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National Uranium Resource Evaluation

GEOPHYSICAL FLIGHT LINE FLYING AND FLIGHT PATH RECOVERY UTILIZING THE LITTON LTN-76 INERTIAL NAVIGATION SYSTEM

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PREPARED FOR:

HIGH LIFE HELICOPTER, INC.

Puyallup, Washington

November 1981

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
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Grand Junction Area Office, Colorado

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Flight Path Recovery Utilizing the
Litton LTN-76 Inertial Navigation System

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SALT LAKE CITY, UTAH

TABLE OF CONTENTS

Geophysical Line Flying Utilizing the Litton LTN-76 Inertial Navigation System	Volume I
Procedures Manual for the Litton LTN-76 Inertial Navigation System	Volume II
INS Program Documentation	Volume III
INSI and I-64 General Description and Technical Manual	Volume IV
Detailed Installation Manual for an Inertial Navigation System as Installed in a Llama Helicopter	Volume V

GEOPHYSICAL LINE FLYING

by: APPLIED GEOPHYSICS, INC.

VOLUME I

Geophysical Line Flying Utilizing the
Litton LTN-76 Inertial Navigation
System

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TABLE OF CONTENTS

	<u>PAGE</u>
1. INTRODUCTION	-3
1.1 History of Use	-3
1.2 Preliminary Research and Development	-4
2. METHODOLOGY OF INS TESTS	-4
2.1 Camarillo, California Tests	-4
2.2 Bakersfield, California, and Beaver, Utah, Tests	-6
3. RESULTS OF TESTS	-6
3.1 Camarillo Test	-6
3.2 Bakersfield and Beaver Tests	-8
3.2.1 Deviation of Actual Flight Path from Programmed Flight Path	-9
3.2.2 Comparison of the INS Flight Path and Precise Flight Path	-9
4. DATA PROCESSING	-17
5. CONCLUSIONS AND RECOMMENDATIONS	-17
6. ACKNOWLEDGMENTS	-18

LIST OF ILLUSTRATIONS

		<u>PAGE</u>
Figure 2-1	Location Map of Camarillo INS	
	Test Survey	-5
Table 2-2	Flight Line Mileage for Areas 1-6	-7
Figure 3-1	Deviation from Programmed	
	Flight Path	
	Area 1	-10
Figure 3-2	" "	-11
Figure 3-3	" "	-12
Figure 3-4	" "	-13
Figure 3-5	" "	-14
Figure 3-6	" "	-15
Table 3-7	Deviation Between INS Path and	
	Photo Point Path	-16

MAPS

(Maps are located on fiche in back pocket.)

MAP 1	Topographic Base Map of Camarillo Test Grid (1:62,500 scale)
MAP 2	Photo-Picked Flight Path; Camarillo Test Grid.
MAP 3	INS Flight Path with 20 minute Control Points.
MAP 4	NURE Reconnaissance Photo Picked Flight Path, 10-Mile Points.
MAP 5	INS Flight Path, Controlled by 10-Mile Points.
MAP 6	Comparison of Map 4 and 5. Map 4 with N & S Errors in Photo Flight Path.
MAPS 7-11	Topographic Base Maps for Areas 1-6. (1:24,000 scale)
MAPS 12-16	Photo-picked Flight Path Compared to Programmed INS Flight Path; Areas 1-6. (1:24,000 scale)
MAPS 17-21	INS Flight Path for Areas 1-6 using 10-mile Control points. (1:24,000 scale)

1. INTRODUCTION

The Litton LTN-76 Inertial Navigation System (INS) with Inertial Track Guidance System (ITGS) software is geared toward the airborne survey industry. This report is a summary of tests performed with the LTN-76 designed to fly an airborne geophysical survey as well as to recover the subsequent flight path utilizing INS derived coordinates.

1.1 History of Use

Applied Geophysics, Inc. first used INS in rugged Alaskan territory in 1974-1975 as a navigator's aid with good results. In 1978 a 36,000 line mile survey was completed in Paraguay, South America, utilizing the Litton INS to guide the pilot over largely jungle terrain. In this instance, INS guidance contributed to a much improved flight path with flight lines quite linear and line spacing very consistent.

At this point we felt a much greater benefit could be realized by recording INS positional data in the data stream along with the rest of the geophysical information. By using INS generated x, y coordinates and using occasional photo-picked points to constrain the INS data at those points, we could derive a much more accurate flight path. This flight path would not have the data distribution problems one encounters when interpolating between photo-picked points in the conventional 35 mm photo method. Furthermore, the time spent in picking photo points could be reduced drastically since the technician only needed to pick occasional absolute points to be used to constrain the INS at those points. Time saved could result in a more accurate flight path with increased turn around time for the client. This idea was subsequently presented to the U.S. Department of Energy in Grand Junction, Colorado, where it was favorably received. In September 1979 the development contract was awarded to Highlife Helicopters of Puyallup, Washington, a survey contractor for the DOE NURE program, with Applied Geophysics, Inc. as principal sub-contractor for development and implementation of the INS program.

1.2 Preliminary Research and Development

In order to record the INS output data it was necessary to design and construct an interface between the Litton LTN-76 and the Geometrics G-714 data acquisition system. The interface was constructed in October-November 1979 and was field checked in December 1979. For a detailed discussion of the interface unit, please see Volume IV of this report.

2. METHODOLOGY OF INS TESTS

The field tests were run in two segments. The first segment was flown in Camarillo, California, on January 21, 1980, on a 450 line mile survey. This was flown by Highlife Helicopters on a NURE gamma ray spectrometer and magnetics survey. The aircraft was a French Aerospatiale Lama helicopter with a 2-man crew. The second segment of tests were flown on a production survey on five (5) small areas in Bakersfield, California, and one area in Beaver, Utah. The Beaver, Utah, area was flown on November 21, 1980, and the Bakersfield, California project was flown in December 1980.

2.1 Camarillo, California, Tests

The tests at Camarillo had two main purposes. One was to operationally test the INS interface under actual field conditions and to accustom the flight crew to geophysical line flying using INS guidance. The second purpose was to acquire a data base which would be used to develop appropriate computer software to automatically plot the drift-corrected flight path of the survey. Figure 2-1 depicts the location map of the survey area. Map 1 serves as a detailed base map of the survey area at a scale of 1:62,500. Map 2 presents a detailed map of the flight lines at 1:62,500 scale. The total program included nine (9) lines, each approximately 50 miles long. The helicopter was refueled between lines 9 and 8, 7 and 6, and 5 and 4, at which time a partial alignment was made to true north and the velocity drift was zeroed out. No absolute updates were performed but cross-track updates were done visually to the survey line.

Figure 2-1

Location Map of
Camarillo INS Test Survey
High Life Helicopters Inc.
Aerial Geophysics Inc.

2.2 Bakersfield, California, and Beaver, Utah Tests

The primary focus of these tests was to determine the navigational accuracy of the Litton LTN-76 INS in performing an airborne survey. In this instance absolute updates to known points on the survey line were performed as well as accurate realignments at refueling stops. For a discussion of absolute updating and alignments, see Volume II of this report. The total line mileage obtained from these six (6) areas was 890 line miles. These are broken into individual line mileage figures in Table 2-2.

3. RESULTS OF TESTS

3.1 Camarillo Test

Map 2 shows the flight path as picked from the 35 mm spotting photography on the 1:62,500 scale U.S.G.S. 15 minute quadrangle maps. Points were picked every 1 to 2 miles with the average being 1.4 miles. This was used as the control, or the precise flight path, in order to evaluate the accuracy of the INS generated flight path. It must be kept in mind that points are subject to errors of the tip and tilt of the aircraft as well as occasional mispicks by the interpreters. Furthermore, the photo-picked flight path is only precise at the locations of the picked points and not at other points that are linearly interpolated between precise points.

Because of the drift of the INS system (detailed in Volume II), the INS x, y coordinates must be constrained at certain points to the locations indicated by the flight path photography. Map 3 shows the INS flight path constrained to the end points and center points of each flight line. The average time between constraint points is 19 minutes and average distance is 25 miles. In many areas the INS flight path is quite accurate, with errors of 200 ft. or less. On Line 9 the error reaches a maximum of 800 ft. and on Line 7 it reaches a maximum of 1000 ft. Average error is 280.9 feet between the precise flight path (Map 2) and the 20 minute constraint point INS flight path (Map 3).

TABLE 2-2

Flight Line Mileage for Areas 1-6

Area 1	Bakersfield, California	41.2 Line Miles
Area 2	Bakersfield, California	39.7 Line Miles
Area 3	Bakersfield, California	105.8 Line Miles
Area 4	Bakersfield, California	164.4 Line Miles
Area 5	Bakersfield, California	165.8 Line Miles
Area 6	Beaver, Utah	371.7 Line Miles

A qualitative evaluation can also be made of the precise 1-2 mile photo-picked path by overlaying Map 3 over Map 2. It can be seen that the linear interpolation between photo-picked points on Map 2 is not accurate but deviations occur from a straight path. Notice the deviation on the east end of Line 11 where the helicopter made a sharp turn in order to climb over a ridge of Sierra Pelona. This is exhibited by the INS flight path but not by the precise 1-2 mile photo-picked path.

Map 4 depicts a flight path using 10 mile photo-picked points conforming to present NURE specifications. Map 5 shows the INS flight path constrained to these same points. Map 5 bears a much closer resemblance to the 1-2 mile precise flight path. A comparison of Map 4 and Map 5 has been quantitized in Map 6 which serves to evaluate the accuracy of the NURE specification 10 mile photo-picked flight path. The solid line in Map 6 is the y error or crosstrack error. The dashed line is the x error or alongtrack deviation. These alongtrack errors occur because of the deviation in aircraft ground speed in areas of rugged topography and customary linear interpolation between photo-picked points. At one point in the test survey this along-track error exceeds one mile. The average crosstrack and alongtrack errors depicted by Map 6 are 270.2 ft. and 956.3 ft., respectively.

3.2 Bakersfield and Beaver Tests

The primary purpose of this set of tests was to determine the accuracy of the INS for flight path guidance on survey lines in the field.

A secondary purpose was to present an INS generated flight path using occasional photo-picked points as constraining points and compare this to the precise 1-2 mile photo-picked path.

3.2.1 Deviation of Actual Flight Path from Programmed Flight Path

Maps 12 through 16 depict the 1-2 mile photo-picked flight path (precise flight path) compared to the flight path (bold lines) that was programmed into the INS from the survey charts of the area. Areas 1 through 5 pertain to the Bakersfield grids and area 6 is the Beaver grid. Maps 7 through 11 are topographic base maps for areas 1 through 6. All scales are 1:24,000, and the nominal line spacing is one-quarter mile. Qualitative inspection shows some areas follow the theoretical flight path quite accurately while some deviations and line crossovers occur on other areas. It must be kept in mind that some deviations are caused by improper programming of the INS or operator error when updating during flight and are not necessarily due to drift of the Inertial Navigation System. Figures 3-1 through 3-6 depict histograms of the crosstrack error between the theoretical programmed flight path and the actual flight path that was flown. Average plus or minus crosstrack deviations are listed on the bottom of each histogram.

3.2.2 Comparison of INS Flight Path and Precise Flight Path

Photo-picked points were selected approximately every 10 miles to constrain the drift of the INS derived coordinates. Maps 17 through 21 show the INS flight path for areas 1 through 6. These maps can be overlaid on Maps 12-16 to see the accuracy between the 10 mile INS path and the 1-2 mile photo-picked precise path. Areas 1-5 do not show optimal accuracy of INS flight path due to an intermittent malfunction in the INS interface unit which prevented some coordinate information from being output to tape. Even with these problems the flight path from areas 1-5 is quite consistent with the precise flight path. Table 3-7 tabulates the errors between the INS path and the precise path. The drift removal was done in a linear fashion between constraining points.

CROSS TRACK DEVIATION FROM PROGRAMMED INS PATH

AREA No. 1 , BAKERSFIELD

AVERAGE ERROR : 474.2 FEET

FIGURE 3 - 1

CROSS TRACK DEVIATION FROM PROGRAMMED INS PATH

AREA No. 2 , BAKERSFIELD

AVERAGE ERROR : 200.8 FEET

FIGURE 3 - 2

CROSS TRACK DEVIATION FROM PROGRAMMED INS PATH

AREA No. 3, BAKERSFIELD

AVERAGE ERROR : 237.4 FEET

FIGURE 3 - 3

CROSS TRACK DEVIATION FROM PROGRAMMED INS PATH

AREA No. 4 , BAKERSFIELD

AVERAGE ERROR : 262.0 FEET

FIGURE 3-4

CROSS TRACK DEVIATION FROM PROGRAMMED INS PATH

AREA No. 5, BAKERSFIELD

AVERAGE ERROR : 230.7 FEET

FIGURE 3 - 5

CROSS TRACK DEVIATION FROM PROGRAMMED INS PATH

AREA No. 6 , BEAVER

AVERAGE ERROR : 296.6 FEET

FIGURE 3 - 6

Table 3-7

Deviations Between 10-mile INS Path and 1-2 Mile Photo Point Path

Area	Average Circular Error	Average East-West Error	Average North-South Error
1	354.9 feet	127.8 feet	302.9 feet
2	162.6 feet	85.6 feet	121.5 feet
3	126.0 feet	79.7 feet	82.1 feet
4	138.2 feet	84.7 feet	92.0 feet
5	228.5 feet	131.3 feet	158.5 feet
6	275.2 feet	188.5 feet	158.3 feet

Results Determined with Linear Error Correction

4. DATA PROCESSING

Since the output of the INS that is being calculated are raw, un-updated INS values, the coordinates need to be referenced to a true position. In this algorithm the coordinates of occasional photo-picked points are used to constrain the INS values to those coordinates. The drift of the INS, being a low frequency oscillation, is then removed between these constraint points utilizing either a linear or cubic spline correction. It has been found that a linear correction is more accurate when the constraining points are close together and the cubic spline when the constraining points are farther apart. Ten mile intervals, which represent approximately eight (8) minutes of flight time, between points seem to be the cut-off in our tests. The cubic spline routine is more accurate in removing drift when points are chosen as constraint points over 10 miles or eight (8) minutes of flight time apart. All the INS flight path maps and error summaries employ a linear drift correcting routine. For a discussion of data processing techniques, please see Volume III of this report.

5. CONCLUSIONS AND RECOMMENDATIONS

Several conclusions can be drawn from the INS tests conducted in Camarillo, California; Beaver, Utah; and Bakersfield, California.

The Camarillo test depicts the inaccuracy of a flight path that is recovered by strictly using photo points and linearly interpolating between them. In the ten mile photo point flight path, errors up to a mile in along track deviation were found. Flight paths using photo picked points at intervals of 1-2 miles, which would be unusual in a production environment, have also been shown to have inaccuracies in interpolated areas. The advantage of INS derived coordinates is that positional information is recorded every second, eliminating data distribution errors, especially in areas of rugged topography. In the Camarillo survey, the INS flight path, using constraining points every twenty minutes, showed an average circular error of 280.9 ft. from the precise 1-2 mile photo picked path. This computed error is probably higher than the true error because of the inadequacy of the precise 1-2 mile photo picked flight path, which is subject to data distribution errors, mispicks by interpreters, tip and tilt of the aircraft, and the use of 1:62,500 scale maps for picking, rather than airphotos.

Utilizing INS derived coordinates decreases the time needed in point picking approximately twelve fold in the instance of twenty minute photo point intervals, as in the Camarillo survey discussed above. What is most important, and difficult to quantitize, is the importance of increased turn around time for the client when recovering flight path using INS coordinates.

Our recommendations are that constraint points should be chosen no farther apart than twenty minutes of flight time in order to attain an accuracy of 280 ft. circular error from the true position. Photo points should be selected from 7.5 minute quadrangle charts, or airphotos, and only points of absolute accuracy should be selected as constraint points in order to arrive at an accurate flight path.

The Bakersfield and Beaver tests describe the accuracy of the INS when used for survey line navigation. The average crosstrack deviation from the programmed flight path in the six areas is plus or minus 275 feet. Unfortunately, maximum deviations of 1000 feet or more do occur in some areas which would invalidate a survey line and necessitate a reflight. We feel that for the most part these deviations are due to improper programming of the INS or operator error while in flight, and do not depict the drift of the INS system.

Our recommendations are that in order to navigate accurately with the INS, certain criteria must be met. Operators must be fully trained, through classes held by Litton Aero Products, for example, and have adequate flight time with the INS in order to feel comfortable with the instrument. Programming and inflight operations must be second nature to the operator in order to achieve maximum precision from the INS. Grid parameters, discussed in Volume II, should be selected carefully from 7.5 minute quadrangle charts.

Our recommendation is that the INS can be used for flight path guidance on grids with line separations of one quarter mile or greater, providing the aforementioned criteria are met.

6. ACKNOWLEDGMENTS

Applied Geophysics, Incorporated would like to thank High Life Helicopters for their patience and cooperation in the field. Samuel De Camp and Tim McDonough of Litton Aero Products are to be congratulated for their help and their close supervision throughout the field study. We would also like to thank the Department of Energy, Grand Junction, Colorado, for the opportunity to conduct these tests.

PROCEDURES MANUAL

by: APPLIED GEOPHYSICS, INC.

Volume II

Procedures Manual for the Litton
LTN-76 Inertial Navigation System

by

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TABLE OF CONTENTS

	<u>PAGE</u>
1. INTRODUCTION	-2
1.1 Scope of Manual	-2
1.1.1 Purpose	-2
1.1.2 Procedures Manual Arrangement	-2
1.2 Basic Theory of INS	-3
2. THE INERTIAL NAVIGATION SYSTEM	-3
2.1 Introduction	-3
2.2 Function Description	-6
3. PREFLIGHT OPERATIONS	-9
3.1 Setting up Flight Logs	-9
3.1.1 Maps	-9
3.1.2 Grid Overlays	-9
3.1.3 Obtaining Grid Parameters	-9
3.1.4 Selecting Absolute Update Points	-14
3.2 Input of Grid Parameters	-14
3.2.1 Alignment of the INS	-16
3.2.1 Input of Grid Parameters	-17
4. INFLIGHT OPERATIONS	-20
4.1 Travel to Survey Area	-22
4.2 Navigation while on Line	-22
4.3 Position Updating	-22
4.4 Turning to next Survey Line	-24
4.5 Travel from Survey Area to Refueling Stop	-25
5. POST FLIGHT OPERATIONS	-25
5.1 Quality Checks	-25
5.2 Short Alignment Procedure	-26
5.3 Shutdown Procedure	-27

LIST OF FIGURES AND TABLES

Figure 2-1	INU	-4
Figure 2-2	MSU	-5
Figure 2-3	CDU	-7
Figure 3-1	ITGS Startup	-10
Figure 3-2	Grid Overlay	-11
Figure 3-3	Grid Mode Variables	-12
Figure 3-4	Non Orthologonal Grid Frame	-15
Table 3-5	AUX Data Entry	-18
Table 3-6	AUX Nominal Values	-19
Table 4-1	Software Switch Assignment	-21
Figure 4-2	Deviation Meters	-23

1. Introduction

1.1 Scope of Manual

1.1.1. Purpose

The purpose of this manual is to guide the user of the Litton LTN-76 Inertial Navigation System in the procedures required to fly an airborne geophysical survey utilizing the Litton unit. The Litton Inertial Navigation System, hereafter called INS, is a selfcontained navigation system that relies on no external transmitter or radio methodology. With the powerful software package integrated into the INS a survey grid of virtually any shape or size can be negotiated by the flight team. This manual is designed to describe the software that pertains to flying a survey grid.

Routine navigation functions, such as one would encounter when guiding a transport aircraft, will not be discussed here unless they pertain to the geophysical mission, such as navigation while enroute to the survey grid. For a discussion of enroute navigation please contact Litton Aero Products for appropriate documents. Furthermore, this manual will not discuss error codes, malfunction procedures and in-depth navigation procedures. Appropriate documentation should be obtained from Litton Aero Products when questions arise that this manual does not cover.

1.1.2. Procedures Manual Arrangement

This manual is arranged into five (5) parts. The first part is the introduction which will basically outline the function of the Inertial Navigation System as it pertains to geophysical line flying. Part II will describe the hardware involved and the functions of the hardware. Part III and Part IV will outline the procedures involved in flying the survey with the INS guidance. Part III will describe the pre-flight operations of translating a given survey grid into parameters that will be accepted by the INS computer. Part IV will then explain the procedures required while inflight to the survey area and while on the survey line. Finally, Part V describes procedures to be followed during refueling and shut-down procedures after the survey mission.

1.2 Basic Theory of INS

An Inertial Navigation System derives and outputs positional and translational information completely divorced from any external reference source. The LTN-76 contains precise, computer controlled gyroscopes to maintain a horizontal reference plane. Two accelerometers are mounted upon this reference plane, one each in the x and y direction. Small changes in velocity, or accelerations, are detected by the accelerometers and transmitted to the General Purpose computer. Knowing initial present position coordinates, the computer then calculates new positional information.

Inertial Navigation Systems exhibit a phenomenon of drift analogous to a pendulum. This schuler oscillation is due to a component of the gravity vector being sensed by the x, y accelerometers at an instant when the platform is not level. Hence, false accelerations are detected by the x, y accelerometers and further incorrect torquing signals are sent to the gyroscopes causing them to precess and thus level out the platform. This sequence causes an oscillation about the level position. This oscillation is given by the schuler period and is 84 minutes in duration. Proper procedures during the survey mission will aid in minimizing these errors.

2. The Inertial Navigation System

2.1. Introduction

The Litton LTN-76 INS consists of four (4) integral units.

1. The INU, Inertial Navigation Unit (Figure 2-1) houses a 4 gimbaled gyro-stabilized platform that consists of 2 accelerometers, one each in the x, y horizontal plane. Also housed in the INU, is the c-4000 digital computer with a 32,000 word program memory capability.

2. The BU, backup battery, is used in the event of failure of aircraft power to the INS.

3. The MSU or Mode Selector Unit (Figure 2-2) is simply a selector that powers up the unit and selects the initial ALIGN mode or the navigation mode for airborne operation.

Figure 2-1

INU

TP72-02-38

MSU

Figure 2-2

4. The CDU, Control and Display Unit (Figure 2-3) is used for all programming input and all positional, attitude and translational output to the operator. The CDU has been designed for easy operator use with all positional functions available. Different memory banks can be examined and survey mission parameters updated or changed at any time through use of various function switches.

2.2. Function Description

1. MSU (Figure 2-2)

- A) OFF - Turns off power to INS
- B) STBY - Present position coordinates are input in this mode. Alignment procedure starts.
- C) ALIGN - Alignment proceeds automatically. The READY NAV annunciator turns on when alignment is complete.
- D) NAV - The Navigation mode is the normal operating mode. Upon entering NAV mode a realignment would have to be done should one switch out of NAV.
- E) ATT REF - Attitude Reference is selected when a system failure occurs while in flight. CDU will not function with MSU in ATT REF mode.

2. CDU (Figure 2-3)

- A) DISPLAY SWITCH - Selects type of positional or navigational guidance data for presentation on left and right numerical display.
- B) AUX/WPT SWITCH - If display switch is on WPT then the AUX/WPT switch corresponds to the coordinates of waypoints 1-9 for insertion or presentation. If display switch is on AUX then auxiliary survey mission data may be entered or displayed.
- C) AUTO/MAN/RMT SWITCH
 - AUTO - System performs track leg changes automatically.

CDU

Figure 2-3

MAN - Track leg changes are done manually.

RMT - Special survey mission parameters are entered and displayed. Also used for remote ranging.

- D) DATA PUSHBUTTONS - Ten (10) keys for entering numerical data. Also used for secondary function listed on pushbutton when pushed in certain sequence.
- E) CLEAR PUSHBUTTON - Entered data is removed if pressed before insert pushbutton is pressed.
- F) INSERT PUSHBUTTON - Enters data into computer. Also used to display secondary data in numerical displays.
- G) HOLD PUSHBUTTON - This is used to freeze present position while on a survey mission allowing the system to continue calculating new positional information.
- H) TKCHG PUSHBUTTON - This is used to initiate a manual track change, overriding the automatic function.
- I) FROM-TO DISPLAY - Shows From waypoint first and To waypoint second in the display. While in grid mode it displays 78 or 87 depending on which line direction the aircraft is on. This also displays special characters during update procedures.
- J) ALERT LIGHT - Comes on when approaching the survey area or when approaching a waypoint.
- K) BATT LIGHT - When INS is on backup battery, this light will come on.
- L) WARN LIGHT - Illuminates when a system failure has occurred or an improper alignment has occurred.

3. Preflight Operations

3.1. Setting Up Flight Logs

Careful preflight preparations will result in a smooth, trouble free airborne survey. Attention to detail and picking accurate survey grid parameters from the survey charts cannot be overstressed. Inaccuracies in setting up the flight log will cause costly delays in flight time and extreme frustration when trying to repick parameters in the field, at refueling stops or while in flight.

3.1.1. Maps

Since the resolution of the LTN-76 is .01 minutes in latitude and longitude, only 7.5 minute topographic charts should be used to conduct an accurate survey. In areas where these maps are not available, 15 minute maps blown up to 1:24,000 scale are required in order to obtain accurate present position coordinates for alignments and position updates at refueling stops. Furthermore, the update points on the survey line need to be accurate in order to constrain the drift of the INS.

3.1.2. Grid Overlays

Survey charts given to the navigator usually are cut into strips or are sectioned in some fashion to make them manageable in the confines of the cockpit. Latitude and longitude coordinates on the edges of the charts are usually lost in this process. All tick marks on a chart should be inked and labeled by the technician compiling the survey charts before segmenting the charts. A grid sheet (Figure 3-2) should be drafted on mylar for the survey area to aid the navigator in interpolating positions between tick marks when obtaining locations on the charts. Since longitude spacing changes with increase or decrease in latitude, several grid sheets may be necessary if the latitude of a survey area changes considerably. From experience, a grid overlay is accurate through approximately 20 miles of latitude change.

3.1.3. Obtaining Grid Parameters

Figure 3-3 depicts the fashion in which the INS needs the survey area to be translated in. The assumptions made are that the survey lines are parallel to each other and that they are equally spaced. The lines do not have to be

ITGS Startup

Figure 3-1

5'X5' GRID for 1/62,500 SCALE MAP in Northern Washington
GRID division 2/10

FIGURE 3-2

Figure 3-3 Grid Mode Variables

the same length, although a rectangular grid is considerably easier to program than one that is non-orthogonal, such as shown in Figure 3-3.

The grid is based on a reference track leg, for example, the first survey line that will be flown on a mission. In Figure 3-3 the aircraft will proceed from the present position WPT 1 to WPT 7. From WPT 7 the aircraft will proceed on a rhumb line to WPT 8 intersecting the first survey line, the reference track leg. Upon exiting the survey area the aircraft will then be guided into a left turn to intercept the second survey line. When finishing the second survey line the aircraft will be guided into a right turn to intercept the third survey line and so forth. The following grid parameters should be obtained from the charts of the survey area for later input to the INS.

A. WAYPOINT 7 AND 8 - These coordinates should be chosen to intercept the first survey line to be flown. They do not need to be end points of the survey line but should be outside the boundaries of the survey grid to be flown. These are chosen to a resolution of .01 minutes.

B. SHUTTER DELAY - Distance in nautical miles to a resolution of .01 NM between waypoint 7 and the beginning of the survey area.

C. GRID LENGTH - Along track distance in nautical miles to a resolution of .01 NM of the first survey line (reference track leg). If the survey grid is rectangular the INS uses the same grid length for all the survey lines. In the case of a non-orthogonal grid, such as Figure 3-3, the computer calculates grid length distances for subsequent lines.

D. LEVEL POINT DISTANCE - Distance in nautical miles between level point and start of survey area. Level point is the point where rhumb line navigation begins and the aircraft begins to align itself on the grid line.

E. GRID SEPARATION - Distance in feet between survey lines. Also needed is whether the first turn when exiting the survey area will be left or right. In Figure 3-3 the turn would be left.

F. INITIAL OFFSET - Number of initial offset grid lines from the reference track leg to the left or right direction. For instance, after a refueling stop one wishes to start on the third grid line from the reference track leg. This would be an initial offset of left 2.

G. NON-ORTHOGONAL ANGLE - Degrees and minutes to a resolution of 1 minute of the angle between the reference track leg and the grid base line. This is used when flying a survey grid that is not rectangular, Figure 3-4.

3.1.4. Selecting Absolute Update Points

To keep inertial drift to a minimum, positional updates must be made while in flight when flying over known points on the survey line. By having the true coordinates of a visual prominence stored in the memory of the computer, one can then update the INS to that true position when overflying it. This is called an absolute update. The INS will hold nine (9) update coordinates. This is adequate for the two-hour mission time of a helicopter survey. The next set of nine update points can be entered at refueling stops. For a fixed-wing survey, once the nine update points have been used, the next set should be inserted while in flight. In either case, update points should be selected from the charts to correspond to 10-15 minutes of flight time apart. In cases of very detailed surveys, one-quarter mile spacing or less, update points should be selected at even smaller intervals. The accuracy and frequency of update points bears a direct relationship to the accuracy of the flight path guidance. Updated points should be selected from the charts that will be easy to spot from the air and in which minimum deviation from the survey line will occur when overflying them.

3.2. Input of Grid Parameters

After obtaining the necessary grid parameters from the survey charts as described in Section 2, the programming of the INS can be started. When initially starting the unit, the initial alignment takes 17 minutes. This is more than enough time to input a set of parameters for the first set of survey lines to be flown. At the refueling stop the next set of parameters for the second set of survey lines can be entered. Remember, after putting in the first set of grid parameters, only a few parameters need to be changed at refueling stops. Usually, only a new set of absolute update points and a different INITIAL OFFSET needs to be entered.

Figure 3-4 Non-Orthogonal Grid Frame

3.2.1. Alignment of the INS

The INS is powered up by first pushing in the circuit breaker on the BU, backup battery and then turning the MSU switch to STBY (Figure 3-1). The battery backup power must be present in order for the unit to turn on. The following procedures should be followed when aligning the INS:

- A) Set CDU display switch to POS (Figure 3-1).
- B) The latitude of the position coordinates is entered first to a resolution of .01 minute. Press DATA PUSHBUTTON N2 (for north latitude), or XTK 8S (for south latitude).
- C) Enter 2 latitude degrees.
- D) Press INSERT. The latitude degrees move to the left of the display and latitude minutes are ready to be input.
- E) Enter 4 digits of the latitude minutes.
- F) Press INSERT. The latitude is now shown in the left display rounded off to the nearest .1 minute.
- G) The longitude to the nearest .01 minute can now be entered. Start by pressing W4 or 6E corresponding to east or west longitude.
- H) Enter longitude degrees.
- I) Press INSERT. Degrees move to left of right display.
- J) Enter 4 digits of longitude minutes.
- K) Press ENTER pushbutton.
- L) The display will now show the latitude and longitude coordinates to a resolution of .1 minutes. To see the .01 resolution, press the INSERT pushbutton. Pressing the INSERT button again will restore the display.
- M) Set MSU to align.
- N) Once the READY NAV light comes on (about 17 minutes), the MSU can be switched to NAV and the aircraft can now be moved or start its mission.

3.2.2. Input of Grid Parameters

Waypoints 7 and 8 which describe the reference track leg are entered in this fashion :

- A. Set AUTO/MAN/RMT to MAN
- B. Set CDU display switch to WPT.
- C. Set WPT switch (thumbwheel) to either 7 or 8 corresponding to which waypoint is to be entered first.
- D. Enter latitude and longitude position of waypoint as described in Section 3.2.1., B through L.
- E. Repeat steps C and D for next waypoint.
- F. The position of the first refueling stop can be put in waypoint position 1. After finishing the first set of survey lines a manual track change from waypoint 0 (which is reserved for the computer to derive present positions) to waypoint 1 would guide the aircraft from the survey area to the refueling stop.

The other grid parameters are entered in the sequence described below and are summarized in Table 3-5.

- A. Set CDU switch to AUX.
- B. Set WPT switch (thumbwheel) to number according to first column in Table 3-5.
- C. Set AUTO/MAN/RMT switch to AUTO or MAN.
- D. To enter a value into the parameter described on the left side of Table 3-5, press pushbutton 5.
- E. Now enter the value described by inserting numerical value and pressing INSERT.
- F. To enter a value described on right side of Table 3-5 press L (left) or R (right) and then enter the value as in Step E.

When flying a relatively standard grid only those parameters listed in Section 3.1.3 need to be entered. The other parameters listed in Table 3-5 can retain their nominal values. These nominal values are listed in Table 3-6.

TABLE 3-5 AUX DATA ENTRY AND DISPLAY TABLE

PUSH BUTTON	5			L(7) or R(9)			REMARKS
DISPLAY WINDOW	LEFT			RIGHT			
wpt #	DATA NAME	UNIT	Decimal Point	DATA NAME	UNIT	Decimal Point	
0	XTK in Fast U-TURN	N.M.	2	TKE in Fast U-TURN	Deg.	1	display only
1	Shutter interval #1	N.M.	2	Auto pilot offset	ft	0	
2	Shutter interval #2	N.M.	2	Grid Separation	ft	0	
3	Grid length	N.M.	2	initial offset Relative line no entry	line	0	
4	Shutter delay	N.M.	2	Altitude	ft	0	
5	Spare ++			Spare ++			
6	Bad update distance	N.M.	2	Spare			
7	Reference point dis.	N.M.	2	ABS line no. entry/display	line	0	
8	Flash time	Sec	0	Non orthogonal angle	*	*	* $\frac{xx}{\text{Deg}}$ $\frac{xx.x}{\text{Min}}$
9	Level point distance /extend U-Turn dis.	N.M. +++	2	Pulse duration	40.96 MSec	0	

++ These display windows give the shutter opening coordinate in LAT/LON for shutter pulse #1 and are subject to be changed without notice.

+++ For EXTEND U-TURN DISTANCE Data entry and display, the AUTO/MAN/RMT switch must be in RMT.

TABLE 3-6 AUX DATA NOMINAL VALUE TABLE

PUSH BUTTON	5			L(7) or R(9)			REMARK
DISPLAY WINDOW	LEFT			RIGHT			
Wpt #	DATA NAME	UNIT	VALUE	DATA NAME	UNIT	VALUE	
0	XTK in Fast U-Turn	N.M.	N.A.	TKE in Fast U-Turn	Deg.	N.A.	display only
1	Shutter #1	N.M.	0.00	Auto pilot offset	ft	0	
2	Shutter interval #2	N.M.	0.00	Grid separation	ft	R 0	
3	Grid length	N.M.	0.00	Relative line no entry	line	0	
4	Shutter delay	N.M.	0.00	Altitude	ft	5000	
5	Spare			Spare			
6	Bad update distance	N.M.	2.00	Spare			
7	Reference point dis.	N.M.	5.00	ABS line no. entry/display	line	N.A.	
8	Flash time	Sec	30	Non orthogonal angle	*	9000.0	* <u>xx</u> ° <u>xx.x</u> Min Deg
9	Level point distance /EXTEND U-TURN DIS.	N.M.	5.00 2.00	Pulse duration	40.96 MSec	10*	*409.6 MSec

N.A. Not applicable

The absolute update points can be entered following this sequence:

- A. Set AUTO/MAN/RMT switch to RMT.
- B. Set CDU display switch to POS.
- C. Set WPT switch (thumbwheel) to 1.
- D. Insert first absolute update point as Sec. 3.2.1, B-L.
- E. Press ENTER.
- F. Enter other 8 absolute update points in WPT position 2 through 9.

One important note is that the update points need to be separated by the Reference Point Distance whose nominal value is 5 nautical miles. If needed, this value can be changed. See Table 3-5, waypoint number 7, left hand side.

4. Inflight Operations

After the grid parameters have been entered, the grid mode can be turned on and the aircraft can proceed to the survey area. Grid mode is activated by a software simulation switch. The procedure is as follows: Refer to Table 4-1.

- A. Set CDU switch to SSW.
- B. Press O to activate Grid Mode.
- C. O will appear in display.
- D. Pressing O once again would deactivate Grid Mode if so desired.

Table 4-1 lists other functions that are accessed by the software simulation switches. These functions are turned on in the fashion listed above. Switch number 7 or 8 are sometimes used.

Once the Grid Mode is activated the survey mission can begin.

TABLE 4-1

SOFTWARE SWITCH FUNCTION ASSIGNMENT TABLE

SWITCH NUMBER	MNEMONIC SYMBOL	FUNCTION DESCRIPTION
0	GRID	Grid mode entry (ON)/interrupt (OFF) switch.
1	INV	Turn ON this switch will invert the grid mode banking angle.
2		To form a rectangular pattern in grid mode.
3	EXT	To extend grid length by one shutter each end.
4		SPARE
5		SPARE
6		Grid Separation redefine switch.
7*		Enter grid mode through Wpt 7 end.
8		Enter grid mode through Wpt 8 end.
9		Force the shutter pulse to be aligned with respect to the

*Switch 7 and 8 are mutual exclusived.

4.1 Travel to Survey Area

With Grid Mode activated and the AUTO/MAN/RMT switch on AUTO, the FROM-TO display should read 07 and the cross-track meter (Figure 4-2) will guide the pilot to the level point. The CDU display switch can be turned to DIS/TIME showing the distance and ETA at present speed before reaching waypoint 7. The ALERT light will come on 2 minutes before overflying the level point. Upon overflying the level point, the INS will initiate an automatic track change and the FROM-TO window will read 78. The aircraft is now on a rhumb line approaching the first survey line. Thirty seconds before the aircraft enters the survey area the ALERT light will flash, then become solid once in the survey area.

4.2 Navigation while on Line

While on line, the pilot only has to follow the crosstrack needle and course deviation meter. The following settings on the CDU display switch will give the following positional information:

- A. DIS/TIM - Distance and ETA to end of survey line
- B. TK/GS - Track angle and ground speed in knots.
- C. HDG/DA - Heading and drift angle.
- D. XTK/TKE - Crosstrack distance from line and track angle error. This information will be the same as is sent to the meters.
- E. DTK/STS - Desired track angle.

4.3 Position Updating

The method of absolutely updating the INS to a pre-determined coordinate on the ground is as follows:

- A. Correlate visual prominence with absolute update point that is marked on charts and has been programmed into computer. Guide aircraft visually over prominence if not on flight line.
- B. Set CDU display switch to UPDATE; the display will list the number of absolute updates in the computer.

Figure 4-2

COURSE DEVIATION METER

CROSS TRACK METER

- C. Press the ABS data key when the aircraft is directly over the visual prominence.
- D. The left display will show the crosstrack error between the update point and where the INS "thinks it is". The right display will show the bearing angle to the north.
- E. If the result appears reasonable, the operator can now effect the update by pressing the INSERT pushbutton.
- F. If the result is unreasonable or the display is flashing (signifying a crosstrack error over 2 nautical miles) pressing the CLEAR button will bypass the update.

In the event an incorrect update point is entered, two error recovery sequences can be effected. A single flush of the latest absolute update can be done by:

- A. Press ABS key. CDU display switch on UPDATE.
- B. Press SNGLF pushbutton.
- C. Press INSERT.

A total flush of the absolute updates can be done by pressing TOTLF instead of SNGF in B above.

4.4 Turning to next Survey Line

30 seconds before the aircraft comes to the end of the survey line, the ALERT light will begin to flash. The ALERT light will go out upon leaving the survey area and a track change will occur automatically and the meter will now be guiding the aircraft to the next survey line. The aircraft should be turned until the needles are centered. The aircraft is now on a rhumb line leading to the beginning of the next survey line.

In the case of a grid that has varying lengths of survey lines, the reference track leg should be programmed with a grid length of the shortest line in the set of lines to be flown on a mission. Then the longer lines can be extended while in flight by switching the AUTO/MAN/RMT switch to MAN, which will extend the current line out until one switches to AUTO, at which time the automatic track leg change will occur, guiding the aircraft to the next line.

This, of course, necessitates visual identification of the end of the survey line.

4.5 Travel from Survey Area to Refueling Stop

By deactivating Grid Mode (Section 4.0) the INS will automatically initiate a track change of 01, Present Position to waypoint 1. If the refueling stop was entered into waypoint 1, the meters will now guide the aircraft to the refueling point. Reactivating the Grid Mode without changing any of the grid parameters will cause the INS to guide the aircraft to the path where the deactivation occurred.

Alternatively, a manual track change can guide the aircraft to a position that was programmed into waypoint 1 through 9 (7 & 8 are, of course, points defining the reference track leg).

- A. Set AUTO/MAN/RMT switch to AUTO or MAN.
- B. Press the TK CHG pushbutton.
- C. Press 0 pushbutton for present position.
- D. Press 1 through 9 pushbutton, depending on which waypoint you wish to navigate to.
- E. Press INSERT.

The aircraft will now be guided to whichever waypoint was entered in Step D.

5. Post Flight Operations

Post flight operations consist of two types of operations; reprogramming and quality checks. When refueling, a new set of nine absolute update points can be entered and grid parameters for the next set of survey lines can be changed if necessary. In the simplest case the grid mode only needs to be reactivated and the crew can continue where it left off upon deactivating the grid mode.

5.1. Quality Checks

Upon landing and when parked the CDU display switch should be set to TK/GS. A ground speed (GS) of greater than 2 or 3 should be suspect. The Present Position reading, CDU display on POS, WPT switch on O, should be close to what the refueling stop coordinates are. This, of course, depends on the accuracy and time since the last absolute update was entered. Any deviation greater than 2 NM per hour since update (or any fraction of this time) is unacceptable.

If the aircraft is to be shut down, the following procedure should be followed as a navigational accuracy check:

- A. Do a total Flush of all absolute updates. See Sec. 4.3.
- B. Set AUTO/MAN/RMT switch to AUTO or MAN.
- C. Do a track change from O to refueling stop coordinates.
 - 1. Press TK CHG
 - 2. Press O
 - 3. Press waypoint number of refueling stop coordinates
 - 4. Press INSERT.
- D. Set CDU display switch to DIS/TIM.
- E. DIS display will give the accumulated error of the raw INS since switching into NAV mode.
- F. Any value over 2 NM per hour of NAV time is unacceptable.

5.2. Short Alignment Procedure

If the aircraft will be doing another set of lines and time is unavailable for a realignment, a short alignment can be done. Sequence is as follows:

- A. MSU selector switch to ALIGN.
- B. Press HOLD pushbutton.
- C. CDU display switch to POS.
- D. Enter refueling stop coordinates as in Section 3.2.1 A-L.

E. Press INSERT.

F. Once READY NAV light illuminates and aircraft is ready to depart, switch MSU into NAV.

5.3 Shutdown Procedure

A. MSU selector switch to OFF.

B. Pull out backup battery (BU) breaker.

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TABLE OF CONTENTS

	<u>Page</u>
1. Introduction to Programs	-1
1.1 Design Goals	-1
1.2 Assumptions or Restrictions Made on Data Sheet	-1
2. Basic Structure of Programs	-1
2.1 Flowcharts	-1
2.1.1 AGI * DOE-INS	-2
2.1.2 AGI * DOE-INS Plot	-3
2.2 I/O Formats	-4
3. Instructions for Use of Programs	-4
3.1 AGI * DOE-INS	-4
3.1.1 File Set Up	-4
3.1.2 Running the Program	-5
3.2 AGI * DOE/INS Plot	-5
3.2.1 File Set Up	-5
3.2.2 Running the Program	-5
4. Future Recommendations for Production Surveys	-6
4.1 Design Considerations	-6
4.2 Production Survey Spline Correction Schemes	-7

LIST OF APPENDICES

Appendix A- AGI "Standard Tape" Format	-8
Appendix B- Documentation of Plot Sub-routines	-11
Appendix C- I/O Routines	-13
Appendix D- UTM, Latitude and Longitude Conversion Routines	-15

1. Introduction to Programs

Two computer programs were designed to process, correct, and display Inertial Navigation System generated flight path. The first program reads a field tape and converts the raw INS data from latitude and longitude coordinates to UTM (Universal Transverse Mercator) coordinates. It then outputs the data in a more convenient format and also updates a file, which contains reference fiducials, with INS x, y, and time data. The second program then corrects the INS data for Schuler drift and generates either a plot of flight path data or prints the coordinates in latitude and longitude for each data point.

1.1 Design Goals

The programs and I/O formats were designed for ease in changing data sets and simplicity from the programmer's viewpoint. With this philosophy certain assumptions are made in the data set; so the data set must undergo some manipulation. These programs were designed as part of an experiment and not set up to process data in a production environment.

1.2 Assumptions or Restrictions Made on Data Set

The programs assume that all input data is in chronological order. This assumption should be valid for the field tape but in general is not valid for the file of digitized coordinates.

2. Basic Structure of programs

2.1 Flowcharts

2.1.1 Agi*doe.ins - Processing the Field Tape into AGI
"Standard Tape" Format.

2.1.2 Agi*doe.ins-plot

2.2 I/O Formats

For Agi*doe.ins there are three input files and two output files. The first input file is the field tape generated by a Geometrics 714 airborne data acquisition system. There are four logical records in each physical record of the tape. The list of variables and format are documented internally. The second input file is a five line list of information which goes into the header block of the output tape. Its format is (I2,10A6) where the first variable contains the number of characters to follow in the alphanumeric string. The third file (unit 14) contains flight line and fiducial numbers identifying to the program which data points will be used for drift correction in the second program. Its format is ().

On output, agi*doe.ins produces an AGI "Standard Tape" and a look-ahead file. The output tape contains a number of different parameters including uncorrected x-y information. A complete description of its format is listed in Appendix A. The look-ahead file mentioned is an updated version of the picked fiducial file (unit 14) and contains the flight line number, fiducial number, uncorrected x, uncorrected y, and time. All x-y data is in UTM coordinates.

The second program, Agi*doe.ins-plot, has four input units and optionally an output tape for plot generation. Unit 1 contains information which will be plotted in the title block. It is five lines long and contains a 2 digit integer number followed by a string. Its format is (I2,8A6). Again, the integer specifies how many characters there are in the string. Unit 2 contains reference fiducial points with UTM coordinates. The variable list is: flight line, fiducial number, x, and y. The third file, unit 3, usually has a corresponding list with the INS values for each fiducial number. Each record contains flight line, fiducial number, x, y, and time in seconds. It is used as a look-ahead file together with unit 2 for correction of INS schuler drift. It is permissible for the reference data in file 2 to be a subset of file 3 as far as fiducial numbers are concerned.

The main output is a plot tape generated for incremental plotters.

3. Instructions for use of Programs

3.1 Agi*doe.ins

3.1.1 File Set Up

An input file of picked fiducial points must be set up so this program can output its look-ahead file. This file

contains the flight line number and fiducial number for all data points which will be used as reference points for drift correction. This file may optionally contain additional points. It must be in chronological order.

3.1.2 Running the Program

If the program is ran in an interactive environment, it will query the user with appropriate prompts. It will ask for the serial number of the input tape, job identification, number of files to output, and serial number of output tape. It will then ask whether a picked fiducial file is available or if only a dump of the input tape is required. Appropriate responses would be: yes, no, or dump. The program will then process the field tape and update the user as to its status. The processing ends when one of the following occurs: two consecutive end of file marks are encountered on the field tape, the program has produced the specified number of output files, or it has read in the last reference fiducial point.

3.2 Agi*doe.ins-plot

3.2.1 File Set Up

For INS drift correction a comparison is made between the reference data points in unit 2 and the INS data points in unit 3. The INS flight path is shifted so it contains the reference points. All points between the reference points are also shifted using linear interpolation. This linear interpolated function closely follows the Schuler drift thusly allowing cancellation of the drift. The reference points (unit 2) are in UTM coordinates and must have a corresponding fid to fid match in unit 3.

3.2.2 Running the Program

The program asks for the following plot information: map scale, dimensions of map in inches, location of first reference point in the plot window (inches from origin), and whether or not to rotate the map -90 degrees. Next it prints a list of options, then queries for either an option or file numbers from the input tape. The default mode is to plot the map and not print out separate latitude and longitude coordinates. The user then enters appropriate file numbers from his input tape. To stop the program enter the command "end".

4. Future Recommendations for Production Surveys

4.1 Design Considerations

In a production environment, an INS correction program should satisfy certain conditions. Ease of use and fast throughput of data are essential for productivity. For production, the program does not need the versatility for changing data sets. The program should be general enough to keep input data manipulation to a minimum. Because of this consideration and the fact that it is necessary to know two or more reference point - INS point pairs in advance, for INS drift correction, a program which makes two passes on the data set is required. This two pass concept was implemented in the two previous programs, where each program made a single scan of the data set.

In a production INS-correction program, the data could be scanned for matches between fiducials from the input file and corresponding fiducials from a UTM reference point file (digitized coordinates). Any matches would be recorded in a temporary file.

On the second scan of the data set the actual INS correction would occur. The correction could be made with a linear drift correction scheme when the time between reference points is small (1-10 minutes) or with a cubic spline correction routine if the time between reference points is greater (5-25 minutes). For the linear correction scheme only two pairs of points are necessary, as opposed to all the reference point - INS point pairs within a time segment, for the cubic spline correction. A time segment would begin at the start of a flight session and end at the finish of that flight. Also, there must not be large time gaps between reference points (>25 minutes). If there is, then a new time segment would start with the first reference point after the gap. Since the Schuler drift has a period of 84 minutes, construction of a function which closely approximates it will be less accurate if the reference points are far apart from each other in time. Reference points should be located close to the beginning and end of the time segment to minimize extrapolation. After creating a drift correction function for a time segment, the input data is re-read, corrected, and outputted.

4.2 Production Survey Spline Correction Scheme

Appendix A - AGI "Standard Tape" Format.

An AGI standard tape consists of one or more files of data, each file containing many parameters. Each file contains a specified number of records and finishes with an end of file mark.

To conveniently access selected parameters of data, a tape format was chosen whereby each parameter is in its own separate physical record. The first record is a header block which contains information concerning its file. This first record is always 180 words long. The following records are variable in length (maximum 1250 words) and contain data for only one parameter (magnetics, for instance). The first word of every record, including the header record, is an integer which identifies the record type. The number of data points in a file are restricted to 1249. Usually a tape file will correspond to a flight line unless the flight line has more than 1249 samples. For long flight lines the data is contained in multiple files.

The header record consists of the following variables:

<u>Position</u>	<u>Length</u>	<u>Variable Name</u>	<u>Use</u>
1	1	ICODE1	Equals 1, block identification
2	4	AGI	String with contractor's name
6	1	TAPEID	Serial number identifying field tape
7	2	JOBID	String identification of job
9	1	MONTH	
10	1	DAAY	
11	1	YEAR	Date survey was flown
12	1	LINE	Flight line number
13	1	HEADNG	Direction of flight line
14	1	RUN	Segment number for flight line
15	1	FIDONE	First fiducial number of file
16	1	FIDEND	Last fiducial number of file

17	1	NDATA	Number of data points in following records. Record size is one greater because of record identification code.
18	1	CONT	Logical; is true if flight line is continued in next file.
19	1	PCONT	Logical; is true if flight line was continued from previous file.
20	1	INFILE	Location of data on original field tape (file number)
44	1	SRATE	Sample rate
46	1	RLAT1	Y-UTM coordinate of first data point in file
47	1	RLAT2	Y-UTM coordinate of last data point in file
48	1	TIME1	First time value in seconds of file (midnight=0.0)
49	1	TIMEND	Last time value
50	1	XYPOS	Logical; is true if file contains x-y data (record numbers 3 and 4)
51	1	MAG	Logical; is true if file contains magnetics data (record number 6)
52	1	SPEC	Logical; flagged if file contains spectrometer data (record numbers 9 through 12)
55	1	RLONG1	X-UTM coordinate of first data point in file
56	1	RLONG2	X-UTM coordinate of last data point in file
57	1	BARO	Logical; indicates whether barometric altitude data is available (record number 8)

64	1	CM	Central meridian of UTM zone
84	2	OPID	Flight operator identification (alpha)
86	1	SYSID	Acquisition system identification (integer)
88	1	TAPESN	Serial number of present tape (alpha)
89	2	TODAY	Date tape was processed (alpha)
91	7	NCHAR	Number of characters in label arrays (integer array)
111	10	LABEL1	Labeling information for file. Could be used in title blocks of plots. (alphanumeric array)
121	10	LABEL2	Same
131	10	LABEL3	Same
141	10	LABEL4	Same
151	10	LABEL5	Same
161	10	LABEL6	Same
171	10	LABEL7	Same

Appendix B - Documentation of Plot Subroutines

CALL IDPLOT (XDIM,YDIM) - Initializes plot routines.
Must be first plot subroutine called.

XDIM, YDIM - Size of plot window, x and y dimensions respectively.

CALL PLOT (X,Y,IPEN) - Moves plotter pen in straight line to new location.

X, Y - Destination of pen in inches relative to origin.

IPEN - A code of 2 causes pen to be lowered onto medium before pen travel, IPEN=3 causes pen to be raised before movement.

CALL SYMBOL (X,Y,HEIGHT,ITEXT,ANGLE,ICODE) - Plots out a special symbol or a string of characters starting at location X, Y.

X, Y - Center location for special symbol or location of bottom left corner for character strings.

HEIGHT - Height of special symbol or characters in string.

ITEXT - Integer identification of special symbol or string of characters (array).

ANGLE - Plot angle.

ICODE - Is negative for special symbols. ICODE=-1 keeps pen up during move, ICODE=-2 drops pen before move. If ICODE is positive then CALL SYMBOL plots character string with ICODE equal to the number of characters in the string.

CALL NUMBRI (X,Y,HEIGHT,INTGR,ANGLE) - Plots an integer number, similar to CALL SYMBOL.

X, Y, HEIGHT, ANGLE - Same meaning as in CALL SYMBOL for character strings.

INTGR - Integer number to be plotted.

CALL LENGTH (INCHES) - Returns the accumulated pen
travel for plot.

INCHES - Total plot inches.

CALL FINI - Ends plot.

Appendix C - I/O Routines

CALL DAY (TODAY) - Returns month, day, and year.

CALL DATIME (TODAY, TIME) - Returns time of day as well.

TODAY - 2 word array (12 characters)
containing MMM DD, YYYY where MMM is
current month (alpha), DD is day in month,
and YYYY is the current year.

TIME - One word containing HH:MM where HH
is hours and MM minutes.

CALL SKPFLS (N, NF, NR) - Skip forward some number of
files and records on a tape.

N - Logical unit number.

NF - Number of files to be skipped.

NR - Number of records to be skipped.

CALL BAKFLS (N, NF) - Positions tape backwards over file
marks. Arguments same as CALL SKPFLS.

CALL REWND (N, K) - Rewinds tape.

N - Logical unit number.

K - K=0 if no file mark is desired before
rewinding.

CALL VARBIN (NW, N, S, M) Procedure to read variable
length tape records.

NW - Number of words transmitted. Note:
this routine always returns an even
integer.

N - Logical unit number.

S - Array to receive data.

M - Maximum number of words expected in
record.

CALL INOUT (J,N,S,M) - Procedure to read or write onto tape.

J - J=0 if writing is desired.
J=1 if reading is desired.

N - Logical unit number.

S - Array where data comes from.

M - The number of consecutive words transmitted.

ITE (N) - Function which returns status of last I/O for logical unit N.

ITE (N) = 0 if status is normal.
= -1 error condition.
= 1 end of file mark read.
= 4 odd number of words read.

Appendix D - UTM, Latitude & Longitude Conversion Routines.

CALL UTM (XUTM,YUTM,RLAT,RLONG,ICM) - Converts data from latitude and longitude to Universal Transverse Mercator coordinates.

XUTM, YUTM - Returned UTM coordinates in meters.

RLAT, RLONG - Latitude and longitude of coordinates.

ICM - Central Meridian of UTM zone.

CALL UTMLL (X,Y,ICM) - Converts UTM coordinates into latitude and longitude.

X, Y - UTM coordinates on input are converted to longitude and latitude respectively.

ICM - Central meridian of UTM zone.

@EDIT,Z AGI*DOE.INS

EDIT <29A> 05/05/81 18:52 INS(5):F

EDIT

PURPOSE: THIS PROGRAM WITH ITS ASSOCIATED SUBROUTINES
 READS MAGNETIC TAPES GENERATED BY A GEOMETRICS 714
 COMPUTER FORMATTED FOR INS DATA RECOVERY AND OUTPUTS
 IN AGI "STANDARD TAPE" FORMAT. ALSO A FILE CONTAINING
 PICKED FIDUCIAL POINTS IS READ AND THEN UPDATED WITH THE
 CORRESPONDING X, Y, AND TIME COORDINATES AS EXTRACTED
 FROM THE INPUT TAPE. THE OUTPUT WILL BE USED BY LATER
 PROGRAMS AS A LOOK AHEAD FILE FOR INS ERROR CORRECTION.
 X - Y DATA FROM THE INPUT TAPE IS CONVERTED FROM LATITUDE
 AND LONGITUDE INTO UTM COORDINATES. OPTIONALLY TITLE BLOCK
 INFORMATION IS READ IN AND ENCODED ONTO THE OUTPUT TAPE.

PGM WRITTEN 2-7-80 BY DWIGHT CATER FOR APPLIED GEOPHYSICS

INPUT UNITS AND FORMATS:

UNIT 1 - INPUT TAPE WRITTEN BY GEOMETRICS 714 COMPUTER.
 LOGICAL RECORD SIZE IS 761 8 BIT ASCII CHARACTERS.
 PHYSICAL RECORD IS 3042 FRAMES OR 676 36 BIT WORDS
 FORMAT DESCRIBED AT LABEL 290

UNIT 2 - TITLE BLOCK INFORMATION FILE
 FORMAT (I2,10A6)

UNIT 14 - FILE OF PICKED FIDUCIAL POINTS
 FORMAT ()

OUTPUT FILES:

UNIT 13 - OUTPUT TAPE , AGI "STANDARD TAPE" FORMAT

UNIT 15 - FIDUCIAL OUTPUT FILE SIMILAR TO UNIT 14
 WITH ADDITION OF UNCORRECTED X-Y VALUES AND TIME

EXTERNAL FUNA @ CONVERSION FUNCTION FROM ASCII TO FIELDATA
 DIMENSION LHOLD(50),RX(1250),RY(1250)
 -,RTIME(1250),IFID(1250),RFEET(1250)
 -,RBARO(1250),IMONTH(13),LMONTH(13)

DATA FOR INTERNAL SUBROUTINE JULIAN

DATA IMONTH/0,31,59,90,120,151,181,212,243,273,304,334,365/
 DATA LMONTH/0,31,60,91,121,152,182,213,244,274,305,335,366/

SPECIFICATIONS FOR AGI "STANDARD TAPE" FORMAT

EQUIVALENCE (ICODE2,RTIME(1)),(ICODE3,RX(1)),(ICODE4,RY(1))
 -, (ICODE5,IFID(1)),(ICODE7,RFEET(1))
 -, (ICODE8,RBARO(1))
 DIMENSION LABEL1(10),LABEL2(10),LABEL3(10),LABEL4(10)
 -, LABEL5(10),LABEL6(10),LABEL7(10)
 -, HEAD(180),AGI(4),NCHAR(7),JOBID(2)

```

    INTEGER FIDONE,FIDEND,CM,TAPESN,TAPEID
    -,OPID(2),SYSID,DAAY,MONTH,RUN,HEADNG,YEAR
    LOGICAL CONT/.FALSE./,PCONT/.FALSE./
    -,SPEC/.FALSE./,MAG/.FALSE./,XYPOS/.TRUE./
    -,BARO/.TRUE./
    EQUIVALENCE (ICODE1,HEAD(1)),(AGI,HEAD(2)),(TAPEID,HEAD(6))
    -, (JOBID,HEAD(7)),(MONTH,HEAD(9)),(DAAY,HEAD(10))
    -, (YEAR,HEAD(11)),(LINE,HEAD(12)),(HEADNG,HEAD(13))
    -, (RUN,HEAD(14)),(FIDONE,HEAD(15)),(FIDEND,HEAD(16))
    -, (NDATA,HEAD(17)),(CONT,HEAD(18)),(PCONT,HEAD(19))
    -, (INFILE,HEAD(20))
    -, (SRATE,HEAD(44)),(RLAT1,HEAD(46))
    -, (RLAT2,HEAD(47)),(TIME1,HEAD(48)),(TIMEND,HEAD(49))
    -, (XYPOS,HEAD(50)),(MAG,HEAD(51)),(SPEC,HEAD(52))
    -, (RLONG1,HEAD(55))
    -, (RLONG2,HEAD(56)),(BARO,HEAD(57))
    -, (CM,HEAD(64))
    -, (OPID,HEAD(84)),(SYSID,HEAD(86)),(TAPESN,HEAD(88))
    -, (TODAY,HEAD(89)),(NCHAR,HEAD(91)),(LABEL1,HEAD(111))
    -, (LABEL2,HEAD(121)),(LABEL3,HEAD(131)),LHOLD(1),(LABEL4,HEAD(141))
    -, (LABEL5,HEAD(151)),(LABEL6,HEAD(161)),(LABEL7,HEAD(171))
    DATA AGI/24HAPPLIED GEOPHYSICS, INC./
    -, ICODE1/1/, ICODE2/2/, ICODE3/3/, ICODE4/4/, ICODE5/5/, ICODE6/6/
    -, ICODE7/7/, ICODE8/8/
    -, OPID/12HHI-LIFE      /, SYSID/714/, RUN/1/

```

C
C
C

SET OTHER VARIABLES FOR PROGRAM EXECUTION

```

    INTEGER POINT(4),HOUR,MIN,SEC,OTAPE,IARRAY(677),FDATA(12)
    -,FFID,FLINE
    LOGICAL START/.TRUE./,FIDFIL/.FALSE./,DUMP/.FALSE./
    -,END/.FALSE./
    DATA POINT/1,762,1523,2284/
    INTAPE=1
    OTAPE=13
    NIN=2
    INSIZE=677
    ICOUNT=1 @ ARRAY INDEX FLAGGED WITH IMPROPER VALUE
    DIFF=300. @ MAXIMUM ALLOWABLE DISTANCE IN METERS BETWEEN CONSECUTIVE POINT

```

C
C
C

QUERY FOR TAPE PROCESSING INFORMATION

```

    WRITE (6,5) INTAPE,OTAPE,NIN
5    FORMAT (' INPUT TAPE UNIT:',I4/' OUTPUT TAPE UNIT:',I4/
    -, ' TITLE BLOCK FILE INPUT UNIT:',I4)
    WRITE(6,10)
10   FORMAT(1X,/,1X,'AGI S/N OF FIELD TAPE?')
    READ(5,15)TAPEID
15   FORMAT(A6)
    WRITE(6,20)
20   FORMAT(1X,/,1X,'JOBID?')
    READ(5,25)JOBID
25   FORMAT(2A6)
    WRITE (6,30)
30   FORMAT (/ ' WHAT IS THE # OF OUTPUT FILES YOU WANT PROCESSED?')
    READ (5,40) LFILE @ LAST OUTPUT FILE
40   FORMAT ( )

```

```

IFILE=1 @ CURRENT OUTPUT FILE
WRITE(6,50)
50  FORMAT(1X,/,1X,'AGI S/N OF STD TAPE (OUTPUT)?')
    READ(5,15)TAPESN
    CALL DATIME (TODAY,TIME)

C
C      GET TITLE BLOCK INFO FROM NIN FILE
C
    INDEX1=1
    DO 70 I=3,7
    INDEX2=INDEX1+9
    READ(NIN,55)NCHAR(I),(LHOLD(IND),IND=INDEX1,INDEX2)
55  FORMAT (I2,10A6)
70  INDEX1=INDEX1+10
    WRITE (6,75)
75  FORMAT (/ ' IS THERE A FID FILE TO INPUT OR DO YOU'
-,' JUST WANT TO DUMP TAPE?')
    READ (5,15) IANS
    IF (IANS.GE.'Y'.AND.IANS.LE.'YES') GOTO 90
    IF (IANS.GE.'DU'.AND.IANS.LE.'DUMP') DUMP=.TRUE.
    FIDFIL=.FALSE.
    FFID=1000000
    GOTO 100
90  FIDFIL=.TRUE.
    READ (14,40,END=9050) FLINE,FFID
C *****
C
C      HAVE TAKEN CARE OF ALL PRELIMINARY REQUESTS NOW READ IN
C      INPUT TAPE
C
100  CALL VARBIN (NW,INTAPE,IARRAY,INSIZE)
C      NW - NUMBER OF WORDS READ IN
C      INTAPE - LOGICAL UNIT OF INPUT TAPE
C      IARRAY - ARRAY WHERE DATA IS STORED
C      INSIZE - MAXIMUM NUMBER OF WORDS EXPECTED IN READ
C
C      TEST FOR EOT OR ERROR CONDITION
C
    IF (ITE(INTAPE).NE.1) GOTO 200 @ NO EOF MARK
    IF (NEOF.GT.1) GOTO 990 @ 2 EOF'S IN ROW SIGNIFYING END OF TAPE
    NEOF=NEOF+1
    GOTO 100
200  IF (ITE(INTAPE).EQ.-1) GOTO 9030 @ ERROR
    NEOF=0 @ RESET

C
C      DECODE DATA FOR 4 RECORDS
C
    DO 500 I=1,4
    IP=POINT(I)
    CALL MVCHAR (IARRAY,IP,8,FDATA,1,6,72,FUNA)
    IF (.NOT.DUMP) GOTO 280

C
C      DUMP OPTION FOR INPUT TAPE
C
    WRITE (6,230) FDATA
230  FORMAT (1X,12A6)

```

GOTO 500

C
C
C
NORMAL DECODE OF DATA

280 DECODE (72,290,FDATA(1),ERR=300)
-IYEAR,JDAY,HOUR,MIN,SEC,ILINE
-,JFID,RALT,BALT,RLATD,RLATM,RLONGD,RLONGM,TEST
290 FORMAT (1X,I2,1X,I3,3(1X,I2),5X,I2,1X,I5,15X,2F6.3,1
-X,F2.0,F4.0,1X,F3.0,F4.0,A1)
GOTO 310

C
C
C
DECODE OF DATA WHEN FLIGHT LINE NUMBER IS ABNORMAL

300 DECODE (72,305,FDATA(1),ERR=9000)
-IYEAR,JDAY,HOUR,MIN,SEC,ALFA
-,JFID,RALT,BALT,RLATD,RLATM,RLONGD,RLONGM,TEST
305 FORMAT (1X,I2,1X,I3,3(1X,I2),3X,A5,I5,15X,2F6.3,1X
-,F2.0,F4.0,1X,F3.0,F4.0,A1)
ILINE=0

C
C
C
TEST SHOULD BE '0' IF INS INTERFACE IS OUTPUTTING DATA CORRECTLY

310 IF (TEST.EQ.'0') GOTO 340
WRITE (6,320) I,ICOUNT
320 FORMAT (' BAD INS STATUS I:',I2,' ICOUNT:',I5)
GOTO 9012
340 IF (ICOUNT.GE.2) GOTO 400

C
C
C
C
FIND MONTH AND DAY FOR THIS FLIGHT LINE AND
RESET LINE #

350 CALL JULIAN (IYEAR,JDAY,MONTH,DAAY,\$9020)
YEAR=IYEAR
LINE=ILINE
ICOUNT=2
IF (.NOT.FIDFIL) GOTO 400
IF (FLINE.EQ.LINE) GOTO 400

C
C
C
LOOK FOR CORRECT FLIGHT LINE NUMBER IN PICKED FIDS FILE

READ (14,40,END=355) FLINE,FFID
IF (FLINE.EQ.LINE) GOTO 400
355 REWIND 14
360 READ (14,40,END=365) FLINE,FFID
IF (FLINE.EQ.LINE) GOTO 400
GOTO 360
365 WRITE (6,370) LINE
370 FORMAT (' COULD NOT FIND LINE: ',I3,' IN FID FILE')
REWIND 14
FLINE=9999 @ LINE NUMBERS USUALLY < 999
FFID=1000000 @ FID NUMBERS USUALLY FIVE DIGIT
400 IF (LINE.NE.ILINE) GOTO 1000 @ OUTPUT DATA
RTIME(ICOUNT) = FLOAT (3600*HOUR+60*MIN+SEC)

C
C
C
CHECK FOR ANY TIME SKIPS

IF (ICOUNT.GT.2.AND.RTIME(ICOUNT).GT.10.0+RTIME(ICOUNT-1))

-GOTO 1000

C
C
C

CONVERT LAT-LONG TO UTM

RLAT=RLATD+RLATM/6000.
RLONG=-RLONGD-RLONGM/6000.
IF (.NOT.START) GOTO 450

C
C
C

FIND ONE CENTRAL MERIDIAN FOR AREA

START=.FALSE.
CM=(INT(RLONG)/6)*6-3 @ TRUE ONLY IF RLONG IS NEGATIVE
WRITE (6,410) CM
410 FORMAT (//' CENTRAL MERIDIAN IS:',I5/)
450 CALL UTM (RX(ICOUNT),RY(ICOUNT),RLAT,RLONG,CM)
IF (ICOUNT.EQ.2) GOTO 452

C
C
C

CHECK FOR GAPS IN X-Y DATA

XDIFF=ABS (RX(ICOUNT)-RX(ICOUNT-1))
YDIFF=ABS(RY(ICOUNT)-RY(ICOUNT-1))
IF (XDIFF.GT.DIFF.OR.YDIFF.GT.DIFF)
-GOTO 1000 @ OUTPUT DATA

452
C

IFID(ICOUNT)=-JFID @ FLAG POINT AS IF PICKED

C
C
C
C

TRY TO FIND MATCH BETWEEN PRESENT FID FROM INPUT
TAPE AND CORRESPONDING FID IN PICKED FID FILE

IF (JFID.LT.FFID) GOTO 470
IF (JFID.EQ.FFID.AND.LINE.EQ.FLINE) GOTO 460
IF (END) GOTO 1000
IF (LINE.NE.FLINE) GOTO 470
WRITE (6,455) FFID,FLINE
455 FORMAT (' MISSED LOOKING FOR FID: ',I5,' ON LINE: ',I3)
READ (14,40,END=457) FLINE,FFID
GOTO 470
457 END=.TRUE.
FFID=-1
GOTO 470

C
C
C

FOUND MATCH, OUTPUT TO FILE 15 AND READ IN NEW FID

460 WRITE (15,465) LINE,JFID,RX(ICOUNT),RY(ICOUNT),RTIME(ICOUNT)
WRITE (6,465) LINE,JFID,RX(ICOUNT),RY(ICOUNT),RTIME(ICOUNT)
465 FORMAT (1X,I3,',',I6,',',F8.1,',',F10.1,',',F7.1)
READ (14,40,END=457) FLINE,FFID

C
C
C

PROCESS PARAMETERS

470 RFEET (ICOUNT) = 500.*RALT
RBARO (ICOUNT) = 1000.*BALT
IF (ICOUNT.GE.1250) GOTO 1050 @ FULL FILE OUTPUT DATA
ICOUNT=ICOUNT+1 @ COUNTER FOR OUTPUT ARRAYS
500 CONTINUE
GOTO 100

C
C

```

C      OUTPUT SECTION: 3 ENTRANCES LABELS 990, 1000, AND 1050.
C
C      HAVE ALL DATA NECESSARY TO OUTPUT ONE FILE IN AGI "STANDARD TAPE"
C      FORMAT
C
C
C
C
990    END=.TRUE. @ LAST OUTPUT FILE OF JOB
C
C      OUTPUT CONTINGENT UPON BREAK IN DATA
C      A)    TIME GAP
C      B)    DISTANCE GAP
C      C)    LINE NUMBER CHANGE
C
1000   ICOUNT=ICOUNT-1
      ASSIGN 350 TO ALT1
      IF (CONT) PCONT=.TRUE.
      CONT=.FALSE.
      IF (ICOUNT.GT.6) GOTO 1100
      WRITE (6,1020) ICOUNT,LINE
1020   FORMAT (// ' DATA TO LITTLE TO OUTPUT ICOUNT: ',I2,' LINE:',I3)
      GOTO 1500
C
C      FULL FILE
C
1050   IF (CONT) PCONT=.TRUE.
      CONT=.TRUE.
      ASSIGN 500 TO ALT1
C
C      TAKE CARE OF HEADER BLOCK PARAMETERS
C
1100   FIDONE=-IFID(2)
      FIDEND=-IFID(ICOUNT)
      NDATA=ICOUNT-1 @ NUMBER OF DATA POINTS IN RECORD
      TIME1=RTIME(2)
      TIMEND=RTIME(ICOUNT)
      RLAT1=RY(2)
      RLAT2=RY(ICOUNT)
      RLONG1=RX(2)
      RLONG2=RX(ICOUNT)
C
C      FIND DIRECTION OF FLIGHT LINE AND ENCODE IN HEADNG
C
      XDIST=RLONG2-RLONG1
      YDIST=RLAT2-RLAT1
      IF (ABS(XDIST).GT.ABS(YDIST)) GOTO 1200
      HEADNG='N'
      IF (YDIST.LT.0.) HEADNG='S'
      GOTO 1300
1200   HEADNG='E'
      IF (XDIST.LT.0.) HEADNG='W'
1300   SRATE=(TIMEND-TIME1)/FLOAT(NDATA) @ CALCULATED SAMPLE RATE
C
C      OUTPUT DATA IN SEPERATE BLOCKS
C
C      INOUT ARGUMENT LIST:
C      ARGUMENT 1 - 0 FOR OUTPUT PROCESS
C      ARGUMENT 2 - UNIT NUMBER FOR OUTPUT TAPE

```

```

C          ARGUMENT 3 - ARRAY TO OUTPUT ON TO TAPE
C          ARGUMENT 4 - NUMBER OF WORDS TO OUTPUT
CALL INOUT (0,OTAPE,HEAD,180)
CALL INOUT (0,OTAPE,RTIME,ICOUNT)
CALL INOUT (0,OTAPE,RX,ICOUNT)
CALL INOUT (0,OTAPE,RY,ICOUNT)
CALL INOUT (0,OTAPE,IFID,ICOUNT)
CALL INOUT (0,OTAPE,RFEET,ICOUNT)
CALL INOUT (0,OTAPE,RBARO,ICOUNT)

C
C          WRITE 3 END OF FILE MARKS AND BACK OVER TWO OF THEM
C
CALL ENFILE (OTAPE)
CALL ENFILE (OTAPE)
CALL ENFILE (OTAPE)
CALL BAKFLS (OTAPE,2)

C
C          UPDATE USER ON CURRENT STATUS
C
WRITE (6,1400) LINE,RUN,MONTH,DAAY,YEAR
1400  FORMAT (// ' PROCESSED LINE:',I4, ' RUN:',I2, '   FLOWN ON '
-,I2,2(' / ',I2))
WRITE (6,1420) FIDONE,FIDEND,TIME1,TIMEND,NDATA,IFILE
1420  FORMAT (/ ' FIDS:',I6, ' TO ',I5, ' TIME:',F7.0, ' TO ',F6.0, /
- ' NUMBER OF DATA POINTS:',I5 /
- ' OUTPUT FILE:',I4 /// )
IF (END.OR.IFILE.GE.LFILE) GOTO 9900
IFILE=IFILE+1
1500  ICOUNT=2
      IHOLD=0
      PCONT=.FALSE.
      GOTO ALT1 @ DECODE MORE DATA
C *****
C
C          ERROR ROUTINES
C
9000  WRITE (6,9010) I,ICOUNT
9010  FORMAT (// ' ERROR IN DECODE ' /
- ' I:',I4, ' ICOUNT:',I5 / )
9012  WRITE (6,9015) FDATA
9015  FORMAT (1X,12A6 // )
      IERROR=IERROR+1
      IF (IHOLD.NE.ICOUNT) IERROR=1
      IHOLD=ICOUNT
      IF (IERROR.LT.5) GOTO 500
9020  STOP
9030  WRITE (6,9040)
9040  FORMAT ( ' ERROR ON READ OF INPUT TAPE PGM ABORTED ' )
      STOP
9050  WRITE (6,9060)
9060  FORMAT ( ' NO DATA IN FID FILE PGM. ABORTED ' )
      STOP
9900  IF (FIDFIL) END FILE 15
      STOP
C *****
C
C          SUBROUTINE TO FIND MONTH AND DAY FROM JULIAN DATE

```

```

C      YEAR - INPUT (INTEGER)
C      JDAY - JULIAN DATE INPUT (INTEGER)
C      MONTH - OUTPUT (INTEGER)
C      DAAY - DAY IN MONTH OUTPUT
C      RETURN 5 - ERROR IN JDAY
C
SUBROUTINE JULIAN (YEAR,JDAY,MONTH,DAAY,$)
LOGICAL LEAP/.FALSE./
INTEGER YEAR,DAAY
LEAP=.FALSE.
IF ((YEAR/4)*4.EQ.YEAR) LEAP=.TRUE.
IF (JDAY.GT.366) GOTO 200
IF (JDAY.GT.365.AND..NOT.LEAP) GOTO 200
IF (LEAP) GOTO 20
DO 10 J=2,13
10  IF (JDAY.LE.IMONTH(J)) GOTO 40
    GOTO 200
DO 20 J=2,13
20  IF (JDAY.LE.LMONTH(J)) GOTO 40
    GOTO 200
40  MONTH=J-1
    IF (LEAP) GOTO 50
    DAAY=JDAY-IMONTH(MONTH)
    RETURN
50  DAAY=JDAY-LMONTH(MONTH)
    RETURN
200  WRITE (6,210)
210  FORMAT (' ***** DAY PORTION OF JULIAN DATE IS BAD *****')
    RETURN 5
END
EOF AT LINE 427
END EDIT NO LINES OUTPUT

```

@EDIT,Z AGI*DOE.INS-PLOT
 EDIT <29A> 05/05/81 18:52 INS-PLOT(4):F
 EDIT

INS-PLOT

PURPOSE: THIS PROGRAM GENERATES FLIGHT PATH RECOVERY
 MAPS OF CORRECTED INS DATA VIA CALCOMP PLOTTER CALLS.
 IT'S INPUT IS A 9-TRACK MAGNETIC TAPE IN AGI "STANDARD TAPE"
 FORMAT AND THREE SEQUENTIAL FILES. THE FIRST, WHICH COULD BE
 OPTIONAL, IS A FILE OF FIVE LINES WHICH IS PLOTTED IN THE TITLE
 BLOCK. FILE 2 CONTAINS THE X-Y DATA USED AS A REFERENCE FOR
 MAKING INS CORRECTIONS. FILE 3 HAS THE CORRESPONDING INS X-Y
 DATA AND IS USED TOGETHER WITH FILE 2 AS A LOOK AHEAD FILE.

OUTPUT CAN BE DIRECTED OPTIONALLY TO A PLOT TAPE OR JUST
 THE CORRECTED DATA CAN BE PRINTED IN LATITUDE AND LONGITUDE.

INPUT UNITS AND FORMATS:

UNIT 1 - IS TITLE BLOCK
 FORMAT (I2,8A6)
 UNIT 2 - REFERENCE FIDS (DIGITIZED COORDINATES)
 FORMAT ()
 UNIT 3 - LOOK AHEAD FILE OF PICKED FIDS UPDATED WITH UNCORRECTED
 INS X, Y, AND TIME DATA
 FORMAT ()
 UNIT 11 - INPUT TAPE, AGI "STANDARD TAPE" FORMAT
 OUTPUT UNIT:

CALCOMP-PLOT IS OUTPUT TAPE

FUTURE CHANGES:

COMPILER (DATA=SHORT)

VARIABLES IN HEAD BLOCK OF AGI "STANDARD TAPE" FORMAT
 EQUIVALENCE (ICODE1,HEAD(1)),(MONTH,HEAD(9)),(DAAY,HEAD(10)),
 -(YEAR,HEAD(11)),(LINE,HEAD(12)),(HEADNG,HEAD(13)),
 -(RUN,HEAD(14)),(FIDONE,HEAD(15)),(FIDEND,HEAD(16)),
 -(NDATA,HEAD(17)),
 -(RLAT1,HEAD(46)),
 -(RLAT2,HEAD(47)),(TIME1,HEAD(48)),(TIMEND,HEAD(49)),
 -(RLONG1,HEAD(55)),
 -(RLONG2,HEAD(56)),
 -(CM,HEAD(64))

INTEGER FSIZE,FSKIP,FID(1250),PFID(400)
 -,RLINE1,RLINE2,RFID1,RFID2
 -,PLINE1,PLINE2,PFID1,PFID2
 DIMENSION HEAD(180),INDEX(50,2)
 DIMENSION XARRAY(1250),YARRAY(1250),TIME(1250)
 DIMENSION ICHAR(8),TODAY(2)
 LOGICAL LROTAT/.FALSE./,START/.TRUE./
 LOGICAL PCONT/.FALSE./,MSECT/.FALSE./
 -,PLOT/.TRUE./,WRITE/.FALSE./
 LFILE=1 @ CURRENT POSITION ON INPUT TAPE WITH RESPECT TO FILES.


```

C
PTIME2=0.
PLINE2=-1

C
C      INPUT PICKED POINT FILE INTO ARRAY
C      SET UP INDEX WITH FLIGHT LINE #'S
C

J=0
DO 10 I=1,400
READ (3,15,END=14) PLINE1,PFID(I)
IF (PLINE1.EQ.PLINE2) GOTO 10
J=J+1
INDEX(J,1)=PLINE1
INDEX(J,2)=I
PLINE2=PLINE1
IF (J.LT.51) GOTO 10
WRITE (6,5)
5  FORMAT (' LINE INDEX ARRAY OVERFLOW PGM. ABORTED')
STOP
10  CONTINUE
WRITE (6,12)
12  FORMAT (' PICKED FID ARRAY OVERFLOW PGM. ABORTED')
STOP
14  LLINE=J
LPOINT=I-1
J=1
REWIND 3

C
C      INPUT PARAMETERS FROM TERMINAL
C

15  FORMAT ()
20  WRITE (6,40)
40  FORMAT (' WHAT IS MAP SCALE ')
READ (5,15) SCALE
WRITE (6,50)
50  FORMAT (' WHAT IS MAP SIZE X & Y ?')
READ (5,15) XDIM,YDIM
WRITE (6,60)
60  FORMAT (' WHAT IS X & Y LOC OF FIRST REFERENCE POINT ON MAP')
READ (5,15) XSTART,YSTART
WRITE (6,80)
80  FORMAT (' ARE LINES TO BE ROTATED')
READ (5,210) IANS
IF (IANS.GE.'Y'.AND.IANS.LE.'YES') LROTAT=.TRUE.

C
C      OPTIONS LIST
C

90  WRITE (6,100) PLOTL,WRITE
100 FORMAT (' KEYWORD: '/
- ' PLOT -',L1,'- GENERATE PLOT TAPE (CALCOMP-PLOT)'/
- ' WRITE -',L1,'- PRINT OUT ALL COORDINATES IN LAT - LONG'/
- ' ANGLE --- PLOT ANGLE FOR FIDUCIALS'/
- ' END --- KILL JOB'/
- ' OPTION --- PRINT THIS OPTION LIST'//)

C
C      PGM JUMPS BACK TO HERE FROM 2000+1 AFTER PROCESSING SET OF FILES
C

```

```

200 WRITE (6,205)
205 FORMAT (' FIRST, LAST FILES OR OPTIONS')
    READ (5,210) IANS
210 FORMAT (A6)
    IF (IANS.LT.0) GOTO 280
    IF (IANS.GE.'P'.AND.IANS.LE.'PLOT') PLOTL=.TRUE.
    IF (IANS.GE.'NOP'.AND.IANS.LE.'NOPLOT') PLOTL=.FALSE.
    IF (IANS.GE.'W'.AND.IANS.LE.'WRITE') WRITE=.TRUE.
    IF (IANS.GE.'NOW'.AND.IANS.LE.'NOWRIT') WRITE=.FALSE.
    IF (IANS.GE.'E'.AND.IANS.LE.'END') GOTO 2500
    IF (IANS.GE.'AN'.AND.IANS.LE.'ANGLE') GOTO 270
    IF (IANS.GE.'OP'.AND.IANS.LE.'OPTION') GOTO 90
    GOTO 200
270 WRITE (6,275)
275 FORMAT (' PLEASE INPUT PLOT ANGLE FOR PICKED FIDUCIALS')
    READ (5,15) ANGLE
    RANGLE=ANGLE/57.295780
    SINANG=SIN(RANGLE)
    COSANG=COS(RANGLE)
    GOTO 200
280 READ(16,15,ERR=200,END=2500) IFILE,NFILE
C
C     FIND FIRST FILE
C
    FSKIP=IFILE-LFILE
    IF (FSKIP.EQ.0.AND.START) GOTO 360
    IF (FSKIP.LE.0) GOTO 310
    LFILE=IFILE
    CALL SKPFLS(11,FSKIP,0)
    GOTO 360
310 IF (IFILE.EQ.1.OR.IFILE.LT.LFILE/3) GOTO 320
    LFILE=IFILE
    FSKIP=IABS(FSKIP)+1
    CALL BAKFLS(11,FSKIP)
    CALL SKPFLS(11,1,0)
    GOTO 360
320 CALL REWND (11,0)
    LFILE=IFILE
    FSKIP=IFILE-1
    CALL SKPFLS (11,FSKIP,0)
    GOTO 360
330 CALL SKPFLS(11,1,0)
    LFILE=LFILE+1
    GOTO 360
360 WRITE (6,370) LFILE
370 FORMAT(' READ FILE ',I3)
C
C     GET HEADING BLOCK
C
    NSIZE=180 @ MAXIMUM NUMBER OF WORDS IN RECORD
    LBLOCK=0 @ CURRENT POSITION IN FILE
    CALL INPUT (HEAD,FSIZE,1,$3000)
    NSIZE=1250 @ DATA BLOCK HAS UP TO 1250 WORDS
    NDATA1=NDATA+1 @ NDATA IS IN HEAD BLOCK
C
C     READ IN TIME, X, Y, AND FIDUCIAL RECORDS.
C

```

```

CALL INPUT (TIME,FSIZE,2,$3000)
CALL INPUT(XARRAY,FSIZE,3,$3000)
CALL INPUT(YARRAY,FSIZE,4,$3000)
CALL INPUT(FID,FSIZE,5,$3000)

```

C
C
C

MAKE SURE FIRST REFERENCE FID IS IN FIRST FILE

```

IF (.NOT.START) GOTO 862
READ (2,15) RLINE1,RFID1,RX1,RY1
DO 470 I=2,NDATA1
470 IF (FID(I).EQ.-RFID1) GOTO 500
480 WRITE (6,485) IFILE
485 FORMAT (' COULD NOT FIND FIRST REFERENCE FID IN FILE: ',I3
-, ' OF INPUT TAPE')

```

C
C
C

PUT IN FRAME ON PLOT

```

500 IF (.NOT.PLOTL) GOTO 862
CALL IDPLOT (XDIM,YDIM)
CALL PLOT (0.,0.,3)
CALL PLOT (0.,YDIM,2)
CALL PLOT (XDIM,YDIM,2)
CALL PLOT (XDIM,0.,2)
CALL PLOT (0.,0.,2)
CALL PLOT (.1,.1,3)
XDIM=XDIM-.1
YDIM=YDIM-.1
CALL PLOT (.1,YDIM,2)
CALL PLOT (XDIM,YDIM,2)
CALL PLOT (XDIM,.1,2)

```

C
C
C

TITLE BLOCK

```

TSIZE=4.
THITE=.75*TSIZE+.1
CALL PLOT (XDIM-TSIZE,.1,2)
CALL PLOT (XDIM-TSIZE,THITE,2)
CALL PLOT (XDIM,THITE,2)
READ(1,660 ) JNUM,ICHAR
660 FORMAT (I2,8A6)
CENTER=XDIM-TSIZE/2.
CHITE=TSIZE/30.
XTITLE=CENTER-(FLOAT(JNUM)*CHITE)/2.
YTITLE=THITE*.75+.1
CALL SYMBOL (XTITLE,YTITLE,CHITE,ICHAR,0.,JNUM)
XTITLE=XTITLE+.02
CALL SYMBOL (XTITLE,YTITLE,CHITE,ICHAR,0.,JNUM)
CHITE=TSIZE/45.
DO 670 ITITLE=1,4
READ (1,660 ) JNUM,ICHAR
XTITLE=CENTER-(FLOAT(JNUM)*CHITE)/2.
YTITLE=THITE*(.625-(.125*FLOAT(ITITLE-1)))+.1
670 CALL SYMBOL (XTITLE,YTITLE,CHITE,ICHAR,0.,JNUM)
CALL DAY (TODAY) @ MONTH, YEAR
ENCODE (41,680 ,ICHAR) TODAY(1),TODAY(2)
680 FORMAT ('BY APPLIED GEOPHYSICS, SLC, UT ',A3,1X,R4)
XTITLE=CENTER-(40.*CHITE)/2.

```

```
YTITLE=.2
CALL SYMBOL (XTITLE,YTITLE,CHITE,ICHAR,0.,40)
CALL PLOT (XDIM-TSIZE,.1,3)
CALL PLOT (.1,.1,2)
```

```
      SET UP SHIFT OF DATA AND PLOT LATITUDE - LONGITUDE TICK MARKS
```

```
XSHIFT=(RX1*39.37)/SCALE
YSHIFT=(RY1*39.37)/SCALE
CALL TICKS (XSTART,YSTART,RX1,RY1,0.,0.,XDIM,YDIM,LROTAT,SCALE,CM)
```

```
*****
```

```
      SET UP FOR LINEAR INTERPOLATION OF DATA BETWEEN
      REFERENCE FIDS
```

```
*****
```

```
      FIND CORRECT REFERENCE POINTS
      PGM. ASSUMES REFERENCE POINTS, PICKED POINTS,
      AND DATA FROM TAPE IS IN CHRONOLOGICAL ORDER
```

```
862  IF (PTIME2.GT.TIME1) GOTO 1010 @ PTIME2 IS NEGATIVE IF SECTION BOUNDARY
      HAVE GOOD INTERPOLATION DATA FOR AT
      LEAST PART OF FLIGHT LINE
```

```
      OLDT1=PTIME1
      PTIME2=ABS(PTIME2) @ RESET
      IF (START) GOTO 880
      GOTO 870
```

```
865  MSECT=.TRUE. @ MULTISECTION INTERPOLATION ON FLIGHT LINE
      OLDT1=PTIME1
```

```
      READ IN NEW REFERENCE POINT KEEPING PREVIOUSLY READ
      REFERENCE POINT
```

```
870  CALL REF1 ($990,$3015)
      GOTO 980
```

```
880  CALL REF2 ($990,$3015)
```

```
      GET DIFFERENCE VALUES FOR INTERPOLATION
```

```
980  OLDDIF=TIMDIF
      TIMDIF=PTIME2-PTIME1
      IF (TIMDIF.GT.0..AND.TIMDIF.LT.1200.) GOTO 1000
```

```
      FIND NEW REFERENCE POINTS BECAUSE OF SECTION BREAK
      EITHER TIME GAP OF 20 MINUTES OR CHANGE OF DAY
```

```
TIMDIF=OLDDIF
PTIME1=OLDT1
PTIME2=-PTIME2 @ FLAG NEGATIVE SO WILL SEARCH FOR NEW REFERENCE POINT
      NEXT FILE
```

```
      JUMPS TO HERE AFTER LAST REFERENCE POINT
      ASSUMES LAST REFERENCE POINT IS ON LAST FILE
```

```
990  IF (IEND.GE.NDATA1) GOTO 1200
      ISTART=IEND+1
      IEND=NDATA1
      GOTO 1140
```

```

C
C      FIND VALUES FOR ERROR CORRECTION
C
1000  XDIF1=PX1-RX1
      XDIF2=PX2-RX2
      YDIF1=PY1-RY1
      YDIF2=PY2-RY2
      XCHANG=XDIF2-XDIF1
      YCHANG=YDIF2-YDIF1
      WRITE (6,1005) RLINE1,RFID1,XDIF1,YDIF1,RLINE2,RFID2
      -,XDIF2,YDIF2,XCHANG,YCHANG
1005  FORMAT (2(/' LINE: ',I3,' FID:',I6,' X DIFFERENCE:',F6.0,
      -' Y DIFFERENCE:',F6.0)/' CHANGE IN X:',F6.0,' CHANGE IN Y:',F6.0//
      -)
      START=.FALSE.
      GOTO 862

```

```

C
C      FIND START FOR A SECTION
C
1010  IF (TIME1.GT.PTIME1.OR..NOT.MSECT) GOTO 1040
      NSTART=IEND
      DO 1020 I=NSTART,NDATA1
1020  IF (TIME(I).GE.PTIME1) GOTO 1030
1025  WRITE (6,1027)
1027  FORMAT (' NO REFERENCE POINT FOR THIS FILE PGM. ABORTED')
      GOTO 3015
1030  ISTART=I
      IF (ISTART.EQ.NDATA1) GOTO 1025
      GOTO 1050
1040  ISTART=2

```

```

C
C      FIND LAST POINT FOR SECTION
C
1050  IF (TIMEND.LE.PTIME2+.5) GOTO 1090
      DO 1060 I=ISTART,NDATA1
1060  IF (TIME(I).GE.PTIME2) GOTO 1070
      WRITE (6,1065)
1065  FORMAT (' DISCREPANCY BETWEEN TIME(NDATA1) AND'
      -,' TIMEND PGM. ABORTED')
      GOTO 3015
1070  IEND=I-1
      GOTO 1100
1090  IEND=NDATA1
1100  IF (.NOT.MSECT) GOTO 1130

```

```

C
C      MAKE SURE SECTIONS MATCH UP IN FLIGHT LINE
C
      IF (ILAST.EQ.ISTART-1) GOTO 1140
      WRITE (6,1105)
1105  FORMAT (' NON-CONTINUOUS SECTIONS PGM ABORTED')
      GOTO 3015
1130  IBEG=ISTART @ FIRST GOOD POINT OF ENTIRE LINE
1140  ILAST=IEND

```

```

C
C      DO INTERPOLATION FOR THIS SECTION OF LINE
C
      DO 1150 I=ISTART,IEND

```

```

        RATIO=(TIME(I)-PTIME1)/TIMDIF
        XARRAY(I)=XARRAY(I)-XDIF1-RATIO*XCHANG
1150    YARRAY(I)=YARRAY(I)-YDIF1-RATIO*YCHANG
        IF (IEND.LT.NDATA1) GOTO 865
1200    MSECT=.FALSE.
C
C            PRINT X-Y DATA OPTION
C
        IF (.NOT.WRITE) GOTO 1250
        DO 1220 I=ISTART,IEND
        CALL UTMLL (XARRAY(I),YARRAY(I),CM)
1220    WRITE (6,1230) FID(I),TIME(I),XARRAY(I),YARRAY(I)
1230    FORMAT (' FIDUCIAL:',I6,' TIME:',F7.0,' LONGITUDE: ',F9.4,
- ' LATITUDE:',F8.4)
1250    IF (.NOT.PLOT1) GOTO 2000
C
C            GET X & Y POSITIONS INTO PLOTTING WINDOW
C
        DO 1300 I=IBEG,ILAST
        XARRAY(I)=(XARRAY(I)*39.37)/SCALE-XSHIFT
1300    YARRAY(I)=(YARRAY(I)*39.37)/SCALE-YSHIFT
C
C            ROTATE DATA OR NOT AND ADD STARTING LOCATION OFFSET
C
        IF (.NOT.LROTAT) GOTO 1315
        DO 1310 I=IBEG,ILAST
        Z=YARRAY(I)
        YARRAY(I)=-XARRAY(I)+YSTART
1310    XARRAY(I)=Z+XSTART
        GOTO 1350
1315    DO 1320 I=IBEG,ILAST
        XARRAY(I)=XARRAY(I)+XSTART
1320    YARRAY(I)=YARRAY(I)+YSTART
C
C            FIND CORRECT PICKED FIDS FOR THIS LINE FOR PLOTTING
C
        DO 1350 I=1,LLINE
1350    DO 1360 I=1,LLINE
1360    IF (INDEX(I,1).EQ.LINE) GOTO 1380
        WRITE (6,1370) LINE
1370    FORMAT (' COULD NOT FIND LINE: ',I3,' IN INDEX PGM. ABORTED')
        GOTO 3015
1380    IF (J.GE.INDEX(I,2).AND.(J.LT.INDEX(I+1,2).OR.I.EQ.LLINE))
- GOTO 1400
        J=INDEX (I,2)
C
C            START PLOTTING FLIGHT LINE
C
1400    NDOWN=3
        IF (PCONT) NDOWN=2
        DO 1520 I=IBEG,ILAST
        IF (-PFID(J).NE.FID(I)) GOTO 1510
        ICODE=-1
        IF (NDOWN.EQ.2) ICODE=-2
C            FOURTH ARGUMENT = 1, PRODUCES CENTERED CIRCLE
        CALL SYMBOL (XARRAY(I),YARRAY(I),.062992,1,0.0,ICODE)
        OFFSET=-.262
        IF (-FID(I).LE.9999) OFFSET=-.331

```



```

IF (-FID(I).LE.999) OFFSET=-.400
IF (-FID(I).LE.99) OFFSET=-.469
IF (-FID(I).LE.9) OFFSET=-.538
XOFF=OFFSET*COSANG+.034*SINANG
YOFF=OFFSET*SINANG-.034*COSANG
CALL NUMBRI (XARRAY(I)+XOFF,YARRAY(I)+YOFF,.069,-FID(I),ANGLE)
J=J+1
IF (J.GT.LPOINT) J=LPOINT
NDOWN=3
1510 CALL PLOT (XARRAY(I),YARRAY(I),NDOWN)
NDOWN=2
1520 CONTINUE
2000 IF (LFILE.LT.NFILE) GOTO 330 @ MORE FILES TO PLOT
GOTO 200
2500 CALL LENGTH (INCHES)
WRITE (6,2510) INCHES
2510 FORMAT (' PLOT WAS',I6,' INCHES LONG')
GOTO 3020
3000 WRITE (6,3010)
3010 FORMAT(' ERROR IN READING FILE PGM ABORTED')
3015 IF (START) STOP
3020 IF (PLOTL) CALL FINI
STOP
C *****
C
C      SUBROUTINE TO READ RECORDS OFF INPUT TAPE
C
C      ARRAY - MEMORY SPACE YOU ARE READING INTO
C      NW - NUMBER OF WORDS READ
C      NBLOCK - RECORD IDENTIFICATION
C      RETURN 4 - UNSUCCESSFUL READ
C
C      SUBROUTINE INPUT(ARRAY,NW,NBLOCK,$)
C      DIMENSION ARRAY(1)
C      EQUIVALENCE(REAL,NREAL)
C      KBLOCK=NBLOCK-LBLOCK-1 @ NUMBER OR RECORDS TO SKIP
C      IF(KBLOCK.EQ.0) GOTO 10
C      CALL SKPFLS(11,0,KBLOCK)
10    CALL VARBIN(NW,11,ARRAY,NSIZE)
C      REAL=ARRAY(1)
C      IF (NBLOCK.EQ.NREAL) GOTO 17
C      WRITE(6,15) NBLOCK,NREAL
15    FORMAT(' PGM ASKED FOR BLOCK',I4,' GOT BLOCK',I4)
C      RETURN 4
17    IF(ITE(11).EQ.-1) RETURN 4 @ ERROR ON READ OF TAPE
C      IF(ITE(11).EQ.1) GOTO 20 @ END OF FILE READ
C      IF(ITE(11).EQ.4) NW=NW-1 @ ODD NUMBER OF WORDS ON READ
C      LBLOCK=NBLOCK
C      RETURN
20    WRITE(6,30)
30    FORMAT(' EOF ENCOUNTERED')
C      RETURN 4
C *****
C
C      ROUTINE TO READ IN REFERENCE POINTS AND THE CORRESPONDING
C      PICKED INS VALUES
C

```

```

C          RETURN 1 - GO DIRECTLY TO OUTPUT DATA
C          RETURN 2 - ABORT PROGRAM
C
SUBROUTINE REF1 ($,$)
RLINE1=RLINE2
RFID1=RFID2
RX1=RX2
RY1=RY2
ENTRY REF2 ($,$)
READ (2,15,END=1200) RLINE2,RFID2,RX2,RY2
15  FORMAT ( )
C
C          FIND CORRECT PICKED POINTS FOR INTERPOLATION
C
IF (START) GOTO 890
PLINE1=PLINE2
PFID1=PFID2
IF (PFID1.NE.RFID1) GOTO 890
PX1=PX2
PY1=PY2
PTIME1=PTIME2
GOTO 930
C
C          FIND MATCH BETWEEN PFID1 & RFID1
C
890  DO 900 I=1,1000
      READ (3,15,END=910) PLINE1,PFID1,PX1,PY1,PTIME1
900  IF (PFID1.EQ.RFID1) GOTO 930
910  WRITE (6,920) RFID1
920  FORMAT (' COULD NOT FIND PICKED FID: ',I6)
      RETURN 2
930  IF (PLINE1.NE.RLINE1) GOTO 890
C
C          GET MATCH UP OF PFID2 & RFID2
C
940  DO 950 I=1,1000
      READ (3,15,END=960) PLINE2,PFID2,PX2,PY2,PTIME2
950  IF (PFID2.EQ.RFID2) GOTO 970
960  WRITE (6,920) RFID2
      RETURN 2
970  IF (PLINE2.NE.RLINE2) GOTO 940
      RETURN
1200 RETURN 1
      END
EOF AT LINE 497
END EDIT NO LINES OUTPUT

```

@EDIT,Z AGI*REL/R\$.TICKS
 EDIT <29A> 05/05/81 18:52 TICKS(16):F
 EDIT

ROUTINE TO MAKE LATITUDE AND LONGITUDE TICK MARKS
 FOR PLOTTING PROGRAMS

XSTART,YSTART - STARTING LOCATION IN WINDOW IN INCHES
 CORRESPONDING TO XUTM,YUTM
 XUTM,YUTM - STARTING LOCATION IN UTM COORDINATES
 XMIN,YMIN,XMAX,YMAX - BOUNDARIES TO PLOT TICK MARKS IN
 ROTATE - LOGICAL FOR -90 DEGREE ROTATION OF TICK MARKS
 SCALE - MAP SCALE
 CM - CENTRAL MERIDIAN

NOTES:

- 1) YMAX USED FOR ROTATION OF TICK MARKS MAKE SURE
 DATA IS ROTATED WITH YMAX

FUTURE CHANGES:

- 1) BE ABLE TO ROTATE AT ANY ANGLE

SUBROUTINE TICKS (XSTART,YSTART,XUTM,YUTM,XMIN,YMIN,XMAX,YMAX,
 -ROTATE,SCALE,CM)
 LOGICAL ROTATE,EVEN,OUT
 IMPLICIT REAL (M)
 REAL INUTM
 INTEGER CM
 DIMENSION LABEL(2)

TIC MARK INCREMENT	5	MIN	IF	SCALE	>1:48000
	2.5	"	"	"	<1:48000
	7.5	"	"	"	>1:100000
	15.	"	"	"	>1:150000
	30.	"	"	"	>1:300000

TICINC=5.0

IF(SCALE .LT. 48000.)TICINC=2.5

IF(SCALE .GT. 100000.)TICINC=7.5

IF(SCALE .GT. 150000.)TICINC=15.

IF(SCALE .GT. 300000.)TICINC=30.

DEGINC=TICINC/60.

WRITE(6,20)SCALE,TICINC

20 FORMAT(' MAP SCALE 1:',F8.0,', TIC MARK SPACING ',F4.1,' MIN')

XM=XMAX-0.49

XMN=XMIN+0.49

YM=YMAX-0.49

YMN=YMIN+0.49

CONV=39.37/SCALE @ CONVERSION OF UTM TO MAP INCHES

INUTM=SCALE/39.37 @ CONVERSION OF MAP INCHES TO UTM

XOFF=XUTM*CONV @ OFFSETS IN INCHES TO PUT TICK MARKS INTO WINDOW

YOFF=YUTM*CONV

FIND LOCATIONS OF FOUR CORNERS OF MAP

IF (ROTATE) GOTO 100

X1=(XMN-XSTART+XOFF)*INUTM

```

X2=(XMX-XSTART+XOFF)*INUTM
Y1=(YMN-YSTART+YOFF)*INUTM
Y2=(YMX-YSTART+YOFF)*INUTM
GOTO 200
100 X1=(YSTART-YMX+XOFF)*INUTM
X2=(YSTART-YMN+XOFF)*INUTM
Y1=(XMN-XSTART+YOFF)*INUTM
Y2=(XMX-XSTART+YOFF)*INUTM
200 MNLONG=X1
MXLONG=X2
MNLAT=Y1
MXLAT=Y2
C
C      IS MAP IN NORTHERN OR SOUTHERN HEMISPHERE ?
C
IF (MAXLAT.LT.0.) GOTO 220
CALL UTMLL(MNLONG,MXLAT,CM)
CALL UTMLL(MXLONG,Y2,CM)
CALL UTMLL(X1,MNLAT,CM)
GOTO 230
220 CALL UTMLL(MNLONG,MNLAT,CM)
CALL UTMLL(MXLONG,Y1,CM)
CALL UTMLL(X1,MXLAT,CM)
230 WRITE (6,235) MNLONG,MXLONG,MNLAT,MXLAT
235 FORMAT (' MINIMUM AND MAXIMUM LONGITUDES:',2F14.7/
-      ' MINIMUM AND MAXIMUM LATITUDES: ',2F14.7//)
C
C      HAVE FOUR CORNERS IN LATITUDE AND LONGITUDE
C      NOW FIND FIRST AND LAST TICKMARKS INSIDE WINDOW
C
MNLONG=MNLONG-RMOD(MNLONG,DEGINC)+DEGINC
MXLONG=MXLONG-RMOD(MXLONG,DEGINC)
MNLAT=MNLAT-RMOD(MNLAT,DEGINC)+DEGINC
MXLAT=MXLAT-RMOD(MXLAT,DEGINC)
NLAT=INT((MXLAT-MNLAT+.001)/DEGINC)+1
NLONG=INT((MXLONG-MNLONG+.001)/DEGINC)+1
WRITE (6,235) MNLONG,MXLONG,MNLAT,MXLAT
WRITE (6,240) NLONG,NLAT
240 FORMAT (' NLONG=',I3,' NLAT=',I3///)
C
C      SET INITIAL CONDITIONS FOR INSIDE LOOP
C
IF (ROTATE) GOTO 250
IBEG=1
IEND=NLONG
ISTEP=1
GOTO 300
250 IBEG=NLONG
IEND=1
ISTEP=-1
300 ASSIGN 400 TO J1
ASSIGN 500 TO J2
ASSIGN 430 TO J3
ASSIGN 425 TO L2
C
C      OUTER LOOP ALWAYS DOES LATITUDE FROM SOUTH TO NORTH
C

```

```

DO 600 ILAT=1,NLAT
EVEN=((ILAT/2)*2.EQ.ILAT)
C
C      DO LONGITUDE IN ALTERNATING DIRECTIONS TO MINIMIZE PLOT TIME
C
DO 500 ILONG=IBEG,IEND,ISTEP
RLONG=MNLONG+FLOAT(ILONG-1)*DEGINC
C
C      FIND TICK MARK LOCATIONS IN WINDOW
C
CALL UTM(X,Y,MNLAT,RLONG,CM)
X=X*CONV-XOFF
Y=Y*CONV-YOFF
IF (ROTATE) GOTO 380
X=X+XSTART
Y=Y+YSTART
GOTO 390
380  YHOLD=Y
     Y=-X+YSTART
     X=YHOLD+XSTART
390  OUT=(.NOT.(X.GT.XMN.AND.X.LT.XMX.AND.Y.GT.YMN.AND.Y.LT.YMX))
     IF (OUT) WRITE (6,395) X,Y
395  FORMAT (' TICK MARK OUTSIDE WINDOW:',2F10.2)
     GOTO J1 (400,440) @ MAKE TICK MARK FIRST OR LONGITUDE LABEL FIRST
400  IF (ILONG.NE.1) GOTO 420
     IF ((EVEN.AND.ROTATE).OR..NOT.(EVEN.OR.ROTATE)) GOTO 410 @ MAKE LAT LABEL
C                                     FIRST THEN TICK MARK
     ASSIGN 425 TO L1
     ASSIGN 415 TO L2
     GOTO 420
410  ASSIGN 420 TO L1
C
C      PLOT LATITUDE LABEL
C
415  CALL DMS(MNLAT)
     WRITE (6,416) LABEL
416  FORMAT (' LATITUDE LABEL: ',A6,A4)
     IF (ROTATE) GOTO 417
     CALL SYMBOL(XMIN+.125,Y-.49,.098,LABEL,90.,10)
     GOTO 419
417  CALL SYMBOL(X-.49,YMAX-.125,.098,LABEL,0.,10)
419  ASSIGN 425 TO L2
     GOTO L1 (420,425)
C
C      PLOT TICK MARK IF IN WINDOW
C
420  IF (OUT) GOTO 422
     CALL SYMBOL(X,Y,.25,3,0.,-1)
     WRITE (6,421) X,Y
421  FORMAT (' PLOTTED TICK MARK AT:',2F10.2)
422  GOTO L2 (425,415)
425  GOTO J3 (430,490) @ DO LONGITUDE LABEL,ALREADY DONE
430  IF (ILAT.NE.NLAT) GOTO 500
     ASSIGN 440 TO J1
     ASSIGN 500 TO J2
     GOTO 450
440  ASSIGN 400 TO J1

```

```

        ASSIGN 400 TO J2
        ASSIGN 490 TO J3
C
C          PLOT LONGITUDE LABEL IF IN WINDOW
C
450  IF (OUT) GOTO 480
      CALL DMS(RLONG)
      WRITE (6,460) LABEL
460  FORMAT (' LONGITUDE LABEL: ',A6,A4)
      IF (ROTATE) GOTO 470
      CALL SYMBOL(X-.49,YMAX-.125,.098,LABEL,0.,10)
      GOTO 480
470  CALL SYMBOL (XMAX-.125,Y+.49,.098,LABEL,-90.,10)
480  GOTO J2 (500,400) @ TICKMARK OR LONGITUDE LABEL FIRST
490  ASSIGN 430 TO J3
500  CONTINUE
      IHHOLD=IBEG
      IBEG=IEND
      ICND=IHOLD
      ISTEP=-ISTEP
600  MNLAT=MNLAT+DEGINC
      RETURN
C *****
C          SUBROUTINE TO CONVERT REAL DEGREES TO - DEG, MIN, & SEC.
C          AND ENCODE LABEL
C
      SUBROUTINE DMS(DEGREE)
      LSIGN=1
      IF(DEGREE.LT.0.)LSIGN=-1
      DEG=ABS(DEGREE)
      LDEG=INT(DEG+1.389E-4)
      LSEC=IFIX(.5+DEG*3600.)
      LDEG36=LDEG*3600
      LDEG=LDEG*LSIGN
      LMIN=(LSEC-LDEG36)/60
      LSEC=LSEC-LMIN*60-LDEG36
      ENCODE(10,100,LABEL)LDEG,LMIN,LSEC
100  FORMAT(I4,':',J2,':',J2)
      RETURN
C *****
C          FUNCTION TO TAKE ACTUAL MODULUS OF REAL NUMBER
C          OUTPUT IS ALWAYS POSITIVE
C          ASSUMES Y IS ALWAYS POSITIVE
C
      FUNCTION RMOD (X,Y)
      RMOD=X-INT(X/Y)*Y
      IF (RMOD.LT.0.) RMOD=RMOD+Y
      RETURN
      END
EOF AT LINE 217
END EDIT NO LINES OUTPUT

```


@EDIT,Z AGI*REL/R\$.UTM

EDIT <29A> 05/05/81 18:52 UTM(20):F

EDIT

SUBROUTINE UTM(X,Y,YLAT,XLON,ICM)

C THIS SUBROUTINE WILL CONVERT THE LONGITUDE AND LATITUDE TO
C UNIVERSAL TRANSVERSE MERCATOR COORDINATES (UTM) WITHIN THE UTM
C ZONE GIVEN. THE PROGRAM PROCESSES N POINTS THEN RETURNS
DOUBLE PRECISION Y1,Y2,Y3,Y4,CNII,CNIII,CNV,CNA6,CNB5,ESQ,PI,SNONS
1,CM,EPSQ,PHRD,SNLAT,CSLAT,SNSQ,CCSQ,TNLAT,TNSQ,ENU,ENSNS,A,EPCS,
2EPCSQ,WON,P,PSQ,PCU,PFR,PFV,PSX,FOUR,TWO,EPCTN,THRE,FIVE,CSFR,
3CSFRR,A6,B5,FE,ALORG
DATA Y1,Y2,Y3,Y4,CNII,CNIII,CNV,CNA6,CNB5,ESQ,PI,SCALE,A,FE,SNONS,
1EPSQ/.11422D0,21.73607D0,5104.57388D0,6367399.689D0,.2424068406D-1
2,.0195870255D-2,.0391740509D-2,.0153460626D-6,.0460381879D-6,.0067
368658D0,3.1415926535898D0,.9996,6378206.4D0,5.D5,4.848136811D-6,6.
48147784948D-3/

C
C *** *** *** *** *** *** *** *** ***
C USE NEXT STATEMENT IF CENTRAL MERIDIAN IS INPUT DIRECTLY.

C
C NOTE: CM IS CENTRAL MERIDIAN IN SECONDS

C
C CM=DFLOAT(ICM)*3.6D3
CC CM=DFLOAT(6*INT((XLON(1)+186.)/6.))-183.)*3.6D3

C
C USE NEXT STATEMENT IF CENTRAL MERIDIAN IS TO BE CALCULATED
C FROM ACTUAL ZONE INPUT.
C CM = (6.*ZONE-183.)*3600.

C
C ALORG = 0.0
C YLATS=YLAT*3600.
C XLONS=XLON*3600.
C PHRD = YLATS*SNONS
C SNLAT = DSIN(PHRD)
C CSLAT = DCOS(PHRD)
C SNSQ = SNLAT*SNLAT
C CCSQ = CSLAT*CSLAT
C TNLAT = SNLAT/CSLAT
C TNSQ = TNLAT*TNLAT
C ENU = A/DSQRT(1.-ESQ*SNSQ)
C ENSNS = ENU*SNONS
C EPCS = EPSQ*CCSQ
C EPCSQ = 1.+EPCS
C WON = (Y4*(PHRD-(SNLAT*CSLAT*10.E-7)*(Y3-CCSQ*(Y2-Y1*CCSQ))))*
1SCALE

P = -(CM-XLONS)*10.E-5
IF (P) 20,10,20

10 X = FE
Y = (WON-ALORG)

GO TO 30

20 PSQ = P*P
PCU = PSQ*P
PFR = PCU*P
PFV = PFR*P
PSX = PFV*P
FOUR = ENSNS*CSLAT*SCALE*10.E3
TWO = FOUR*SNLAT*CNII

```

EPCTN = EPCSQ-TNSQ
THRE = TWO*CNIII*CCSQ*(4.*EPCSQ+EPCTN)
FIVE = FOUR*CNV*CCSQ*EPCTN
CSFR = CCSQ*CCSQ
CSFRR = 1./CSFR
A6 = PSX*TWO*CNA6*CSFR*(60.*EPCTN+CSFRR+540.*EPCS-330.*EPSQ)
B5 = PFV*FOUR*CNB5*CSFR*(20.*EPCTN+CSFRR+52.*EPCS-58.*EPSQ-16.)
X = (P*FOUR+PCU*FIVE+B5)+FE
Y = ((PSQ*TWO+PFR*THRE+WON+A6)-ALORG)

```

```

30 CONTINUE

```

```

CC  WRITE(6,1000)CM,X,Y,YLAT,XLON,ALORG,PHRD,
CC  -   SNLAT,CSLAT,SNSQ,CCSQ,TNLAT,TNSQ,ENU,ENSNS,EPCS,
CC  -   EPCSQ,WON,P,PSQ,PCU,PFR,PFV,PSX,FOUR,TWO,EPCTN,
CC  -   THRE,FIVE,CSFR,CSFRR,A6,B5

```

```

C1000 FORMAT()

```

```

RETURN

```

```

END

```

```

EOF AT LINE 71

```

```

END EDIT NO LINES OUTPUT

```

@EDIT,Z AGI*REL/R\$.UTMLL

EDIT <29A> 05/05/81 18:52 UTMLL(5):F

EDIT

SUBROUTINE UTMLL(X,Y,ICM)

C
C THIS ROUTINE CALCULATES THE LONGITUDE AND LATITUDE OF THE
C COORDINATE POSITION X,Y IN UTM METERS RELATIVE TO UTM
C ZONE ZONENO (RELATIVE TO THE CENTRAL MERIDIAN)

C
C INPUTS - X UTM METERS, Y UTM METERS, ZONENO ZONE NO.

C
C REAL LON,LAT
C DOUBLE PRECISION ESQ,PI,MTOF,MTOFI,SECRD,FE,CONS1,CONS2,
C 1CONS3,CONS4,A,SCALE,PPRD,SEPQ,SNLT,CSLT,CSSQ,EPSQ,SNONS,
C 2PHRD,PHIS,Q,SNLAT,CSLAT,SNSQ,CCSQ,TNLAT,TNSQ,ENU,ENSNS,
C 3QSQ,QFR,QSX,EPCSQ,SVN,EGHT,D6,DLAM,EPCS,QCU,QFV,SCLAT,
C 4ENSNS,ANINE,TEN,E5
C DATA ESQ/.006768658D0/,PI/3.1415926535898D0/,A/6378206.4D0/,
C 1SCALE/.9996D0/,CONS1/.24682D0/,CONS2/30.02335D0/,
C 2CONS3/5078.64977D0/,CONS4/.157049981D0/,SEPQ/.0408887094D0/

CC ZONENO=17

11 CONTINUE

C
C *** *** *** *** *** *** *** *** ***

C
C USE NEXT STATEMENT IF CENTRAL MERIDIAN IS INPUT DIRECTLY.

C
C NOTE: CM IS CENTRAL MERIDIAN IN SECONDS

CC
CM=ZONENO*3600.
CM=FLOAT(ICM)*3600.

C
C IF ACTUAL ZONENUMBER IS INPUT, CALCULATE CENTRAL MERIDIAN (CM)
C USING FOLLOWING STATEMENT.
C CM=(6.*ZONENO-183.)*3600.

C
C MTOF=39.37/12.
C MTOFI = 12./39.37
C SECRD = 648000./PI
C FE=500000.*MTOF
C EPSQ = ESQ/(1.-ESQ)
C SNONS=1./SECRD
C LAT=X*MTOF
C LON=Y*MTOF
C PPRD=(Y*CONS4*1.0E-6)/SCALE
C SNLT=DSIN(PPRD)
C CSLT=DCOS(PPRD)
C CSSQ=CSLT*CSLT
C PHRD=((CONS1*CSSQ+CONS2)*CSSQ+CONS3)*(SNLT*CSLT)*1.0E-6+PPRD
C PHIS=PHRD*SECRD
C Q=((LAT-FE)*MTOFI)*1.0E-6
C IF(Q) 300,200,300
200 DLAM=0.0
LAT=PHIS/3600.
GO TO 400
300 SNLAT=DSIN(PHRD)
CSLAT=DCOS(PHRD)

```

SNSQ=SNLAT*SNLAT
CCSQ=CSLAT*CSLAT
TNLAT=SNLAT/CSLAT
TNSQ=TNLAT*TNLAT
ENU=A/DSQRT(1.0-ESQ*SNSQ)
ENSNS=ENU*SNONS
EPCS=EPSQ*CCSQ
EPCSQ=1.0+EPCS
QSQ=Q*Q
QCU=Q*QSQ
QFR=Q*QCU
QFV=Q*QFR
QX=Q*QFV
SCLAT=1.0/CSLAT
ENSNS5=ENU**4*ENSNS
SVN=(( (TNLAT/(2.0*ENU*ENSNS))*EPCSQ)/SCALE**2)*10.0D11
EGHT=(( (TNLAT/(24.0*ENU**3*ENSNS))*(5.+3.*TNSQ+SEPQ*(CCSQ-SNSQ)
1-(3.0*EPSQ**2*CCSQ)*(CCSQ+3.*SNSQ))/SCALE**4)*10.0D23
D6=(QX*(TNLAT/(720.*ENU**5*ENSNS))*(61.+(45.*TNSQ)*(2.+TNSQ-
1EPSQ*SNSQ)+EPSQ*(107.*CCSQ-162.*SNSQ))/SCALE**6)*10.0D35
ANINE=(SCLAT/ENSNS)/SCALE*1.0E6
TEN=(SCLAT/(6.*ENU**2*ENSNS))*(1.+2.*TNSQ+EPCS)/SCALE**3*1.0D18
E5=QFV*(SCLAT/(120.*ENSNS5))*(5.+(4.*TNSQ)*(7.+6.*TNSQ)
1+(2.*EPSQ)*(3.*CCSQ+4.*SNSQ))/SCALE**5*1.0D30
LAT=(PHIS-SVN*QSQ+EGHT*QFR-D6)/3600.
DLAM=ANINE*Q-TEN*QCU+E5
400 CONTINUE
LON=(CM+DLAM)/3600.0
X=LON
Y=LAT
RETURN
END
EOF AT LINE 86
END EDIT NO LINES OUTPUT

```

TECHNICAL MANUAL

by: Applied Geophysics Inc.

Volume IV

INSI and I-64

General Description

and

Technical Manual

by

Applied Geophysics Inc.
675 South, 400 East
Salt Lake City, Utah 84111

May 1981

Table of contents

1.	INTRODUCTION	-2
2.	INSI CARD	-2
2.1.	Introduction	-2
2.2.	History	-2
2.3.	Application	-2
2.4.	Design Purpose	-3
3.	ARINC	-5
3.1.	Specifications	-5
3.2.	Basic Format	-5
3.3.	Label Format	-7
3.4.	Data Format	-7
3.4.1.	BCD	-7
3.4.2.	Binary	-7
4.	CABLING	-9
5.	FEATURES OF THE INSI	-11
5.1.	Status Port	-11
5.1.1.	Status Port Definitions	-11
5.2.	Instruction Port	-12
5.3.	Test Port	-12
5.4.	Data Port	-12
6.	INSI SPECIFICATIONS	-13
6.1.	Physical	-13
6.2.	Electrical	-13
6.3.	Dynamic	-13
6.4.	Operating environment	-13
7.	USER OPTIONS	-13
7.1.	Label Combining	-13
7.2.	Valid Frame	-14
8.	I-64 CARD.	-14
8.1.	Introduction	-14
8.2.	Application	-14
8.3.	Features	-14
8.4.	Specifications	-14
8.4.1.	Physical	-14
8.4.2.	Electrical	-15
8.4.3.	Dynamic	-15
8.4.4.	Operating Environment	-15
9.	THEORY OF OPERATION	-16
9.1.	The INSI card.	-16

Table of contents

9.1.1.	INSI/I-64 Modification.	-18
9.1.2.	RAM Reading	-18
9.2.	The I-64 card	-20
9.2.1.	EPR0M	-20
9.2.2.	Clock	-20
9.2.3.	Program Counter	-21
9.2.4.	Latch Decoder	-21
9.2.5.	Reset	-21
9.3.	As a Complete System.	-21
10.	EXAMPLE CONFIGURATION	-22
10.1.	Geometrics Configuration	-22
10.2.	I-64 Cycle	-22
10.3.	Program Format	-23
10.3.1.	Octal Program	-25

1. INTRODUCTION

In order to test the flight path capabilities of the LTN-76 Inertial Navigation System, INS generated information needs to be recorded while in flight. This manual is a description of the interface units developed to interface between the LTN-76 and an airborne data acquisition system.

2. INSI CARD

General Description

2.1. Introduction

The INS Interface Unit (INSI) is a synchronized random access memory, designed to plug directly into an Applied Geophysics Inc. CMDR-7000 Digital Acquisition System. The INSI may also be used in conjunction with an Applied Geophysics Inc. I-64 card and INSI chassis box with 5 volt power supply. This configuration allows the INSI to be interfaced to virtually any computer, 4 bit to 64 bit, TTL or CMOS 5 volt logic.

2.2. History

The INSI unit was designed to meet the need for an interface between the Litton LTN-76 Inertial Navigation System and an airborne digital data acquisition system requiring position, velocity, and attitude information.

2.3. Application

The Applied Geophysics Inc., INSI unit may be used anywhere data transfer is required from any LTN-XX INS System, designed to comply with ARINC Standards, to a digital system similar to the CMDR-7000. The Applied Geophysics Inc. I-64 card allows the INSI to communicate with a wide variety of digital data acquisition systems. The INSI will mate with any of the Litton ITGS systems, Delco Carousel, or similar systems, as long as the system complies with ARINC Standard 561.

2.4. Design Purpose

The INSI design purpose is fourfold:

1. Convert serial information in ARINC 561 format to parallel data.
2. Check format.
3. Store data in memory.
4. Output parallel data without having to synchronize timing or handshaking.

Figure 1-0

-4

3. ARINC

3.1. Specifications

The INSI complies with ARINC Standard 561 specifications as outlined in Digital Data System Compendium, ARINC Report 419-1, published December 1, 1975. For a copy of this report please write to:

Aeronautical Radio, Inc.
2551 Riva Road
Annapolis, Maryland 21401

3.2. Basic Format

The information transmitted by ARINC 561 may be coded in binary or Binary Coded Decimal (BCD). Each word transmitted will be 32 bits long. The first 8 bits sent are the label; up to 256 different labels can be used while complying with ARINC 561. The remaining 24 bits may be data, sign, matrix, parity or pad. Internally, the INSI unit handles the 24 bits of the ARINC word as a single word and will process either binary or BCD data. Figure 2.0.

ARINC 561 TIMING DIAGRAM

Figure 2-0

3.3. Label Format

The first 8 bits of the 32 bit serial word comprise the label or address. The first bit received, bit 1, is the most significant bit, and the eighth bit is the least significant bit of the label.

3.4. Data Format

3.4.1. BCD

The remaining 24 bits of the 32 bit serial word contain the data. In BCD format, bits 9,10,11 and 12 equal one BCD digit where bit 9 is the least significant bit (lsb) and bit 12 is the most significant bit (msb) of the least significant digit (lsd) in the data stream. Bits 13 to 16, 17 to 20, 21 to 24, and 25 to 28 are also 4-bit BCD digits. The most significant digit (msd) is composed of only 2 bits, bit 29 and bit 30. Bits 31 and 32 form an auxiliary 2-bit word. See figure 2.1.

3.4.2. Binary

ARINC has specified bit 32 as the parity bit, and bits 31 and 30 as the matrix word, or sign/status flag. Bit 29 is the most significant bit of a 15 bit number and has a binary weight of $1/2$. Bit 28 is the second most significant bit (2sb) and is weighted $1/4$. Bit 15 is the least significant bit (lsb) of the binary number and has a weight of $1/32768$. Bits 14 thru 9 are used as pads. See figure 2.1.

SERIAL BCD WORD STRUCTURE

BIT POSITION	32-31	30-29	28-25	24-21	20-17	16-13	12-9	8-1
VALUE		2-1	8-4-2-1	8-4-2-1	8-4-2-1	8-4-2-1	8-4-2-1	1-2-4-8-16-32-64-128
PARITY		BCD (MSD)	BCD (2SD)	BCD (3SD)	BCD (4SD)	BCD (LSD)	BCD (PAD)	LABEL
	0 0	1 0	0 1 0 0	0 1 1 1	1 0 0 0	0 1 1 0	0 0 0 0	1 0 0 0 1 1 0 0
EXAMPLE:		2	4	7	8	6	PAD	49

BINARY DATA WORD STRUCTURE

BIT POSITION	32	31-30	29											9	8-1			
VALUE	PARITY	MATRIX	1/2	1/4	1/8	etc.				1/32768	PAD				1-2-4-8-16-32-64-128			
EXAMPLE:		1 0 0 0	0 0	1 0	0 0 0 0 0 0 0 0	0 0 0 0 0 0 0 0	1	0 0 0 0 0 0 0 0	0					0 1 1 0 1 1 0 1				
			$1/8 + 1/32768 = 0.125030517578125$											182				

Figure 2-1

4. CABLING

The INSI requires three separate input signals: they are Data, Sync and Clock. This unit is normally configured to accept +12 volts (one) and 0 volt (zero) logic levels as specified by the ARINC 561 standard. However, the INSI unit can be strapped for TTL inputs or extremely high voltage inputs of up to 400 volts. All interconnecting cables should be shielded pairs, with the shield acting as a common ground, the HI side as signal active, and the LO side acting as the reference. The pair should be treated as a balanced transmission line. All ARINC connections into the INSI are made thru an Amphenol, 15 pin "D" type connector. See Figure 3.

ARINC 561 CABLING DIAGRAM

Figure 3-0

5. FEATURES OF THE INSI

The INSI unit also has several features available to meet the requirements of different systems.

5.1. Status Port

The data acquisition system can address the status port and inquire about errors that may exist or may have existed since the last interrogation. The status bits are listed in the following table:

STATUS PORT
8 bit byte

Figure 5-1.

	bit 0	bit 1	bit 2	bit 3	bit 4	bit 5	bit 6	bit 7
clock status	1	X	X	X	X	X	X	X
sync status	X	1	X	X	X	X	X	X
data status	X	X	1	X	X	X	X	X
format error	X	X	X	1	X	X	X	X
read set	X	X	X	X	1	X	X	X
test enabled	X	X	X	X	X	1	X	X
valid frame	X	X	X	X	X	X	1	X
reading	X	X	X	X	X	X	X	0

All signals are logic high true, except "reading =0"

5.1.1. Status Port Definitions

1. Clock status bit: High indicates no clock from ARINC system.
2. Sync status bit: High indicates no sync from ARINC system.
3. Data status bit: High indicates no data from ARINC system.
4. Format error bit: High indicates improper format from ARINC system. This bit will also indicate if missing sync.
5. Read set bit: High indicates INSI has received instruction to ignore all incoming signals from ARINC. Automatic memory update is disabled.

6. Test enabled bit: High indicates INSI has received an instruction placing it into the test mode, halting all ARINC input signals.
7. Valid frame bit: High indicates: a) RAM not busy and, b) all words in memory are current and in the same time sync.
8. Reading bit: Low indicates INSI busy during current read of status port.

note: The clock, sync, data, and format error bits will remain set until the status port has been read. Reading the status port clears the error registers, as does the power reset circuitry.

5.2. Instruction Port

There are four instructions that can be given to the INSI unit:

Instruction	Octal Code
Read set.....	001
Produce IRQ when at next valid frame.....	002
Halt INSI unit at next valid frame.....	100
Enable test mode.....	200

5.3. Test Port

The data acquisition system can simulate ARINC input through the INSI I/O port to test all RAMs, control, address, and data direction logic. A test program could test all components within the INSI unit with the exception of the ARINC input buffer A57 and part of the input selector A58.

5.4. Data Port

1. 8 bit bidirectional 3-state data bus.
2. 16 bit address bus, offering 1 LSTTL load.
3. Buffered control lines, directly compatible to the I-64 card.

6. INSI SPECIFICATIONS

6.1. Physical

weight < 10 oz.
size 13" long, 9" high, .75" thick.

6.2. Electrical

The unit requires 5 volts DC at approximately 1.2 amps per INSI card.

6.3. Dynamic

Data, sync, and clock rates should not exceed 1 MHz, and rise and fall times should not exceed 500 nanoseconds. The output bus is 1-64 oriented and the access time during a read of RAM does not exceed 565 nanoseconds.

6.4. Operating environment

Temperature range: 5C to 40C.

Relative humidity: 5% to 90% non-condensing.

7. USER OPTIONS

7.1. Label Combining

Label combining strips the most significant bits from the label causing more than one label to occupy the same place in RAM. This is beneficial if the ARINC system is generating the same parameter several times within the major information cycle. This is selectable through piano switches located on the INSI card.

7.2. Valid Frame

Valid Frame identification allows user to place a location cue anywhere within the frame of information. This is useful in identifying a starting or stopping point in the read mode. This is selectable through piano switches located on the INSI card.

8. 1-64 CARD.

8.1. Introduction

The 1-64 card was designed to emulate, in a slight fashion, a microprocessor chip. A set of serial registers increments an EPROM with alternating addresses and instructions.

8.2. Application

As used with the INSI unit, the 1-64 card acts as the interface and data latches.

8.3. Features

1. High speed operation
2. Interface with 4, 8, 12, 16, and 32 bit data systems.

8.4. Specifications

8.4.1. Physical

weight: < 10 oz..
size: 13" long, 9" high, .75" thick.

8.4.2. Electrical

The 1-64 unit requires +5 vdc @ 1 ampere, +12 vdc @ 0.2 amperes, and -5 vdc @ 0.1 amperes.

8.4.3. Dynamic

The 1-64 card uses a simple 555 timer oscillator, for high speed and stability.

8.4.4. Operating Environment

Temperature range: 5C to 40C.

Relative humidity: 5% to 90% non-condensing.

9. THEORY OF OPERATION

The theory of operation will be covered for the separate modules and the complete interface system:

- a) The INSI card.
- b) The I-64 card.
- c) As a complete system.

9.1. The INSI card.

Refer to Sheet 1A of the fold-out schematics.

All three signals input through J-1 into the three resistor networks, (R6,R7,R14,R15), (R8,R9,R13,R15) and (R10,R11,R12,R16). These resistor networks serve to match ARINC impedance specifications and to reduce the signal amplitude to approximately one-half the normal value of 12vdc. Since the timing or synchronization signals are not conditioned, a provision has been made to compensate or phase shift any or all three signals. If no conditioning or phase shifting is done, the time lag between Clock and Sync can cause a narrow pulse to be generated by A43. This pulse may erroneously reset the binary counters, A55 and A56.

It has been found that 100pf is necessary at C44 to produce a delay of approximately one microsecond. However, no two INS units are identical in timing, and in some instances a value of 750pF is necessary. A57 is a CMOS CD4049 inverting buffer with a fan out capability of one TTL load. It was chosen because of its high input impedance and high noise immunity. This design guarantees a noise margin of one volt and has been very reliable.

The three signals are then sent through a TTL inverting buffer, A58, which also serves as a signal selector switch. The signal selector switch, A58, can thus receive signals from some source other than the ARINC inputs, and at a much higher speed than ARINC standards. At present, these signals come from the I/O port and could be used by the host system in a test routine.

Refer to figure 9.1.

ARINC standards indicate a down clock whenever data is stable. Due to the choice of components used here, we have inverted the clock signal to be an up-clock.

Refer to Sheet 1B of the fold-out schematics.

A47 is an open-ended shift register (it is never reset). The data

is clocked through A47 continuously and only A46 latches the label (serial address); this is done when the decode pulse goes high again. See figure 9-1, A43-6. The label is then ANDed with stripping switches A44. The resulting label is then presented to A19 for future latching.

A59, A60, and A61 are also open-ended serial registers and receive the same data and clock as the serial register A47. They convert the ARINC serial data into parallel data for internal data storage. When 24 bits after the label have been clocked into the serial registers, the label and parallel data are latched into A19, A48, A49, and A50.

Refer to sheet 1A of the fold-out schematics.

At the end of the decode or reset pulses, when sync goes high, the binary counters A55 and A56 are permitted to count. Only when they have received 24 clock pulses will there be an output at A52-8. This high waits at A52-5 until A52-4 goes high; only then will there be an output on pin 6 of A52.

Since the Binary Counters were being clocked by the inverted clock signal, A52-4 will not go high until the next clock cycle after count 24. The output of A52-6 is delayed by A54 before it is sent out as the Latch Clock. This action is to allow the shift registers time to settle down before acquisition. The amount of delay is $\pm 150\text{ns}$.

When A52-6 went high, and if there was an over-count at A63-8, a high will result at A15-3, thus setting the Format Error F/F. This signal is made available to the status registers A11 on Sheet 2B of the fold-out schematics.

Refer to sheets 1A and 1B of the fold-out schematics

A18 is a magnitude comparator used here to look for a match. The label was waiting at the data inputs of latch A19. If the label code matches the cue code of the magnitude comparator (switches on A31), a high will be produced (FE) and presented to A15-12, the data input to the F/F. Every time A43-6 goes low, a high is sent to A15-11 (after a delay by A54: $\pm 150\text{ns}$). If (FE) were high, then an output is produced, called Valid Frame (VF), and will remain high until reset by the write reset strobe.

Each time a latch clock is produced by A42-12, it sets the write enable F/F A14-3. This places A14-5 and A62-9 high. If A62-10 is high, NOT READING, a high will be presented to A62-5. Since A62-4 is already high, an output will occur producing a differentiated pulse to A51-5. This pulse, which is typically 200ns wide, is inverted and sent through A39 as the write strobe. This strobe

pulse is used to strobe the data into the RAM. The label at the output of A19

was buffered and controlled by Addressor Port A20.

A51 and its associated components determine the settling time before resetting the F/Fs. This is typically 470ns.

9.1.1. INSI/I-64 Modification.

Refer to Sheet 2B of the fold-out schematics.

1. Locate A14 pin 8.
2. Cut trace 1/8" from pin 8.
3. Insert jumper between pin 11 hole and remaining trace, leaving pin 8 open.

This modification places the Valid Frame signal onto the edge connector pin 64. It will be used to tell the I-64 whenever it is at the cue address.

9.1.2. RAM Reading

All RAM read functions are done using 6800 microprocessor conventions (Memory-mapped I/O, VMA). If the RAM was busy being read when it came time to write a new word into it, the word would remain in the latches for a period of time not exceeding 43 milliseconds. At that time, if the RAM was still busy, the word would be lost and a new word and new label would take its place. Most 6800 microprocessor based systems working at 1 MHz could have read the entire RAM several times over within that time interval.

Figure 9-1.
INSI Timing Signals

9.2. The I-64 card

The I-64 card attempts to emulate a microprocessor in that it can move data from the INSI RAM to one or more of the 16 four bit data latches, and can present the contents of the EPROM to the same latches. This is very useful in troubleshooting.

9.2.1. EPROM

The heart of the I-64 card is the EPROM (Erasable Programmable Read Only Memory), a 2708 (1K x 8 bits) integrated circuit. The PROM has been programmed with data in all even numbered addresses as RAM addresses to be latched by the address latch A28. The data in the odd numbered addresses have been programmed as instruction words, to be latched into the instruction latch A26. Thus PROM address "0"(0000 0000), when enabled, will be presented to the address latch A28. This address now goes to the I/O port on the INSI card and constitutes the lower 8 bits of the RAM address. The PROM is then incremented once, presenting the instruction word to the instruction latch A26. If the prior address was address 255 (1111 1111), then gate A30 will output a low to A44-1, which places a low at A44-6 and then A42-4,-10, thus preventing A27 from being enabled onto the 4 bit data bus. A44-3's low is made high by A48-2 and A45-1 which produces a low at A45-3 thus enabling A29. Enabling A29 will place the contents of the EPROM Instruction Latch, most significant bits (D7,D6,D5,D4), onto the 4 bit data bus instead. This can be useful in troubleshooting by simply programming with (0000) or (1111), et cetera.

In normal operation, A30-8 will be high, thus allowing A42-6 or A42-8 to take control of the data buffer A27. The instruction latch bit (D0) determines whether the upper or lower 4 bits of the 8 bit data bus be presented to the 4 bit bus. Bits 2 and 3 (D1 and D2) determine part of the address structure, namely A8 and A9 of the I/O port on the INSI card, which determine DE1, DE2 or DE3 of the RAM enable circuitry. Each RAM area has 256 8 bit bytes and there are 3 such RAMs. Bit 4 (D3) of the instruction latch determines whether data stored in RAM will be read or whether the status port will be read.

9.2.2. Clock

The clock, for this system, is an MC555 timer running at approximately 500kHz (A32). This clock supplies the necessary I/O clock for the INSI card, and when divided, provides the 250kHz for

the I-64 card. The division is done by A33-5 along with the clock-sync-enabler A41-2. The 250kHz clock signal is symmetrical and will always begin from a low state and stop in a low state.

A34, A35, A36, A37, A38, A39 and A40 are a multi-phase generator, producing 4 phases of the same clock. This is to take care of the various propagation delays through-out the INSI and I-64 card. Even though the 4 clock phases have different starting times, they will always terminate together. This is done by A41-6,-8,-11 and A33-5.

9.2.3. Program Counter

A22, A23 and A24 comprise the program counter with A25 insuring no incrementation on first count. This is because position "0" (0000 0000) in the EPROM is a valid address position. A44-11 and A44-8 determine ODD or EVEN by sensing bit 1 (D0) of the program counter.

9.2.4. Latch Decoder

A20 is a 1 of 16 decoder which decodes bits 2,3,4 and 5 of the program counter. This results in a decoded state every two counts, hence there will be 32 counts to scan all 16 latches.

9.2.5. Reset

A31 is a power-up reset circuit using another MC555 timer. This reset circuit does not reset anything on the I-64 card, but is used instead, on the INSI card to reset all registers.

9.3. As a Complete System.

When both the INSI and I-64 card are used together, they must share a common bus. This is because they are bus oriented for microprocessors. They also may share the same power supplies.

The power supply used in the DOE evaluation program was a Power-One, +5vdc, -12vdc, and +12vdc, 50Hz, to 400Hz, 115vac input type. This way it could be used on the bench for debugging and could use the Litton palletized 115vac.

10. EXAMPLE CONFIGURATION

10.1. Geometrics Configuration

The Geometrics G-714 Airborne Digital Data Acquisition System was required to output an enable high line, TTL compatible, for the first 16 four bit words of information. Then, while keeping the enable line high, it strobes high and fast on another line to increment the next 16 words. It then strobes again for the last 16 words.

Upon completion of the data cycle, it returns the enable and strobe lines low. This allows the RAM to be updated with the newest set of parameters.

10.2. 1-64 Cycle

The G-714 system outputs a high level to the 1-64 card J3-14. This high waits at A43-2 until the Valid Frame pulse arrives from the INSI card. When VF arrives, which is within 43 milliseconds, the result is a high at A43-3.

The high goes to A43-4, A25-1, -13, A42-2, A22-1, A23-1 and A24-1. This removes all of the reset constraints applied otherwise. The high present at A43-4 is waiting until the same high from A43-3 goes to A33-12, through differentiator RCP3, A19-12 and setting A33-9 high. This high is returned to A43-5 along with the high on A43-4 producing a high A41-2. In this configuration, the clock will output a total of 32 clock cycles at which time A20-17 will go low. This low is seen as a low at A33-13 thus resetting the F/F making A33-9 low which disables A43-6 thus completing one 1-64 cycle.

The G-714 must now, with its enable still high, output a fast positive pulse to J3-13. This strobe will set A33-9 high which will continue the 1-64 cycle another 32 clock cycles. This process is repeated again for a total of 96 clock cycles or 3 groups of 16 four bit words.

The G-714 must now place both TTL lines low to enable the INSI card to refresh its memory.

10.3. Program Format

As an example, the program format used for the Geometrics G-714 in the DOE evaluation will be shown and explained. See figure 10-2.

Figure 10-1.
SERIAL DATA POSITIONS FROM ARINC DATA BUS.

	RAM 1 (DE1)		RAM 2 (DE2)		RAM 3 (DE3)	
Serial Bit Position	32-29	28-25	24-21	20-17	16-13	12-09
"LABEL"	---	---	---	---	---	---
0 (0000 0000) bit 8 bit 1			LA MN X10	LA MN X1	LA MN X.1	LA MN X.01
1 (1000 0000)				SIGN N/S	LA DG X10	LA DG X 1
2 (0100 0000)			LO MN X 10	LO MN X 1	LO MN X.1	LO MN X.01
3 (1100 0000)			SIGN E/W	LO DG X100	LO DG X10	LO DG X 1
4 (0010 0000)			TH DG X100	TH DG X10	TH DG X 1	TH DG X.1
5 (1010 0000)		PITCH MSB	AND XXXX	ROLL XXXX	BINARY XXXX	WORD LSB
6 (0110 0000)		SIGN N/S	SPEED X1000	FEET X100	PER X10	SECOND X1
7 (1110 0000)		SIGN E/W	SPEED X1000	FEET X100	PER X10	SECOND X1

MN=MINUTES
 DG=DEGREES
 X=MULTIPLY BY
 LA=LATITUDE
 LO=LONGITUDE
 TH=TRUE HEADING
 N=NORTH
 S=SOUTH
 E=EAST
 W=WEST

10.3.1. Octal Program

Figure 10-3 shows the octal program used in the DOE evaluation program. It encompasses addresses 0 to 95 in the EPROM or 0000-0000 to 1111-1010. The following table shows what parameter of data went to data latches 1 to 16 on the I-64 card:

Figure 10-2.
LATCH EQUATES per SCAN

First Scan (enable high only).

Latch	Significance
-------	--------------

1=	Latitude sign (north=1111), (south=1101).
2=	Latitude degrees X10.
3=	Latitude degrees X 1.
4=	Latitude minutes X10.
5=	Latitude minutes X 1.
6=	Latitude minutes X.1.
7=	Latitude minutes X.01.
8=	Longitude sign (east=1111), (west=1101).
9=	Longitude degrees X100.
10=	Longitude degrees X 10.
11=	Longitude degrees X 1.
12=	Longitude minutes X10.
13=	Longitude minutes X 1.
14=	Longitude minutes X .1.
15=	Longitude minutes X.01.
16=	INSI status registers.

Second scan (enable high first strobe).

1=	True Heading degrees X100.
2=	True Heading degrees X 10.
3=	True Heading degrees X 1.
4=	True Heading degrees X .1.
5=	North South Velocity Sign (north=1111), (south=1101).
6=	N/S Velocity feet/sec. X1000
7=	N/S Velocity feet/sec. X 100.
8=	N/S Velocity feet/sec. X 10.
9=	N/S Velocity feet/sec. X 1.
10=	East West Velocity Sign (east=1111), (west=1101).
11=	E/W Velocity feet/sec. X1000.
12=	E/W Velocity feet/sec. X 100.
13=	E/W Velocity feet/sec. X 10.
14=	E/W Velocity feet/sec. X 1.
15=	PAD from EPROM, (0000).
16=	PAD from EPROM, (0000).

Figure 10-2 cont.

Third scan (enable high second strobe).

1= Pitch and Roll Binary Word, (MSB). **
2= Pitch and Roll Binary Word. **
3= Pitch and Roll Binary Word. **
4= Pitch and Roll Binary Word. **
5= Pitch and Roll Binary Word, (LSB). **
6=PAD from EPROM, (0000).
7=PAD from EPROM, (0000).
8=PAD from EPROM, (0000).
9=PAD from EPROM, (0000).
10=PAD from EPROM, (0000).
11=PAD from EPROM, (0000).
12=PAD from EPROM, (0000).
13=PAD from EPROM, (0000).
14=PAD from EPROM, (1111).
15=PAD from EPROM, (1111).
16=PAD from EPROM, (1111).

Figure 10-3.
OCTAL CODE FOR EPROM

200
002
200
005
200
004
000
003
000
002
000
005
000
004
300
003
300
002
300
005
300
004
100
003
100
002
100
005
100
004
000
010
040
003
040
002
040
005
040
004
140
000
140
003
140
002
140

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LAMA INSTALLATION MANUAL

by: APPLIED GEOPHYSICS INC.

VOLUME V

Detailed Installation Manual
for an
Inertial Navigation System
as installed in a
Lama Helicopter

by

Applied Geophysics Inc.
675 South 400 East
Salt Lake City, UTAH
84111

May 1981

Table of contents

1.	LAMA HELICOPTER	-2
1.1.	Introduction	-2
1.2.	Specifications	-2
1.3.	Purpose and Scope	-3
1.4.	Familiarity	-3
2.	LITTON INS PALLET	-12
2.1.	Introduction	-12
2.2.	Options	-14
2.2.1.	Ordering	-14
2.3.	Specifications	-14
2.3.1.	Shock and Crash Safety	-14
2.3.2.	Dimensions and Weights	-15
3.	INS INTERFACE (INSI)	-20
3.1.	Introduction	-20
3.2.	Specifications	-20
3.3.	Cabling	-20
4.	METERING	-23
4.1.	Cross Track	-23
4.2.	Course Deviation	-23
4.3.	Radar Altimeter	-23
5.	INSTALLATION	-30
5.1.	INS Installation	-31
5.1.1.	Materials List	-31
5.1.2.	Control and Display Unit	-31
5.1.3.	Pallet System	-32
5.1.4.	Pallet Wiring	-35
5.1.5.	Course Deviation Meter	-37
5.2.	INSI Unit	-37
5.3.	Check-Out	-52
5.4.	Final Assembly	-53
5.5.	Final Check	-53

1. LAMA HELICOPTER

1.1. Introduction

This manual will describe the installation of the Litton LTN-76 Inertial Navigation System, peripheral meters and equipment in a French Aerospatiale Lama helicopter.

CAUTION: BE SURE THE INSTALLER HAS READ AND UNDERSTOOD ALL OF SECTION 1 BEFORE PLANNING THE INSTALLATION.

1.2. Specifications

The Lama helicopter uses a 28 volt, 100 amp D.C. generator as the primary electrical source. The generator also serves as the starter motor for the turbine engine. If you should experience an excessive amount of noise from the generator, a probable cause could be that the generator commutator is scored or scratched; the result of passing 300 amps or more on each start cycle. The best possible cure for this type of problem is to change the generator.

Always keep in mind total power consumption when making additions to existing power distribution systems. In this application, the system can supply only 100 amps under the best of conditions.

Lama helicopters traditionally come with a 28 volt D.C. auxilliary power input receptacle. This receptacle is not fused, so care must be exercised to prevent a short or possible harm to on-board equipment.

In the design of the helicopter, a preventative measure was included inhibiting engine start-up and battery charging through the APU receptacle. As long as there is 28 V.D.C. applied to the APU receptacle, the aircraft battery master switch will not function. This helicopter uses a Nickel-Cadmium battery; if the

charging rate were to be exceeded, damage could result.

Helicopters vibrate, especially when decelerating and when hovering. Do not try to avoid using the shock absorbers where their use is specified in this manual. There are several rules and regulations outlined by the FAA concerning aircraft alterations, inspection, repairs, acceptable methods, techniques and practices, which this manual follows.

For a copy of this reference, write to:

Aviation Maintenance Publishers
Box 890
Basin, Wyoming 82410

Identify the publication in your order as: EA-AC 43.13-1A&2A

1.3. Purpose and Scope

This manual will provide all of the information needed to complete an installation of Litton Aero Product Division LTN-76 Inertial Navigation System, Applied Geophysics Inc., Inertial Navigation Systems Interface (INSI), necessary meters, cables and hardware.

This manual is not intended as a reference for designers, nor is it sufficient in content to make alterations or modifications to aircraft structures or devices whose applicability or installation may be governed by the FAA.

1.4. Familiarity

All persons involved with this type of installation should first read this manual, then become familiar with the helicopter as it pertains to the installation. Compare figures 1-1 thru 1-7 of this section to the helicopter in which the installation will be made.

Locate and examine the following items:

1. Aircraft equipment mounting holes; behind co-pilot chair in the floor. See figure 1-1.
2. Access hole and cover plate in left side of console next to co-pilot seat. See figure 1-2 and 1-3.
3. Locate lower rail on rear cabin wall. See figure 1-2.
4. Locate helicopter battery access and battery. See figure 1-2.
5. Examine position of geophysical equipment rack with respect to rear cabin wall; check for clearance between wall and rack for the INS1 chassis. The INS1 chassis will require at least 3.5" of space. See figure 1-2 and 1-7.
6. Determine which meter panel will be used for this installation. With the cyclic fully forward, check for adequate clearance. See figure 1-2.
7. Check helicopter console for sufficient room for installation of Litton CDU. See figure 1-3.
8. Check, for accessibility, the screened ventilation ports in the rear cabin wall near floor. One or more of the screens may already have been removed to facilitate some prior installation. See figure 1-4.
9. Locate helicopter fuse box, on left side behind fuel tank, below engine, behind cowling. See figure 1-5.
10. Locate the common ground bolt at the bottom of left rear engine support frame. See figure 1-5.
11. Open fuse box and check for spare 100 amp fuse for INS power. Install, if necessary, referring to figure 1-6.

Prior to the installation, it will be necessary to remove the co-pilot chair, the rear seat and both helicopter doors. If you are satisfied with your inspection and familiarization, and are planning to use the Litton INS, then proceed to the next section titled Litton INS Pallet .

Figure 1-1.
LAMA HELICOPTER CABIN AREA
TOP SIDE VIEWING IN

* SOME HELICOPTERS MOUNTING HOLES HAVE BEEN PRE-TAPPED AT FACTORY, SOME AT MAINTENANCE SHOPS, AND OTHERS AT LOCAL LEVELS. IT MAY BE NECESSARY TO TAP EXISTING HOLES, IN WHICH CASE BE SURE TO USE METRIC TAPS.

Figure 1-2.
LAMA HELICOPTER CABIN AREA
LEFT SIDE VIEWING IN

* THE INSI CHASSIS REST S DIRECTLY ON REAR CABIN LOWER SEAT SUPPORT RAIL.

** SHOWN MOUNTED AT REAR OF EQUIPMENT RACK, INSI IS DESIGNED TO MOUNT DIRECTLY INTO RACK. STANDARD 17" MOUNTINGS USED ON CHASSIS.

Figure 1-3.
LAMA HELICOPTER
CONSOLE VIEW

Figure 1-4.
LAMA HELICOPTER CABIN AREA
WIRING LAYOUT

Figure 1-5.
LAMA HELICOPTER
LEFT SIDE EXPANDED VIEW

Figure 1-6.
LAMA HELICOPTER
FUSE BOX

Figure 1-7.
LAMA HELICOPTER CABIN AREA
RIGHT SIDE VIEWING IN

2. LITTON INS PALLET

Series 456100

Reference: Litton publication 605004

2.1. Introduction

This section introduces a versatile, self-contained, standardized pallet system developed by Litton Aero Products Division. The LTN-51, LTN-72 and LTN-76 Navigation Guidance Units are mounted in the pallet assembly, minimizing any structural changes when installing the pallet in all types of aircraft. Flexibility of the integral pallet system is further demonstrated because the system is not hardwired and can be either a permanent or portable installation.

All necessary mechanical trays, wiring, backup battery and cooling fans are part of the system. Also, all power, signal and control lines are brought in and out of the pallet on five standard aircraft connectors. On some newer pallets, there may be 8 connectors.

To accommodate any mounting hole pattern whatsoever, the pallet has a separable, undrilled base plate which allows maximum installation capability in remote positioning of the pallet and Inertial Navigation Unit. The cockpit Control/Display Unit and Mode Selector Unit are coupled to the pallet through various cable lengths.

Power input (1490 watts initial and 465 long term) is single phase 115 vac 400 Hz. The pallet generates 26 vac synchro excitation and 5 vac edge-light from this input. If only D.C. input power is available, an optional integral inverter package can be provided to generate the required ac power.

Since the Lama helicopter does not have 115vac 400 Hz., it is necessary to utilize the Litton optional integral inverter package. See figure 2-1.

Figure 2-1.
STANDARD PALLET SYSTEM
with INTEGRAL INVERTER PACKAGE

2.2. Options

An optional base plate may be used for better lateral stability as shown in figure 2-2. It is not available from Litton Aero Products, and would have to be manufactured locally. Its use is covered in section 5, titled Installation.

2.2.1. Ordering

When ordering the pallet and cables from Litton, you should specify "D.C. PALLET SYSTEM" with 10" cables for the CDU, MSU and Cross Track Meter. Make sure to order Cross Track Meter and the connector for the end of the cross track cable to the pallet. The D.C. power cables should be at least 20" long.

An optional remote control switch for the inverters is also available from Litton Aero Products Division. See System Block Wiring Diagram, figure 2-3.

A cover for the INU and battery is also available. However it weighs 13 lbs. and is not recommended. It is large, difficult to install and remove and is not practical. See figure 2-4.

2.3. Specifications

2.3.1. Shock and Crash Safety

The pallet is designed to meet operational shock and crash safety requirements as specified by document D0-138 prepared by the Radio Technical Commission for Aeronautics (RTCA), "Environmental Conditions and Test Procedures for Airborne Electronic/Electrical Equipment and Instruments".

Properly installed and secured to airframe structure, a loaded pallet will sustain 6G, 11 millisecond shocks as required in each of the three orthogonal axis without structural damage and maintain operational integrity. It will sustain a 15G, 11 millisecond shock in the same axis without structural failure, as required for crash safety.

REF: Para 6.1 and 6.2, D0-138 (RTCA)

2.3.2. Dimensions and Weights

To determine the correct dimension and weight for any combination of pallet assembly, inverter assembly, base and covers, refer to figure 2-5, and calculate as follows:

Add heights and weights of only those assemblies used. For example:

Base	1.13 in. and 8 lb
Pallet	11.78 in. and 27 lb
Covers	3.03 in. and 13 lb

15.94 in. and 48 lb

Figure 2-2.
STANDARD PALLET SYSTEM
with OPTIONAL BASE PLATE

Figure 2-3.
SYSTEM BLOCK WIRING DIAGRAM

Figure 2-4.
STANDARD PALLET SYSTEM
OPTIONAL COVERS

Figure 2-5.
STANDARD PALLET SYSTEM
WEIGHTS and MEASURES

3. INS INTERFACE (INSI)

The INSI chassis box consists of the following:

- a) 1ea INSI Card.
- b) 1ea I-64 Data Card.
- c) 1ea Power Supply (115vac 50Hz to 400Hz input).

3.1. Introduction

The INSI unit used for the DOE evaluation program has been programmed to take data from the INS ARINC bus and pass it along to the Geometrics G-714 Airborne Digital Data Acquisition Computer. For more information on the INSI unit, please refer to Volume IV of this report.

3.2. Specifications

weight: approx. 12.2 lbs.
size: 3.5"h, 19" wide, 14" deep.
standard 17" mounting holes
Power consumption: 1/2 amp max..
See figure 3-1.

3.3. Cabling

J-1, on the INSI chassis box, is the signal input plug from the INS. P-1 and P-2 are the parallel data output ports which go to the Geometrics G-714 computer. P-3 also goes to the G-714, but it is a communications line from the G-714 to the INSI, used for strobing data into the G-714. The communications port uses two lines plus a ground. The primary line outputs a TTL logic high to enable the INSI unit to ready the first 64 bits of data, while the second line strobes the INSI unit twice more, incrementing an additional 128 bits.

Refer to figure 3-2 for wiring connections.

Figure 3-1.
INSI CHASSIS BOX
with
INSI and I-64 Card Installed

Figure 3-2.
SYSTEM BLOCK DIAGRAM

4. METERING

There will be three meters discussed here, of which all or none may be utilized.

4.1. Cross Track

A Cross Track Meter is available from Litton Aero Products Division and should be ordered with the pallet and accessories. The meter is a standard 3" diameter hole mounting with 3 #6 mounting holes.

The meter has a scale displaying approximately plus or minus 750 feet of cross track error. This meter is very useful in providing the pilot with a means of accurate steering. The signal for this meter comes directly from the INS pallet plug J-5. Be sure plug is provided by Litton Aero Products. See figure 4-1.

4.2. Course Deviation

This meter system is not provided by Litton Aero Products. This metering system was not required by the Department of Energy or High-Life Helicopters. It was used, however, as a navigational aid during all phases of the evaluation. The meter displays a left or right 30 deg. course deviation which is especially useful when changing waypoints or major course changes. See figure 4-2.

The meter requires a plus or minus 10vdc signal at 200ma for proper display control. The meter is very "stiff" to prevent bouncing due to rapid descent and vibration. The meter and special phase demodulator were designed and manufactured by Applied Geophysics Inc.

The meter is a standard 2.5" diameter hole with 3 #6 holes for securing to panel. The demodulator receives the signal from the INS Pallet plug J-5, as does the Cross Track Meter. See figure 4-3.

4.3. Radar Altimeter

A radar altimeter usually accompanies a geophysical survey aircraft. If not, a recommended location for the meter is shown in figure 4-4. Figure 4-5 depicts an optional three meter panel.

Having the radar altimeter together with the deviation meters has proven to be very effective.

Figure 4-1.
LITTON AERO PRODUCTS DIVISION
CROSS TRACK METER

USE #6 INSTRUMENT
HARDWARE

3" DIAMETER HOLE

Figure 4-2.
APPLIED GEOPHYSICS INC.
COURSE DEVIATION METER

USE #6 INSTRUMENT
HARDWARE

2 1/2" DIAMETER HOLE

USE 1/4" INSIDE DIAMETER
TERMINAL LUGS

Figure 4-3.
SYSTEM BLOCK WIRING DIAGRAM

Figure 4-4.
LAMA HELICOPTER CABIN AREA
WIRING LAYOUT

Figure 4-5.
LAMA HELICOPTER
OPTIONAL METER PANEL

5. INSTALLATION

A materials list will precede each set of installation areas or phases. The installation section will assume the user is performing a turn-key installation.

Perform the following steps in the order given:

1. Disconnect the aircraft battery; tag battery leads to prevent accidental reconnection.
2. Remove co-pilot chair.
3. Remove rear seat, if installed.
4. Remove both helicopter doors.
5. Clean out cabin area of all loose debris which may interfere with the installation.
6. Install 100 AMP fuse in fuse box. See figure 5-1.
7. Drill 1/2" hole in bottom of fuse box.
See figure 5-1.
8. Remove helicopter belly-pan for access to equipment mounting holes behind co-pilot chair.*
9. Clean out equipment mounting holes in floor, and check for existing threads in both holes. If there are no threads, drill and tap with metric size only.*
10. Install appropriate meter panel to the right side of instrument panel directly in front of pilot's 4 o'clock vision. Mount panel with a minimum of 2 but no more than 3 # 10 panhead screws with star washers and nuts. See figure 5-2.
11. Install individual meters with # 6 instrument hardware. See figure 5-3.

* It is necessary to have a qualified A&P mechanic perform these tasks.

5.1. INS Installation

Be sure that all materials are available.

5.1.1. Materials List

- a) Plastic grommet material, 1 foot length.
- b) 26" X 19" plywood board 3/4" thick exterior.
- c) 8ea, 5/16"-18 nc-2 THD, nuts.
- d) 1/4"-20-1/2" long with 7/16 hex-head, bolts, 8 ea.
- e) 1" dia., 1/16" thick washers for 1/4" bolts. 8 ea.
- f) Lock washers for 1/4" hardware, 8 ea.
- g) Metric bolts, 3" long, fully threaded, to match equipment mounting holes in helicopter floor.
- h) 2" dia. washers for metric bolts. 2 ea.
- i) Nuts; metric, castellated, for metric bolts. 2 ea.
- j) Duct tape or hurricane tape. 1 ea. roll.
- k) Wire cable wraps, 6" x 1/8", box of 100.
- l) Wire cable wraps, 10" x 1/8", box of 100.
- m) Electrical tape, plastic 1 ea. roll.
- n) Barry-Mount shock absorbers, model H64-BA-40, 8 ea.
- o) Barry-Mount shock absorbers, model A43-051, 4 ea..
- p) Terminal lugs, #6 insulated, 4 ea..
- q) Extension cord, with ground and 3 outlets, 3 feet long.
- r) # 10 panhead screws with nuts and star washers. 20 sets.
- s) 4ea, 3/4" Flat washers, 1/16" thick for 5/16" hardware bolts.
- t) Aluminum stock, 1 foot square, .030" thick, aircraft alloy.
- u) 4ea, 1" flat washers, 1/16" thick, for 5/16" bolts.
- v) 4ea, lockwashers for 5/16" bolts.

5.1.2. Control and Display Unit

Referring to figures 5-4 and 5-5, perform the following steps:

1. Determine location for CDU. It should not be any lower than 4" from the lower edge of the console. Otherwise the cabling harness will prevent normal installation.

2. Remove console access hole cover plate. Using it as a template, take the 1 foot square aluminum stock and make a duplicate cover plate. Store away the original cover plate or return it to the helicopter facility. Using the duplicate cover plate, drill or punch-out a 2" diameter hole, 1/2" above lower center fastening screw. Cover edge of 2" hole with plastic

grommet material. Try fitting CDU cable thru the 2" hole. If it won't fit, make a cut in cover plate from about the 5 o'clock position into the 2" hole. Once this has been done, place cover plate aside for later installation.

3. Route CDU cable through the console access hole. Bring cable 8" past console face and connect cables to CDU.

4. Install CDU into the console, slowly removing any cable slack left in the console, and using the 4 fasteners, fasten the CDU to the console. Remove slack thru access hole.

5. Through access hole, check cables for any possible chaffing or cutting; insulate cables if necessary.

6. Place other end of cable through the access hole cover plate 2" hole. If you had to make a cut from edge to 2" hole, place cable through cut into hole and patch cut with a piece of duct tape. Reinstall plastic grommet and secure with duct tape. See figure 5-5.

7. Install cover plate over access hole leaving 2" of slack cable inside of console. CAUTION: DO NOT STORE EXCESS CABLE INSIDE OF CONSOLE.

8. Route CDU cable on floor along side of console, use a small piece of duct tape to hold it temporarily.

5.1.3. Pallet System

Refer to figure 5-6 while performing the following steps:

1. Remove the two screws holding the D.C. power plug bracket to the pallet assembly.

2. Unplug J-3 inverter connector from the pallet assembly.

3. Remove the 4 bolts holding pallet assembly to the pallet support assembly.

3A. Disregard steps 4,5,6,7 and 25, if you have planned on the use of the optional base plate.

4. Remove the battery tray sufficiently to access the area beneath the tray.

5. Position the D.C. power bracket on the underside of the pallet assembly, directly beneath the battery tray area, with the pin

orientation toward rear of cabin. See figure 5-7.

6. Using a scribe or awl, mark the mounting holes.

7. Drill holes and check hardware. Do not mount at this time.

8. Remove cover plate from connector box on the pallet assembly.

9. Locate the two 115vac sources from J-3. Determine which is used for the heaters and which is used for the electronics. Refer to the pallet assembly blueprints.

10. Using the 3 foot extension cord, connect the cord to the electronics 115vac line (observe L0 and H1 side), directly at the connector. Solder and insulate the connections either with tape or RTV.

11. Connect extension cord ground to pallet assembly connector box mounting screws.

12. Enlarge one of the rear corner holes to permit extension cord access.

13. Replace cover on connector box. If extension cord is binding, enlarge hole further. Then wrap tape around cord at corner to prevent cutting and shorting.

14. Check the 4 mounting holes at the corners of the pallet assembly, to see if they will allow use of the 1/4" hardware.

15. Check the pallet support legs to see if they will allow the passage of 1/4" hardware. They may have nut plates installed here. If so, remove them.

16. Locate the 8 Barry-Mounts, model # H64-BA-40, and optional base plate, if you are using it, and assemble according to figure 5-12. Be sure to use the # 10 hardware to mount shocks to either the base plate or to themselves. Place shocks or base plate assembly aside temporarily.

17. On the pallet support base assembly, make 4 holes approximately near the corners, drill size .320". These holes will be used to hold the pallet system to the A43-051 shock absorbers.

18. Place pallet support base assembly on top of the plywood board, making it as square as possible, and properly centering the unit. Now circumscribe the four holes onto the plywood board.

19. Remove the pallet assembly and drill the plywood with a .320" drill bit.
20. Turn plywood board upside down and with a 3/4" bit, drill out 3/8" or half way, for countersinking.
21. Clean the plywood board of splinters and dust.
22. Install the 4 Barry-Mounts Model # A43-051, between the plywood and the pallet support assembly, using the 5/16" hardware. See figure 5-14.
23. Install the shocks and/or optional base plate to the pallet support assembly, using the 1/2" long 1/4"-20-UNC-2B hardware with flat washers and lockwashers.
24. Mount the pallet assembly to the shock absorbers, using the 1/2" long 1/4" hardware. Be sure to use flat washers and lock washers.
25. Mount the D.C. power bracket beneath the battery tray. Disregard this step and go on to step 25A, if you are using the optional base plate.
- 25A. Leave the D.C. connector plug loose, but tied to one of the support legs.
26. Mount the battery tray.
27. Reconnect J-3 to inverter assembly.
28. Place the entire pallet system inside the helicopter and position it sufficiently forward so that the equipment locking handles will clear the rear cabin wall.
29. Install the battery and the INU in to their respective trays and lock handles.
30. Slide pallet system as far rear as possible.
31. Replace the helicopter left side door. Place yourself inside helicopter and close the door.
32. Slide the pallet system toward the front 3", then slide the pallet system towards the door and stop when within 3" of the door.
33. Remove door.
34. With chalk or light marker, mark the floor where the pallet

left side plywood aligns with the floor.

35. Try to unlock equipment handles and remove both the battery and INU. If you do not succeed, move the pallet system forward until you are successful with only minor maneuvering of the pallet system. Be sure it has not slipped off the left side mark.

36. Temporarily install co-pilot chair and check position making sure of sufficient clearance with pallet assembly. Then remove the chair and continue to next step. See figure 5-13.

37. From under the helicopter, with an awl or scribe, mark the plywood board through the two holes.

38. Remove the battery and INU; then remove the pallet system from the helicopter.

39. Remove the pallet support assembly from the plywood board.

40. Drill the two holes in the plywood board and check for proper fit with the metric bolts.

41. Place the plywood board in the helicopter over the two equipment mounting holes and secure the board with the metric hardware. Be sure to use the 2" flat washers on top and underneath, along with the castellated nuts. Are the T-nuts still in the plywood board?

42. Place the pallet support assembly on the plywood board, then carefully reinstall the 4 rubber shock absorbers. This time, when you install the 1/4" hardware, be careful not to penetrate the helicopter floor with the bolts.

43. Reinstall battery and INU checking for clearances.

44. Remove battery and INU until later.

5.1.4. Pallet Wiring

1. Locate the 20 foot power cables.

2. Connect the cable plug to the D.C. connector plug directly beneath the battery tray on the underside of the pallet assembly.

3. Route the cables along the back and out the rear ventilation port.

4. Install plastic grommet material around the rear ventilation

port. Continue to route cables toward the rear of helicopter to the fuse box.

5. Secure power cables to main frame of helicopter using 10" x 1/8" wire wraps. Be sure there is no possible chaffing or cutting of cables. Also be sure cables are not routed through racks etc. which may have to be jettisoned. Continue to route the cables all the way back to the fuse box. See figure 5-8.

6. Route the positive (+) cable up to the fuse box and place it through the 1/2" hole cut in the box earlier, and over to the 100 amp. fuse, and cut the cable at that point. See figure 5-1.

7. Route the negative (-) cable over to the common grounding bolt, located at the bottom of the left rear engine frame, and cut at that point. See figure 5-9.

8. Install # 6 terminal lugs at ends of cables, solder and insulate with either tape or heat shrink tubing.

9. Connect the cables to their respective connecting points.

10. At this time, have the A&P mechanic inspect the fuse box, and the equipment mounting bolts for proper positioning and torque. Proceed upon approval to the next step.

11. Replace the fuse box cover with the safety wire restraints.

12. Replace the cowling over the fuse box area.

13. Replace the belly-pan.

14. Have A&P mechanic inspect the cowling and the belly pan.

15. Recheck power cable installation for possible trouble areas.

16. Connect the CDU cable to the pallet assembly connector box J-1.

17. If the remote on/off switch box for the inverters is used, fasten it to a convenient place such as the rear support leg of the pallet support assembly.

18. Install the battery making sure locking handles are locked and safety-wired.

19. Connect the MSU cable to J-2 of the connector box on the pallet assembly, and the other end to the MSU connector, and route cable toward rear and around the pallet system. Place the MSU

temporarily on the floor.

5.1.5. Course Deviation Meter

1. If the course deviation meter and demodulator are to be used, mount the demodulator on the side of the pallet assembly, using 10" wire wraps to secure it to the handle. See figure 5-8.
2. Plug demodulator A.C. power plug into the extension cord coming from the pallet assembly.
3. Connect cables provided for the course deviation meter and demodulator. See figure 5-10.
4. Connect signal input cable between the demodulator and the pallet assembly connector J-5.
5. Route the cross track and course deviation meter cables forward along with the CDU cable, then up and over the instrument console hump; around to the optional meter panel.

5.2. INSI Unit

Refer to figure 5-11 for the following steps:

1. Mount the INSI chassis on its side, with the A.C. power cord on the bottom. Place it behind the geophysical equipment rack. Placing it in the rack would be better, if there is room.
2. Plug the A.C. power cord into the extension cord from the pallet assembly.
3. Plug the signal cable to J-4 of the pallet assembly then to J-1 of the INSI chassis box.
4. Connect the interconnecting cables between the INSI unit and the Geometrics G-714 computer as shown in figure 5-10.
5. Use duct tape or manufacture a set of brackets to hold the INSI chassis in place.

Figure 5-1.
LAMA HELICOPTER
FUSE BOX

Figure 5-2.
PILOT'S 3 O'CLOCK VIEW LAMA HELICOPTER

Figure 5-3.
LAMA HELICOPTER
OPTIONAL METER PANEL

Figure 5-4.
LAMA HELICOPTER
CONSOLE and INSTRUMENT PANEL

Figure 5-5.
LAMA HELICOPTER
CONSOLE ACCESS and COVER PLATE

Figure 5-6.
LAMA HELICOPTER CABIN AREA
TOP SIDE VIEWING IN

* SOME HELICOPTER MOUNTING HOLES HAVE BEEN PRE-TAPPED AT FACTORY, SOME AT MAINTENANCE SHOPS, AND OTHERS AT LOCAL LEVELS. IT MAY BE NECESSARY TO TAP EXISTING HOLES, IN WHICH CASE BE SURE TO USE METRIC TAPS.

Figure 5-7.
PALLET ASSEMBLY
D.C. RECEPTACLE

* MOVE POWER PLUG ASSEMBLY FROM EXISTING POSITION "A" TO POSITION "B", DIRECTLY BENEATH THE BATTERY TRAY, AND TO THE REAR OF INVERTER'S INPUT-OUTPUT PLUG. BATTERY TRAY MUST BE REMOVED TO DRILL AND MOUNT THE MOUNTING BRACKET WITH PLUG.

Figure 5-8.
LAMA HELICOPTER CABIN AREA
WIRING LAYOUT

Figure 5-9.
LAMA HELICOPTER
LEFT SIDE EXPANDED VIEW

Figure 5-10.
SYSTEM BLOCK WIRING DIAGRAM

Figure 5-11.
EQUIPMENT RACK with INSI CHASSIS BOX
RIGHT SIDE EXPANDED VIEW

Figure 5-12.
SHOCK ABSORBERS
H64-BA-40 BARRY-MOUNTS

Figure 5-13.
LAMA HELICOPTER
LEFT SIDE VIEWING IN
with INS INSTALLED

Figure 5-14.
SHOCK ABSORBERS
A43-051 BARRY-MOUNTS

5.3. Check-out

1. Check all wiring for proper routing.
2. Route CDU cable with cross track and course deviation cables alongside the bottom of the console, as tightly packed as possible. Then tape them in securely with duct tape.
3. Using wire wraps, tie down all loose cables.
4. Have the A&P mechanic inspect the work done.
5. Install INU into the pallet assembly. Be sure to lock handles and safety wire them.
6. If an inverter remote power switch was used, be sure it is turned off.
7. Check to ensure the MSU switch is off.
8. Check and be sure battery master switch in helicopter is turned off.
9. Remove tag from helicopter battery leads, and reconnect the battery.
10. Reset pallet battery circuit breaker.
11. With A&P mechanic standing-by, power up the system.
12. Turn-on helicopter battery master power switch.
13. Check for malfunctions or a faint 400 Hz. whine.
14. If using inverter remote switch, turn it on, and listen for faint 400 Hz. whine from inverters.
15. Switch MSU switch to STBY. The system should be running with the fan on and the CDU illuminated. Do not leave the system on for more than a few minutes or the battery will discharge.
16. Turn-off all power switches.

5.4. Final Assembly

1. Replace helicopter doors.
2. Replace co-pilot seat. If it does not fit, the pallet assembly has been mounted too far forward and will have to be repositioned.

5.5. Final check

1. After having checked the entire system out on the ground with an auxilliary power unit and after the A&P mechanic has signed off the installation, perform an in-flight test to be sure of no vibration associated problems.