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NIKE ZEUS
AUTOMATIC DESTRUCT
RANGE
SAFETY PROGRAM
FOR
THE IBM 7090 COMPUTER

by T.O. Rickman and R. Holguin

LAND-AIR, INC.
PARADYN DIVISION
POINT MUGU, CALIFORNIA
A SUBSIDIARY OF
DYNAELECTRON CORPORATION
This report was prepared under contract number N-123(61756)19425A/PMR for use by Paradyn and Test Data Division personnel to provide a range safety service in support of the NIKE-ZEUS project at the Pacific Missile Range.

Copies are available on request from the Test Data Division, Range Operations Department, Code 3280, Pacific Missile Range.

Approved:
R. M. CONWAY, Manager
Paradyn Division
Land-Air, Inc.

Approved: WALTER L. MILNE
Contract Tech Coordinator
Test Data Division

Approved: CHARLES J. THORNE
Head, Test Data Division
Range Operations Department
The computer accepts input data from four sources. The first of these sources called System A, consists of an AN/FPS-16 radar, which is slaved to a Cotar. The radar outputs range only and the Cotar outputs direction cosines alpha and beta. System B is the Missile Tracking Radar (MTR) which outputs raw polar data at the rate of 8.123 samples per second. The MTR was designed and is operated by the project personnel of Western Electric Corp. System C is the AN/FPS-16 radar of System A when it is released by the Cotar and is free to track skin and to output polar coordinate data. A second AN/FPS-16 radar, free to operate in the skin-track mode, is identified as System D. Systems A and D together make up the Pacific Missile Range (PMR) system which is input at the rate of 20 samples per second.

A single system is chosen to control destruct computations and impact predictions. The choice is based on data quality as determined by comparing rates of change in position and differences in velocity with predetermined standard, resolving the relative qualities of the data of the four systems with the ranking of the system reliabilities which are in the order A, B, C, D.

Since the MTR samples only at a rate of 8.123 samples per second, redundant data is received when there is no new tracking information. When a new data sample is sent, it is flagged as such for the computer. Space position is computed only on new data samples, but the MTR on-target indication is checked at a 20-sample-per-second rate.

The final output from the computer is a real time recorded history tape that contains all raw tracking information and all computed information from the four systems. This tape may be used later to simulate the missile flight or to output postflight missile data.
FOREWORD

The NIKE-ZEUS Range Safety Automatic Destruct Program was designed to provide a means of range safety control of the NIKE-ZEUS Anti-Missile Missile. Since this missile has a very high acceleration at lift off and since it is ground guided, the range safety problem is increased considerably. The velocity and acceleration of the missile is so high that human reaction is not quick enough to destroy an unsafe missile and contain the resulting fragments within a safe area. Consequently, an automatic destruct system had to be devised to provide safety measures for this type of danger. It was therefore specified that the range safety computer be capable of destroying an unsafe missile automatically.

The incorporation of an automatic destruct system in a range safety computer is a very broad and complex problem. Since a program of this type has never been attempted at Point Mugu, a contract was awarded to Aeronutronics Corp., a division of the Ford Motor Co. at Newport Beach California to study the problem and to submit a proposal to the Range Safety Officer at Point Mugu.

The programing was developed by R. Holguin and T. Rickman in a comparatively short time. Land-Air received the program specifications from Aeronutronics on 8 January 1962, and the program was ready for Range Safety checkout on 19 February 1962.

Because of the increased speed of the IBM 7090 over the 709, and also because of the experience gained from the earlier program, computation time for the automatic destruct program has been reduced considerably. The 709 program took approximately 46 milliseconds of computation time for three systems, and the more complex 7090 program takes approximately 18 milliseconds of computation time for four systems. The program uses approximately 21894 cells of core memory, of which approximately 12000 are tables.

Although reprogramming the NIKE-ZEUS problem for the computer was accomplished in near record time, it could not have been done without the devoted efforts of the following people: Mr. P. Rotsheck of Cubic Corp.; Mr. B. Larey, Mr. C. LeRoy and Mr. J. Harvey of Range Development Dept.; Mr. R. Long and Mr. R. Wilkerson of IBM Corp.; Mr. J. Yost of Bell Telephone Labs; Mr. L. Powell of Western Electric Co. Many other people devoted their time and effort to this project, but their names are too numerous to mention here. Sections 1, 2, and 3 were taken with appropriate changes from Land-Air, Inc. Report 26, "Computer Programing for Real Time Impact Prediction and Destruct Control." The report was edited and prepared for publication by Mr. T. Wakai of Land-Air, Inc.
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This is a real time digital computer application to predict impact location and to control the missile destruct device. Working from the input sources the computer edits the data it receives, selects a sample and computes the information required for output. Among this output is information for driving three remotely located plotting boards, data quality lights and a signal to a destruct control device.

1.1 DESTRUCT PHILOSOPHY
The destruct philosophy is to destroy any missile that appears to endanger the mainland or any island except San Nicolas Island and Anacapa Island or appears to be leaving the predetermined boundaries of the missile range. The destruct on minimum downrange velocity is designed to protect against turns toward the mainland. The destruct on fragment impact points is designed to protect islands and prohibit the missile from leaving the confines of the Pacific Missile Range. Destruct will also be commanded if the computer loses data from all tracking systems caused by tracker failure or transmission failure, for it would not be safe to allow a highly maneuverable missile to wander around if reliable information about its position is not known. The criteria for sending a destruct command will be described later in this document.

1.2 SYSTEM HARDWARE
Figure 1 presents the major parts of the system's equipment. The input and output equipment is shown only in very minor detail and is so treated throughout this manual, with emphasis reserved for the central subject, the computer programing. The purpose of this publication, therefore, permits no more than reference to such important components of the total system as the Cubic DH-10 Digital Distribution Units (DDU), Input/Output Buffer, DH-14 Digital Multiplex Synchronizer (DMS); the Collins transmission equipment; and the contributions from the Range Development Department of PMR.

1.3 VOICE COMMUNICATIONS
In addition to the data system, there are two voice communication networks detailed for use by the system's operating personnel. These circuits, identified as 705 and 706, are shown in Figure 2. In general, network number 705 is the input network and includes a phone jack at the DDU rack at each tracking site in addition to those shown. Conversely, network 706 is used by personnel whose major concern is output. Note that station 4 is patched into both nets.

The telephone positions are serially numbered with the numbers circled and located in the illustration approximately at the users working station.
Figure 1. Range Safety System
Figure 2. Voice Communications
1.4 COMPUTER PERSONNEL
Personnel manning these stations are as follows:

1. Equipment technical
2. Equipment technical
3. Equipment technical
4. Computer controller
5. Computer console operator
6. Tape handler
7. Logger
Spare Unassigned

The computing function requires a crew of four people: the console operator, who is in charge of the computer operation, the tape handler, the logger, and the computer controller. The computer controller is located, not in the computer room, but in Building 53, near the output displays.

1.5 PROGRAMING
The computer was programmed and checked out by the Land-Air programing staff from specifications prepared under another contract by Aeronutronic. The program is built with facility for selecting automatically from 4 systems.

There are a number of constants that must be entered in the program prior to the operation. These constants are determined by others and given to the programmer. The effect of admitting these constants to the program resembles more a program modification than a single insertion or switch. This information is, therefore, given the programmer several days in advance of the operation.

1.6 PREOPERATION CHECKOUT
The preoperation checkout consists of component checks, partial system checks and an end-to-end check. The computer checkout is a procedure that requires from three to four hours to complete. It is run completely on the day before the operation and is repeated on the day of the launch and finished, by plan, at least fifteen minutes prior to liftoff.

1.6.1 Customer Engineer's Check
The computer with all its components, is prepared for use by the manufacturer's customer engineers (CE's) who run their diagnostic programs and make any adjustments thereby discovered necessary. This is a procedure that consumes 30 to 45 minutes. The computer is then turned over to the operators.

1.6.2 Tape Handler's Preparations
At the same time, the tape handler cleans the magnetic tape heads and readies the tapes. The latter consists of selecting six reels of degaussed tape, and stripping and removing scratched or worn tape from the leader end to a point where good clean tape begins. He also mounts the program tape, impact constants tape and the first of the simulator trajectory tapes.
Also at the same time, the output equipment and the plotting boards are undergoing independent checkout procedures.

1.6.3 Check Sum Comparisons

There are two points of interest in checking out the computer; reading the program and impact tables into core, and inputting simulated data. Both are programmed to be checked through use of the check sum techniques.

1.6.3.1 Core Check

When the operating program, including a check sum word, has been read into core, a logical summation is made of the program words entered. The results of this summation is then compared with the check sum word. Any difference is flagged by a statement printed out on-line. The cause for difference is found and removed. The procedure is also applied to the transfer of tables to core and assures the correct transfer of this information.

1.6.3.2 Program Check

The other point of interest in computer checkout consists of running the program, using simulated input. Four tapes containing thirty seconds each of raw computer input data, identified as Case I through Case IV, have been furnished by Aeronutronic for this purpose. Case I contains data representing a perfect flight through the planned trajectory. The flight represented by the Case II data develops an $\dot{X}$ velocity component smaller than $\dot{X}_{\text{min}}$, the specified minimum, and results in destruct signals. Case III also ends in destruct signals but as a consequence of the trajectory straying outside the safe impact area. Case IV contains loss of track or bad data in one or more inputs so the complete problem logic is tested.

1.6.3.2.1 Standard Tapes

Each of these tapes has been processed by the program to produce output tapes. The first thirty words of each record consists of the raw input; the remainder, computed output. All errors in the program have been found and corrected. When the computer is functioning at par, it can recreate any of these output tapes. Therefore, these tapes qualify as standards and are so used.

1.6.3.2.2 Tape Comparison

The original checkout of the program to produce the standard tapes was heavily consumptive of personnel time. The manual check of subsequent checkout tapes against the standard would be a prohibitive time consumer. Hence, this work is given to the computer for which a program is coded to make such a comparison using the logical check sum technique.

Whenever the program finds disagreement between the newly run output tape and the standard tape the fact is printed out on-line. The program is stopped and the cause of the disagreement is examined. As the program is continually improved and experience with it grows, it becomes increasingly the cause of disagreement in this checkout procedure. At the same time, the procedure becomes, more positively, a check on the computer itself.

Land-Air, Inc.
1.6.4 Check Output to Plotting Boards

When the computer is checked out, the output system and plotting boards are placed on-line and the four simulated input tapes are rerun. At this stage, the computer controller can observe the output at the remotely located plotting boards where the pens track out the familiar traces in response to the program and simulated data. This test serves as an independent check on the earlier warmup and checkout of the output and transmission facilities and of the plotting board calibrations. It also provides an independent view of the computer program performance.

1.6.4.1 System Checkout With Radars

The final step is the integration of the total system where the input instruments are placed on-line to enable a real time test. The test proceeds by operating the radars and cotar according to instructions from the computer controller. A typical request by him of the radar operator would be to direct the radar beam to the launch pad and set in a constant range, such as the known range from the radar to the pad. Then, outputting this range, the operator would be asked to slew through 360° of azimuth. When the complete system is operating properly, such an input would produce a circular trace on the plotting board chart. The trace turns about the radar site as a center, and begins and ends at the launch pad. Both of these points are preplotted on the (X,Y) chart. The radar operator would again direct the beam to the launch pad and slew the beam upward through sixty or more degrees of elevation angle. This action, since the radar is located near the Y axis, would produce a vertical line from the launch pad representation on the (X,Z) chart. The operation is repeated for all radars except the one slaved to the cotar.

1.6.4.2 System Checkout With Cotars

The radar-cotar input is tested in another manner. A beacon, aboard an aircraft, transmits a signal that the cotar can receive. On receiving the signal, the cotar directs the radar to this point. As a result, the radar sends range and the cotar sends the cosines of \( \alpha \) and \( \beta \) to the computer. When the output is processed by the computer program and sent to the plotting boards the pens take the position of the aircraft in flight on the (X,Y) and (X,Z) charts.

1.7 Computer Operation

When the checkout procedure is completed satisfactorily, the range safety system is "all green". The program continues to operate by recycling, reading from tape and outputting to tape with the real time inputs disconnected. The real time input sources and the output displays are placed on-line by a console sense switch. The computer operator does this on command of the computer controller. No further human intervention is permitted thereafter. One tape unit is used to record the raw input to the computer for postoperation uses. The unit is idle until the liftoff signal is received.
The digital computer will operate from two independent and unrelated input systems to provide the real time safety services. The logic in the use of these inputs is such that maximum confidence accompanies the computer output when both inputs are functioning. Deterioration or loss of one input system only lowers the confidence level associated with the computer output, but completely reliable output can result from only one good input.

2.1 PMR INPUT SYSTEM

The PMR offers a choice of three separate input systems. They are received at the computer but only one is used in the computations and referred to as the PMR system. The choice is made automatically by the program on a priority basis.

2.1.1 Cotar/FPS-16

An FPS-16 radar and a cotar will comprise one of the choices where the radar is slaved to the cotar. In this union the radar will output range only, with the remaining position information coming from the cotar. Therefore, the cotar will have the dual role of outputting direction cosines as its data contribution, and also information to the radar tracking serves to maintain the radar track. This input system, System A, will then supply range $R_p$ in feet; cosine $\alpha$, and cosine $\beta$. The sampling rate is twenty per second.

2.1.2 FPS-16

The second choice offered by the PMR is an FPS-16 radar alone. These systems, C & D, will input to the computer; range $R_F$ in feet, azimuth angle $A_F$, and elevation angle $E_F$, both in degrees, at the rate of twenty samples per second.

2.2 MTR INPUT SYSTEM

The MTR input system, System B, is a component of the missile project. This radar is permanently in the system and outputs range $R_M$ in feet, azimuth $A_M$, and elevation $E_M$, both in degrees. The sampling rate is about 8.13 per second.
The computer input data appears in a record of thirty 24-bit words. The record is divided into five 6-word fields devoted to timing, elevation angle, range, azimuth, and parity check. Each field is divided into six words. The first word in each field is reserved for AN/FPS-16 radar input. The second word in each field receives the cotar input; the third word, the Missile Tracking Radar (MTR) input; the fourth word the input from the second AN/FPS-16 radar. These record details are further tabulated below.

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<thead>
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<th>Computer Words</th>
<th>Information</th>
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<tr>
<td>1. Timing</td>
<td>Range Time FPS-16 radar</td>
</tr>
<tr>
<td>2.</td>
<td>&quot;&quot; COTAR</td>
</tr>
<tr>
<td>3.</td>
<td>&quot;&quot; MTR</td>
</tr>
<tr>
<td>4.</td>
<td>&quot;&quot; FPS-16 radar</td>
</tr>
<tr>
<td>5.</td>
<td>&quot;&quot; Zero</td>
</tr>
<tr>
<td>6.</td>
<td>&quot;&quot;</td>
</tr>
<tr>
<td>7. Elevation</td>
<td>Elevation FPS-16 radar</td>
</tr>
<tr>
<td>8.</td>
<td>&quot;&quot; Corrections COTAR</td>
</tr>
<tr>
<td>9.</td>
<td>&quot;&quot; Elevation MTR</td>
</tr>
<tr>
<td>10.</td>
<td>&quot;&quot; Elevation FPS-16 radar</td>
</tr>
<tr>
<td>11.</td>
<td>&quot;&quot; Zero</td>
</tr>
<tr>
<td>12.</td>
<td>&quot;&quot;</td>
</tr>
<tr>
<td>13. Range</td>
<td>FPS-16 radar</td>
</tr>
<tr>
<td>14.</td>
<td>&quot;&quot; Direction cosine COTAR (θ)</td>
</tr>
<tr>
<td>15.</td>
<td>&quot;&quot; Range MTR</td>
</tr>
<tr>
<td>16.</td>
<td>&quot;&quot; FPS-16 radar</td>
</tr>
<tr>
<td>17.</td>
<td>&quot;&quot; Zero</td>
</tr>
<tr>
<td>18.</td>
<td>&quot;&quot;</td>
</tr>
<tr>
<td>19. Azimuth</td>
<td>Azimuth FPS-16 radar</td>
</tr>
<tr>
<td>20.</td>
<td>&quot;&quot; Direction cosine COTAR (α)</td>
</tr>
<tr>
<td>21.</td>
<td>&quot;&quot; Azimuth MTR</td>
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<td>22.</td>
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<td>&quot;&quot; Zero</td>
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<td>24.</td>
<td>&quot;&quot;</td>
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<td>25. Parity</td>
<td>Misc. Information FPS-16 radar</td>
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<td>26.</td>
<td>&quot;&quot; &quot;&quot; COTAR</td>
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<td>27.</td>
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<td>&quot;&quot; &quot;&quot; FPS-16 radar</td>
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<td>29.</td>
<td>&quot;&quot; Zero</td>
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<td>&quot;&quot;</td>
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</table>

3.1 **FPS-16 RADAR INPUT FORMAT**

Input to the computer from the AN/FPS-16 radar appears in five-word format of 24 bits per word. The usage of these words in the order of their appearance in Figure 3 is as follows:

Land-Air, Inc.
| WORD 1 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 |
|--------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|        | 0  | X  | TVC| TVC| TVC| TVC| TVC| TVC| TVC| TVC| T15| T14| T13| T12| T11| T10| T9 | T8 | T7 | T6 | T5 | T4 | T3 | T2 | T1 |

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<thead>
<tr>
<th>WORD 25</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

**LEGEND**

- **A**: Azimuth
- **E**: Elevation
- **T⁻¹**: Identification (Octal Code)
- **X**: On Target
- **P⁻ BD**: Parity (Bad Data)
- **R**: Range
- **P⁻ CH**: Parity (Longitudinal)
- **T⁻ N**: Time (PMR)
- **T⁻ VC**: Time (Vernier Count)
- **X**: Constant "One" Bits
- **0**: Constant "Zero" Bits

**Figure 3. AN/FPS-16 Radar Input Format**
3.1.1 Word 1 (First Radar Word)
The integer portion of the binary expression of range time appears as \( T \) in bits 21 through 35. The low order bit is 35 which represents two seconds as the finest time expression. The finer portion of the range time expression appears as \( T_{ve} \) in bits 14 through 20. These counts change at the rate of 40 counts per second and recycle every two seconds or 80 counts.

Annexing the counts of this, the vernier counter, to the course range time counter it becomes possible to sense range time to a fineness of 0.025 seconds. The vernier counter does not present a direct reading of the fine component of the time, however, since it does not register nor recycle at zero. Instead, the counter progresses to 80 and then returns to 1. It is, therefore, necessary to subtract a binary 1 from a readout of the vernier counter to obtain a reading of the fine component of range time.

The remaining bits, 12 and 13, of Word 1 are as shown in Figure 3 and are of no concern to the computer programing.

3.1.2 Word 7 (Second Radar Word)
This word receives the elevation angle \( E \) in bits 19 through 35. A readout of these bit positions results in the expression of a fraction of a circle. The value associated with each bit, beginning with the high order bit 19, is:

\[
\frac{\pi}{2^0}, \frac{\pi}{2^1}, \frac{\pi}{2^2}, \ldots, \frac{\pi}{2^{16}}.
\]

Bit 14 in this word displays a 0 when the radar is off track and a 1 when the radar is on track. The other bit positions are of no concern to the computer programing.

3.1.3 Word 13 (Third Radar Word)
This word expresses range in yards using bit positions 14 through 35. The low order bit 35, identified as \( R_1 \), has the value of 0.5 yards. The series \( R_1 \) through \( R_{19} \) is associated with the values:

\[
2^{-1}, 2^0, 2^1, \ldots, 2^{19}.
\]

Other bits in this word are unrelated to the computer programing.

3.1.4 Word 19 (Fourth Radar Word)
This word is devoted to the expression of azimuth angles. It is used and described the same as Word 7 except for bit position 14 which has no use in this word.
3.1.5 **Word 25 (Fifth Radar Word)**

The only part of this word used in the computer processing of the data is the bit appearing in position 12 labeled PBD. This is a parity bit and is interpreted thus:

1  Bad data  
0  Good data.

3.2 **COTAR INPUT FORMAT**

Input to the computer from the Cotar appears in a five-word format of 24 bits per word. The usage of these words in the order of their appearance in the record and in Figure 4 is as follows:

| Record Word 2 | First Cotar Word | Range Time  
|---------------|------------------|------------
| Record Word 8 | Second Cotar Word | Frequency Corrections 
| Record Word 14 | Third Cotar Word | Cosine β  
| Record Word 20 | Fourth Cotar Word | Cosine α  
| Record Word 26 | Fifth Cotar Word | Parity Check

3.2.1 **Word 2 (First Cotar Word)**

This word receives the range timing information associated with the Cotar data in a manner exactly the same as Word 1. For details, refer to Word 1 under FPS-16 Radar Input.

3.2.2 **Word 8 (Second Cotar Word)**

This word contains three unrelated groups of data identified as Kr, Kc and Q. Kr is a constant, Kc is a variable factor, and Q a quality bit.

3.2.2.1 **Kr, Transmitter Constant**

There exists in the system a Cotar frequency correction term Kr. This correction represents the magnitude of the transmitter frequency deviation from the Cotar design frequency fb. The value of Kr in megacycles is not transmitted, but is tabled in the computer opposite a set of code numbers as arguments. The term is constant for any transmitter frequency and is introduced by a code, set in bit positions 22 through 26, noted A10 through A14. This code is the argument for the table lookup to obtain Kr.

3.2.2.2 **Kc, Doppler Compensation**

The doppler effect is measured by the Cotar and expressed as single cycles per second. The output of this measuring device appears as a whole number in bit positions 27 through 35, labeled A1 through A8.

3.2.2.3 **Q, Data Quality**

Position 14, labeled Q is a quality bit. This is the output of a device in the Cotar that compares the signal received with a standard determined by the setting of Kr. Bit 14 displays a 1 if the comparison is favorable and a 0 if it is unfavorable. Criteria for making the distinction is a Cotar matter and of no concern to the program. The program accepts or rejects on the basis of this bit, however.
### Legend

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q&lt;sub&gt;n&lt;/sub&gt;</td>
<td>Data Quality</td>
<td>T&lt;sub&gt;n&lt;/sub&gt;</td>
</tr>
<tr>
<td>I&lt;sub&gt;N&lt;/sub&gt;</td>
<td>Identification Octal Code</td>
<td>T&lt;sub&gt;VC&lt;/sub&gt;</td>
</tr>
<tr>
<td>A&lt;sub&gt;N&lt;/sub&gt;</td>
<td>Data Parameter</td>
<td>X</td>
</tr>
<tr>
<td>B&lt;sub&gt;N&lt;/sub&gt;</td>
<td>Cosine 1 (β)</td>
<td>0</td>
</tr>
<tr>
<td>C&lt;sub&gt;N&lt;/sub&gt;</td>
<td>Cosine 2 (α)</td>
<td>P&lt;sub&gt;CH&lt;/sub&gt;</td>
</tr>
<tr>
<td>P&lt;sub&gt;BD&lt;/sub&gt;</td>
<td>Parity (bad data)</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 4. Cotar Input Format**

Land-Air, Inc. 13
3.2.3 Word 14 (Third Cotar Word)
The binary representation of a number that is proportional to the
direction cosine $\beta$ or its complement appears in bit positions 18 through
35, labeled $B_1$ through $B_{18}$. Position 17 is a sign bit. If this bit is 0,
the contents of positions 18 through 35 are interpreted as proportional to
the direction cosine $\beta$ with a negative sign. If bit 17 is 1, the contents
of these positions are interpreted as proportional to the positive one's
complement of the direction cosine $\beta$. This information is the output from
a set of code wheels. The required function is the product of this output
multiplied by an instrument constant.

3.2.4 Word 20 (Fourth Cotar Word)
This word is used exactly the same as Word 14 above except the angle $\alpha$
is processed instead of $\beta$.

3.2.5 Word 26 (Fifth Cotar Word)
This word is used for the Cotar input in exactly the same manner as
Word 25 serves the FPS-16 Radar Input.

3.3 MISSILE TRACKING RADAR INPUT FORMAT
Input to the computer from the Missile Tracking Radar (MTR) appears in
a five-word format of 24 bits per word. The usage of these words in the
order of their appearance in Figure 5 is as follows:

<table>
<thead>
<tr>
<th>Record Word</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>First MTR Word</td>
</tr>
<tr>
<td>9</td>
<td>Second MTR Word</td>
</tr>
<tr>
<td>15</td>
<td>Third MTR Word</td>
</tr>
<tr>
<td>21</td>
<td>Fourth MTR Word</td>
</tr>
<tr>
<td>27</td>
<td>Fifth MTR Word</td>
</tr>
<tr>
<td></td>
<td>Range Time</td>
</tr>
<tr>
<td></td>
<td>Elevation Angle</td>
</tr>
<tr>
<td></td>
<td>Slant Range</td>
</tr>
<tr>
<td></td>
<td>Azimuth Angle</td>
</tr>
<tr>
<td></td>
<td>Parity Check</td>
</tr>
</tbody>
</table>

3.3.1 Word 3 (First MTR Word)
This word receives the range timing information associated with the
MTR data in a manner exactly the same as in Word 1. For details, refer to
Word 1 under FPS-16 Radar Input.

3.3.2 Word 9 (Second MTR Word)
This word receives the elevation angle $E$ in bits 18 through 35. A
readout of these bit positions results in the expression of a fraction of
a circle. The value associated with each bit, beginning with the high
order bit 18, is:

$\pi/2^0, \pi/2^1, \pi/2^2, \ldots, \pi/2^{17}$.

Bit position 14, labeled $W$, signals liftoff in addition to on and off
track. Initially the position is inactive. At liftoff the position displays
a 1. Thereafter, throughout the operation, this bit is interpreted as
follows:
<table>
<thead>
<tr>
<th>WORD 3</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>24</th>
<th>25</th>
<th>26</th>
<th>27</th>
<th>28</th>
<th>29</th>
<th>30</th>
<th>31</th>
<th>32</th>
<th>33</th>
<th>34</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>x</td>
<td>Tvc</td>
<td>Tvc</td>
<td>Tvc</td>
<td>Tvc</td>
<td>Tvc</td>
<td>Tvc</td>
<td>Tvc</td>
<td>Tvc</td>
<td>T15</td>
<td>T14</td>
<td>T13</td>
<td>T12</td>
<td>T11</td>
<td>T10</td>
<td>T9</td>
<td>T8</td>
<td>T7</td>
<td>T6</td>
<td>T5</td>
<td>T4</td>
<td>T3</td>
<td>T2</td>
</tr>
</tbody>
</table>

| WORD 9  | 0  | 0  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 1  |

| WORD 15 | 0  | 0  | R22 | R21 | R20 | R19 | R18 | R17 | R16 | R15 | R14 | R13 | R12 | R11 | R10 | R9  | R8  | R7  | R6  | R5  | R4  | R3  | R2  | R1  |

| WORD 21 | 0  | 0  | 1  | 1  | 1  | 1  | 1  | A18 | A17 | A16 | A15 | A14 | A13 | A12 | A11 | A10 | A9  | A8  | A7  | A6  | A5  | A4  | A3  | A2  | A1  |

| WORD 27 | P0  | 0  | P_{CH}^2 | P_{CH}^3 | P_{CH}^4 | 0  | P_{CH}^2 | P_{CH}^3 | P_{CH}^4 | X  | P_{CH}^2 | P_{CH}^3 | P_{CH}^4 | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  |

**LEGEND**

- **A** Azimuth
- **E** Elevation
- **I_N** Identification (Octal Code)
- **W** On Target
- **P_{BD}** Parity (Bad Data)
- **R** Range
- **P^n** Parity (Longitudinal)
- **T_N** Time (PMR)
- **T_{VC}** Time (Vernier Count)
- **X** Constant "One" Bits
- **0** Constant "Zero" Bits

---

Figure 5. **Missile Tracking Radar Input Format**

Land-Air, Inc. 15
0 Off Track
1 On Track

The computer program is concerned with no other bits in this word.

3.3.3 Word 15 (Third MTR Word)

The major use of Word 15 is to receive slant range. The low order bit in bit position 35 as received has the value .09367972 meters which is treated in the program as .30734815 feet. The range is thus treated in these terms with bit position 15 noted $R_{o1}$ as the high order bit.

The MTR samples at a rate of 8.123 samples per second but the program is designed for a sampling rate of twenty samples per second. In order that it process only new data it will test on bit position 14, labeled $R_{o2}$. A new data sample will introduce a 1 in this position which will change to a 0 when the sample has been processed.

No other parts of this word concern the computer program.

3.3.4 Word 21 (Fourth MTR Word)

This word receives the azimuth angle and is the same as Word 9 except that bit 14 is unassigned. For details beyond this exception, refer to Word 9 of this section.

3.3.5 Word 27 (Fifth MTR Word)

This word is used for the MTR input in exactly the same manner as Word 25 serves the Radar Input.
Before the COTAR data is edited, it must be corrected for the frequency of the NIKE-ZEUS telemetry system. The true direction cosines are computed from the following equations:

\[ C_{1T} = K_0 C_1 \]
\[ C_{2T} = K_0 C_2 \]

where

\[ K_0 = \frac{1}{K_r + (K_c - 100)\omega} \]
\[ 1 + fb \]

where

\[ C_{1T} = \text{TRUE } C_1 \]
\[ C_{2T} = \text{TRUE } C_2 \]
\[ K_r = \text{COTAR OPERATING FREQUENCY} \]
\[ K_c = \text{FREQUENCY CORRECTION} \]
\[ C_1 = \text{COTAR COSINE BETA} \]
\[ C_2 = \text{COTAR COSINE ALPHA} \]
\[ fb = \text{COTAR BASE FREQUENCY} \]
\[ \omega = \text{FREQUENCY CORRECTION} \]

4.1 PREDICTION

Before the data received is edited, the lockout indication must be checked. If the interval between the first word of the sample from a source that arrives first and the first word of the sample from a source that arrives last is greater than 3.3 milliseconds, lockout occurs. If the lockout indicator shows that a lockout has occurred, no editing is performed; and values for all trackers are predicted using the following equations:

**COTAR**

\[ (\cos \alpha)_{\text{PRED}} = \cos \alpha(t - \Delta t) + 0.05 \cos \alpha(t - \Delta t) \]
\[ (\cos \beta)_{\text{PRED}} = \cos \beta(t - \Delta t) + 0.05 \cos \beta(t - \Delta t) \]

**AN/FPS -16**

\[ R_{\text{PRED}} = R(t - \Delta t) + 0.05 R(t - \Delta t) \]
\[ A_{\text{PRED}} = A(t - \Delta t) + 0.05 A(t - \Delta t) \]
\[ E_{\text{PRED}} = E(t - \Delta t) + 0.05 E(t - \Delta t) \]
4.2 EDITING

If the lockout indicator shows that no lockout has occurred, the following editing is performed on raw data. The data is good when the following inequalities are satisfied:

\[
\begin{align*}
\text{COTAR} & \\
R_{\text{PRED}} &= R(t - \Delta t) + 0.123 \dot{R}(t - \Delta t) \\
A_{\text{PRED}} &= A(t - \Delta t) + 0.123 \dot{A}(t - \Delta t) \\
E_{\text{PRED}} &= E(t - \Delta t) + 0.123 \dot{E}(t - \Delta t)
\end{align*}
\]

\[
\begin{align*}
C_{1T}(t) - C_{1T}(t - \Delta t) &< \Delta C_{1T} \\
C_{2T}(t) - C_{2T}(t - \Delta t) &< \Delta C_{2T} \\
C_{1T}(t) - C_{1\text{TPRED}}(t - \Delta t) &< C_{1T} \\
C_{2T}(t) - C_{2\text{TPRED}}(t - \Delta t) &< C_{2T}
\end{align*}
\]

\[
\begin{align*}
R_m(t) - R_m(t - \Delta t) &< \Delta R_m \\
A_m(t) - A_m(t - \Delta t) &< \Delta A_m \\
E_m(t) - E_m(t - \Delta t) &< \Delta E_m \\
R_m(t) - R_{m\text{PRED}}(t - \Delta t) &< \Delta R_m \\
A_m(t) - A_{m\text{PRED}}(t - \Delta t) &< \Delta A_m \\
E_m(t) - E_{m\text{PRED}}(t - \Delta t) &< \Delta E_m
\end{align*}
\]

(This computation is made when new data flag indicates new data. Thus \((t - \Delta t)\) refers to previous point when new data flag indicated new data.)
BOTH AN/FPS-16's

\[ R_F(t) - R_F(t - \Delta t) < \Delta R_F \]
\[ A_F(t) - A_F(t - \Delta t) < \Delta A_F \]
\[ E_F(t) - E_F(t - \Delta t) < \Delta E_F \]

\[ R_F(t) - R_{FPRED}(t - \Delta t) < \Delta R_F \]
\[ A_F(t) - A_{FPRED}(t - \Delta t) < \Delta A_F \]
\[ E_F(t) - E_{FPRED}(t - \Delta t) < \Delta E_F \]

*\( B \) is computed only for those variables, if any, that were predicted at the previous sample.

4.3 LOGIC FOR DETERMINING WHETHER SAMPLE IS GOOD OR BAD

The following table shows the logic used to determine whether the new sample is good or bad. This logic must be used in determining the status of each variable of every sample.

<table>
<thead>
<tr>
<th>The editing performed under A where</th>
<th>The editing performed under B where</th>
<th>Is the variable good or bad</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 = good</td>
<td>0 = good</td>
<td>good</td>
</tr>
<tr>
<td>1 = bad</td>
<td>1 = bad</td>
<td>bad</td>
</tr>
</tbody>
</table>

* This editing is not performed because a lockout occurred on the previous sample and the previous raw data is not reliable.

** This editing is not performed because the variable was not predicted at the previous sample.

If the variable is bad, a predicted variable must be used from the equation given previously under "PREDICTION."

Land-Air, Inc.
Two additional checks on Cotar data must be made to assist in determining whether or not the Cotar data is acceptable.

One check is defined by the inequality
\[ \cos^2 \alpha + \cos^2 \beta > 1. \]

If the above inequality is satisfied, the Cotar data is bad but no predictions are made for the direction cosines.

The other check, which is computed only when either the MTR or Free AN/FPS-16 has good data, is defined by the following inequality.

If
\[ \sqrt{\Delta x^2 + \Delta y^2} > \Delta P, \]

the Cotar/FPS-16 system is bad;

where
\[ \Delta x = X_{\text{Cotar}/16} - X_{\text{MTR}}, \]
\[ \Delta y = Y_{\text{Cotar}/16} - Y_{\text{MTR}} \quad \text{only if MTR is good and beacon is good for MTR} \]

and
\[ \Delta P = 0.022 R_{\text{FPS-16}} \quad \text{for} \quad 0 < R_{\text{FPS-16}} < R_1 \]
\[ = 0.022 R_1 \quad \text{for} \quad R_1 < R_{\text{FPS-16}} < R_9 \]
\[ = 0.022 R_1 + K_P (R_{\text{FPS-16}} - R_9) \quad \text{for} \quad R_9 < R_{\text{FPS-16}} \]

where
\[ R_1 = 80,000 \text{ feet} \]
\[ R_9 = 300,000 \text{ feet}. \]

When the above inequality is not satisfied, data is flagged bad, but we do not predict new variables.
4.4 **TIME COMPUTATION**

Time from lift off is computed using the equation:

\[ t_{CL} = (R_t - R_{t_{LO}}) + t_0 \]

where

- \( t_{CL} = \text{Time from lift off} \)
- \( R_t = \text{Current Range Time} \)
- \( R_{t_{LO}} = \text{Range time at lift off} \)
- \( t_0 = .031 \text{ seconds} \)
SMOOTHING AND DIFFERENTIATION

For smoothing and differentiation of position data \( (R, A, E, \cos \alpha, \cos \beta) \) which must be done for each system, the value for \( R_i \) is chosen as being typical of the computations to be made on all variables. Moreover, in each case the coefficient that is subscripted 0 multiplies the most recent data point. In those cases where the data point was replaced by a predicted value, the predicted variable should be used in the differentiation.

5.1 THE POLYNOMIAL FILTER USED FOR COTAR AND AN/FPS-16's

\[ R = \sum_{i=0}^{n} a_i R_i \]

where

\[ n = 10 \]

Values for the coefficient \( a_i \) for the above polynomial filters are:

FOR \( \cos \alpha \) AND \( \cos \beta \)

\[
\begin{align*}
a_0 &= 5.7628307 \\
a_1 &= 1.1806834 \\
a_2 &= -0.8847345 \\
a_3 &= 1.5672828 \\
a_4 &= -1.6260023 \\
a_5 &= -1.5259270 \\
a_6 &= -1.4816031 \\
a_7 &= -1.4683728 \\
a_8 &= -1.2021071 \\
a_9 &= -0.85410835 \\
a_{10} &= 2.8966360
\end{align*}
\]

FOR BOTH FPS-16's

\[
\begin{align*}
\text{RANGE} & \quad a_0 = 7.9725221 \\
& \quad a_1 = -1.6765070 \\
& \quad a_2 = -1.4739212 \\
& \quad a_3 = -1.3094937 \\
& \quad a_4 = -1.1859405 \\
& \quad a_5 = -1.1054617 \\
& \quad a_6 = -1.0697722 \\
& \quad a_7 = -1.0801248 \\
& \quad a_8 = -1.1373278 \\
& \quad a_9 = -1.2417558 \\
& \quad a_{10} = 3.3077836
\end{align*}
\]

\[
\begin{align*}
\text{AZIMUTH} & \quad a_0 = 7.3318873 \\
& \quad a_1 = -1.1507921 \\
& \quad a_2 = -1.1507921 \\
& \quad a_3 = -1.2209142 \\
& \quad a_4 = -1.2460577 \\
& \quad a_5 = -1.2262227 \\
& \quad a_6 = -1.2460577 \\
& \quad a_7 = -1.2262227 \\
& \quad a_8 = -1.2460577 \\
& \quad a_9 = -1.2460577 \\
& \quad a_{10} = 3.4827484
\end{align*}
\]
5.2 THE POLYNOMIAL FILTER USED FOR THE MTR

\[ R = \sum_{i=0}^{n} N_i R_i \]

where

\( n = 4 \).

**RANGE**

\( N_0 = 8.3731038 \quad N_3 = -3.9396092 \)
\( N_1 = -4.6527669 \quad N_4 = 3.9475150 \)
\( N_2 = -3.7282431 \)

**AZIMUTH**

\( N_0 = 6.2779017 \quad N_3 = -3.1389505 \)
\( N_1 = -1.5113466 \quad N_4 = 3.0226941 \)
\( N_2 = -4.6502974 \)

**ELEVATION**

\( N_0 = 6.3709325 \quad N_3 = -2.9891376 \)
\( N_1 = -1.7095003 \quad N_4 = 2.9417390 \)
\( N_2 = -4.6140394 \)
COORDINATE CONVERSION

Before the coordinate conversion can be performed, the range from the MTR must be updated using the following equation:

\[ R_m = \sum_{i=0}^{n} \alpha_i R_i \]

where

\( n = 4 \quad \alpha_0 = 1.5215871 \quad \alpha_3 = -0.13272919 \)

\( \alpha_1 = -0.3518084 \quad \alpha_4 = 0.16204728 \)

\( \alpha_2 = -0.19909648 \)

If the data point were replaced by a predicted value, the predicted value should be used in the filter. The coefficient with subscript 0 multiplies the most recent data point.

The following coordinate system will be used for coordinate conversion: a right-hand cartesian coordinate system \((X,Y,Z)\) centered at the NIKE-ZEUS launch pad, where the \(X-Y\) plane is tangent to the garth at the launch pad and the \(+X\) axis points down the launch azimuth, \((218.5^\circ T)\) and \(Z\) is normal to earth's surface at the launch pad. The equations used for coordinate conversion depend on the system being used.

Position data \((X,Y,Z)\) and velocity data \((X,Y,Z,\text{velocity})\) must be computed twenty times per second for each of the systems A, C and D, and must be computed on new data samples for system B.

The following equations are used in coordinate transformation:

\[
X_p = (X_i \cos \theta - Y_i \sin \theta) - X_T \\
Y_p = (X_i \sin \theta + Y_i \cos \theta) - Y_T
\]

where

\( X_i = X \) element of position measured tangent at the tracking instrument where \(+X\) is due east

\( Y_i = Y \) element of space position tangent at instrument with \(+Y\) pointing true north
\[
\sin \theta = \text{sine of launch azimuth measured from true north} \\
\cos \theta = \text{cosine of launch azimuth measured from true north}
\]

\[
X_T = X \text{ element of position of instrument measured in pad coordinate system with } +X = 218.5^\circ T
\]

\[
Y_T = Y \text{ element of position of instrument measured in pad coordinate system with } +Y = 128.5^\circ T.
\]
EDITING OF COMPUTED VALUES

The editing of computed values is good only if the following inequalities are satisfied. The computed velocities from each system must be edited using the following inequality:

\[ V(t) - V(t - \Delta t) < \Delta V \]

where

\[ \Delta V = C + C_1 R \]

and where \( C \) and \( C_1 \) are constants and \( R \) is range.

In addition, velocities of each good system must be compared using the following inequalities:

\[ V_A - V_B < \Delta V_{AB} \]
\[ V_A - V_D < \Delta V_{AD} \]
\[ V_B - V_C < \Delta V_{BC} \]
\[ V_B - V_D < \Delta V_{BD} \]
\[ V_C - V_D < \Delta V_{CD} \]

where

\[ A = \text{FPS-16/Cotar system} \]
\[ B = \text{MTR system} \]
\[ C = \text{Released FPS-16 system} \]
\[ D = \text{Free FPS-16 system} \]

all \( \Delta V \)'s are of the form:

\[ \Delta V = K + K_1 R \]

where \( K \) and \( K_1 \) are constants and \( R \) is range of high order system.

To help determine whether the FPS-16 radars (released and free) are tracking the booster or sustainer, \( V_R < V_{\text{min}} \) must be satisfied. Where \( V_{\text{min}} = 3500 \) feet per second.
The logic for determining which systems have good data is discussed in this section.

8.1 LOGIC USED FOR COTAR/FPS-16 SYSTEM

The items considered in determining whether or not the data from this system are good are as follows: (1) the parity bits and ontarget from Cotar and FPS-16; (2) an edit of raw data \( C_1 \), \( C_2 \), and \( R_F \); (3) an edit of missile velocity.

The following table describes the logic for determining whether system A has good data:

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<th>COTAR</th>
<th>COTAR</th>
<th>FPS-16</th>
<th>FPS-16</th>
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where

\( 0 = \) good

\( 1 = \) bad

\( \Ø = \) good or bad

8.2 LOGIC USED FOR MTR

The items considered in the MTR system are (1) parity bit; (2) an edit of raw data; (3) an edit of velocity; (4) check on time since last new data sample; (5) has coast been exceeded.

The following table describes the logic used in determining whether the MTR data is good or bad.
8.3 LOGIC FOR RELEASED FPS-16

The items considered in the released FPS-16 system are (1) check of time from liftoff; (2) Cotar quality bit; (3) parity bit; (4) on-target bit; (5) edit of raw data; (6) missile velocity; (7) check of \( V \) vs \( V_{\text{min}} \).

The following table describes the logic considered in determining whether system C is good or bad.

8.4 LOGIC FOR FREE FPS-16

The items considered for the free FPS-16 system D are (1) parity; (2) on-target bit; (3) edit of raw data; (4) edit of velocity; (5) \( V > V_{\text{min}} \).

The following table describes the logic in determining whether system D is good or bad.
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<th>PARITY</th>
<th>ONTARGET</th>
<th>EDIT R</th>
<th>EDIT A</th>
<th>EDIT E</th>
<th>EDIT V</th>
<th>V &gt; V_{min}</th>
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Land-Air, Inc.
Once the status of the data from the four tracking systems has been established, the following logic is used to determine which of the four systems should be used for display outputs and destruct computations.

Information needed for this decision are as follows:

1. Is System A good?
2. Is System B good?
3. Is System C good?
4. Is System D good?
5. Which intersystem velocity comparisons are good?
6. Which system was chosen for previous sample?
7. Is the beacon-working signal good?

In the following table used for the logic in selecting the system, the nomenclature below is used.

A = COTAR/FPS-16
B = MTR
C = RELEASED FPS-16
D = FREE TRACK FPS-16
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Land-Air, Inc.
### VELOCITY COMPARISONS

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where 0 - good 1 - bad Ø - either good or bad.

where the item is left blank - not computed.
Instantaneous impact point (IIP) is defined as the predicted point of impact of the missile parts if the missile were destroyed at the instant.

10.1 IIP EQUATION

The IIP of only the heaviest expected part \( \frac{w}{C_D^0} = 165 \text{ lb/ft}^2 \) will be computed. The impact point of this part is given as follows:

\[
X_i = r \cos \beta + X \\
Y_i = r \sin \beta + Y
\]

where \( \beta = \tan^{-1} \frac{Y'}{X'} \)

The value \( r \) (range to impact) is stored in the computer as a function of velocity, missile heading angle and height above launch pad \( Z \). The least significant bit of \( r \) is equal to 500 feet, therefore carry range can only be accurate to \( \pm 500 \) feet.

10.2 VELOCITY AND HEADING ANGLE EQUATIONS

The equations for determining the velocity and heading angle of the missiles are:

\[
\text{Velocity} = \sqrt{\dot{X}^2 + \dot{Y}^2 + \dot{Z}^2}
\]

\[
\text{Missile heading angle} = \tan^{-1} \frac{Z'}{\sqrt{X'^2 + Y'^2}}
\]

\( Z' \) = height of the missile above the tangent plane at the launch pad.

10.3 RANGE TO IMPACT TABLE

A description of the range to impact tables follows. The table is stored as a function of \( V_1, \gamma_1, Z_1 \).

RANGE OF VARIABLES

\( V_1 \) 0 to 12,000 ft/sec

\( \gamma_1 \) -30 deg to + 90 deg

\( Z_1 \) 0 to 400,000 feet
10.4 **INTERPOLATION**

Linear interpolation is used in $\gamma_1$ and $V_1$, and parabolic interpolation in $Z_1$ to determine $r$ when initial conditions lie between stored values. When initial conditions lie outside the table of stored values, the end point of the table is used.

For interpolation from the stored tables, parabolic interpolation is used for one variable, and linear interpolation is used for two variables.

The following is an example of parabolic interpolation of $Z$:

If $Z = 13,000$ feet

$$a_Z = \frac{Z - Z_1}{H_Z}$$

$$a_Z = \frac{13,000 - 10,000}{10,000} = 0.3$$

$Z_0 = 0; Z_1 = 10,000; Z_2 = 20,000; Z_3 = 30,000$

$H_Z = 10,000$

Steps:
1) test $a_Z$ if $a_Z \leq 0.5$, use $Z_0, Z_1, Z_2$
   if $a_Z > 0.5$, use $Z_1, Z_2, Z_3$

2) determine appropriate values of $R_{V_1\gamma_1Z_0}, R_{V_1\gamma_1Z_1}, R_{V_1\gamma_1Z_2}$ from tables for example:
3) perform linear interpolation of one variable:

example: \( R_{\gamma_1 Z_0} = R_{\gamma_1 Z_0} + a_\gamma (R_{\gamma_2 Z_0} - R_{\gamma_1 Z_0}) \)
determine \( R_{\gamma_1 Z_0} \)

4) perform second linear interpolation:

example: \( R_{\gamma_2 Z_0} = R_{\gamma_2 Z_0} + a_\theta (R_{\gamma_2 Z_0} - R_{\gamma_1 Z_0}) \)
determine \( R_{\gamma_2 Z_0} \)

5) perform parabolic interpolation to determine carry range to impact:

example: \( R_{\gamma Z} = R_{\gamma Z_1} + a_Z (R_{\gamma Z_2} - R_{\gamma Z_1}) + \frac{(a_Z)(1 - a_Z)}{2} \left[ R_{\gamma Z_3} - 2 R_{\gamma Z_2} + R_{\gamma Z_1} \right] \)

Note: if \( a_Z \geq .5 \) and consequently \( Z_3 \) was used, formula for parabolic interpolation changes to the following:

\[ R_{\gamma Z} = R_{\gamma Z_3} + a_Z (R_{\gamma Z_4} - R_{\gamma Z_3}) + \frac{(a_Z)(1 - a_Z)}{2} \left[ R_{\gamma Z_1} - 2 R_{\gamma Z_2} + R_{\gamma Z_3} \right] \]

10.5 EQUATIONS FOR COMPUTING RANGE TO IMPACT USING TABLE

The following are the equations used for computing range to impact using table.

Problem: Find \( R_i = f(Z,V,\theta) \) from a table of \( R \) at even intervals of \( Z,V,\theta \) with linear interpolation of the variables \( V,\theta \) and parabolic interpolation of \( Z \).

The tabular values are

\[ Z; \ 10,000 \text{ ft} = H_Z \]
\[ V; \ 2,000 \text{ ft/sec} = H_V \]
\[ \theta; \ 5^\circ = H_\theta \]

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\[ a_\theta = \frac{\theta - \theta_1}{H_\theta}, \quad a_V = \frac{V - V_1}{H_V}, \quad a_Z = \frac{Z - Z_1}{H_Z} \]

if \( a_z \leq .5 \) use example 1
if \( a_z > .5 \) use example 2

Example 1. find \( f(Z,V,\theta) \) where \( Z_1 < Z < Z_2 \)
\[ V_1 < V < V_2 \]
\[ \theta_1 < \theta < \theta_2 \]

From the table get the following values if \( R_{i,j,k} = f(Z_i,V_j,\theta_k) \)
\[
\begin{align*}
R_{1,1,1} & \quad R_{2,1,1} & \quad R_{3,1,1} \\
R_{1,1,2} & \quad R_{2,1,2} & \quad R_{3,1,2} \\
R_{1,2,1} & \quad R_{2,2,1} & \quad R_{3,2,1} \\
R_{1,2,2} & \quad R_{2,2,2} & \quad R_{3,2,2}
\end{align*}
\]

Compute with linear interpolation
\[
\begin{align*}
S_{1,1} &= R_{111} + a_\theta (R_{112} - R_{111}) \\
S_{1,2} &= R_{121} + a_\theta (R_{122} - R_{121}) \\
S_{2,1} &= R_{211} + a_\theta (R_{212} - R_{211}) \\
S_{2,2} &= R_{221} + a_\theta (R_{222} - R_{221}) \\
S_{1} &= S_{11} + a_V (S_{12} - S_{11}) \\
S_{2} &= S_{21} + a_V (S_{22} - S_{21}) \\
S_{3} &= S_{31} + a_V (S_{32} - S_{31})
\end{align*}
\]
and \( S_1 = S_{11} + a_V (S_{12} - S_{11}) \)
\( S_2 = S_{21} + a_V (S_{22} - S_{21}) \)
\( S_3 = S_{31} + a_V (S_{32} - S_{31}) \)

Compute with parabolic interpolation
\[
R_1 = S_1 + a_Z (S_2 - S_1) + \frac{a_Z (a_Z - 1)}{2} (S_1 - 2S_2 + S_3)
\]

Example 2: If \( a_z > .5 \) use the following values
\[
\begin{align*}
R_{0,1,1} & \quad R_{0,2,1} & \quad R_{1,1,1} & \quad R_{1,2,1} & \quad R_{2,1,1} & \quad R_{2,2,1} \\
R_{0,1,2} & \quad R_{0,2,2} & \quad R_{1,1,2} & \quad R_{1,2,2} & \quad R_{2,1,2} & \quad R_{2,2,2}
\end{align*}
\]
\[ S_{01} = R_{01} + a_0 (R_{012} - R_{011}) \]
\[ S_{11} = R_{11} + a_0 (R_{112} - R_{111}) \]
\[ S_{02} = R_{02} + a_0 (R_{022} - R_{021}) \]
\[ S_{21} = R_{21} + a_0 (R_{212} - R_{211}) \]
\[ S_{12} = R_{12} + a_0 (R_{122} - R_{121}) \]

\[ S_0 = S_{01} + a_v (S_{02} - S_{01}) \]
\[ S_1 = S_{11} + a_v (S_{12} - S_{11}) \]
\[ S_2 = S_{21} + a_v (S_{22} - S_{21}) \]

\[ \text{change } a_Z = \frac{Z - Z_1}{H_Z} \]
\[ \text{to } a_Z = \frac{Z - Z_2}{H_Z} \]
\[ R_1 = S_2 + a_Z (S_2 - S_1) + \frac{a_Z (a_Z + 1)}{2} \left( S_0 - 2S_1 + S_2 \right) \]
DESTRUCT COMPUTATIONS AND LOGIC

The following items are necessary for making destruct decisions regardless of which system is used.

(1) If, during the time interval defined by $5.2 < t < 16$ seconds, $\dot{X}$ computed by using data from the selected system falls below prescribed minimum, $\dot{X}_{\min}$ destruct should be commanded on this sample, i.e.:

$$\dot{X} < \dot{X}_{\min} \quad \text{command destruct}$$

$\dot{X}_{\min}$ is an increasing ramp computed from missile position and time liftoff.

(2) If, during the interval between 5.2 seconds after liftoff and the time when $X$, the present position of the missile, reaches 300,000 feet down range, the predicted impact point lies outside of the imposed range safety boundaries, the signal for destruct is sent immediately.

11.1 MAXIMUM ALLOWABLE COAST
Maximum allowable coast time is a function of $C_{\min}$ no data time. On the sample where MTR coast occurs, $C_{\min}$ begins counting down to zero. Therefore, the maximum coast time is the amount of no data time computed when coast is initiated.

11.2 NECESSARY INPUTS FOR COMMAND DESTRUCT

$X$, $Y$, $Z$

$\dot{X}$, $\dot{Y}$, $\dot{Z}$

$$\cos \beta = X \sqrt{\dot{X}^2 + \dot{Y}^2}$$

$t_{CL}$ = time from liftoff

$X$ = impact point

$R_C$ = carry range
11.3 STEPS IN THE AUTOMATIC DESTRUCT PROGRAM

1. Is data good?
   Yes → 2
   No → 62

2. Is system A good?
   Yes - use "a" constants → 4
   No → 3

3. Is MTR good?
   Yes - use "b" constants → 4
   No - use "c" constants → 4

4. Is $t_{CL} < K_1$?
   Yes → 67
   No → 5

5. Is $t_{CL} < K_2$?
   Yes → 6
   No - store $C_{D1} = C_{D2} = K_{10} → 16$

6. Compute $X_D = K_3 + K_4 Z$

7. Is $X < X_D$?
   Yes → 65
   No → 8
   $\frac{(z\dot{x} - \dot{z} X_D) + [(z\dot{x} - \dot{z} X_D)^2 + 2z^2(X - X_D)K_5]}{ZK_5}$

8. Compute $C_1 = \frac{(z\dot{x} - \dot{z} X_D) + [(z\dot{x} - \dot{z} X_D)^2 + 2z^2(X - X_D)K_5]}{ZK_5}^{\frac{1}{2}}$

9. Compute $C_{D1} = C_1 - K_{61} (C_{D1} ≤ 0)$

10. Store $C_{D1}$

11. Compute $X_D = \frac{K_{81} Z + K_{81}}{Z + K_{91}}$

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12. Is \( \dot{x} < \dot{x}_D \)?  
   Yes \rightarrow 65  
   No \rightarrow 13  

13. Compute \( C_{D2} = \frac{\dot{x} - \dot{x}_D}{K_5} \)  

14. Store \( C_{D2} \)  

15. Is \( t_{CL} < K_{11} \)?  

16. Is \( R_C < K_{12} \)?  
   Yes \rightarrow 17  
   No \rightarrow 25  

17. Compute \( tan D_{R1} = K_{39} + \frac{K_{40}}{R_C} \)  

18. Is \( Y + K_{151} \cos \beta < \dot{x} \tan D_{R1} \)?  
   Yes \rightarrow 65  
   No \rightarrow 18a  

18a. Is \( t_{CL} > K_{38} \)?  
   Yes \rightarrow 18b  
   No \rightarrow 19  

18b. Compute \( C_R = \frac{(\dot{Y} + K_{221} \cos \beta) - (\dot{x} \tan D_{R2})}{K_{23}} \)  

18c. Store \( C_R \rightarrow 21 \)  

19. Compute \( C_R = \frac{(\dot{Y} + K_{151} \cos \beta) - (\dot{x} \tan D_{R1})}{K_{1e}} \)  

20. Store \( C_R \)  

21. Compute \( tan D_{L1} = K_{41} + \frac{K_{40}}{R_C} \)  

22. Is \( Y + K_{181} \cos \beta < \dot{x} \tan D_{L1} \)?  
   Yes \rightarrow 23  
   No \rightarrow 65  

23. Compute \( C_L = \frac{(\dot{x} \tan D_{L1}) - (\dot{Y} + K_{181} \cos \beta)}{K_{1e}} \)
24. Store $C_L \rightarrow 52$

25. Is $X < K_{19}$?
   Yes $\rightarrow$ 26
   No $\rightarrow$ 34

26. Compute $\tan D_{R2} = \frac{K_{20}}{K_{21}}$

27. Is $\dot{Y} + K_{221}\cos \beta < \dot{X}\tan D_{R2}$?
   Yes $\rightarrow$ 65
   No $\rightarrow$ 28

28. Compute $C_R = \frac{(Y + K_{221}\cos \beta) - (\dot{X}\tan D_{R2})}{K_{23}}$

29. Store $C_R$

30. Compute $\tan D_{L2} = \frac{K_{41}}{R_C} + \frac{K_{42}}{R_C}$

31. Is $\dot{Y} + K_{251}\cos \beta < \dot{X}\tan D_{L2}$?
   Yes $\rightarrow$ 32
   No $\rightarrow$ 65

32. Compute $C_L = \frac{(\dot{X}\tan D_{L2}) - (Y + K_{251}\cos \beta)}{K_{23}}$

33. Store $C_L \rightarrow 52$

34. Is $X < K_{26}$?
   Yes $\rightarrow$ 35
   No $\rightarrow$ 66

35. Is $Z < K_{27}$?
   Yes $\rightarrow$ 36
   No $\rightarrow$ 44

36. Compute $\tan D_{R3} = \frac{K_{28}}{K_{29}}$
37. Is \( \dot{Y} + K_{301} \cos \beta < \dot{X}_{\text{tan}D_R} \)?  
   Yes \rightarrow 65
   No \rightarrow 38

38. Compute \( C_R = \frac{(\dot{Y} + K_{301} \cos \beta) - (\dot{X}_{\text{tan}D_R})}{K_{31}} \)

39. Store \( C_R \)

40. Compute \( \tan D_{L3} = K_{41} + \frac{K_{45}}{R_C} \)

41. Is \( \dot{Y} + K_{331} \cos \beta < \dot{X}_{\text{tan}D_L} \)?  
   Yes \rightarrow 42
   No \rightarrow 65

42. Compute \( C_L = \frac{(\dot{X}_{\text{tan}D_L}) - (\dot{Y} + K_{331} \cos \beta)}{K_{31}} \)

43. Store \( C_L \rightarrow 52 \)

44. Compute \( \tan D_{R4} = \frac{K_{29}}{K_{29}} \)

45. Is \( \dot{Y} + K_{341} \cos \beta < \dot{X}_{\text{tan}D_R} \)?  
   Yes \rightarrow 65
   No \rightarrow 46

46. Compute \( C_R = \frac{(\dot{Y} + K_{341} \cos \beta) - (\dot{X}_{\text{tan}D_R})}{K_{35}} \)

47. Store \( C_R \)

48. Compute \( \tan D_{L4} = K_{41} + \frac{K_{45}}{R_C} \)

49. Is \( \dot{Y} + K_{361} \cos \beta < \dot{X}_{\text{tan}D_L} \)?  
   Yes \rightarrow 50
   No \rightarrow 65

50. Compute \( C_L = \frac{(\dot{X}_{\text{tan}D_L}) - (\dot{Y} + K_{361} \cos \beta)}{K} \)

51. Store \( C_L \)

52. Is \( C_{D1} < C_{D2} \)  
   Yes \rightarrow 53
   No \rightarrow 55

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53. Is $C_{D1} < C_{R}$?
   Yes $\rightarrow$ 54
   No $\rightarrow$ 57

54. Is $C_{D1} < C_{L}$?
   Yes $\rightarrow$ 58
   No $\rightarrow$ 57

55. Is $C_{D2} < C_{R}$?
   Yes $\rightarrow$ 56
   No $\rightarrow$ 57

56. Is $C_{D2} < C_{L}$?
   Yes $\rightarrow$ 59
   No $\rightarrow$ 61

57. Is $C_{R} < C_{L}$?
   Yes $\rightarrow$ 60
   No $\rightarrow$ 61

58. Store $C_{D1} = C_{min} \rightarrow$ 64
59. Store $C_{D2} = C_{min} \rightarrow$ 64
60. Store $C_{R} = C_{min} \rightarrow$ 64
61. Store $C_{L} = C_{min} \rightarrow$ 64
62. Compute $C_{min}^{(new)} = C_{min} - K_{37}$
63. Is $C_{min}^{(new)} < 0$
   Yes $\rightarrow$ 64
   No $\rightarrow$ 65

64. Store $C_{min}^{(new)}$ for previous $C_{min} \rightarrow$ 67
65. Command destruct $\rightarrow$ 67

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66. Turn off automatic destruct

67. Perform Impact computations for next sample

Note: Cmin is defined as maximum allowable no data time.

11.4 DEFINITION OF CONSTANTS

\[
\begin{align*}
K_1 &= 5.2 \text{ seconds} & K_2 &= 20 \text{ seconds} \\
K_3 &= -850 \text{ feet} & K_4 &= 0.32426 \\
K_5 &= 710 \text{ feet/} \sec^2 \\
K_{6a} &= 1.2778 & K_{6b} &= 1.5593 \\
K_{7a} &= 1165 & K_{7b} &= 1205 \\
K_{8a} &= 12.135 \times 10^6 & K_{8b} &= 8.87 \times 10^6 \\
K_{9a} &= 19000 & K_{9b} &= 14000 \\
K_{10} &= 10 \text{ seconds} & K_{11} &= 6.5 \text{ seconds} \\
K_{12} &= -71150 \text{ feet} & K_{14} &= 74500 \text{ feet} \\
K_{15a} &= -805 & K_{15b} &= -933 \\
K_{16} &= 633 \text{ ft/} \sec^2 & K_{17} &= 71150 \text{ feet} \\
K_{18a} &= 805 & K_{18b} &= 933 \\
K_{19} &= 35000 \text{ feet} & K_{20} &= -103450 \text{ feet} \\
K_{22a} &= -865 & K_{22b} &= -940 \\
K_{23} &= 678 \text{ ft/} \sec & K_{24} &= 131900 \text{ feet} \\
K_{25a} &= 865 & K_{25b} &= 940 \\
K_{26} &= 300000 \text{ feet} & K_{27} &= 100000 \text{ feet} \\
K_{28} &= 256000 \text{ feet} \\
K_{30a} &= -902 & K_{30b} &= -1010 \\
K_{31} &= 710 \text{ ft/} \sec & K_{32} &= 202000 \text{ feet} \\
K_{6c} &= 1.7638 \text{ (sec)} & K_{7c} &= 1305 \text{ (ft/} \sec\text{)} \\
K_{8c} &= 4.995 \times 10^6 \text{ (ft}^2/\text{sec)} & K_{9c} &= 9000 \text{ feet} \\
K_{15c} &= -905 \text{ (ft/} \sec\text{)} & K_{21} &= 158700 \text{ feet} \\
K_{18c} &= -905 \text{ (ft/} \sec\text{)} & K_{22c} &= -963 \text{ (ft/} \sec\text{)} \\
K_{25c} &= 963 \text{ (ft/} \sec\text{)} & K_{28c} &= -177800 \text{ feet} \\
K_{30c} &= -1000 \text{ (ft/} \sec\text{)} & \\
\end{align*}
\]
\[ k_{33a} = 902 \quad k_{33b} = 1010 \quad k_{33c} = 1000 \text{ (ft/sec)} \]

\[ k_{34a} = -570 \quad k_{34b} = -640 \quad k_{34c} = -670 \]

\[ k_{35} = 450 \text{ ft/sec}^2 \]

\[ k_{36a} = 570 \quad k_{36b} = 640 \quad k_{36c} = 670 \text{ (ft/sec)} \]

\[ k_{37} = .05 \text{ seconds} \quad k_{38} = 9.5 \text{ seconds} \quad k_{39} = -1.11 \]

\[ k_{40} = -5000 \text{ feet} \quad k_{41} = .71 \quad k_{42} = 20000 \text{ feet} \]
The following are outputs from the computer:

A. Plot board displays


Note: X is measured positive along the launch azimuth (218.5°T), and Y is measured positive at 128.5°T.

B. Missile destruct control (destruct signal required)

The destruct signal must be compatible with the digital-to-analog converter. A signal is sent for both destruct commands and do not destruct commands.

C. Data quality lights

The following two-level outputs must be provided for quality light control:

1. Indication of good or bad data from the PMR systems. A, C, or D.
2. Indication of good or bad data from system B, the MTR system.

D. History tape

The following information is recorded, in real time, to make a launch history tape for postflight reduction and future launch simulation.
Words 1-30 - Raw Input Tracking Data

31 - Liftoff Time
32 - Time from Liftoff
33 - PMR Range Time
34 - Clock Time
35 - Sense Switch Settings
36 - Entry Key Settings
37 - Data Indicator Word
38 - Sense Lights
39 - X System A
40 - Y System A
41 - Z System A
42 - $\dot{X}$ System A
43 - $\dot{Y}$ System A
44 - $\dot{Z}$ System A
45 - Velocity System A
46 - X System B
47 - Y System B
48 - Z System B
49 - $\dot{X}$ System B
50 - $\dot{Y}$ System B
51 - $\dot{Z}$ System B
52 - Velocity System B
53 - X System C
54 - Y System C
55 - Z System C
56 - \( \dot{X} \) System C
57 - \( \dot{Y} \) System C
58 - \( \dot{Z} \) System C
59 - Velocity System C
60 - X System D
61 - Y System D
62 - Z System D
63 - \( \dot{X} \) System D
64 - \( \dot{Y} \) System D
65 - \( \dot{Z} \) System D
66 - Velocity System D
67 - X Impact Component
68 - Y Impact Component
69 - C1 Flag: if = 0, System A is good; \# 0, System A bad
70 - C2 Flag: if = 0, System B is good; \# 0, System B bad
71 - C3 Flag: if = 0, System C is good; \# 0, System C bad
72 - C4 Flag: if = 0, System D is good; \# 0, System D bad
73 - C5 Flag: if = 0, System A ontarget; \# 0, System A not ontarget
74 - C6 Flag: if = 0, System B ontarget; \# 0, System B not ontarget
75 - C7 Flag: if = 0, System C ontarget; \# 0, System C not ontarget
76 - C8 Flag: if = 0, System D ontarget; \# 0, System D not ontarget
77 - C9 Flag: \( \Delta \) Vel System A; \# 0, bad; = 0, good

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78 - C10 Flag: \( \Delta \) Vel System B; \( \neq 0 \), bad \( = 0 \), good

79 - C11 Flag: \( \Delta \) Vel System C; \( \neq 0 \), bad \( = 0 \), good

80 - C12 Flag: \( \Delta \) Vel System D; \( \neq 0 \), bad \( = 0 \), good

81 - C13 Flag: \( = 0 \), beacon good; \( \neq 0 \), beacon bad

82 - C14 Flag: Intersystem Vel Comparison AB; \( = 0 \), good; \( \neq 0 \), bad

83 - C15 Flag: Intersystem Vel Comparison AD; \( = 0 \), good; \( \neq 0 \), bad

84 - C16 Flag: Intersystem Vel Comparison BC; \( = 0 \), good; \( \neq 0 \), bad

85 - C17 Flag: Intersystem Vel Comparison BD; \( = 0 \), good; \( \neq 0 \), bad

86 - C18 Flag: Intersystem Vel Comparison CD; \( = 0 \), good; \( \neq 0 \), bad

87 - C19 Flag: Previous System Switch Switch; \( 0 \) = System A, \( 1 \) = System B, \( 2 \) = System C, \( 3 \) = System D

88 - C20 Flag: Interprogram

89 - C21 Flag: Interprogram

90 - C22 Flag: X test; \( 0 \) = good, non-zero = bad

91 - C23 Flag: +Y Boundary; \( 0 \) = good; \( \neq 0 \), bad

92 - C24 Flag: -Y Boundary; \( 0 \) = good; \( \neq 0 \), bad

93 - C25 Flag: Overall Data Quality; \( = 0 \), good; \( \neq 0 \), bad

94 - C26 Flag: Has liftoff occurred; \( = 0 \), yes; \( \neq 0 \), no

95 - C27 Flag: Lockout indicator; has lockout occurred; \( = 0 \), no; \( \neq 0 \), yes

96 - C28 Flag: New data MTR; \( = 0 \), yes; \( \neq 0 \), no

97 - C29 Flag: Position check; \( = 0 \), good; \( \neq 0 \), bad

98 - C31 Flag: Interprogram switch

99 - C32 Flag: Interprogram switch

100 - \( \dot{\dot{x}} \) vs \( \dot{z} \) converter output setting

101 - \( \dot{\dot{x}} \) vs \( \dot{y} \) converter output setting
102 - X vs. Z converter output setting
103 - X vs. Y converter output setting
104 - $X_{imp}$ vs. $Y_{imp}$ converter output setting long range
105 - $X_{imp}$ vs. $Y_{imp}$ converter output setting short range
106 - Time vs. Liftoff converter output setting
107 - Destruct Word converter output setting
108 - Gamma Angle PMR System
109 - Beta Angle PMR System
110 - Gamma Angle MTR System
111 - Beta Angle MTR System
112 - Type Destruct
113 - Indicator data word
114 - Cosine Alpha from Cotar
115 - Cosine Beta from Cotar
116 - Cosine Gamma from Cotar
117 - $C_{min}$: maximum no data time
118 - $X_D$: X position roof component
13.1 ENTRY KEY SELECTION FOR FPS-16 SYSTEM SELECTION

KEYS 1 - 2 - 3 - 4 - 5 (KEYS DOWN)

<table>
<thead>
<tr>
<th>RADAR ID</th>
<th>DMS CHANNEL 1</th>
<th>DMS CHANNEL 4</th>
<th>DMS CHANNEL 5</th>
<th>DMS CHANNEL 6</th>
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<tr>
<td>003001</td>
<td>None</td>
<td>3</td>
<td>2</td>
<td>2,3</td>
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<td>2,4,5</td>
<td>2,3,4,5</td>
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</table>

KEYS 7 - 8 - 9 - 10 - 11 (KEYS DOWN)

<table>
<thead>
<tr>
<th>RADAR ID</th>
<th>DMS CHANNEL 1</th>
<th>DMS CHANNEL 4</th>
<th>DMS CHANNEL 5</th>
<th>DMS CHANNEL 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>003001</td>
<td>None</td>
<td>9</td>
<td>8</td>
<td>8,9</td>
</tr>
<tr>
<td>003002</td>
<td>11</td>
<td>9,11</td>
<td>8,11</td>
<td>8,9,11</td>
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<td>003003</td>
<td>10</td>
<td>9,10</td>
<td>8,10</td>
<td>8,9,10</td>
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<td>003004</td>
<td>10,11</td>
<td>9,10,11</td>
<td>8,10,11</td>
<td>8,9,10,11</td>
</tr>
</tbody>
</table>

13.2 SENSE SWITCH SELECTION

PROGRAM I = Main program operating in real time

PROGRAM II = Communication program for auxiliary programs for pre-flight and postflight

PROGRAM III = Region for equipment checkout

PROGRAM I

SENSE SWITCHES  1  2  3  4  5  6  7  8  9

UP SIMULATE NO RECORD FROM TAPE PLOT

DOWN TERMINATE EXIT NO FORCE FORCE FORCE
TO RECORD SYSTEM SYSTEM SYSTEM

PROG II A B D

Land-Air, Inc. 57
PROGRAM I (cont'd)

SENSE SWITCHES

10 11 12

UP

REWIND

DOWN

FORCE

SYSTEM

NO

REWIND

FORCE

PLOT

COTAR

FLIGHT

PROGRAM II

SENSE SWITCHES

7 8 10 11

UP

DOWN

EXIT

EXIT

EXIT TO

EXIT TO

TO

PRINTOUT

PROGRAM III

COMPARE

ROUTINE

PROGRAM III

SENSE SWITCHES

1 2 3 4 8 11

UP

PMR

MTR

NO

NO

EXIT

RED

RED

DESTRUCT

CLOVER

TO

LIGHT

LIGHT

TO

PROGRAM II

DOWN

PMR

MTR

DESTRUCT

PLOT

EXIT

GREEN

GREEN

COMMAND

CLOVER

TO

LIGHT

LIGHT

LEAF

PROGRAM I
During a real time operation, the first step is to select the input equipment and to read in 30 words of raw data, which is the basic block of data information from the tracking instruments. Since the tracking information enters the buffer system at the rate of 20 samples per second, the next 30 words of data will appear approximately a 20th of a second later. Therefore, all computations must be completed in this time period.

The successful transmission of data from the input system into core storage of the computer will be signaled by the input system through an end of record pulse. As soon as this pulse has been detected by the computer, the computation involving use of these 30 words begins.

As a preliminary step, the parity, ontarget, quality and data editing limits are checked. This provides information as to the quality of the incoming data. Time is converted from the raw data format in which it was input, into a suitable decimal format. The Cotar direction cosines are then converted to a usable decimal format along with the range, azimuth, and elevation from the two FPS-16's and the MTR.

If missile lift-off has occurred as shown by the lift-off indicator, a lift-off flag is set for the program. If a lockout has occurred, all raw tracker information must be predicted and the raw input data is ignored.

After converting raw data to a usable decimal format, the Cotar cosines are edited. If the sum of the squares of cosine alpha and cosine beta is greater than 1, Cotar data is flagged bad, and therefore the Cotar cosines will not be predicted; thus System A is flagged bad. Next, if the cosines have passed the previously mentioned test, the range from the Cotar to the missile is computed. The cosine information from the Cotar and the range, azimuth and elevation from all radars are then fed into the differentiator, which computes the components required for velocity computations for systems A, B, C, D. The present position and velocity components are then computed for all systems.

The next steps are essential to the logic, involving the decision to destroy or not to destroy. All flags pertaining to this phase have been set in the main program; these flags are based on data quality, editing limits, and velocity limits imposed in the program.

The changes in velocities are checked next. If the change in velocity \( \Delta V \) (for any particular system, A, B, C, or D) between the current velocity \( V_c \) and the previous velocity \( V_p \) exceeds the normal change in velocity \( \Delta V \) for \( V_c \) the current position of the missile, the current velocity \( V_c \) is flagged bad for that particular system. This relationship may be expressed by the inequality below:

Land-Air, Inc.
If

\[ \Delta V_{cp} < \Delta V_n \]

where

\[ \Delta V_{cp} = V_c - V_p \]

then \( V_c \) is flagged bad.

The logic for determining the system to be used for destruct also includes an intersystem velocity comparison. If System A is good, then System C is automatically flagged good, and no intersystem velocity comparison is made for Systems A and C. Therefore, we have intersystem velocity comparisons with A and B, A and D, B and C, B and D, and C and D. If all systems are flagged bad, then the system used for the previous sample will be used for destruct logic.

When the program has finally determined which system is to be used for destruct logic, the position data from that system is used to compute instantaneous impact point.

After all computations have been made of the missile position, velocity, and impact point, the decision is made whether the missile should be destroyed. Then, all outputs are sent from the computer to the plot boards and to data quality lights; and a "destruct" or "do not destruct" command is sent to the Target Intercept Computer (TIC). All raw and computed information is then recorded on a flight history tape and the program recycles, returning to the beginning for another data sample.
GLOSSARY

A = azimuth

a, a_1, a_0, etc. = coefficients

C = constant

C_1 = constant other than C

C_1 = Cotar cosine α

C_2 = Cotar cosine β

C_{min} = maximum allowable no data time

E = elevation

fb = Cotar base frequency

K = constant

K_1 = constant other than K

K_0 = coefficient

K_c = frequency correction

K_r = Cotar operating frequency

R = range

R_c = carry range

R_t = current range time

R_{tLO} = range time at lift off

t = time

t_{CL} = time from lift off

Δt = increment of time

(t - Δt) = time of previous point

V = velocity
ΔV = change in velocity

VA = velocity determined from System A

VB = velocity determined from System B

VC = velocity determined from System C

VD = velocity determined from System D

Vmin = prescribed minimum velocity

X = X-coordinate

(Ẋ, Ẏ, Ẇ) = velocity data

Xₜ = X element of position measured tangent at tracking instrument when +X is due east

Xₜ = X element of position of instrument measured in pad coordinate system with +X = 218.5°T

Ẋ = velocity component along X-axis

Y = Y-coordinate

Ŷ = velocity component along Y-axis

Yₜ = Y element of space position tangent at instrument with +Y pointing true north

Yₜ = Y element of position of instrument measured in pad coordinate system with +Y = 128.5°T

Z = Z-coordinate

Z' = height of missile above tangent plane at launch pad

Ž = velocity component along Z-axis

α, β, γ = direction angles

α₁, α₂, α₃ etc. = coefficients

θ = azimuth (from true north)

φ = elevation (from true north)

ω = frequency correction
Subscripts:

A = System A = Cotar/FPS-16
B = System B = MTR
C = System C = Released FPS-16
D = System D = Free FPS-16

PRED = Predicted
M = MTR
F = FPS-16
T = true
t = time
LO = lift off
<table>
<thead>
<tr>
<th>AD-</th>
<th>Div 15</th>
<th>UNCLASSIFIED</th>
</tr>
</thead>
</table>
2. Programming  
3. Mathematical Computer Control Systems  
4. Radar Ranging Systems  
1. Richman, T. and R. Holguin, auth.;  
II. Wakai, T. ed.  
III. Pacific Missile Range  
IV. Contract N-123 (61756) 19425A/PFR |
AD-computation and impact prediction is based on data quality as determined by comparing the rates of change in position and velocity differences with predicted standards. This choice is also influenced by the ranking of the input systems that is based on their respective inherent reliabilities.

The computer output consists of predicted missile impact location, present position, velocity, acceleration displayed at a remote location. The same output and also all raw input data are recorded on tape for postflight usage.