15 rps. The outer cylinder has nine parasitic elements that superimpose nine lobes on the cardioid pattern. This gives an amplitude modulated signal with two frequency modulations of 15 Hz and 135 Hz. The transponder further emits bearing reference pulses as the peak of each lobe points East. When the lobe, which coincides with the peak of the cardioid, points East, a special "North" reference pulse code is transmitted. The airborne equipment measures the phase relationship of the maximum signal amplitude relative to the North reference pulses in order to determine the bearing of the aircraft relative to the beacon. The distance measuring part of TACAN equipment is like radar except that the return signal comes from a beacon used to produce strong artificial echoes. The beacon will respond to numerous simultaneous interrogations. To make this possible, the pulse repetition rate of the airborne transmitter is caused to jitter in a random manner. The slant range is determined to roughly 0.25 nautical miles under most conditions.

3.2.3 Doppler Navigation

Airborne Doppler is a SHF (micro-wave) system of navigation using the terrain or water below as a reference. Depending on the particular doppler system used, some or all of the following data can be made available to the crew:

(1) Component velocities and distances run, along, across, and perpendicular to the aircraft axes.

(2) Ground speed.

(3) Drift angle.

(4) Angle of attach.

(5) Height above terrain.

If True Air Speed, Pitch, and Heading Angles are available from such sources as an inertial system, then the following secondary data may be obtained:

(1) Wind speed and direction.
(2) Climb angle.
(3) Track angle.

The Doppler systems may have various configurations of antenna beams directed at different angles toward the earth. A two-beam system may be used to measure ground speed and drift. A three-beam system is basically sufficient to extract all three velocity components, but a four-beam symmetrical arrangement is often used.

4.0 ATTITUDE ERRORS

The three attitude coordinates are:

Roll Angle	α	alpha
Pitch Angle	β	beta
Yaw Angle	γ	gamma

Figure B-2 serves to define each of these angles. There are the standard Euler angles as defined by a "right hand" rule. However, it should be noted that the sign of these angles vary considerably throughout published literature. See Korn and Korn, reference 2, section 14.10-6, for a discussion of this coordinate system and the diverse choice of signs. In some airborne systems these positional coordinates are limited by preset stops which may introduce non-linear errors.

CORRELATIONS BETWEEN ATTITUDE AND POSITIONAL COORDINATES

With a cursory examination of these six coordinates, it is apparent that errors in three of them will produce the larger errors. An error in yaw angle alone will produce a divergence of the azimuth angle of bearing. This azimuth error will always be quite close in magnitude, but opposite in sign, to the yaw error. Errors in longitude and latitude will produce an error in the position of the line-of-bearing as a function of the azimuth angle, but this does not effect the azimuth angle. If the azimuth angle is in the vicinity of zero or 180 degrees, an error of longitude will be reflected directly, and of nearly the same value, in the longitude of the fix estimations. At azimuth angles of 90 and 270 degrees, the line-of-bearing and consequently the fixes are unaffected by errors in longitude. The effects of errors in latitude are analogous in their effect but displaced by 90 degrees.

It is not so obvious that an error in the three remaining coordinates (altitude, roll, and pitch) should have any effect on the line-of-bearing. Indeed an error in altitude alone should only change the slant range and have no effect on the line-of-bearing. However, when coupled with errors in roll and pitch, there is a definite mathematical relation or coupling. The significance of an error in altitude remains to be evaluated. Errors in roll and pitch (which have less effect on the error of the fix estimate than yaw, longitude, and latitude) directly cause errors in azimuth angle on the line of bearing.

5.0 ANTENNA ERRORS

Orientation with respect to the platform
Difference between the mechanical axis and RF axis
Beam width

These first two antenna errors are directly related to the platform attitude coordinate errors. In fact, the orientation of the antenna with respect to the platform and the difference between the mechanical axis and the RF axis are best described by Euler angles. If the axis defining these coordinates are chosen originally in coincidence, first-order approximations will serve to considerably simplify the maze of trigonometric functions relating these angles. These three Euler angles can be identified as pitch, roll, and yaw. For small errors in these angles, the errors may be simply added to the corresponding platform angles. It should be noted at this point that the RF boresight error is a function of the radio frequency.

Beam width is always a function of the antenna geometry and frequency. A phases antenna system's beam width will vary considerably with change in aspect angle.

6.0 INSTRUMENTATION ERRORS

Bias (Systematic errors)
Noise (Random errors)

Bias errors, for example, are systematic errors such as boresite errors, parallax errors in instrument readings, and bezel errors. Bias errors are usually minimized by calibration procedures.

Noise errors are due to random phenomenon such as receiver noise. This noise normally produces random errors in bearings by increasing the region of uncertainty when determining the minima of a signal or the change in sign from the phase of a signal. There are many techniques of minimizing the effects of noise depending on the source and nature of the noise (see reference 5). In high frequency receivers, the receiver's "front end" is a high source of thermal noise, so the high gain required is usually obtained "rear end." Commonly, the band pass of filtering is reduced to the minimum that will not deteriorate the information content. The effect of impulse noise such as noise emanating from electrical ignitions can be minimized by amplitude clipping just above the signal level.

7.0 ERROR TABULATION

The sensor positional error is equally important in fixing, whether the fixing is done with a mobile ground unit or with an airborne sensor system. The attitude errors are most important in airborne sensors. The sensor geometric error refers to such errors as the difference between the geometric and RF axis of a direction finding-antenna or even an optical tracker. Range is included with the geometric sensor errors for convenience only.

The specifications and tolerances will always include the units. The exact meaning of the specification and tolerance columns will depend on the instrument involved.

TABULATION OF ERROR BUDGET

SYSTEM ________________________________

COMPONENT ________________________________

A/N NUMBER ________________________________

MODEL ________________________________

CLASSIFICATION	SPEC	TOLERANCE
1. Sensor Positional Errors		
a. Longitude		
b. Latitude		
c. Altitude		
d. Position (linear distance)		
2. Sensor Attitude Errors		
a. Reference meridian (North)		
b. Roll		
c. Pitch		
d. Yaw		
e. Rates (TBD)		
3. Sensor Geometric Errors		
a. Azimuth		
b. Elevation		
c. Range		
4. Instrument errors		
a. Bias (systematic or secular errors)		
b. Noise random errors		

References:

NOTES:

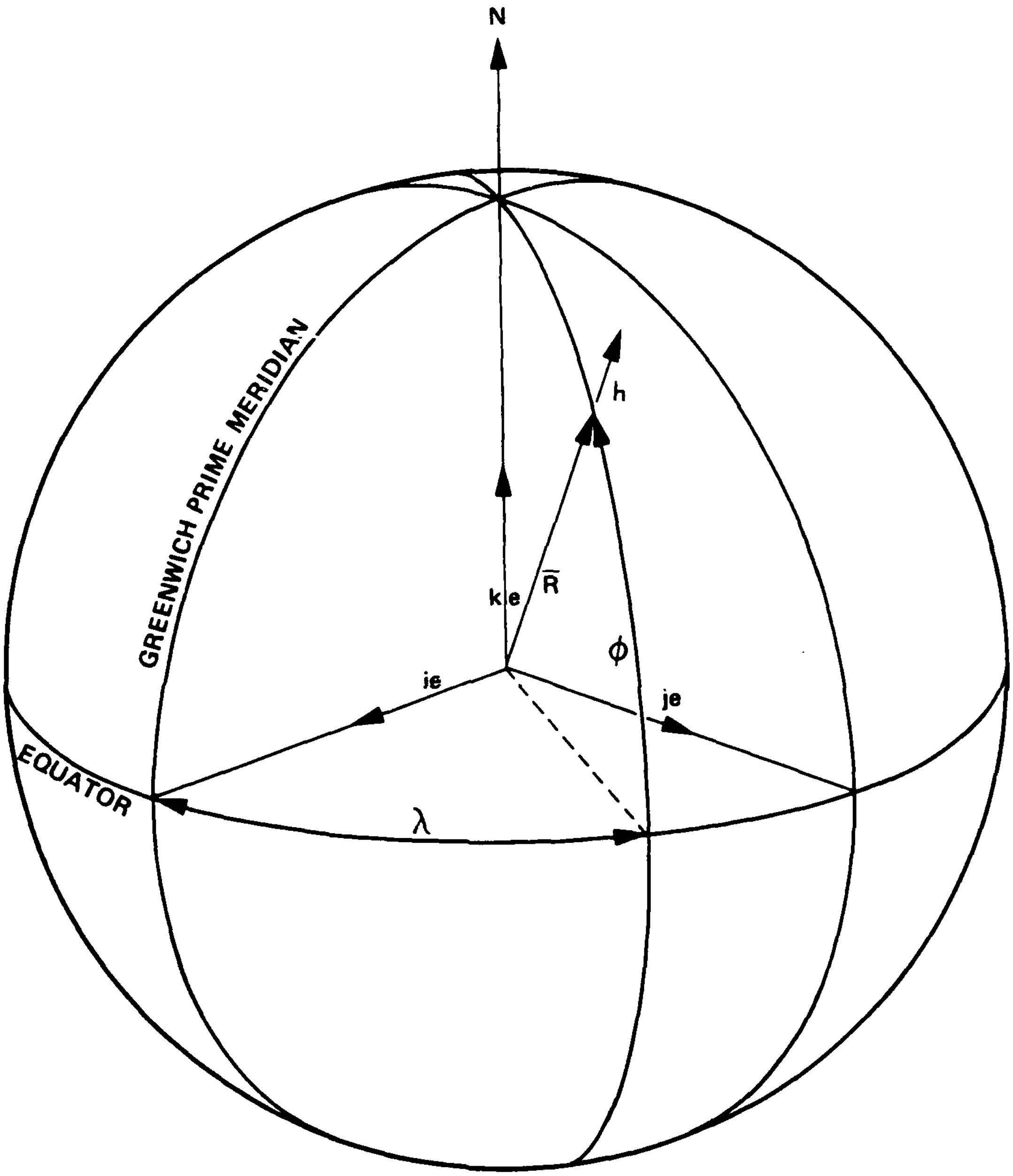

Figure 1. Geocentric Positional Coordinates

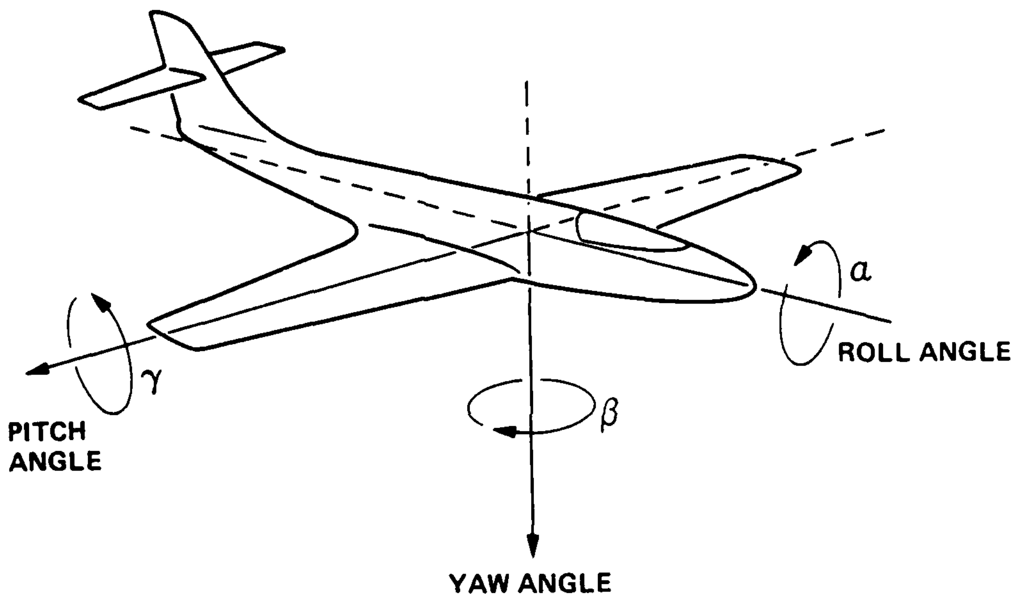

Figure 2. Attitude of the Platform

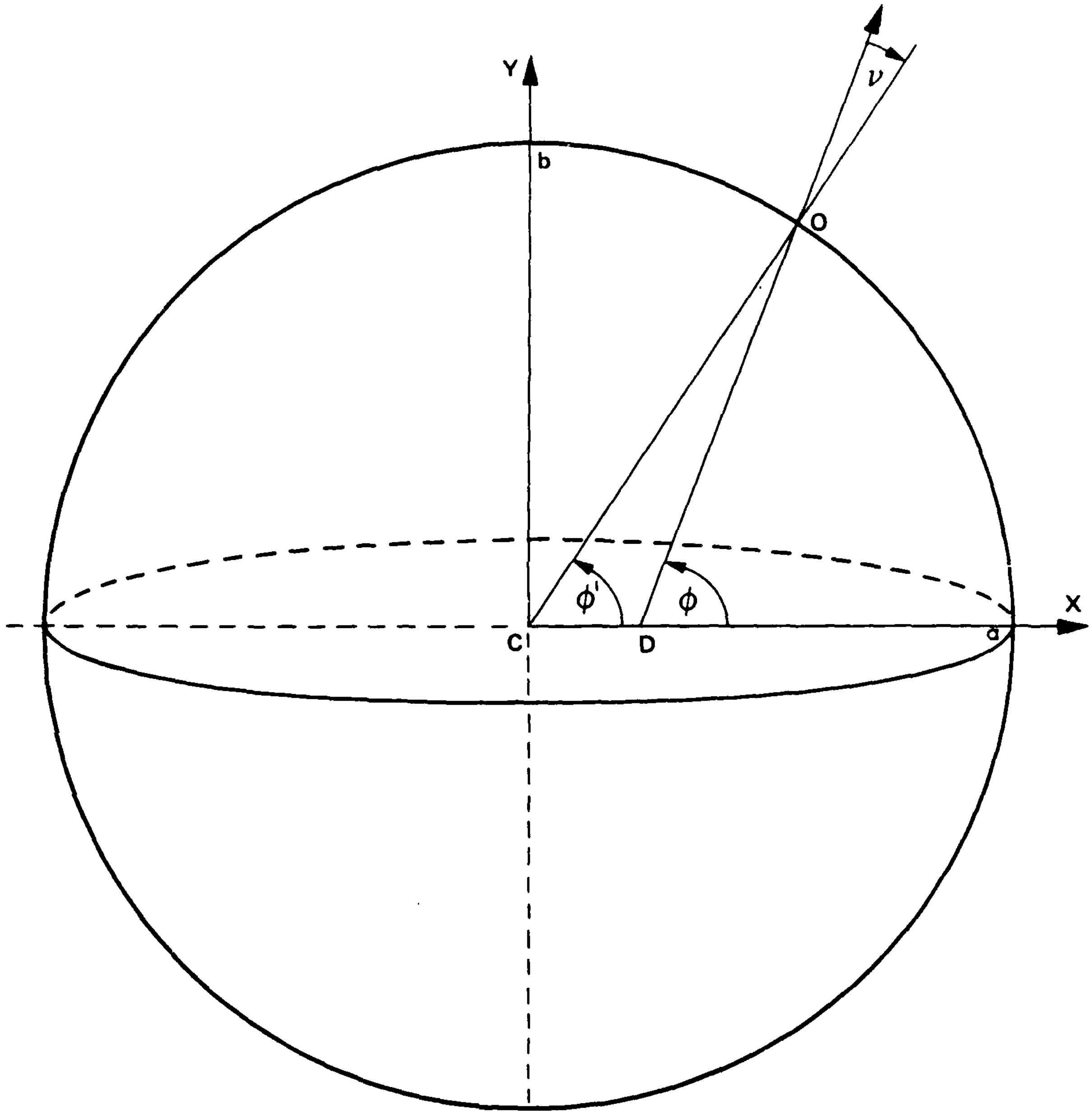

Figure 3. The Geoid and Latitude

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APPENDIX C

GUARDRAIL V ERROR BUDGET

TABULATION OF ERROR BUDGET

SYSTEM __________
COMPONENT __________
A/N NUMBER __________
MODEL __________

CLASSIFICATION	SPEC	TOLERANCE
1. Sensor Positional Errors		
a. Longitude		
b. Latitude		
c. Altitude		
d. Position (linear distance)		
2. Sensor Attitude Errors		
a. Reference meridian (North)		
b. Roll		
c. Pitch		
d. Yaw		
e. Rates (TBD)		
3. Sensor Geometric Errors		
a. Azimuth		
b. Elevation		
c. Range		
4. Instrument errors		
a. Bias (systematic or secular errors)		
b. Noise random errors		

References:

NOTES:

APPENDIX D

ALGORITHMS IN STANDARD FORM

1 GUARDRAIL PROCESS

DESCRIPTION:
GUARDRAIL V (AN/USD-9) is a tactical, airborne, remotely-controlled radio emitter intercept and direction finding system which provides tactical commanders with near real-time intelligence information. The IPF (AN/TSG-105 VI) is the information processing and control center or sensor ground station of GUARDRAIL V. The IPF manages all mission functions and, through Tactical Commander's terminal (TCT), provides support to field commanders with near real-time location information on emitters operating within a specific RF spectrum in the surveillance area. to p1173

Sensor management is performed by the Corps' All Source Analysis Center (ASAC) through two-way secure communications provided by the Combat Electronic Warfare Intelligence Unit (CEWI).

O & O:
GUARDRAIL V (AN/USD-9) is an NSA-fabricated, USASA-operated airborne and ground-based, remotely-controlled COMINT collection and emitter-location system. It was fielded utilizing non-standard equipment and is only an interim capability until the militarized CEFLY LANCER program is completed and the follow on equipment is procured.

The system is capable of performing search, intercept, initial processing, target location, control and reporting. GUARDRAIL forms a major part of the USASA Aviation Company (Forward), which is normally assigned to the USASA Battalion.

The function of the system is to provide near real-time intelligence support to tactical Army commanders. In addition to the ground support and maintenance equipment, it has five major components: the Distant Airborne Relay Facility (DARF), the Airborne Relay Facility (ARF), the Mobile Relay Facility (MRF), the Integrated Processing Facility (IPF), and the Tactical Commander's Terminal (TCT). GUARDRAIL is a mobile system with the ARF and DARF aboard RU-21H type aircraft and the ground elements consisting of a semi-trailer mounted IPF (AN/TSG-105 VI), shelter mounted MRFs, man-portable TCTs, and van-mounted support facilities.

The IPF (AN/TSG-105 VI) is the information processing and control center or sensor ground station of GUARDRAIL V. The IPF manages all mission functions and, through Tactical Commander's terminal (TCT), provides support to field commanders with near real-time location information on emitters operating within a specific RF spectrum in the surveillance area.

Sensor management is performed by the Corps' All Source Analysis Center (ASAC) through two-way secure communications provided by the Combat Electronic Warfare Intelligence Unit (CEWI).

GUARDRAIL

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GUARDRAIL V (AN/USD-9) is an NSA-fabricated, USASA-operated airborne and ground-based, remotely-controlled COMINT collection and emitter-location system. It was fielded utilizing non-standard equipment and is only an interim capability until the militarized CEFLY LANCER program is completed and the follow on equipment is procured.

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Sensor management is performed by the Corps' All Source Analysis Center (ASAC) through two-way secure communications provided by the Combat Electronic Warfare Intelligence Unit (CEWI).

SYNONYMS: AN/USD-9
GRV

APPENDIX E

DATA BASE ENTRIES FOR GUARDRAIL V

Utilizes Analysis Report

Utilizes Structure

COUNT	LEVEL	NAME
1	1.0	GR_main
2	1.1	GR_confix
3	1.1.1	GR_autfix
4	1.1.1.1	GR_Strfix
5	1.1.1.2	GR_bldir
6	1.1.1.2.1	GR_getfix
7	1.1.1.2.2	GR_putfix
8	1.1.1.2.3	GR_psnvec
9	1.1.1.2.4	GR_calc
10	1.1.1.2.5	GR_putpar
11	1.1.1.3	GR_consis
12	1.1.1.3.1	GR_calc
13	1.1.1.3.2	GR_eigen
14	1.1.1.3.3	GR_rngck
15	1.1.1.3.4	GR_dirdel
16	1.1.1.3.4.1	GR_calc
17	1.1.1.3.4.2	GR_getpar
18	1.1.1.3.4.3	GR_putfix
19	1.1.1.4	GR_iterfl
20	1.1.1.4.1	GR_calc
21	1.1.1.4.2	GR_eigen
22	1.1.1.4.3	GR_rngck
23	1.1.1.5	GR_cmpel
24	1.1.1.5.1	GR_eigen
25	1.1.1.5.2	GR_evalfn
26	1.1.1.5.3	GR_s2anp2
27	1.1.2	GR_manfix
28	1.1.2.1	GR_calc
29	1.1.2.2	GR_cmpel
30	1.1.2.2.1	GR_eigen
31	1.1.2.2.2	GR_evalfn
32	1.1.2.2.3	GR_s2anp2
33	1.1.2.3	GR_iteren
34	1.1.2.3.1	GR_calc
35	1.1.2.3.2	GR_eigen
36	1.1.2.3.3	GR_rngck
37	1.2	GR_fix
38	1.2.1	GR_autfix
39	1.2.1.1	GR_Strfix
40	1.2.1.2	GR_bldir
41	1.2.1.2.1	GR_getfix
42	1.2.1.2.2	GR_putfix
43	1.2.1.2.3	GR_psnvec
44	1.2.1.2.4	GR_calc
45	1.2.1.2.5	GR_putpar

46	1.2.1.3	GR_consis
47	1.2.1.3.1	GR_calc
48	1.2.1.3.2	GR_eigen
49	1.2.1.3.3	GR_rngck

GUARDRAIL

GUARDRAIL

COUNT	LEVEL	NAME
50	1.2.1.3.4	GR_dirdel
51	1.2.1.3.4.1	GR_calc
52	1.2.1.3.4.2	GR_getpar
53	1.2.1.3.4.3	GR_putfix
54	1.2.1.4	GR_iterfl
55	1.2.1.4.1	GR_calc
56	1.2.1.4.2	GR_eigen
57	1.2.1.4.3	GR_rngck
58	1.2.1.5	GR_cmpel
59	1.2.1.5.1	GR_eigen
60	1.2.1.5.2	GR_evalfn
61	1.2.1.5.3	GR_s2anp2
62	1.2.2	GR_setgr
63	1.2.3	GR_delfix
64	1.2.4	GR_xredrw

Utilizes Matrix

Explanation of the Utilizes Matrix:

The rows are input PROCESS names, and the columns are PROCESSES UTILIZED by (or a SUBPART of) the rows.

(i, j) value	meaning
U	Column j is UTILIZED by Row i
S	Column j is a PART of Row i
B	Column j is both UTILIZED by, and a PART of Row i

Utilizes Matrix

	1 GR_confix	2 GR_fix	3 GR_autfix	4 GR_manfix	5 GR_Strfix	6 GR_bldir	7 GR_consis	8 GR_iterfl	9 GR_cmpel	10 GR_getfix	11 GR_putfix	12 GR_psnvec	13 GR_calc	14 GR_putpar	15 GR_eigen	16 GR_rngck	17 GR_dirdel	18 GR_getpar	19 GR_evalfn
1 GR_main	U	U																	
2 GR_confix			U	U															
3 GR_autfix					U	U	U	U	U										
4 GR_bldir										U	U	U	U	U					
5 GR_consis													U		U	U	U		
6 GR_dirdel											U		U					U	
7 GR_iterfl													U		U	U			
8 GR_cmpel															U				U
9 GR_manfix									U				U						
10 GR_iteren													U		U	U			
11 GR_fix			U																

Utilizes Matrix

```
                        24 GR_xredrw ------------------- /
                      23 GR_delfix ------------------ / |
                    22 GR_setgr -------------------- / | |
                  21 GR_iteren ------------------ / | | |
                20 GR_s2anp2 ------------------- / | | | |
                                                 | | | | |
----------------------------------------------+-----------+
 1 GR_main -----------------------------------|           |
 2 GR_confix ---------------------------------|           |
 3 GR_autfix ---------------------------------|           |
 4 GR_bldir ----------------------------------|           |
 5 GR_consis ---------------------------------|           |
                                              +-----------+
 6 GR_dirdel ---------------------------------|           |
 7 GR_iterfl ---------------------------------|           |
 8 GR_cmpel ----------------------------------| U         |
 9 GR_manfix ---------------------------------|   U       |
10 GR_iteren ---------------------------------|           |
                                              +-----------+
11 GR_fix ------------------------------------|     U U U |
----------------------------------------------+-----------+
```

GUARDRAIL

Count Table for Row Names

Row	Name	Type	SUBPARTS	UTILIZES	Both
1	GR_main	PROCESS	0	2	0
2	GR_confix	PROCESS	0	2	0
3	GR_autfix	PROCESS	0	5	0
4	GR_bldir	PROCESS	0	5	0
5	GR_consis	PROCESS	0	4	0
6	GR_dirdel	PROCESS	0	3	0
7	GR_iterfl	PROCESS	0	3	0
8	GR_cmpel	PROCESS	0	3	0
9	GR_manfix	PROCESS	0	3	0
10	GR_iteren	PROCESS	0	3	0
11	GR_fix	PROCESS	0	4	0
	Total		0	37	0
	Average		0.00	3.36	

GUARDRAIL

Count Table for Column Names

Column	Name	Type	PART OF	UTILIZED	Both
1	GR_confix	PROCESS	0	1	0
2	GR_fix	PROCESS	0	1	0
3	GR_autfix	PROCESS	0	2	0
4	GR_manfix	PROCESS	0	1	0
5	GR_Strfix	PROCESS	0	1	0
6	GR_bldir	PROCESS	0	1	0
7	GR_consis	PROCESS	0	1	0
8	GR_iterfl	PROCESS	0	1	0
9	GR_cmpel	PROCESS	0	2	0
10	GR_getfix	PROCESS	0	1	0
11	GR_putfix	PROCESS	0	2	0
12	GR_psnvec	PROCESS	0	1	0
13	GR_calc	PROCESS	0	6	0
14	GR_putpar	PROCESS	0	1	0
15	GR_eigen	PROCESS	0	4	0
16	GR_rngck	PROCESS	0	3	0
17	GR_dirdel	PROCESS	0	1	0
18	GR_getpar	PROCESS	0	1	0
19	GR_evalfn	PROCESS	0	1	0
20	GR_s2anp2	PROCESS	0	1	0
21	GR_iteren	PROCESS	0	1	0
22	GR_setgr	PROCESS	0	1	0
23	GR_delfix	PROCESS	0	1	0
24	GR_xredrw	PROCESS	0	1	0
	Total		0	37	0
	Average		0.00	1.54	

GUARDRAIL

Attribute Report

REPORT SPECIFICATION:

1 tree-level H='TREE LEVEL' COL=14
2 mathematical-field H='MATHEMATICAL FIELD' COL=25

*** No SYSTEM-PARAMETERS

	TREE LEVEL	MATHEMATICAL FIELD
GR_main	root	logical
GR_confix	middle	logical, trigonometric
GR_autfix	middle	logical
GR_Strfix	N/A	N/A
GR_bldir	middle	multivariate-inference
GR_getfix	N/A	N/A
GR_putfix	N/A	N/A
GR_psnvec	N/A	N/A
GR_calc	leaf	matrix-theory
GR_putpar	N/A	N/A
GR_consis	middle	multivariate-inference
GR_eigen	leaf	matrix-theory
GR_rngck	N/A	N/A
GR_dirdel	middle	multivariate-inference
GR_getpar	N/A	N/A
GR_iterfl	middle	matrix-theory
GR_cmpel	middle	multivariate-analysis
GR_evalfn	leaf	matrix-thoery
GR_s2anp2	leaf	multivariate-inference
GR_manfix	middle	matrix-algebra
GR_iteren	middle	matrix-theory
GR_fix	middle	logical
GR_setgr	N/A	N/A
GR_delfix	leaf	logical, file-manipulation
GR_xredrw	N/A	N/A

PSA477: The following objects have no ATTRIBUTES.

GR_Strfix
GR_getfix
GR_putfix
GR_psnvec
GR_putpar
GR_rngck
GR_getpar
GR_setgr

GUARDRAIL

GR_xredrw

Task 5 Description

1 GR_MAIN_T05 PROCESS

DESCRIPTION:
The subroutine MAIN gives control to the TASK05 subroutine that processes the current job. MAIN receives control from the Inter-data Operating System when the next job in the TASK05 queue is to be processed.

Utlizies Analysis Report

Utilizes Structure

COUNT	LEVEL	NAME
1	1.0	GR_MAIN_TO5
2	1.1	GR_EXTRNL
3	1.1.1	GR_FLASH
4	1.1.1.1	GR_DRAW
5	1.1.2	GR_CRNODE
6	1.1.2.1	GR_TIME
7	1.1.2.1.1	GR_RRECRD
8	1.1.2.2	GR_DATE
9	1.1.2.3	GR_INSNOD
10	1.1.2.3.1	GR_GNOME
11	1.1.2.3.2	GR_SLOPE
12	1.1.2.3.3	GR_ADBEAR
13	1.1.3	GR_INSNOD
14	1.1.3.1	GR_GNOME
15	1.1.3.2	GR_SLOPE
16	1.1.3.3	GR_ADBEAR
17	1.2	GR_FETCH
18	1.2.1	GR_DEACTV
19	1.2.2	ACTIVE
20	1.2.3	GR_ACTIVE
21	1.2.3.1	GR_WRITFL
22	1.3	GR_COPY
23	1.3.1	GR_COPNOD
24	1.3.1.1	GR_INSNOD
25	1.3.1.1.1	GR_GNOME
26	1.3.1.1.2	GR_SLOPE
27	1.3.1.1.3	GR_ADBEAR
28	1.4	GR_EDIT
29	1.4.1	GR_CONEDT
30	1.4.1.1	GR_EDTPRO
31	1.4.1.1.1	GR_DISPL
32	1.4.1.1.2	GR_FLASH
33	1.4.1.1.2.1	GR_DRAW
34	1.4.1.2	GR_SETINP
35	1.4.1.3	GR_ENDEDT
36	1.4.1.3.1	GR_COPNOD
37	1.4.1.3.1.1	GR_INSNOD
38	1.4.1.3.1.1.1	GR_GNOME
39	1.4.1.3.1.1.2	GR_SLOPE
40	1.4.1.3.1.1.3	GR_ADBEAR
41	1.4.1.3.2	GR_DELNOD
42	1.4.1.3.2.1	GR_DLBEAR
43	1.4.1.3.3	GR_INSNOD
44	1.4.1.3.3.1	GR_GNOME
45	1.4.1.3.3.2	GR_SLOPE

```
46  1.4.1 3.3.3           GR_ADBEAR
47  1.4.2       GR_SETGR
48  1.5     GR_CONEDT
49  1.5.1       GR_EDTPRO
```

COUNT	LEVEL	NAME
50	1.5.1.1	GR_DISPL
51	1.5.1.2	GR_FLASH
52	1.5.1.2.1	GR_DRAW
53	1.5.2	GR_SETINP
54	1.5.3	GR_ENDEDT
55	1.5.3.1	GR_COPNOD
56	1.5.3.1.1	GR_INSNOD
57	1.5.3.1.1.1	GR_GNOME
58	1.5.3.1.1.2	GR_SLOPE
59	1.5.3.1.1.3	GR_ADBEAR
60	1.5.3.2	GR_DELNOD
61	1.5.3.2.1	GR_DLBEAR
62	1.5.3.3	GR_INSNOD
63	1.5.3.3.1	GR_GNOME
64	1.5.3.3.2	GR_SLOPE
65	1.5.3.3.3	GR_ADBEAR
66	1.6	GR_INSERT
67	1.6.1	GR_DEACTV
68	1.6.2	GR_ACTIVE
69	1.6.2.1	GR_WRITFL
70	1.6.3	GR_FINDFL
71	1.6.4	GR_CRNODE
72	1.6.4.1	GR_TIME
73	1.6.4.1.1	GR_RRECRD
74	1.6.4.2	GR_DATE
75	1.6.4.3	GR_INSNOD
76	1.6.4.3.1	GR_GNOME
77	1.6.4.3.2	GR_SLOPE
78	1.6.4.3.3	GR_ADBEAR
79	1.6.5	GR_INSNOD
80	1.6.5.1	GR_GNOME
81	1.6.5.2	GR_SLOPE
82	1.6.5.3	GR_ADBEAR
83	1.6.6	GR_FLASH
84	1.6.6.1	GR_DRAW
85	1.6.7	GR_DFERR

Utilizes Matrix

Explanation of the Utilizes Matrix:

The rows are input PROCESS names, and the columns are PROCESSES UTILIZED by (or a SUBPART of) the rows.

(i, j) value	meaning
U	Column j is UTILIZED by Row i
S	Column j is a PART of Row i
B	Column j is both UTILIZED by, and a PART of Row i

	1 GR_EXTRNL	2 GR_FETCH	3 GR_COPY	4 GR_EDIT	5 GR_CONEDT	6 GR_INSERT	7 GR_FLASH	8 GR_CRNODE	9 GR_INSNOD	10 GR_DRAW	11 GR_TIME	12 GR_DATE	13 GR_RRECRD	14 GR_GNOME	15 GR_SLOPE
1 GR_MAIN_TOS	U	U	U	U	U	U									
2 GR_EXTRNL							U	U	U						
3 GR_FLASH										U					
4 GR_CRNODE									U		U	U			
5 GR_TIME													U		
6 GR_INSNOD														U	U
7 GR_FETCH															
8 GR_ACTIVE															
9 GR_COPY															
10 GR_COPNOD									U						

GUARDRAIL

Utilizes Matrix

```
                                                    1   1 1 1 1 1
                                  1 2 3 4 5  6 7 8 9 0   1 2 3 4 5
------------------------------+----------+----------+-----------
11 GR_EDIT ------------------ :        U :          :
12 GR_CONEDT ---------------- :          :          :
13 GR_EDTPRO ---------------- :          :   U      :
14 GR_ENDEDT ---------------- :          :       U  :
15 GR_DELNOD ---------------- :          :          :
                              +----------+----------+-----------
16 GR_INSERT ---------------- :          :   U U U  :
------------------------------+----------+----------+-----------

                          30 GR_DFERR -------------------
                        29 GR_FINDFL -------------------
                      28 GR_DLBEAR -------------------
                    27 GR_DELNOD -------------------
                  26 GR_DISPL -------------------

                25 GR_ENDEDT ------------------- /
              24 GR_SETINP ------------------- /
            23 GR_EDTPRO ------------------- /
          22 GR_SETGR ------------------- /
        21 GR_COPNOD ------------------- /

      20 GR_WRITFL ------------------- /
     19 GR_ACTIVE ------------------- /
    18 ACTIVE ------------------- /
   17 GR_DEACTV ------------------- /
  16 GR_ADBEAR ------------------- /

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 1 GR_MAIN_T05 -------------- :          :          :
 2 GR_EXTRNL ---------------- :          :          :
 3 GR_FLASH ----------------- :          :          :
 4 GR_CRNODE ---------------- :          :          :
 5 GR_TIME ------------------ :          :          :
                              +----------+----------+-----------+
 6 GR_INSNOD ---------------- : U        :          :
 7 GR_FETCH ----------------- :   U U U  :          :
 8 GR_ACTIVE ---------------- :        U :          :
 9 GR_COPY ------------------ :          : U        :
10 GR_COPNOD ---------------- :          :          :
------------------------------+----------+----------+-----------+
```

Utilizes Matrix

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
11 GR_EDIT							U								
12 GR_CONEDT								U	U	U					
13 GR_EDTPRO											U				
14 GR_ENDEDT						U						U			
15 GR_DELNOD													U		
16 GR_INSERT		U		U										U	U

GUARDRAIL

Count Table for Row Names

Row	Name	Type	SUBPARTS	UTILIZES	Both
1	GR_MAIN_TOS	PROCESS	0	6	0
2	GR_EXTRNL	PROCESS	0	3	0
3	GR_FLASH	PROCESS	0	1	0
4	GR_CRNODE	PROCESS	0	3	0
5	GR_TIME	PROCESS	0	1	0
6	GR_INSNOD	PROCESS	0	3	0
7	GR_FETCH	PROCESS	0	3	0
8	GR_ACTIVE	PROCESS	0	1	0
9	GR_COPY	PROCESS	0	1	0
10	GR_COPNOD	PROCESS	0	1	0
11	GR_EDIT	PROCESS	0	2	0
12	GR_CONEDT	PROCESS	0	3	0
13	GR_EDTPRO	PROCESS	0	2	0
14	GR_ENDEDT	PROCESS	0	3	0
15	GR_DELNOD	PROCESS	0	1	0
16	GR_INSERT	PROCESS	0	7	0
	Total		0	41	0
	Average		0.00	2.56	

GUARDRAIL

Count Table for Column Names

Column	Name	Type	PART OF	UTILIZED	Both
1	GR_EXTRNL	PROCESS	0	1	0
2	GR_FETCH	PROCESS	0	1	0
3	GR_COPY	PROCESS	0	1	0
4	GR_EDIT	PROCESS	0	1	0
5	GR_CONEDT	PROCESS	0	2	0
6	GR_INSERT	PROCESS	0	1	0
7	GR_FLASH	PROCESS	0	3	0
8	GR_CRNODE	PROCESS	0	2	0
9	GR_INSNOD	PROCESS	0	5	0
10	GR_DRAW	PROCESS	0	1	0
11	GR_TIME	PROCESS	0	1	0
12	GR_DATE	PROCESS	0	1	0
13	GR_RRECRD	PROCESS	0	1	0
14	GR_GNOME	PROCESS	0	1	0
15	GR_SLOPE	PROCESS	0	1	0
16	GR_ADBEAR	PROCESS	0	1	0
17	GR_DEACTV	PROCESS	0	2	0
18	ACTIVE	PROCESS	0	1	0
19	GR_ACTIVE	PROCESS	0	2	0
20	GR_WRITFL	PROCESS	0	1	0
21	GR_COPNOD	PROCESS	0	2	0
22	GR_SETGR	PROCESS	0	1	0
23	GR_EDTPRO	PROCESS	0	1	0
24	GR_SETINP	PROCESS	0	1	0
25	GR_ENDEDT	PROCESS	0	1	0
26	GR_DISPL	PROCESS	0	1	0
27	GR_DELNOD	PROCESS	0	1	0
28	GR_DLBEAR	PROCESS	0	1	0
29	GR_FINDFL	PROCESS	0	1	0
30	GR_DFERR	PROCESS	0	1	0
	Total		0	41	0
	Average		0.00	1.37	

Dictionary Report

1 GR_MAIN_T05 PROCESS

DESCRIPTION:
The subroutine MAIN gives control to the TASK05 subroutine that processes the current job. MAIN receives control from the Interdata Operating System when the next job in the TASK05 queue is to be processed.

2 GR_EXTRNL PROCESS

DESCRIPTION:
This subroutine processes the EXTERNAL command, which enables the operator to enter an LOP through the terminal by supplying the aircraft location and direction of arrival.
The external data is appended to the end of the requesting operator's active file and marked as external data rather than actual data from a platform.

3 GR_FLASH PROCESS

DESCRIPTION
The FLASH subroutine is used to display a specified LOP to a specified operator. The LOP is drawn three times to give a flashing effect
INSERT flashes an LOP being inserted into an LOP file during a DF command.
EDTPRO flashes an LOP that has been identified with cross-hairs during an EDIT command.
EXTRNL flashes an LOP being defined by an EXTERNAL command

4 GR_DRAW PROCESS

5 GR_CRNODE PROCESS

DESCRIPTION:
This subroutine creates an LOP data node for an LOP data file. Most of the individual elements are passed to CRNODE: current time and date, map elements.

6 GR_TIME PROCESS

7 GR_RRECRD PROCESS

DESCRIPTION:

The RRECRD subroutine reads the next record of DF display data from a chained disk file into a common array. The data is needed to create either a baseline or angular error plot.

The BTIME and TIME subroutines call RRECRD where those plot control subroutines require the plot data.

8 GR_DATE PROCESS

9 GR_INSNOD PROCESS

DESCRIPTION

The INSNOD subroutine inserts a given node into a LOPDATA file within a large buffer and updates the affected file data Completion of the node insertion implies determination of the map dependent elements, such as the aircraft location on the screen, distorted direction of arrival and slope for the LOP

10 GR_GNOMF PROCESS

DESCRIPTION

This is a gnomonic projection subroutine which calculates the new screen coordinates of a point defined by a latitude and longitude given the center location and scale factor for the graphics area

11 GR_SLOPE PROCESS

DESCRIPTION.

This is a gnomonic projection subroutine which calculates the new slope and new distorted angle for rescaled LOP and ellipse data. All calculations are based on the spherical shape of the world.

12 GR_ADBEAR PROCESS

DESCRIPTION:

The purpose of the ADBEAR subroutine is to add an LOP to an acceptable fix or to add it to the set of unassigned LOPs It performs a "wild bearing test" upon the data to determine if it falls within an acceptable confidence parameter range. Next the data is checked for direction, to make sure it is pointing in the direction of an emitter and not away from it. The LOP is tested in this manner against all of the fixes in the file buffer

If the LOP passes the wild and direction tests for more than one fix, the one where the LOP has the largest probability of occurring is chosen.

13 GR_FETCH PROCESS

DESCRIPTION:
This processes the FETCH command, which defines a specified file to be the requesting operator's active file.

Four types of FETCHs may be made:

1. Active - requester's active file
2. Local - specified file belonging to the requester
3. New - new file belonging to the requester
4. External - specified file belonging to another operator

14 GR_DEACTV PROCESS

DESCRIPTION:
This updates an operator's frequency catalog, using the current active file in response to a request, either from the operator or the system, for a new active file.

15 ACTIVE PROCESS

16 GR_ACTIVE PROCESS

DESCRIPTION.
The ACTIVE subroutine activates a LOP data file, residing in the specified large buffer, as an operator's active file

The following subroutines use ACTIVE:

a. FETCH, when it determines that the operator has explicitly defined a new active file.
b. XLOPFL, during initialization, whenever an operator's active file number in task common is invalid and is forced to file 1.
c. INSERT, whenever a DF request is issued at a frequency other than that assigned to the operator's current file. In this case, the active file is changed to a file having the requested DF frequency so that the DF data can be inserted.

17 GR_WRITFL PROCESS

18 GR_COPY PROCESS

DESCRIPTION
The COPY subroutine processes the COPY command, which involves scanning a specified source file for a specified set of LOP data nodes and copying those into the requesting operator's active file.
The subroutine copyies the set of LOP data nodes indicated by the fix number contained in the COPY command:

No fix number ==> all LOP data nodes
Fix number = 1, 2 or 3 ==> specified fix number
Fix number = 0 ==> all unassigned LOP data nodes

19 GR_COPNOD PROCESS

DESCRIPTION
This subroutine copies a specified LOP data node from one source file to the end of a specified destination file

20 GR_EDIT PROCESS

DESCRIPTION
The EDIT subroutine is used to start processing the EDIT command It edits the operator's active file by parsing the EDIT command saving the destination file number, if specified, in an array EDIT also requests graphics input so the operator can enter the edit functions using crosshairs to specify which LOP is to be edited

21 GR_CONEDT PROCESS

DESCRIPTION
CONEDT, the continuation edit subroutine, handles all graphics input for the EDIT command. The graphics input contains the x-y coordinates of the crosshairs, as well as the key that was pressed. The coordinates are used by EDTPRO to determine which LOP is being edited. The pressed key is used to determine which edit function is required:

I = identify
E = examine
D = delete
R = restore
C = copy
M = move

22 GR_EDTPRO PROCESS

DESCRIPTION

GUARDRAIL

This subroutine performs the intermediate processing for edit functions. Each time an edit function is entered, the CONEDT subroutine calls EDTPRO to handle it.

Intermediate processing implies recording the edit function in the requesting operator's active file, but not performing the edit function. It is performed during final processing by the ENDEDT subroutine. EDTPRO reads the active file, scans it for the closest LOP to the crosshair intersection, records the edit function if necessary for future processing, and writes the active file back to disk. EDTPRO also calls the display subroutine, DISPL, to format and output the data.

23 GR_DISPL PROCESS

DESCRIPTION:
The DISPL subroutine displays data pertinent to a selected LOP in response to the edit function "E" (examine). DISPL is used to extract, format and display the data which is extracted from the specified node within the requesting operator's active file and displayed in the command area of the screen.

The display contains the following elements.

Line 1	Location of aircraft in latitude, longitude, or military grid format
Line 2	Direction of arrival, in degrees
	Day, month, and year of DF
	Time of DF, in hours and minutes
Line 3	Aircraft roll angle, in degrees
	Aircraft tail number
	Platform used for DF
	Edit function associated with LOP or fix number assigned

24 GR_SETINP PROCESS

25 GR_ENDEDT PROCESS

DESCRIPTION:
The ENDEDT subroutine performs the final processing necessary for the EDIT command. When the operator terminates the EDIT command by pressing the "T" key, CONEDT calls ENDEDT, the end edit subroutine. This can also be called to abnormally terminate the EDIT command.

26 GR_DELNOD PROCESS
DESCRIPTION:
The DELNOD subroutine deletes a specified node from a LOPDATA file within a large buffer and deletes the effect of the node on all related data.

27 GR_DLBEAR PROCESS

DESCRIPTION:
The purpose of the DLBEAR subroutine is to delete an LOP from a fix or to decrement the number of unassigned LOPs if the LOP is unassigned.

28 GR_SETGR PROCESS

29 GR_INSERT PROCESS

DESCRIPTION:
This subroutine inserts DF data gathered from active platforms into the LOP data file belonging to the DF operator who made the request

The requesting operator's old active file, or a newly selected active file, is updated using the gathered DF data. It is appended to the end of the file.

30 GR_FINDFL PROCESS

DESCRIPTION:
The FINDFL subroutine is called only by the INSERT subroutine, to select a file into which DF data will be inserted. The subroutine finds a LOP data file whose frequency matches the given DF frequency by scanning the frequency catalog, already stored in a large buffer, for a frequency within the given delta of the DF frequency.

31 GR_DFERR PROCESS

DESCRIPTION:
This subroutine determines which DF error messages to display, formats the error messages, and sends them to be displayed.
The INSERT job calls DFERR to describe faults detected during a normal DF request. The BITE job calls DFERR to describe faults detected during a DF test using Built-In Test Equipment (BITE). SAVEDF job calls DFERR to describe faults detected during a calibration gather DF.